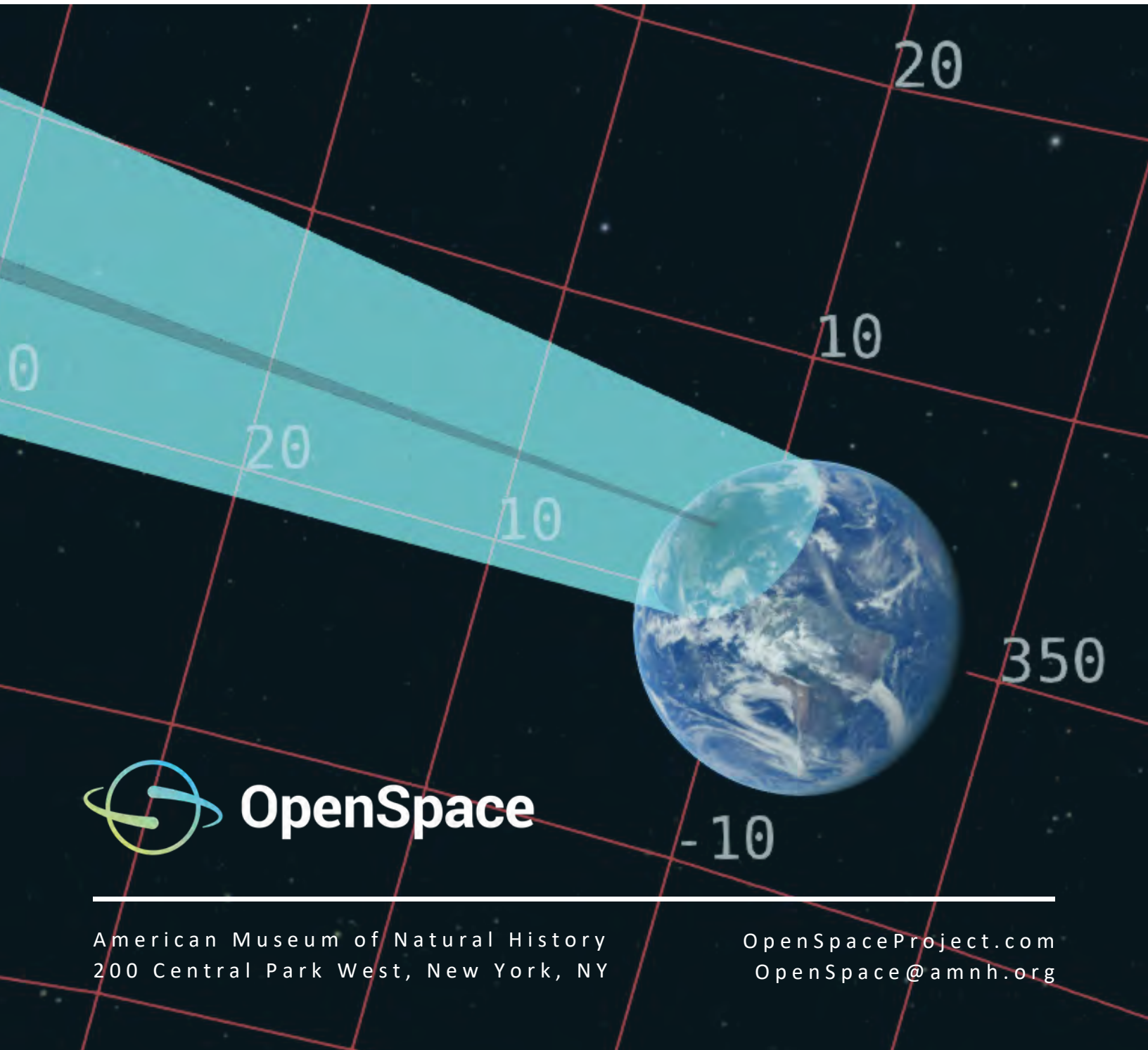
2023

OPENSPACE ANNUAL REPORT

NASA Science Mission Directorate Science Activation Program



OpenSpace

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2023 ANNUAL PROGRESS REPORT

NASA Science Mission Directorate Science Activation Program
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I. ADMINISTRATIVE

- **Name and address of the recipient's institution** & **Cooperative Agreement Number**: American Museum of Natural History, 200 Central Park West, New York, NY 10024; NNX16AB93A
- **Name of the Principal Investigator**: Dr. Rosamond Kinzler
- **Cooperative Agreement Title:** NASA Science Mission Directorate Science Education Cooperative Agreement Notice (CAN) - 2015
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- **Period covered by the report**: November 2022 – October 2023

II. ACCOMPLISHMENTS

The American Museum of Natural History (AMNH) is pleased to submit its eighth yearly update concerning the achievements of *OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond*. The primary mission of the OpenSpace project is to create and foster a pipeline that conveys visual science data from various NASA SMD divisions to Informal Science Institutions (ISIs) and the wider public. A crucial element of this mission is the creation of the open-source software called OpenSpace, along with its advocacy for use in non-formal educational environments through a collaboration with a range of ISI partners.

In the eighth year of the project, AMNH achieved notable advancements in these goals via continuous code enhancement, content visualization, public presentations, and community engagement. A more in-depth discussion of our Year Eight activities is provided below.

Software Development

The OpenSpace software has continued to improve in Year Eight 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 and Imaging (SCI) Institute. Faculty, software engineers, and graduate research associates at each of these locations have collaboratively enhanced the overall software by continuing to develop effective code and algorithms to handle data intensive tasks, integrate new data sets from NASA and other sources, and improve the user interface.

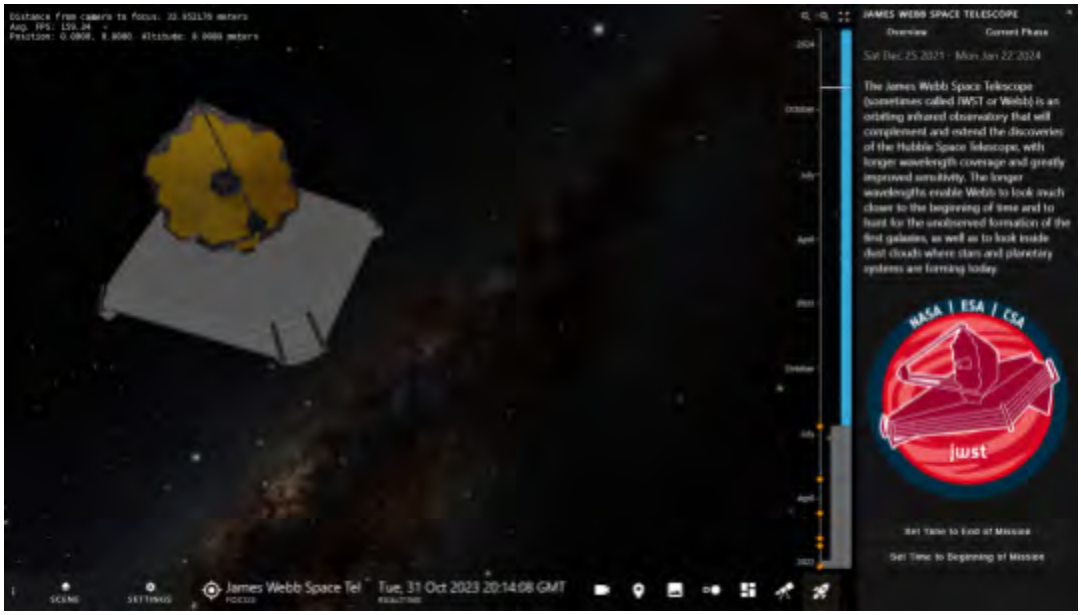
During this period, one new major release of OpenSpace software was published; Beta-12 (v0.19.0) was released on June 27, 2023. Four minor releases were also published: two to Beta-11 (v0.18.1 and v0.18.2) and two to Beta-12 (v0.19.1 and v0.19.2). Informed by feedback from our ISI partners and other OpenSpace users, these modifications not only enhanced the software's stability and user-friendliness but also introduced new content and features. Full changelogs can be found in *Appendix C*.

Major new features and computational improvements include:

- *Getting Started Tour*: This feature provides an introductory walkthrough designed to help new users familiarize themselves with the software's main features, functionalities, and user interface. The tour can be launched from within the software to allow new users to quickly grasp the software's capabilities and start using it efficiently. The Getting Started Tour offers scenarios for users to practice navigating with the mouse, changing color layers, and adjusting time settings.
- *Customize the Complexity of the User Interface*: This update has added the ability for users to modify the complexity of the user interface by adjusting which settings or properties within the software are displayed to the user. For example, an advanced user might want to see all available settings, whereas a beginner might only want to see basic settings to avoid feeling overwhelmed.
- *Video Playback*: With video playback, users can overlay videos onto various shapes, specifically spheres (globes), and flat surfaces (planes). Users are able to play the videos at their native frame rate, or adjust the playback speed to cover specific time durations. This flexibility is useful for accommodating visualizations of events happening over a wide range of temporal periods and has been highly beneficial in utilizing NOAA's Science On a Sphere® content in OpenSpace.
- *GeoJSON Files on Globes*: This feature can be used to render line strips and polygons onto the surface of any planet, allowing users to annotate and enhance map textures.

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

- *Mission GUI for Mission Milestones*: This new user interface provides information about mission duration and milestones. This is a first step towards making mission profiles more accessible to users without prior content knowledge.



The Mission User Interface for JWST includes an overview of the telescope and a timeline to jump to different phases of the mission in OpenSpace.

Content Development

The development of new content is continually influenced by our users' requirements and feedback and is enriched through partnerships with NASA agencies and infrastructure, along with external scientists and institutions, as detailed below.
OpenSpace currently offers 23 preset profiles. The continued content development has led to the introduction of five new profiles and improvements to several existing ones.

New Profiles

- *Eclipses:* This profile contains umbral and penumbral shadow cones to visualize eclipses in real time. Additional information on eclipses and an interactive timeline of eclipses in the last century and for the next century are available in the Missions user interface.
- *ESA's JUICE Mission:* This profile visualizes ESA's JUICE mission that will explore Jupiter and three of its icy moons.
- *Artemis I Mission:* The spacecraft and its trajectory around the moon were added. In particular the trajectory around the moon was visualized in two different ways.
- *Empty:* The empty profile can be used as a starting point for users to visualize their own 3D models or data sets separately.
- *Offline:* This profile includes low resolution maps of planets that can be used without internet access.

Enhanced Content for Existing Profiles

New Assets

- Objects that can be used for scale comparisons, for example the Eiffel Tower, the Statue of Liberty, the Golden Gate Bridge, etc.
- New maps for Earth, Mars, Venus, and the moon Triton

Accessibility

A main focus of the OpenSpace SciAct 2.0 project has been to improve the user experience. In Year Eight, we began work with Prime Access Consulting (PAC) to focus our efforts to enhance the accessibility of the software. Prime Access Consulting specializes in accessibility and inclusive design and has supported the OpenSpace team to pinpoint the most urgent areas for accessibility.

User Interface

After reviewing OpenSpace version 0.18.2, the team at PAC shared two recommendation reports for the software's user interface and launcher (the startup menu), attached in *Appendix C*. The recommendations include updating the software to meet Web Content Accessibility Guidelines (WCAG) 2.1 standards, which are foundational to making web content more accessible to people with disabilities, especially for users who rely on access technologies (screen readers, voice recognition software, etc.). Our developers are currently implementing these recommendations with the intent of having them fully integrated into OpenSpace by Year Nine.

Our long-term goals for increasing the accessibility and impact of OpenSpace extend well beyond the interface, however. We have discussed partnering with PAC to develop new strategies for communicating OpenSpace's rich data libraries in ways other than visual representation, such as through data sonification and 3D printing. Diversifying the software's output formats would serve not only visually impaired individuals but all people through multimodal engagement. We plan to actively seek funding for this work.

Sonification

Over the past two years, the development team and external contributors have worked on connecting OpenSpace with the open-source sonification engine SuperCollider, which has opened an avenue into a number of promising research projects about the use of sound as a communication channel to the general public. This builds on the work by Elmquist *et al.*[2] to use spatial audio to highlight the temperature, mass, rotational speed, and relative location of the

[2] E. Elmquist, M. Ejdbo, A. Bock, N. Rönnberg (2021), *OpenSpace Sonification: Complementing Visualization of the Solar System with Sound*, Proceedings of the 26th International Conference on Auditory Display ICAD.

planets in the solar system and major moons of Jupiter and Saturn. This integration has been extended to facilitate the sonification of DNA barcoding sequence data from within OpenSpace, which has subsequently been presented to multiple public audiences.

These two use-cases provide the foundation for a deeper use of sonification, particularly for users with limited eyesight. The current development goals aim to integrate this functionality into the master branch of OpenSpace by Year Nine and thus increase the accessibility of the software further.

Stakeholder Meetings

Over the course of the eighth year, several meetings were held involving OpenSpace stakeholders.

Developer Meetings
Developers and project leaders from AMNH, Linköping University, New York University, and the University of Utah convened at AMNH on May 1 and 2. This meeting was the first in-person meeting for developers since 2019 and focused on evaluating the development objectives for the newest release and future plans. Details of this meeting can be found in *Appendix C*. Developers continued to work together in-person from May 3-5 at AMNH. The meeting was largely focused on continued development of the software to reach version 1.0 by spring of 2025. To that end, the team articulated several guiding mantras that would characterize the release and help guide our development work moving forward:

- "Developers don’t create the majority of content"
- “People should be able to share content without us involved”
- "The average user/builder doesn't need to touch text files"
- "The average dome technician doesn't need to contact us"
- "Training by OpenSpace team members is not necessary"
- "Bugs and breaks are well documented and communicated to users”

OpenSpace developers explored AMNH's new Richard Gilder Center for Science, Education, and Innovation.

OpenSpace project team and ISI Network pose after two days of meetings at AMNH.

Informal Science Institution (ISI) Network

Our annual ISI Network meeting took place at AMNH on July 24 and 25. Partners from the six funded ISI institutions, together with project evaluators and developers, participated in this event. The meeting facilitated sharing of innovative software applications and provided a platform for direct feedback between our ISI superusers and software developers. Part of the meeting was dedicated to developing strategies that would empower our funded partners to engage their communities in OpenSpace trainings and workshops. In addition to magnifying the reach and impact of OpenSpace, this distributed model of user support is vital to building a strong open-source ecosystem that will help sustain the software in the future. Details of the meeting can be found in *Appendix C*.

OpenSpace Trainings

In Year Eight, we transitioned our "Micah monthly" meetings to "OpenSpace Community Monthlies." Originally these virtual meetings were conceived to share updates with our funded ISI Partners. We found that many OpenSpace users outside of this group wanted to contribute and network with other OpenSpace users. Now these meetings are open to any OpenSpace user, from novice to expert level, within and outside of informal science institutions. Regular attendees include the planetarium at Towson University's Christian Ready and the MIE Alliance's Jeff Nee. This group has become an important source of feedback before and after software releases.

Additionally, the creation of an online booking page at the end of Year Seven has allowed Micah Acinapura, software developer at AMNH, to offer impromptu training sessions and support when requested.[3] To date, this booking page has accounted for 16 sessions spanning 13 different institutions.

[3] https://calendly.com/openspaceproject/openspace-support

Year Eight ISI Partner Network Activities

Adler Planetarium

The Adler hosted a special night of programs in conjunction with the fall 2022 meeting of the American Geophysical Union (AGU) in Chicago. A special program was offered for AGU attendees in the Grainger Sky Theater highlighting OpenSpace content. Over **2,200 visitors** attended this night of AGU programming. This was the first time OpenSpace visuals were shown in real-time in the Adler's major public dome theater. To make this possible, the Adler installed a new alignment system for the computer cluster that operates OpenSpace in the theater. Since this upgrade, the Adler plans to develop future programs incorporating OpenSpace content in the dome and the Space Visualization Lab on the lower level. Additionally, a new Data Visualization Engineer, Lauren Corlies, was hired this year to spearhead these efforts.

In Year Eight, Adler hosted two high school interns who worked on a variety of projects, from producing new visuals in OpenSpace to creating eclipse content for visitors. Interns also worked on developing a new guest-facing interface for OpenSpace to be deployed in the Space Visualization Lab. This interface will allow visitors to interact directly with OpenSpace while being guided through narrative content related to NASA missions and priorities such as the Apollo moon landings and the upcoming 2024 total solar eclipse.

Finally, the Adler continued to share and develop content for digital online outreach. Six online videos featuring OpenSpace have been highlighted on Adler's social media channels and attracted a total of approximately **9,000 views** on YouTube.

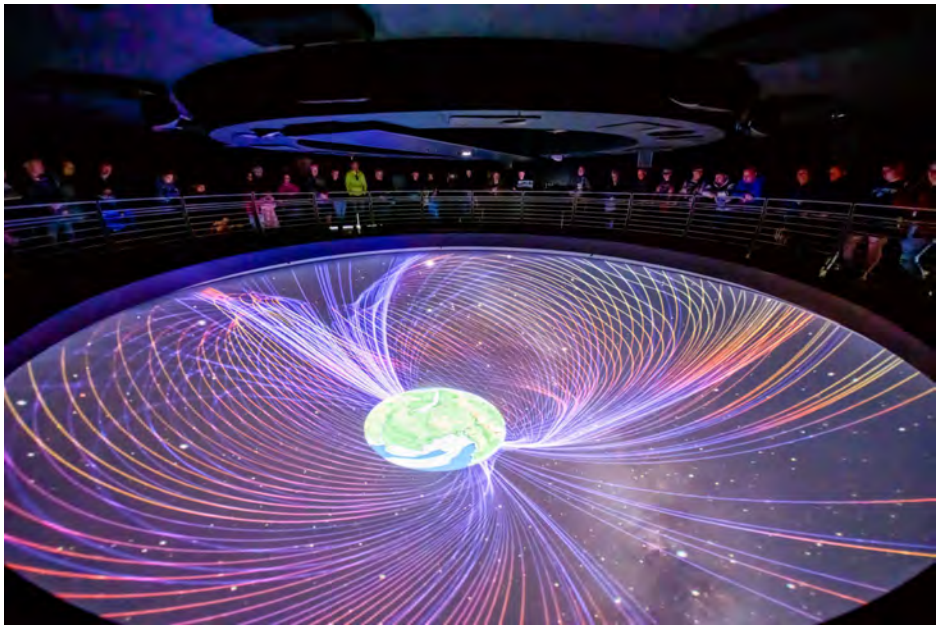
American Museum of Natural History (AMNH)

In Year Eight, OpenSpace was used in a range of activities to reach over **6,829 people on-site** and **108,734 online**.

Monthly public programs continued in the Hayden Planetarium to explore topics related to Earth and space science in OpenSpace. "Astronomy Live" programs offered a family friendly interactive tour of the universe and a view of the constantly changing night sky, while "Frontiers Lectures" invited Subject Matter Experts to share breaking science with adult audiences. These programs were attended by approximately 5,000 on-site visitors.

During Black History Month, AMNH hosted "Teen SciCafe: Stars to Freedom" which welcomed teenagers to join astronomer Jackie Faherty and historian Georgette Grier-Key to explore how Freedom Seekers used stars to find their way north. This program was attended by 250 students.

For Earth Day, OpenSpace participated in the museum's EarthFest with a day of programming in AMNH's Big Bang Theater. Subject Matter Experts and museum educators presented on Earth's role in the solar system and other topics every 20 minutes throughout the day. Over 650 visitors attended these OpenSpace presentations. Other special events in the dome included the album release party for Quavo, a hip hop artist. OpenSpace visuals wowed over 650 music fans, many of whom were first time visitors to the planetarium.



Museum visitors view the Earth's magnetosphere during EarthFest at AMNH.

OpenSpace collaborated with the OSIRIS-REx Mission team to present a NASA Twitch stream in anticipation of the capsule's return. Dr. Anjani Polit, Mission Implementation Systems Engineer for OSIRIS-REx and Micah Acinapura, OpenSpace developer, discussed the mission's milestones and answered questions on air. The broadcast has been viewed over 46,300 times.

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

Internships: 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 recent missions. A high school student in the museum's LANG program created social media content in OpenSpace during a summer internship. Additionally, two students from Shinshu University in Matsumoto, Japan, added content from the Hayabusa II mission to OpenSpace as part of their internship at AMNH.

Education Programming: OpenSpace was also used in three one-week sessions of the Museum's Digital Universe Flight School where 69 rising 9th and 10th graders learned to pilot the software. The software was regularly used in classes such as Ocean Worlds, reaching an additional 45 students. Over 150 elementary school students were also engaged

in two dome presentations where OpenSpace was used to investigate the terrains of different planetary bodies.

Pre-service Teacher Preparation: The Museum's Masters of Arts in Teaching Earth Science Residency (MAT-ESRP) program consistently uses OpenSpace for its group of 15 graduate students. When they graduate, these teachers are dedicated to serving high-needs 7th-12th grade public school classrooms in the USA, with the majority choosing to teach in NYC. They utilize OpenSpace in multiple ways including for astrophysical research as part of their MAT degree program.

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

California Academy of Sciences (Cal Academy)

In Year Eight, California Academy of Sciences created new opportunities for visitor engagement through on-site programs using OpenSpace. In total, Cal Academy reached **35,910 people online** and **293,586 people on-site** in Year Eight.

The Morrison Planetarium continued its daily programs “Tour of the Universe” and “Living Worlds,” which feature OpenSpace. These programs were also incorporated into Cal Academy’s weekly NightLife program, which invites adults over 21 to the museum to explore after hours. With 399 shows, “Tour of the Universe” reached 52,275 visitors on-site and 750 “Living Worlds” shows reached 72,069 visitors on-site. Cal Academy expanded the reach of its in-person planetarium program with a weekly simulcast streamed on YouTube and Facebook resulting in an additional 732 live viewers.

In March, Cal Academy replaced its “Living Worlds” program with the fulldome show “Dark Universe,” narrated by Neil deGrasse Tyson. The program incorporates a live flight of OpenSpace to demonstrate how the Universe has evolved over time. In all, the 669 shows reached 131,520 visitors on-site.

Cal Academy continued its monthly Benjamin Dean lecture series where Subject Matter Experts present recent science for the public featuring OpenSpace as a supplement. These lectures reached 758 visitors on-site.

Additionally in Year Eight, Cal Academy continued its “Landscapes of the Solar System” program in Hohfeld Hall. This was a new program in Year Seven and reached 18,950 people this year. Hohfeld Hall transitioned to a new show “Asteroid Adventures,” a family friendly, 15-minute program flown live in OpenSpace in June 2023. Hosted by planetarium staff, the show explores

OpenSpace's various asteroid mission content including OSIRIS-REx, Hayabusa I and II, and DART and reached 15,236 visitors this year.

Denver Museum of Nature & Science (DMNS)

In Year Eight, Denver Museum of Nature & Science continued its Digital Earth programs in the Gates Planetarium. In collaboration with the National Parks Service, DMNS developed a "Digital Earth Caves" program that incorporated into OpenSpace dozens of 3D models derived from photogrammetry of rock formations and 360° panoramic images from inside and outside Carlsbad Caverns in New Mexico. This program was presented at multiple DMNS public events, as well as at the American Alliance of Museums (AAM) 2023 conference during the evening party at DMNS for conference attendees. During Year Eight, this popular program reached over **560 people**. Upcoming year-end Digital Earth programs with OpenSpace will focus on the Colorado River and seismology.

DMNS also created opportunities for two Teen Science Scholars to engage in STEM experiences using OpenSpace. These interns were mentored by Dr. Ka Chun Yu, Co-I and Curator of Space Science, to research binary exoplanetary systems, create new visualization modules to depict in OpenSpace, and create a planetarium show in OpenSpace. In total the interns presented eight presentations of their work to approximately **180 people**.

DMNS Teen Scholars work with Dr. Ka Chun Yu to visualize data.

Teen Scholars present their own planetarium show in OpenSpace.

Houston Museum of Natural Science (HMNS)

In Year Eight, HMNS continued to improve its OpenSpace Lab with new content and technology. Now open every day, the OpenSpace lab has been experienced by over **36,000 visitors**. The lab features 16 computers that display a variety of games, such as Seeing with Sound and TicTacToe, that integrate OpenSpace visualizations with science trivia questions. This year, three new games geared toward younger audiences were added to the lab: Scramble, Match Game, and

Sequence. The museum is currently working on more complex content-based games to be unveiled in summer 2024, as well as expanding the Lab to include three additional interactive computer stations.

In October 2023, HMNS hosted Dr. Patricia Reiff, professor of physics and astronomy at Rice University, for an event that prepared visitors for the annular eclipse. During this event, visitors were given a screening of the museum's "Totality Over Texas" planetarium show, which uses 13 OpenSpace scenes, making up one-third of the program.

Also in Year Eight, HMNS hosted 27 high school summer astronomy interns. These interns worked in the OpenSpace Lab to complete a variety of projects. In addition to offering OpenSpace demonstrations to museum visitors and working on the interactive games mentioned above, interns supported solar viewing demonstrations to prepare for eclipses by teaching visitors how to use eclipse glasses and pinhole projectors, as well as provided informational handouts for upcoming eclipses. Additionally, interns created sections in OpenSpace for a future planetarium show called "The Cosmic Connection."

North Carolina Museum of Natural Sciences (NCMNS)
In Year Eight, NCMNS utilized OpenSpace to create visualizations for public programs, community and school presentations, and exhibition content. In all, the museum reached over **260,423 people on-site** and **629 online**.

The annual Astronomy Days was held in person at the museum for the first time in three years. OpenSpace was featured prominently throughout the two-day event on interactive kiosks and digital displays. Programming also included multiple OpenSpace presentations: "Asteroid Forensics: Unraveling the Origins of our Solar System" presented by Pierre Haenecour of the University of Arizona's Lunar and Planetary Lab and Co-I Dr. Rachel Smith, and "From Apollo to Artemis'' presented by AMNH Co-I Carter Emmart on both days. The event was attended by 12,552 people.

Co-I Smith also presented "The Search Beyond Earth" for the Lunchtime Discovery Series, a virtual program organized by the NC Department of Environmental Quality Office of Environmental Education and Public Affairs. Throughout Year Eight, NCMNS virtual programs reached over 350 live viewers.

In addition, Co-I Smith presented numerous in-person programs utilizing OpenSpace throughout Year Eight. Several programs engaged adults such as presentations at the Traditions and the Waltonwood Lake Boone retirement communities, and a live-flown lunar presentation at the museum's Apollo 17 50th Anniversary event. Additional presentations included "Exploring Protoplanetary Chemistry Across the Galaxy'' for the Greensboro Astronomy Club and "The

Dynamic Habitable Zone: Earth, Our Planetary Neighbors, and Worlds Beyond'' for the North Carolina SciTech Expo on Earth Day. These programs reached over 725 people.

Throughout Year Eight, the museum's interactive kiosks featuring curated videos have continued to be a major attraction for visitors of all ages. The thematic, user-driven video kiosks offer on-demand OpenSpace videos that highlight a range of data such as asteroids, Voyager, and JWST. Additionally in Year Eight, the Astronomy & Astrophysics Research Lab updated its fly-through videos on display with the latest mission data. The Lab is used by undergraduate interns to create visualizations in OpenSpace. Co-I Dr. Rachel Smith also welcomed visiting high school students from the STEMcx summer camp and adults from the Women in Power to tour and explore the lab.

Dr. Smith is an avid promoter of OpenSpace, and has expanded its reach to multiple institutions. Additional uses of OpenSpace in conference presentations and by partner institutions, the Appalachian State University and Museum of Life and Science, are described in the section below.

Additional Year Eight Community, Academic, and ISI Activities

The following is a sampling of known activities using OpenSpace **beyond the funded partners**. The project team is continuously learning about the growth of the project beyond known users and it is therefore impossible to paint a complete picture of OpenSpace's reach and impact. This is further explained in the Network Evaluation Report attached in *Appendix B*. New users are denoted with an asterisk.

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." Dr. Smith also used OpenSpace in her presentation "Observations of Young Stellar Objects and Protoplanetary Systems across the Galaxy" at the Physics and Astronomy Colloquium. Fellow App State professor and director of the Dark Sky Observatory Dr. Dan Caton continued to use OpenSpace in his introductory astronomy course and for public in-person observing nights. Dr. Caton trained several of his undergraduate students to pilot OpenSpace for these programs. In all, OpenSpace was experienced by over 285 people at App State.

***Charleston Planetarium Society (Charleston, SC)**
Interim Director R. Scott Harris used OpenSpace for weekly online planetarium programs that run for one hour on Saturday mornings on Facebook Live. These programs have reached 1,863 online viewers. Harris has also used OpenSpace directly in secondary and post-secondary earth

science and geology classes as well as community outreach events such as STEM Day at the State Farm Arena in Atlanta, GA.

City College of New York (CCNY) Planetarium (New York, NY)
CCNY Planetarium Director Dr. James Hedberg has continued to be a "superuser" and contributor to OpenSpace. In addition to utilizing the software in his undergraduate upper-level physics classes, Dr. Hedberg continued to make short educational videos to share on Instagram and other social media channels using OpenSpace to illustrate important concepts. The 29 videos explored a range of OpenSpace content such as the annular eclipse, Apollo and Artemis missions, and lunar geography, with the most popular videos featuring music by Radiohead, the Smashing Pumpkins, and Tom Petty. In total, these videos have amassed 15.3 million views and 297,800 likes to date. The CCNY Planetarium also hosted in-person programs on the Artemis mission and the Moon.

Michigan Science Center (Detroit, MI)
The Michigan Science Center developed a fulldome planetarium system around OpenSpace in June 2023 to engage audiences with astronomical data and prepare visitors for the April 2024 eclipse. "A Lunar Journey," which focuses on our Moon, eclipses, and other moons in the Solar System is shown daily. The program has reached a total of 2,786 people. Additionally, a program is currently being developed for all Detroit Public School Community District 3rd graders to visit the planetarium and experience OpenSpace, which will commence in Year Nine.

In addition, Michigan Science Center, in partnership with AMNH, received a NASA Team II award of $966,462 to create an out-of-school STEM learning program called "Urban Skies – Equitable Universe: Using Open Space to Empower Youth to Explore Their Solar System and Beyond" for 7th and 8th graders to develop technical, computational, public speaking, and content-based skills through immersive engagement with NASA mission data.

Mochileros Astronómicos (Asunción, Paraguay)
Bryant Gonzalez Vasquez founded Mochileros Astronómicos to spread space and science knowledge to communities across South America with little access to informal education resources. Vasquez continued to use OpenSpace in Year Eight in both onsite and online programs, including Zoom livestream demonstrations that explored topics such as star formation, constellations, and the solar system. In May 2023, Vasquez used OpenSpace in his presentation "Lunes del Sistema Solar" ("Moons of the Solar System") at the Ciclo de Conferencias Astronómicas for the Club Astronómico de Querétaro José Franco in Querétaro, Mexico, reaching 340 people. Additionally, Vasquez continued to travel South America to offer shows in the mobile planetarium. These mobile planetarium activities (Planetario Canopus) in

Paraguay reached approximately 3,000 people through public events and 2,000 people in eight public schools.

Museum of Life and Science (Durham, NC)
The Museum of Life and Science, a partner institution of NCMNS, has continued to collaborate with Co-I Dr. Rachel Smith to highlight OpenSpace. In Year Eight, the museum's lunar surface video rendered in OpenSpace permanently on display in the Aerospace exhibit reached over 147,400 people.

Norrköping Visualization Center C (Norrköping, Sweden)
Visualization Center C uses OpenSpace both in school programs and public activities. In Year Eight, 2,079 students aged 14-15 experienced OpenSpace. 148 preschoolers also attended OpenSpace programs. Among the general public, 4,997 visitors attended 155 OpenSpace shows, including real-time and recorded versions. In addition, several hundred people have engaged with OpenSpace during organized visits to The Center, including research visits, conferences, VIP groups, etc. Finally, OpenSpace is used in four installations on the exhibit floor of The Center, which served approximately 104,000 visitors throughout the year.

***Planetarium at P-Tech (Paterson, NJ)**
The Planetarium at P-Tech used OpenSpace to present complex climate science topics to the Girl Scouts of Northern New Jersey summer program, where over 100 participants were engaged in interactive climate change lessons. Additionally, P-Tech began using OpenSpace to create engaging educational videos for its audiences on YouTube, Instagram, and other social media, as well as to present in its portable planetarium. Pre-rendered fulldome presentations of OpenSpace are currently under development for next year.

The Girls Scouts of Northern New Jersey troop visit the Planetarium at P-Tech.

Southwest Minnesota State University (SMSU) (Marshall, MN)
The Southwest Minnesota State University planetarium continues to use OpenSpace frequently in its ongoing outreach and college-level astronomy objectives. Nearly every visitor that comes to the planetarium is exposed to OpenSpace. Over the past year SMSU focused heavily on the SkyBrowser feature highlighting the JWST images, new solar eclipse features released with version 0.19.0, and OpenSpace's OSIRIS-REx profile, which was used to create a series of programs leading up to the mission's sample return. Over the past year SMSU had 6,000 visitors exposed to OpenSpace. The dominant audience is generated from K-12 schools visiting on field trips.

SpaceDome Mobile Planetarium (Zürich, Switzerland)
Erich Strehler, school teacher and founder of SpaceDome Mobile Planetarium continues to use OpenSpace for monthly presentations at greater Zürich area public schools for students. In addition to his school, SpaceDome presented OpenSpace for 50 students from a neighboring school. SpaceDome also presented at the Space Festival in Zürich and the pre-launch party for the Euclid Mission at the University of Applied Sciences Northwestern Switzerland, reaching around 300 people. SpaceDome also began using an 8m dome to increase the amount of spectators at each presentation and hopes to continue expanding to new audiences.

Springfield Science Museum (Springfield, MA)
The Springfield Science Museum offers a range of OpenSpace content geared toward different ages. For younger students, the focus is on planets visible in the night sky, while older students experience more complex science topics such as discovered exoplanets and how constellations distort depending on position. 750 students from school field trips engaged with OpenSpace. Additionally, at special events, Earth and Moon content has been presented in a small auditorium, reaching approximately 300 people.

Towson University (Towson, MD)
As a new user in Year Seven, the Towson University Planetarium deepened its use of OpenSpace by hosting 4,134 visitors in 132 events. Christian Ready, planetarium director and lecturer for the department of physics, astronomy and geosciences, has utilized OpenSpace in a variety of ways. Sometimes the software is used to showcase what is up in the sky at night or to give a brief tour of the solar system or even the Universe as a prelude to a fulldome movie. For example, in one show, Towson used the Bastille Day 2000 profile to demonstrate extreme activity on the Sun as an introduction to a rendered movie about the Sun. Other times live OpenSpace presentations are the main show. Examples include shows about JWST, OSIRIS-REx, and upcoming eclipses.

University of Nebraska–Lincoln Ralph Mueller Planetarium (Lincoln, NE)
This year, the Ralph Mueller Planetarium used OpenSpace for a program on climate change for Upward Bound students, 9th-10th graders preparing for college. The University of Nebraska State Museum and Mueller Planetarium are now closed for renovations, but plans for OpenSpace are underway. The museum was awarded a NASA Team II award to engage local 7th-9th graders in STEM experiences focused on Earth. OpenSpace will be used to visualize changes in Earth's systems for participating students.

Versant Power Astronomy Center, University of Maine (Orono, ME)
Versant Power Astronomy Center used OpenSpace in the dome for two special climate presentations and four JWST community events, as well as a variety of solar system presentations over the course of this year. Versant is continuing to find ways to integrate it into ongoing planetarium programming to share information and news about the universe. Approximately 750-1000 visitors have experienced OpenSpace presentations in Year Eight.

***WonderDome (Sheffield, United Kingdom)**
WonderDome, founded in 2014 and based in Sheffield, England, began using OpenSpace in mobile planetarium shows offered to schools across the United Kingdom. WonderDome's presenters provide interactive, immersive presentations for primary school aged children (4-11 years old) and also other community groups. OpenSpace has been used to create pre-rendered video content covering the planets and moons to enhance these presentations. The videos are also set to WonderDome's own cosmic soundtrack created by the team to fully immerse the audience.

***ZOOM Children's Museum (Vienna, Austria)**
ZOOM Children's Museum began using OpenSpace as part of its hands-on exhibition for children aged 6-12 at the museum in Vienna (without entry for schools). At the ZOOM Children's Museum, the dome hangs from the ceiling and from the outside looks like a Mars rover. Inside the dome, children use OpenSpace in the "Welcome to the Future" program to recognize the importance and fertility of planet Earth, as well as travel through space to Earth to discover flora and fauna worth protecting.

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

- A Time for Science (Greenville, NC)
- *Aquatarium (Brockville, Ontario, Canada)
- Ars Electronica Center (Linz, Austria)
- *Asheville Museum of Science (Asheville, NC)
- Astronomy on Tap (New York, NY)
- *ASU School of Earth & Space Exploration (Tempe, AZ)
- *ASU Thunderbird School of Global Management (Phoenix, AZ)
- Como Park Elementary School (Saint Paul, MN)
- Fiske Planetarium, University of Colorado Boulder (Boulder, CO)
- Hampden Sydney College (Hampden Sydney, VA)
- Herndon High School (Herndon, VA)
- Hubble Planetarium (Brooklyn, NY)

- Intrepid Sea, Air & Space Museum (New York, NY)
- Jewish Museum of Milwaukee (Milwaukee, WI) (Temporary)
- *Laurel Highlands School District (Fayette County, PA)
- *Lawrence Hall of Science (Berkeley, CA)
- Lower East Side Girls Club (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)
- National Museum of Science and Technology (Stockholm, Sweden)
- Naturhistorisches Museum Wien (Vienna, Austria)
- New Brighton Area Schools (New Brighton, PA)
- New York University (New York, NY)
- Oakton High School (Oakton, VA)
- Paulucci Space Theater (Hibbing, MN)
- Phillip and Patricia Frost Museum of Science (Miami, FL)
- *Science Museum of Western Virginia (Roanoke, VA)
- The B612 Foundation (Mill Valley, CA)
- The Journey Museum (Rapid City, SD)
- Umevatoriet (Umeå, Sweden)
- Universeum (Gothenburg, Sweden)
- *University of New South Wales Wollongong (Wollongong, Australia)
- *University of North Dakota (Grand Forks, ND)
- University of Utah (Salt Lake City, UT)
- *VEGA Observatory Haus der Natur (Salzburg, Austria)
- Wauwatosa West High School (Wauwatosa, WI)
- West Springfield High School (West Springfield, VA)
- *West Virginia University (Morgantown, WV)

Recent evaluation efforts surfaced the following previously unknown OpenSpace users:

- *African Circular Business Alliance (Cape Town, Western Cape, South Africa)
- *Anchorage Museum (Anchorage, AK)
- *Astro Group South Sardinia (Castiadas, Sardinia, Italy)
- *Astrolab Iris (Ieper, Belgium)
- *Austin Community College (Austin, TX)
- *Bromsgrove School (Bromsgrove, United Kingdom)
- *Brookhaven National Laboratory (Upton, NY)
- *Brooklyn Technical High School (Brooklyn, NY)
- *Connecticut Science Center (Hartford, CT)

- *Exploratório - Centro Ciência Viva de Coimbra (Coimbra, Portugal)
- *IMERSS (Galiano Island, BC, Canada)
- *New Zealand Astrobiology Network (Carterton, New Zealand)
- *Nyx Space (Golden, CO)
- *One World Immersive (Denver, CO)
- *Robeson Planetarium (Lumberton, NC)
- *Sonnenborgh (Utrecht, Netherlands)
- *Spherical (Oakland, CA)
- *StoryDome (Langley, WA)
- *Technical University of Munich (Munich, Germany)
- *The Admiral Vasile Urseanu Astronomical Observatory (Bucharest, Romania)
- *The Human Space Program (Natick, MA)
- *Traveling Universe (Chiang Mai, Thailand)
- *Universidad de Córdoba (Córdoba, Spain)
- *University of Cape Town (Cape Town, South Africa)
- *University of Groningen (Groningen, Netherlands)

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

- Canberra Deep Space Communication Complex (Paddys River, Australia)
- Henry Ford College Hammond Planetarium (Dearborn, MI)
- Joseph Moore Museum at Earlham College (Richmond, IN)
- Ontario Science Centre (Toronto, Ontario)
- Pottsville Area High School (Pottsville, PA)
- University of Texas Arlington Planetarium (Arlington, TX)
- Williamsville Space Lab Planetarium (Williamsville, NY)
- Vaughan Planetarium (Laramie, WY)

Instances of OpenSpace Start-ups

The above ISI uses are known to the project team, however there are many more instances of OpenSpace around the world. The map below is a comprehensive snapshot of OpenSpace software startups for North America since 2021.

Planetarium Vendors

As interest in OpenSpace grows, strengthening vendor relationships is vital for the project team. The Elumenati consistently updates OpenSpace in their 31 planetarium GeoDome Network across 13 states and three countries. Additionally, we've teamed up with SSIA Technologies for several dome installations, with our Software Integration Engineer spearheading the OpenSpace updates. This engineer is also collaborating with Ash Enterprises to introduce OpenSpace to their domes. Meanwhile, Turkey-based SureyyaSoft has merged OpenSpace with their Shira Presenter tech in the Shira Dome Console, expanding its reach. Evans & Sutherland, the world's leading planetarium vendor, reached out to a member of our development team at Co-I University of Utah's Scientific Computing and Imaging Institute to install OpenSpace on the dome in their headquarters. This is a key step in reaching integration of OpenSpace into their platform.

III. STATUS/CHANGES/ISSUES

Issues

Apple's M1 and M2 chips continue to pose a problem for OpenSpace users as they do not support double precision floating point operations which are used throughout OpenSpace to get the level of precision required to visualize many of the data sets we contain. Our developers are exploring potential paths to running single precision without massive performance losses.

We are committed to releasing the software for older Intel Macs as we continue to research this issue. An external software engineer, Anton Marini, who was recently introduced to the project, has embraced the challenge of getting OpenSpace to run well on the M1/M2 chips and is actively working on the problem – a testament to the power and opportunity of open-source software. In addition, the development of *OpenSpace Cloud*, which is being funded through our augmentation, will enable Mac users to run OpenSpace remotely without performance loss.

Personnel Changes

Ylva Selling, Research Engineer at NYU Tandon School of Engineering, has left her position. Interest in the position is high as we've already received over 120 applicants. We are working with computer science professor at NYU Co-I Dr. Claudio Silva to identify the best candidate.

IV. DISSEMINATION ACTIVITIES, COLLABORATORS AND CROSS-COLLABORATION AGREEMENTS ACTIVITIES

Website (www.openspaceproject.com)
The OpenSpace website serves as the gateway for prospective users. It provides a snapshot of the project, presents the team, lists participation opportunities, and includes a software download link. Visitors can also access our community workspaces, social media channels, and stay informed about upcoming events from the site.

Since November 2022, OpenSpaceProject.com has received over 65,000 total visits. Of these visits, United States IP addresses again led in geography, accounting for over 29,000 (45.8%) visitors. This was followed by seven countries with over 1,000 visits: Sweden, India, United Kingdom, Germany, Canada, Netherlands, and Australia. An additional 49 countries had over 100 visitors each. Our geographical spread has continued to grow.

Approximately 47% of visits are direct, while 37% of visits originate through search engines like Google, Bing, and DuckDuckGo. The AMNH website referral link accounted for the most visits with over 2,000, while the next highest referrals originate from the OpenSpace Survey Monkey link that is shared at public programs.

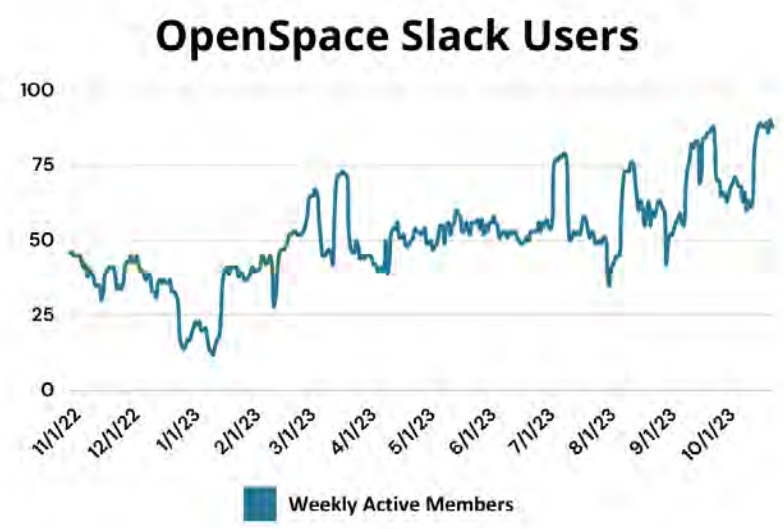
Support and Community Channels

Wiki (wiki.openspaceproject.com): The wiki site used for the latest software documentation transitioned to a new website (https://docs.openspaceproject.com) in Year Eight. The new home for OpenSpace documentation allows for multiple versions to be maintained on one site. The new platform also allows for code highlighting and callouts that will help users find the most relevant information.

GitHub (https://github.com/OpenSpace/): GitHub hosts the public source code for OpenSpace. Both users and developers can report software issues, suggest fixes for bugs, and contribute to the codebase there. In Year Eight, three external developers committed to the OpenSpace GitHub.

Reddit (https://www.reddit.com/r/OpenSpaceProject/): The OpenSpace Reddit acts as an auxiliary support platform and a space to discuss software applications. With 104 members currently, the main topic of discussion are support questions.

Slack (openspacesupport.slack.com; team-openspace.slack.com): Besides aiding the project team, these communication and file-sharing platforms serve as a hub for community-led collaboration. In Year Eight, we simplified the public Slack workspace by adding a welcome channel that shares introductory information and a help/questions channel for users to direct their questions. Simultaneously, we promoted user engagement in public channels. The public OpenSpace Support Slack now supports 884 members, with an average of 51 members actively participating each day.



Google Group (https://groups.google.com/g/openspace-isi and https://groups.google.com/g/openspaceproject) Two Google groups were created in Year Eight to support our funded ISI partners and the larger OpenSpace community. These

channels aim to improve communication among our stakeholders that do not use Slack (our primary communication channel).

Email Newsletter: Our newsletter reached an audience of 418 subscribers, encompassing ISI professionals, SMEs, and the public. This year, as other communication avenues gained traction, we transitioned to a quarterly release schedule.

OpenSpace Social Media Platforms

Facebook (@OpenSpaceVisualization): In Year Eight, OpenSpace Facebook followers increased to 942. The account reached 840 unique accounts and received 495 profile visits, up 79% compared to Year Seven.

Instagram (@openspaceproj): The OpenSpace Instagram account continued to grow and expand over the past year. In Year Eight, our followers increased to 2,296 and we received more than 1,300 profile visits. The 6 content-focused videos garnered 6,641 views to date and all content posted in Year Eight had a cumulative reach of 7,460.

LinkedIn (@OpenSpace): In June 2023, the project team created a LinkedIn page to highlight conference activities and employment and internship opportunities. In the last four months, the page has received 267 page views and 181 followers.

Twitch (@OpenSpaceProj): This year, the team began experimenting with Twitch livestreams. The OpenSpace account currently has 9 followers and our only broadcast was a casual overview of new eclipse features. We hope to continue experimenting with this platform in Year Nine to reach a new audience of gamers and developers who frequent the platform.

X (@openspaceproj): Our followers grew to 1,103 and the account received 34,700 impressions, a 179% increase compared to Year Seven.

YouTube (www.youtube.com/c/OpenSpaceSoftware): This year, the OpenSpace YouTube channel saw over 389,716 impressions, 25,230 views, and over 1,000 watch hours. This does not include the AMNH flagship or other partner YouTube channels. Our total subscribers increased to 3,216. US IP addresses made up approximately 20% of viewers and India was the next frequent country with 6% of viewers.

Press Coverage

Visualizations from OpenSpace were featured in several news articles highlighting the discovery of 2022 SF289, the 600-foot-long asteroid discovered by ATLAS, an asteroid impact early warning system developed by the University of Hawaii and funded by NASA. Articles were

published in USA Today[4], New York Post[5], GeekWire[6], and the Planetary Society.[7] Additionally, OpenSpace was included in an Astrobites feature on climate communication in education spaces.[8]

Conferences, Colloquia, and Symposium

American Geophysical Union (AGU) (December 11-15): Multiple sessions at the 2022 AGU Fall Meeting included OpenSpace content. PI Ro Kinzler presented "Unlocking the Universe: OpenSpace Software at Informal Science Institutions" and Co-I Carter Emmart presented "Earth in Context: Exploring Comparative Planetology Using OpenSpace." Emmart also presented "Interactive Comparative Planetology using OpenSpace" on the NASA Hyperwall. An additional program at the Adler Planetarium demonstrated a variety of OpenSpace content including heliophysics, the Artemis mission, the SkyBrowser WorldWide Telescope integration, and more in a program designed for AGU attendees. In total, approximately 415 professionals engaged with OpenSpace at AGU.

American Astronomical Society (AAS) (January 8-12): Co-Is Rachel Smith and Ka Chun Yu presented an astrobiology/exoplanet-themed program for the NASA Hyperwall in the exhibit hall for approximately 30 conference attendees. Co-I Carter Emmart presented "Exploring Heliophysics Through Interaction" and "Showing Webb Operations and Observations" on the NASA Hyperwall for 48 conference attendees. Emmart also participated in the SciAct pre-conference workshop hosted by the Universe of Learning.

APS Conferences for Undergraduate Women in Physics (CUWiP) (January 20-22, 2023: California Academy of Science's Jacque Benitez presented on science visualization and science education philosophy including using OpenSpace as a tool.

Glue-con (February 16-17, 2023): Developer Micah Acinapura presented OpenSpace to 75 conference attendees.

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[4] Natalie Neysa Alund, *'Potentially hazardous', 600-foot asteroid seen by scanner poses no immediate risk to Earth, scientists say,* USA Today (August 2, 2023). https://www.usatoday.com/story/news/nation/2023/08/02/six-hundred-foot-asteroid-potentially-hazardous-spotted/70512924007/

[5] Meghan Powers, *'Potentially hazardous asteroid' detected with new algorithm,* New York Post (August 3, 2023) .https://nypost.com/2023/08/03/potentially-hazardous-asteroid-detected-with-new-algorithm/

[6] Alan Boyle, *Scientists successfully test algorithm for identifying potentially hazardous asteroids*, GeekWire (July 31, 2023). https://www.geekwire.com/2023/heliolinc3d-algorithm-asteroid-dirac/

[7] Rae Paoletta, *A new algorithm finds its first potentially hazardous asteroid,* Planetary Society (August 30, 2023). https://www.planetary.org/planetary-radio/2023-algorithm-potentially-hazardous-asteroid

[8] Roel Lefever, *Earth Week x Astrobites 2023: "Climate Communication in Education Spaces" Recap*, Astrobites (April 21, 2023). https://astrobites.org/2023/04/21/earth-week-x-astrobites-2023-climate-communication-in-education-spaces-recap/

54th Lunar and Planetary Science Conference (LPSC) (March 13–17, 2023): Dr. Marina Gemma presented a poster “Planetary Science in OpenSpace: All-in-One Visualization” and engaged approximately 100 scientists.

Swiss Astronomical Society Annual Meeting (April 1, 2023): OpenSpace user Erich Strehler was invited to speak on his mobile planetarium production using OpenSpace; over 200 people attended.

Beijing International Film Festival / Committee for Special Effect Theaters Annual Conference (April 23, 2023): Mike Smail discussed OpenSpace as part of a talk on educational programs at the Adler Planetarium. The presentation was aimed at highlighting educational opportunities for Chinese science museums with dome theaters and engaged 75 professional attendees.

American Alliance of Museums (AAM) (May 19-22, 2023): The Denver Museum of Nature & Science hosted an evening party as part of the AAM annual conference. Three programs using OpenSpace were presented in the Gates Planetarium for conference attendees.

Stars for All U.S. Regional Planetarium Conference (June 20-24, 2023): The OpenSpace team led a pre-conference training workshop for 21 planetarium professionals. An exhibit booth during the conference also engaged 100 people. Sessions presented by Paulette Epstein from Michigan Science Center, Ellen Torres Thompson from Lawrence Hall of Science, and MJ West from Minnesota State University at Moorhead, included content using OpenSpace.

PUNCH Science Meeting (July 6-7): Developer Micah Acinapura presented NASA CCMC datasets in OpenSpace for 40 scientists.

Gordon Research Conference: Visualization in Science and Education (July 16 - 21, 2023): OpenSpace presented a poster on collaborative work with GMRI. “Putting Climate Change in the Planetarium” discussed the planetarium program at the Middle Atlantic Planetarium Conference in Year Seven that brought local climate change stories to the dome. James Hedberg presented a poster on using OpenSpace for social media content generation. Co-I Carter Emmart also presented “Open Space: A 3D Atlas of the Universe.”

SIGGRAPH (August 6-10, 2023): Co-Is Carter Emmart and Dr. Alexander Bock presented two interactive sessions at the Electronic Theater Pre-Show event to about 4,000 conference attendees.

Live Interactive Planetarium Symposium (LIPS) (September 12-14): The Michigan Science Center hosted the Live Interactive Planetarium Symposium and presented OpenSpace to 46 planetarium professionals.

dotAstronomy (October 2-5): Dr. Jackie Faherty and Micah Acinapura presented OpenSpace to 50 scientists, and 35 attended a special presentation in the Hayden Planetarium.

Geological Society of America (GSA) Annual Meeting (October 15-18): AMNH Co-I Dr. Denton Ebel presented "OpenSpace: Visual Learning For Planetary and Solar System Exploration" in an oral session for approximately 12 scientists. Ebel and Dr. Rachel Smith also presented OpenSpace on the NASA Hyperwall in the exhibition space, reaching an additional 200 scientists.

Large-Scale Structures Originating from the Sun (LASSOS) 2023 Workshop (October 16-18, 2023): CCMC Developer Elon Olsson presented the capabilities and opportunities of OpenSpace for LASSOS at the 2023 annual workshop.

Academic Publications

M. Brossier, R. Skånberg, L. Besançon, M. Linares, T. Isenberg, A. Ynnerman, A. Bock (2023), *Moliverse: Contextually embedding the microcosm into the universe,* Computers, Computers & Graphics, Volume 112, 2023, Pages 22-30, ISSN 0097-8493.

Conference Abstracts

C. Emmart, R. Kinzler, M. Acinapura, M. Villa, V. Trakinski (2022), *Earth in Context: Exploring Comparative Planetology Using OpenSpace*, AGU Fall Meeting 2002, id. ED13B-03.

B. Miller, J. Keller, M. Acinapura, C. Emmart (2022), *Tool and Asset Development for Occultation Visualization within OpenSpace Planetarium Software,* AGU Fall Meeting 2022, id. ED52C-0185.

J. Faherty, D. Desir, A. Meisner, A. Schneider, M. Kuchner, J. Kirkpatrick, D. Caselden (2023), *Discovery, Astrovisualization and Public Engagement through Citizen Science,* American Astronomical Society Meeting #241, id. 140.04. Bulletin of the American Astronomical Society, Vol. 55, No. 2.

M. E., Gemma, M. Villa, C. Emmart, V. Trakinski, R. L. Smith, M. Acinapura, B. Abbott, J. Faherty, D. S. Ebel, R. Kinzler, *Planetary Science in OpenSpace: All-in-One Visualization,* 54th Lunar and Planetary Science Conference, LPI Contribution No. 2806, id.2596.

R. Kinzler, C. Emmart, A. Bock, Y. Selling, E. Lindgren, M. Ejdbo, M. Acinapura, M. Villa, V. Trakinski (2022), *WorldWide Telescope in OpenSpace: Placing Exploration in Context,* AGU Fall Meeting 2022, id. ED55B-06.

R. Kinzler, A. Johnston, R. Smith, C. Sumners, R. Wyatt, K. Yu, M. Villa, M. Acinapura, C. Emmart, V. Trakinski, A. Bock, M. Mac Low, D.S. Ebel (2022), *Unlocking the Universe: OpenSpace Software at Informal Science Institutions,* AGU Fall Meeting 2022, id. ED35B-02.

Graduate Theses

OpenSpace continues to be a focus of master student thesis projects 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 Eight:

- Elfström, R. *Visualising earth's magnetosphere interacting with the solar wind using numerical methods and semi-transparent surfaces* (Bachelor's Thesis, Umeå University, Umeå, Sweden). 2022.
- Engberg, A. *Investigating the Chemical Cartography of the Galaxy Through Visualization* (Master's Thesis, American Museum of Natural History). 2023.[9]
- Lindquist, V. and Molin, J. *Astronomy Software Integration with OpenSpace in Distributed Systems* (Master's Thesis, University of Utah Scientific Computing and Imaging Institute). 2023.
- Nilsson, M. and Riddell, R. Using Point Cloud Interpolation to Present a Cosmic View of Life (Master's Thesis, American Museum of Natural History). 2023.[10]

Cross-Collaboration with Science Activation Awards

We have had ongoing conversations, development activities, and public programming in collaboration with other SciAct projects.

Cosmic Storytelling with NASA Data: This year, we expanded our existing partnership with the CosmicDS team, working together to integrate data from Glue and AAS WorldWide Telescope into OpenSpace. We plan to continue this collaborative effort into Year Nine.

Gulf of Maine Research Institute (GMRI): The OpenSpace team collaborated with GMRI on a poster presentation at the 2023 Gordon Research Conference. The poster shared the team's strategies and lessons learned from working together to present climate change stories in the planetarium.

Smoky Mountains STEM Collaborative: The OpenSpace team provided support to SMSC staff who developed programming using the software, including a live OpenSpace demonstration.

STEM Enhancement in Earth Science (SEES): The OpenSpace team planned to support SEES mentors in using OpenSpace, however this effort was postponed until further documentation is available.

[9] Thesis successfully defended, online publication to come.
[10] Thesis successfully defended, online publication to come.

Science Through Shadows: In Year Eight, developer Micah Acinapura supported intern work at Fiske Planetarium to implement occultations into OpenSpace. This work has been implemented into the most recent release of OpenSpace software.

Cross-Collaboration with NASA Infrastructure Projects

Museum & Informal Education Alliance: Jeff Nee has been a regular attendee to OpenSpace monthlies where he provides regular feedback and makes requests from developers; OpenSpace supported his efforts to generate media with OpenSpace related to the Heliophysics Big Year.

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 met with NASA Treks to discuss productive ways to collaborate and create a pipeline to share new data products. We are continuing to focus on bringing planetary body surface maps from Treks into OpenSpace.

Solar System Ambassadors: The OpenSpace team supported multiple Solar System Ambassadors to use the software for outreach presentations.

NASA Science Visualization Studio: On October 11th and 12th, Mark Subbarao and Eleni Kostis from NASA SVS visited AMNH and met with staff to discuss several avenues for collaboration. Ideas that rose to the top include creating an SVS profile in OpenSpace and engaging Masters students and/or hiring staff to develop a pipeline to bring continuously updated data from SVS's new Earth Information Center directly into OpenSpace.

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 Eight:

- NASA SCoPE: OpenSpace participated in four mission liaison workshops hosted by NASA SCoPE. Additionally, OpenSpace collaborated with two early-career scientists to submit seed grants. Dr. Mark Popinchalk's spring 2023 proposal "Spinning Stars in OpenSpace" was funded to visualize data from the NASA Transiting Exoplanet Space Satellite (TESS) in OpenSpace. Additionally, Sarah Treadwell's fall 2023 proposal "Searching for Origins of Life: The Lost City and Icy Worlds" was selected to visualize data from Lost City Hydrothermal Field in OpenSpace.
- NASA Astrobiology Guild: OpenSpace developer Micah Acinapura and Co-I Rachel Smith presented an OpenSpace demonstration for the June 2023 Astrobiology Guild meeting.

As a result of this presentation, Sarah Treadwell, mentioned above, reached out to the project team to brainstorm a possible collaboration which resulted in a successful SCoPE-funded project.

- Planetary ReaCH: The OpenSpace team hosted a Culturally Inclusive Planetary Engagement Workshop at AMNH.
- Digital Learning Week: OpenSpace participated in SciAct's first Digital Learning Week in May 2023 including providing two livestream field trips that took students from their classrooms on a tour of the cosmos and a visit to JWST.

NASA-Funded SMEs in Year Eight

In Year Eight, 25 NASA-funded Subject Matter Experts contributed to and/or used OpenSpace, including eight new SMEs (indicated with an *asterisk). This brings the total number of unique SMEs to 96. The table below describes how each SME utilized OpenSpace; in some instances, SMEs used the software in multiple ways.

Subject Matter Expert	Public Program	Formal Education	For Research	Contributed Data or Code
*Dr. Jennifer Blank (Senior Researcher, NASA Ames)	X			
Dr. Harold Connolly (Mission Sample Scientist, NASA OSIRIS-REx and JAXA Hayabusa II)	X			
Dr. Darren De Zeeuw (Research Associate, NASA Goddard Space Flight Center Community Coordinated Modeling Center)				X
Dr. Denton Ebel (Co-I, AMNH)	X			
Dr. Mostafa El Alaoui (Research Associate, NASA Goddard Space Flight Center Community Coordinated Modeling Center)				X
Dr. Jackie Faherty (Sr. Scientist and Sr. Education Manager, Departments of Astrophysics and Education, AMNH)	X	X	X	
*Dr. Or Gaur (Associate Professor of Astrophysics, University of Portsmouth Institute of Cosmology and Gravitation)	X			

Dr. Marina Gemma (Planetary Scientist, Department of Earth and Planetary Sciences, AMNH)	X			
Dr. Martha Gilmore (Planetary Geologist, Wesleyan University)	X			
*Dr. Thomas Greene (Astrophysicist; Director, Ames Center for Exoplanet Studies)	X			
Dr. Alyssa Goodman (PI, Harvard University)			X	X
*Dr. Pierre Haenecour (Assistant Professor, University of Arizona Lunar & Planetary Lab)	X			
Dr. John Keller (PI, ROSES, University of Colorado Boulder)		X		X
Dr. Masha M. Kuznetsova (Director, NASA GSFC CCMC)				X
Dr. Leila Mays (Deputy Director, NASA GSFC CCMC)	X			X
*Dr. Stefanie N Milam (JWST Deputy Project Scientist for Planetary Science)	X			
Jeff Nee (Education Specialist, NASA Jet Propulsion Laboratory)				X
*Theo O'Neill (Research Scientist, Harvard University)			X	
Dr. Bob Pappalardo (Project Scientist, NASA Jet Propulsion Laboratory)	X			
*Anjani Polit (Mission Implementation Systems Engineer, OSIRIS-REx)	X			
Dr. Mark Popinchalk (Educator, AMNH)	X		X	
Dr. Lutz Rastaetter (Research Assistant, Fields And Particles, NASA GSFC CCMC)				X
Dr. Rachel Smith (Co-I, NCMNS)	X	X		
*Dr. Samantha K. Trumbo (NASA Europa Clipper Science Team)	X			
Dr. Catherine Zucker (NHFP Hubble Fellow, Space Telescope Science Institute)			X	X

Other SMEs in Year Eight

An additional (non-NASA) 18 SMEs also used OpenSpace as a tool for exploring and communicating space science data for a broad audience, including 10 new SMEs (indicated with an *asterisk). This brings the total of unique (non-NASA) SMEs to 48.

Subject Matter Expert	Public Program	Formal Education	For Research	Contributed data or code
*Dr. Emma Bunce (Director, Institute for Space at the University of Leicester and JUICE mission)	X			
Dr. Dan Caton (Professor of Physics and Astronomy, Director of Observatories, Appalachian State University)	X	X		
*Dr. Saavik Ford (Professor; Research Associate, Department of Astrophysics, BMCC CUNY, AMNH)	X			
Dr. James Hedberg (Director, CCNY Planetarium, City College of New York)	X	X		X
Dr. Ed Lu (Executive Director, the Asteroid Institute, B612 Foundation)	X		X	X
Dr. Bob Raynolds (Research Associate, DMNS)	X			
Allan Posner (Astrodynamicist, the Asteroid Institute, B612 Foundation)				X
Dr. Alex Ji (Assistant Professor, Astronomy and Astrophysics, University of Chicago)				X
Trent Hare (Cartographer, USGS Astrogeology Science Center)				X
Lucian Plesea (Web GIS developer, ESRI)				X
*Dr. Patricia H. Reiff (Professor, Department of Physics and Astronomy, Rice Space Institute, Rice University)	X			

*Dr. Barry McKernan (Professor; Research Associate, Department of Astrophysics, BMCC CUNY, AMNH)	X			
*Dr. Joachim Moeyens (Research Software Engineer, University of Washington)			X	X
*Dr. Susan Clark (Assistant Professor of Physics, Stanford University)	X			
*Dr. Robert Jedicke (Professor of Astronomy, University of Hawaii)	X			
*Dr. Risa Wechsler (Director, Kavli Institute for Particle Physics and Cosmology)	X			
*Dr. Nia Imara (Assistant Professor, UC Santa Cruz)	X			
*Dr. Keith Hawkins (Galactic Archaeologist and Assistant Professor of Astronomy, University of Texas at Austin)	X			

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 Eight, HG&Co worked with the AMNH team to conduct four strands of evaluation activity: a survey to assess present and future OpenSpace uses at funded OpenSpace partners; a survey to assess software use and needs of known OpenSpace users outside the funded partners; a survey to assess Subject Matter Experts who have engaged with OpenSpace; and qualitative interviews with OpenSpace users to describe unique and representative case studies. *Appendix B* includes a summary of these activities along with full reports.

Top-Level Metric Projections

During the initial funding phase, OpenSpace's primary metric was the count of interactive NASA data "profiles" within the software. For Phase II, we shifted our focus to measure project growth by tracking the number of OpenSpace users. Our target is to attain 100 users by Year 10. As Year Eight concludes, the OpenSpace community counts 87 active users.

SciAct Alignment

The OpenSpace leadership team collaborated with the evaluator to align the project with the SciAct portfolio-level activities led by PRE. This collaboration ensured consistency with mid-level objectives and pinpointed which program indicators corresponded 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 the 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) In this report, it's highlighted that OpenSpace aims to enhance public involvement in NASA's scientific and engineering efforts through ISI initiatives for audiences of every age bracket. During Year Eight, OpenSpace was employed in 398+ programs and 9 exhibits to convey scientific and engineering principles, with 179 of these events being facilitated by the OpenSpace ISI Partner Network (funded under the NASA SciAct grant). This makes the

cumulative count of OpenSpace-driven programs 985. The programs and displays on-site engaged 879,857 individuals this year, culminating in a total on-site engagement of 2.5 million.

(1b, 1c) This year, online engagement continued to increase, encompassing views of live online sessions, recorded programs, and curated videos. In Year Eight, roughly 16.5 million individuals were reached online through OpenSpace, escalating the total online engagement to over 66 million. Moreover, through the OpenSpace website and its social media channels, the digital outreach further expanded by more than 497,000, elevating the overall digital footprint of OpenSpace owned content to exceed 5.9 million.

(1b, 1c, 3c) In Year Eight, the OpenSpace funded partners hosted 37 interns, spanning from high school to undergraduate levels, across diverse durations including multi-week and semester-long internships. These interns received mentorship in data visualization and code development. To date, 256 internships have utilized OpenSpace.

Total Activity, Years 1-8

	NASA SMEs	ISIs and other organizations	Programs	On-site reach[11]	Online reach[12]	Other online reach[13]
Y8	25[14]	87[15]	398	879,857	16,454,301	497,716
Y1-8 Total	**96**	**103**	**985**	**2,500,086**	**66,958,312**	**5,973,262**

VI. KNOWN FUTURE PLANS

In Year Nine, our aim is to expand our user community. We'll pinpoint and tackle obstacles that hinder or deter a diverse user base from adopting the software. Additionally, we plan to incorporate new data sets to offer a broader range of programs.

Software and Content Development Goals

Software and content development activities planned for Year Nine include:

- Implement accessible user interface recommendations
- Ancillary materials

[11] On-site reach includes programs and exhibition experiences on-site at funded and non-funded ISIs and other public institutions that share their metrics.
[12] Online reach includes views of online programs, recordings of these programs, and produced videos.
[13] Other online reach includes visits to the OpenSpace website, the reach of OpenSpace social media, and views of OpenSpace content.
[14] 8 of the NASA-affiliated SMEs are new to the project in Year Eight.
[15] 40 of the public institutions are new to the project in Year Eight. Of the 87 known users, 60 are US based.

    - Documentation
    - Program guides
    - Training videos
- Continue development of *OpenSpace Cloud*

ISI Partner Network Goals

ISI Partner Network programs planned for Year Nine include:

- Frontiers Lecture with Dr. Alyssa Goodman, Dr. Jackie Faherty, and Dr. Catherine Zucker (December 2023, AMNH)
- Frontiers Lecture: Parker Solar Probe with Dr. Kelly Korreck (January 2024, AMNH)
- Astronomy Days (January 2024, NCMNS)

Additional goals for the ISI Partner Network include:

- Hosting OpenSpace trainings at partner sites
- Consulting accessibility experts to improve public programs
- Collaborate to develop effective OpenSpace programs about 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 Nine:

- 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 2023) in three sessions:
    - “ED34A: Amazing Technologies and Capabilities That Contribute to STEAM II Oral”
    - “SY11D: Data Visualization as a Communication Tool in Earth and Space Science eLightning”
    - “U41B: 2023 and 2024 Solar Eclipses: Engaging Your Communities with Science Experiments and Education Activities II Poster”
- Develop dissemination strategy pertaining to the following conferences:
    - AAS (January 2024)
    - LPSC (March 2024)
    - Elumenati GeoDome Network Meeting (May 2024)
    - AAS (June 2024)
    - International Planetarium Society Conference (July 2024)
    - ASTC (October 2024)
    - GSA (October 2024)
    - AGU (December 2024)

VII. Appendix A: OpenSpace Profiles

These profiles are available for every OpenSpace user and do not include any custom profiles created by users.

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.

Artemis: This profile visualizes NASA’s Artemis 1 mission. The profile starts focusing on the Artemis I Orion spacecraft as it approaches the Moon on Monday, November 21, 2022. An updated Mission user interface allows the user to jump to relevant mission milestones.

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.

Eclipses: This profile includes assets to support telling stories about eclipses. The profile starts focused on Earth with umbral and penumbral shadow cones visible. Additional information on eclipses and an interactive timeline of eclipses in the last century and for the next century are available in the Missions user interface.

Empty: This profile does not contain any graphics and is to be used to visualize the user's own 3D models or datasets.

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.

Night Sky: This profile visualizes the night sky from Earth. The profile starts on Earth, with a camera view of the horizon and night sky. Users can adjust the date and time settings to view the sunrise and sunset.

Offline: This profile includes low resolution maps of planets that do not require internet connection.

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 Eight Summary Evaluation Report

OpenSpace Year Eight: Subject Matter Expert (SME) Survey Report

OpenSpace Year Eight: Funded Partner Survey Report OpenSpace Year Eight: Network Survey Report

OpenSpace Year Eight: User Case Studies Booklet

2023 SciAct 2.0

OpenSpace Evaluation Report

Background and Overview of Studies

This overview report covers the highlights of evaluation findings for the OpenSpace project for Year 8 as of October 2023. There are 4 reports altogether for this year, this overview and three separate reports for different audiences. Highlights of all three other reports are included within this document.

Our evaluation strategy for OpenSpace is based on our overarching questions, designed to examine different audiences and types of impact, as well as to align with SciAct's Mid-level Objectives (MLOs). The overarching evaluation questions and corresponding MLOs for the OpenSpace project are:

Formative Evaluation Questions

1. Do the trainings and workshops address the needs of potential users?
2. Is the network effectively supported? Is it growing?
3. What supports and processes are needed to make the internships more impactful?
4. How can the team make the OpenSpace Project more accessible?
5. Is there evidence of peer-to-peer support and collaboration?
6.

Summative Evaluation Questions

1. Has the use of OpenSpace increased?
2. To what extent does the OpenSpace software allow for a diversity of programming?
3. Do interns and other student participants have authentic interactions with NASA SMD assets?
4. Do interns and other student participants have gains in 21st Century skills?
5. Do NASA SMEs and other scientists show increased familiarity, interest in, and use of OpenSpace?
6. Does using OpenSpace increase interest and engagement in SMD content and STEM learning?
7. Does OpenSpace increase the access to, use of space-based scientific visualizations by ISIs and others?

For the Year 8 OpenSpace evaluation, we undertook different methodologies and focused on different audiences than in previous years. In previous years, our evaluations mostly focused on assessing the impact of OpenSpace public programs, examining the internship programs at our partner sites to see how these programs meet our goals, and assessing the health of the OpenSpace collaboration, including team alignment, coordination, and investment. These are all worthy topics, and meet specific goals. Both the OpenSpace public programs and the internship programs consistently rate programs of high quality and demonstrate impact year after year. As such, we moved our focus this year to other components of the OpenSpace activities, including aspects of the project aligned with different mid-level objectives. Specifically, we were interested how the ways varying audiences use OpenSpace continue to grow.

Formative Evaluation Questions	Audiences	OpenSpace Specific Outcomes
#2 Is the network effectively supported? Is it growing?	Informal Science Institutions, SMEs, other network members & potential members	Broaden dissemination, adoption, and implementation of OpenSpace among ISIs MLO **1B 1C**
#5 Is there evidence of peer-to-peer support and collaboration?	Entire OpenSpace team Informal Science Institutions, SMEs, other network members & potential members	Broaden dissemination, adoption, and implementation of OpenSpace among ISIs Continue to feed the pipeline with visualized content MLO **1B 1C**

Summative Evaluation Questions	Audiences	OpenSpace Specific Outcomes
#2 To what extent does the OpenSpace software allow for a diversity of programming?	Informal Science Institutions, SMEs, other network members & potential members	Broaden dissemination, adoption, and implementation of OpenSpace among ISIs Increased use of OpenSpace by ISIs, NASA SMEs, and SciAct projects MLO **1B**
#5 Do NASA SMEs and other scientists show increased familiarity, interest in, and use of OpenSpace?	SMEs & other SciAct Projects	Increased participation of NASA SMEs in research and public outreach Enhance collaborations with SciAct projects and NASA SMEs MLO **1B**

Each of these questions had limited evaluation data available to date, making them the focal points for this year's assessment.

To gauge the expansion of the network and the diversity of usage, we built upon last year's evaluation with input from subject matter experts. Growing the OpenSpace user community, with increased participation from scientists and other subject matter experts (SMEs), enhances the quality and sophistication of data visualizations. In the 2022 OpenSpace evaluation, we conducted interviews with SMEs to gain insights into their use of OpenSpace, the benefits derived from its use, any obstacles encountered, and their requests for future updates. These interviews delved deeply into how, under what circumstances, and for what specific purposes SMEs utilize OpenSpace. As one SME expressed, "OpenSpace is excellent for both exploring and communicating data."

The diversity of uses we discovered in these interviews inspired our team to better document the various ways people employ OpenSpace across different audiences and contexts.

First, we administered a survey to Subject Matter Experts. Building on the previous year's survey, we formulated questions to categorize how SMEs currently utilize OpenSpace, their future plans for the platform, and their insights on its growth and open-source nature.

The second survey targeted the funded OpenSpace partners, comprising five informal education institutions: Adler Planetarium, American Museum of Natural History, California Academy of Sciences, Denver Museum of Nature and Science, and Houston Museum of Natural Science. This survey also explored their current usage of OpenSpace, future plans for the platform, ideas about its growth and open-source aspects, and inquiries related to integrating OpenSpace into the museums' activities.

The third survey was aimed at the broader network of unfunded OpenSpace users who have adopted the platform. Understanding how these individuals and institutions employ OpenSpace will enable the project team to strategize for continued growth.

Finally, we developed a booklet featuring Use Case examples of OpenSpace. Each example showcases a different way OpenSpace can be employed for diverse audiences. These examples span from interactive museum floor exhibits to a tool for SMEs to use in collaboration with colleagues and for outreach purposes.

Key Takeaway from these Evaluation Studies

The primary message from this year's studies focuses on the diverse applications of OpenSpace. These use cases vary across different types of institutions, in various contexts, with diverse audiences, and with different objectives. The most common goals include:

- → Scientists conducting research,
- → Scientists engaging in discussions about scientific research with peers,
- → Scientists presenting their research through outreach opportunities,
- → Public programs using OpenSpace as a tool for explaining Earth and Space Sciences,
- → Utilizing OpenSpace as an interactive exhibit on the floor, with various modes of hands-on engagement.

Users of OpenSpace across all these contexts emphasized how the software platform enables them to work with visualizations in ways they cannot achieve otherwise. The open-source nature of the project is instrumental in fostering support and expanding the OpenSpace user community. Collectively, these studies demonstrate that OpenSpace successfully achieves its goal of facilitating a diverse range of programming for a wide array of users, including subject matter experts.

OpenSpace Year 8:
Subject Matter Expert (SME) Evaluation Report

October 30, 2023

VISITOR-CENTERED PLANNING, STRATEGY, AND EVALUATION

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OpenSpace Year 8:
Subject Matter Expert (SME) Evaluation Report

October 30, 2023

Summary of Findings

The Subject Matter Experts (SMEs) showed engagement and interest in OpenSpace's future in this study. We see a variety of current uses and exciting predictions of future uses. SMEs, inspired by the flexibility and uniqueness of the software, recommend ways to increase awareness and use of the program to support it in the future.

- Almost half of respondents have visualized new data or created new assets for OpenSpace.
- One third of respondents intend to increase their use of OpenSpace in the upcoming year, while the remaining two-thirds intend to use OpenSpace the same amount in upcoming years.
- SMEs use OpenSpace for presenting, mentoring & researching, and enjoy collaborating with other users.
- Almost all respondents said that being open-source was important.
- Respondents were very likely to be or become part of OpenSpace's open-source community, and only slightly less likely to contribute to its development.

Study Overview and Goals

Subject Matter Experts (SMEs) are a critical audience for NASA's Science Activation Program as they share expertise with communities, as mentors, as advisors, and as presenters at workshops and conferences.[1] Adoption of the software by SMEs can amplify the impact on the general public, the primary audience for OpenSpace. The team, therefore, wants to expand its evaluation focus on SMEs in the future, while maintaining its focus on the general public.

HG&Co and the OpenSpace team decided to enhance our understanding of how SMEs are using OpenSpace with a survey, similar to the survey used for Funded Partners, that explores the following goals:

→ The ways in which SMEs are using OpenSpace now,
→ SMEs' intended future uses,

[1] https://science.nasa.gov/learn/sme-map/

→ SMEs' connections to the project's open-source community and what they think it needs for growth.

This approach achieved the year's evaluation goal of exploring a breadth of uses to demonstrate the flexibility of OpenSpace and the creativity around it.

Methods

In April through June of 2023, a survey was sent to all of the SMEs the project is aware of to have interacted with OpenSpace since Year 1, 2016 (a total of 88 NASA-funded SMEs and 38 other SMEs). In earlier years, SMEs were invited as presenters. Over time, SMEs have used OpenSpace in a variety of ways as a tool for outreach, research, and collaboration. Nineteen SMEs completed a 25-question online survey, which was a mix of open- and closed-ended questions.[2] Respondents were offered an OpenSpace t-shirt as an incentive.

Sample

These SMEs cited institutional affiliations that were mostly NASA-funded, -adjacent or NASA itself. These were centers for research, flight, or observation (n=10).

B612 Asteroid Institute
Caltech-IPAC [Science & Data Center for Astrophysics & Planetary Sciences]
Chandra X-ray Observatory/ Smithsonian Astrophysical Observatory
NASA
NASA CCMC [Community Coordinated Modeling Center]
NASA GISS [Goddard Institute for Space Studies]
NASA GSFC [Goddard Space Flight Center]- *Two respondents cited this institution.*
NASA JPL [Jet Propulsion Laboratory]
NASA JSC/ SRAG [Johnson Space Center / Space Radiation Analysis Group]

In addition to the institutions above that are housed at research centers, seven respondents mentioned being connected to universities and colleges. Those are:

City College of New York
City University of New York- *Two respondents cited this institution.*
Columbia University
Harvard University
University of Colorado, Boulder
University of Vienna, Austria

[2] One respondent also answered the Funded Partner survey.

Museums were mentioned three times: the American Museum of Natural History from two different respondents, and the North Carolina Museum of Natural Science from one. Lastly, one SME listed themselves as a "freelancer."

The roles that the nineteen respondents reported are listed here exactly as they were written, as each is unique with varying degrees of nuance:

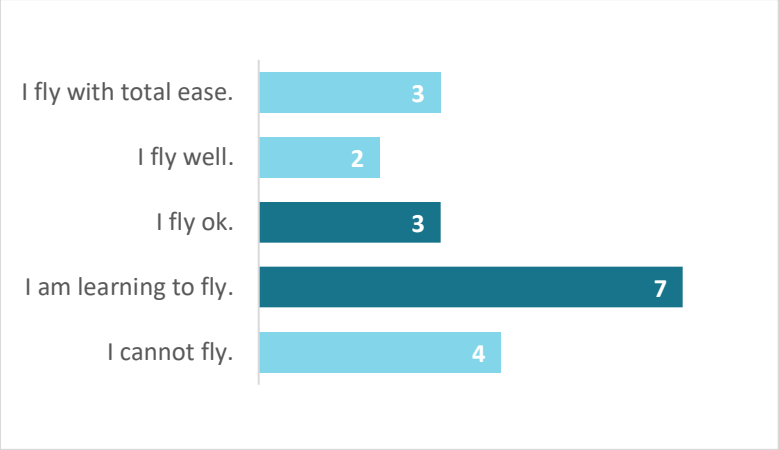
Associate Professor & Research Associate
Astrodynamisist / Tester
Astrophysics student
Education Specialist
Freelance
Full Professor
Graduate Student/Planetarium Presenter
Head, Astronomy & Astrophysics Research Lab/Curator, Meteorites
Physics Faculty / Planetarium Director
Professor
Program and project manager
Program Scientist
Research Scientist
Scientist
Space Weather Physicist
Virtual Reality developer
Visualization Scientist
Visualization, Modeling, Science
Viz scientist

Learning Methods and Flying Ability

These respondents mostly learned how to use OpenSpace from someone on the project team (12 of 19), with many also learning from colleagues (n=7) or teaching themselves (n=5). A few mentioned not having used OpenSpace extensively (n=2) or, on the other hand, one is a funded partner who learned how to fly, or operate the software, by being part of the OpenSpace project team for the past eight years and now teaches other how to fly.

In this sample of nineteen SMEs, the majority (n=15) have some ability to fly in OpenSpace. There is not a smooth curve in these results: a few fly with ease (n=3), the plurality is learning to fly (n=7), and about one-fifth of respondents cannot fly (n=4).

Over Half the Respondents have a Small Ability to Fly (n=19)



When asked if they would want to learn or continue to learn how to fly, over half (11 of 19) said that was either *somewhat likely* (n=6) or *highly likely* (n=5). Many explained that improving flying skills was dependent on their work responsibilities or lighter weight versions of the software.

> *Because it's DA BEST! Really, it makes the brain work in ways they cannot in 2D, or lame 3D visualizations.*

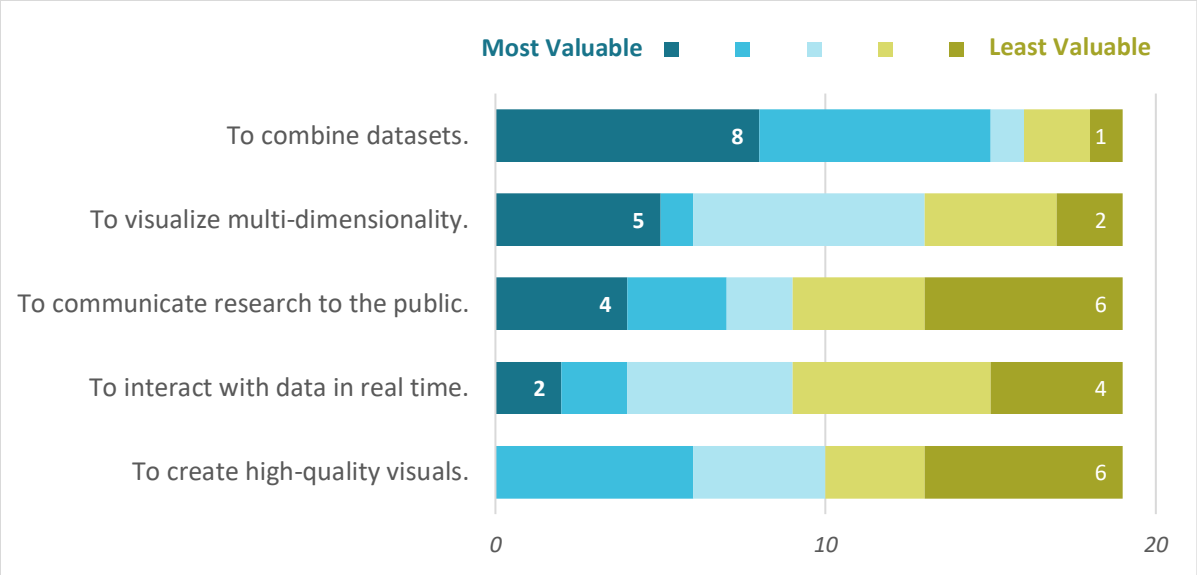
> *I want to learn how to navigate with ease for public shows.*

Only two respondents said learning to fly better was unlikely.

Current SME Uses for OpenSpace

We asked the respondents what they valued most about OpenSpace and provided the following options to rank on a scale from one (least valuable) to five (most valuable). We see a clear indication of what is most valuable: *to combine datasets* and *visualize multi-dimensionality* is of highest value, with *high quality visuals* ranked as having moderate value across the board.

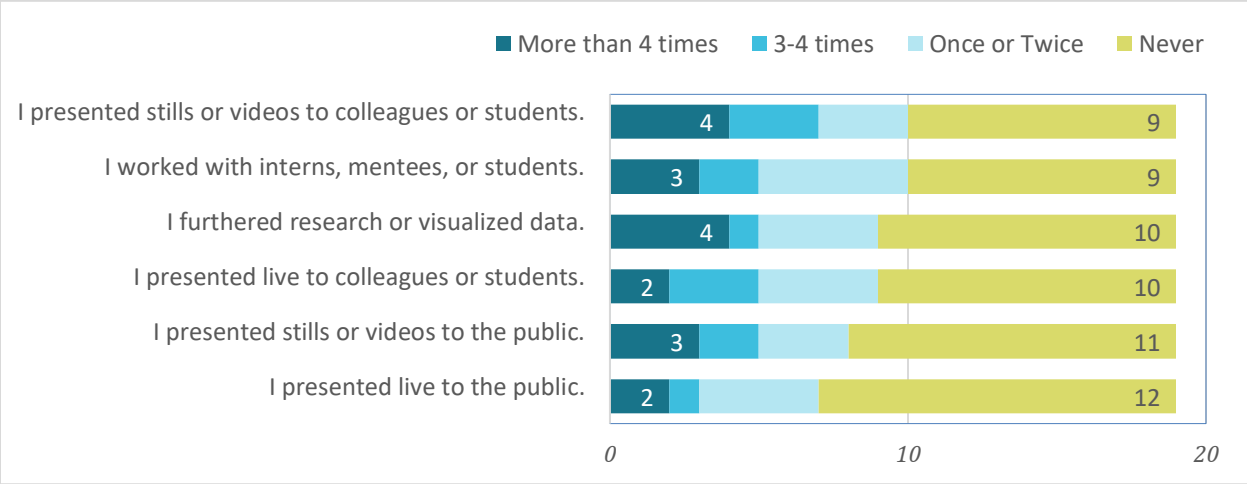
SMEs Highly Value OpenSpace's Ability to Combine Datasets & Visualize Multi-Dimensionality (n=19) *



*Answers do not add up to sample size because respondents could select multiple answers.

SME respondents identified the types of activities for which they used OpenSpace over the past twelve months, noting the frequency for each activity. In the stacked graph below, the blues represent those who have used OpenSpace in the past year, and the green is those who have not.

Around Half of SMEs Use OpenSpace for Presenting, Mentoring & Researching (n=19)



A little more than half (10 of 19) of respondents said that they *present stills or videos to colleagues or students,* and/or *work with interns, mentees or students.* Presenting live to the public was done with the least frequency for this group of SMEs.

A Variety of Interesting Uses

To further understand how SMEs are using OpenSpace, we asked the respondents about the most interesting thing they did with the software in the past year. Most of the nineteen (n=11) mentioned their most interesting experience including **working on presentations that would be presented to the public** in some way:

> *Created new exhibits with user interface where they can select short videos "on demand", made with OpenSpace. These kiosks have 4 different themes and are very popular with visitors.*
>
> *I helped with the Bastille Day CME visualization and presentation for the American Museum of Natural History.*
>
> *I viewed stills & videos on social media and coordinated public outreach presentations that used OpenSpace.*
>
> *A bit more than 12 months ago, but I rendered out a flight across the lunar terrain for a planetarium show.*

Others (4 of 19) spoke about processes of **collaboration** and co-working being their most interesting moments with OpenSpace:

> *Work with OpenSpace project personnel to promote and explore collaboration opportunities.*
>
> *I benefitted from the work of my excellent collaborators, that used Open Space to produce fantastic visualization material for papers and talks.*
>
> *Sharing my expertise with the development team was a fantastic experience.*

A few SME respondents felt that OpenSpace for their **research** was the most interesting use, one noting that it was over a year prior to the survey but still wanting to include it.

> *Well, really I had worked with OpenSpace more than 12 months ago (i.e. a few years ago), so I'm speaking regarding that :). At that time, we were considering using it to help us visual space in VR for visualizing the Gaia mission, but also potentially for other projects like showing planetary magnetic fields, etc.*
>
> *Orbit projections / visibility for STEREO-B.*
>
> *Some archeoastro viz.*

New Assets Created by Nearly Half

We asked if respondents had ever visualized new data or created new assets for OpenSpace. Slightly under half (9 of 19) confirmed and described examples, though one respondent said that there were "too many" to name.

> *Added custom lunar flags model for my lunar flight.*
>
> *Numerous potentially hazardous asteroids*
>
> *I visualized additional local group galaxies.*
>
> *Kameleon datasets*
>
> *See MilkyWay3d.org*
>
> *Not myself, but I helped develop the model used for the Bastille Day CME visualization.*

SME Thoughts on OpenSpace being Open-Source

It is extremely important to the SMEs that OpenSpace is open-source software. **Almost all** respondents said that being open-source was *very important* (n=14) or *somewhat important* (n=4). Nobody ranked the quality as *unimportant*; one person was neutral. From the reasons given by fourteen of the respondents, the focus of customization rises to the top.

One SME who selected being open-source as *very important* explained that OpenSpace is unique in this way, and it has the potential to be a game changer.

> *It's the whole point/purpose of OpenSpace. There are plenty of commercial options. In fact, working more with commercial planetarium companies to better incorporate/utilize OpenSpace in their systems would benefit the entire field in so many ways.*

Being Open-Source Is Most Important for Its Allowance of Customization (n=14) *

7	Allows for customization and adaptability	• ***It could be an incredible tool for interacting with NASA data -- both scientific and operational mission data.*** • ***It's an inspiring tool! Anything that's in space can be added to and visualized in OpenSpace.*** • *To interoperate with other packages (e.g., glue, WWT)*

3	Is free and accessible to more users	• *To allow access by anyone that has a love for science and wants to further their knowledge or teach others themselves.* • *Open-source is very important for inclusion of all audiences, and also seems to engage the public more as they at least can know they can be a part of the project in some way.*
3	Benefits the field and science learning	• *To allow access by anyone that has a love for science and wants to further their knowledge or teach others themselves.* • *Open-source is very important for inclusion of all audiences, and also seems to engage the public more as they at least can know they can be a part of the project in some way.*
3	Makes OpenSpace generally inspiring and future-thinking	• *Open source is the way of the future*

*Answers do not add up to sample size because respondents could select multiple answers.

More than Half SMEs Want to Contribute to Open-Source Development

Slightly more than half of the respondents (11 of 19) said that they were interested in contributing to the open-source development of OpenSpace, either *somewhat* (n=7) or *highly interested* (n=4).

> *Want to learn as much as possible and keep up to date with any changes or improvements.*

SMEs interested in contributing mostly wanted to create new assets (n=4) or help code (n=2), but often mentioned nervousness about the time commitment.

> *I usually end up working more than I should. I wouldn't have much time to help with any coding, but I would be able to help integrate the radiation belt visualization if someone else on the team developed it.*

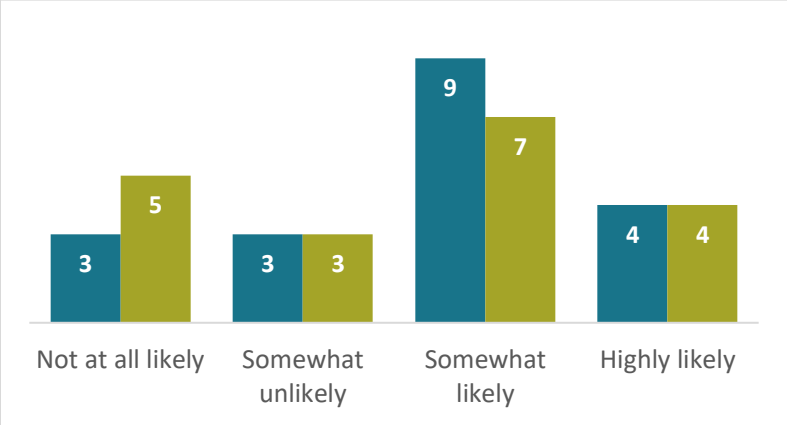
Another respondent had a holistic vision for their involvement:

> *Producing content for OpenSpace users and generally being a part of the community with testing, feedback, and help with beginners, as well as helping spread the word about OpenSpace.*

Of the little less than half of the respondents who were uninterested in contributing (n=8), two said they'd like to contribute but believe they do not believe that they have the skills to do so.

However, the respondents SMEs were more likely to be-- or become-- part of the open-source community than to contribute to development. This question was intentionally vague to allow respondents to interpret membership in the community, which may include anything from being an active member on OpenSpace Slack or GitHub, or just following newsletters. Over two-thirds (13 of 19) respondents said they were *somewhat* or *highly interested* to be in this community, compared to the eleven who wanted to support development.

Respondents More Likely to Be Part of the Open-Source Community than to Contribute to the Open-Source Community (n=19)



About half of those who are likely to be or join the open-source community is **time and funding dependent** (6 of 13).

> *Well, I tend to be pretty busy with NASA work, so it depends on my time.*

Others are interested, but they want to be part of the planning, so they know what's coming next.

> *Need more public-facing discussion about what's coming next and roadmaps.*

Of those who are not likely to join the open-source community (n=6), the main reason given is lack of skills (5 of 6).

A Variety of Outreach Activities Believed Most Valuable to Expand the Open-Source Community

SMEs volunteered ideas to support the growth of the open-source community. These reasons often overlap, but focusing on adapting new methods of outreach and intentionally expanding the community were the respondents' focuses.

Outreach and Advertisements Appeal to SMEs (n=19)

8	Suggested types of outreach
5	Expand community connections
3	More training
2	Make OpenSpace more user-friendly

Respondents seemed confident and excited to share ideas about how to increase forms of outreach or advertisements (n=8).

> *Try to develop more projects involving NASA missions :).*
>
> *Not exactly sure. Just make sure people know about OpenSpace and people who want to help develop it would help if they can.*
>
> *It's not like OpenSpace doesn't have the expertise/servers to host its own RocketChat or Mattermost community. I completely understand that Slack is valuable, though, so no judgment, [but cost] is something to keep in mind, especially as we want the community (and potentially the Slack costs) to grow.*

There were three comments that overlapped between the above section and expanding community connections.

> *Open space demos at astronomy workshops/conferences. Invest in helping researchers without good coding skills to use Open Space for talks and publishing, asking for citations to Open Space in return. I don't know of a competitor to Open Space that can fly in a 3D data set so beautifully. A render of a particular data set presented at a large conference can go a long way in promoting Open Space.*
>
> *Make decisions and the reasons for them more publicly and with more input from the community if you really want one. You're not Apple and can't just tell the users what features they want.*

But there were two ideas specific to building new community connections.

> *Participate in open source working groups and promote open-source standards.*
>
> *Being able to couple to Python open-source tools could widen the audience.*

A few respondents suggested more types of training specifically to support the open-source community (n=3).

> *Tutorials on how to add data sets? I think there is good documentation on how to use it, but not to modify.*
>
> *A lightweight version, more support, maybe workshops or something?*
>
> *More training webinars for good use cases/or more advertisement of them?*

Future Uses for OpenSpace

As SMEs had varying levels of knowledge about the contemporary states of OpenSpace, including aspects of new software updates, the quotes below include a wide range of hopes for some software capacities, from ones that already exist to complete pipedreams, as well as some well-informed predictions.

Frequency of Use For Majority Expected to Remain the Same

When asked about the frequency that they will use OpenSpace in the next twelve months, most respondents said it would stay the same (n=12), with several selecting an increase (n=6), and only one selecting a decrease.

Most SMEs expected usage to remain **consistent** (n=12), though current use varied from never to frequent.

> *Most of what we are doing with OpenSpace is working great and we plan on continuing use in the lab as well as exhibits, programs, and teaching.*

Those who spoke of increased use sometimes mentioned technological improvements that would encourage this change.

> *I'd like to increase, but more user-friendly offline mode, and more tutorials (even "rough" cuts of Micah showing people simply how to do to things) are needed.*
>
> *Basically, OpenSpace would have to function competitively on the Mac OS for me to really delve into using it for data viz projects. I don't have convenient access to Linux/Windows.*

Others spoke of institutional need being the only reason to increase.

There's a chance I could start using OpenSpace again :)... it depends on our needs for visualizing constellations of spacecraft orbiting various planets and moons.

Six SMEs answered that they will **increase their usage.**

It is a tool I will be using during my internship, and we will be working on coding for occultations. I aim to be involved in more planetarium shows at the Museum, and also may win a grant to teach OpenSpace to high school teachers.

I hope to finally learn to use OpenSpace and continue to increase my outreach activities.

Only one respondent said they will decrease the frequency of use, saying, "Faltering Mac support will likely mean I will use it less." Note that since this survey took place, access for Mac users has increased.

SMEs Looking Towards Different Uses in the Next Year and Beyond

SMEs were asked whether they will use OpenSpace differently than they have to date **in the upcoming twelve months.** The plurality of respondents (8 of 19) said that they would *probably* (n=5) or *definitely* (n=3) use the software differently. Their explanations included a variety of uses, including deepening current abilities, learning new abilities, and creating new assets.

I will use it more in depth to use as an operator, as well as practice coding to make changes for occultations not aligning with current coding.

I am planning a new use for OpenSpace to complement a new meteorite display.

I essentially made my own version of OpenSpace before I knew about OpenSpace. It was a visualization of spacecraft trajectories and Earth's radiation belts. I've always wanted to work with [my colleague] to integrate it into OpenSpace.

Here at NASA, we train certain Mission Control groups on space weather. I'd like to use OpenSpace as a tool for this training.

If I am awarded a grant to teach high school teachers about OpenSpace, that will be a new way of using it.

Become a user, to help in my own research.

We'll be analyzing different sets of asteroids and potential-impact scenarios.

The respondents who mentioned that they would *probably not* use OpenSpace differently (n=6) cited unchanging institutional roles, their usage amount and type being set, and "platform issues" (again, the "faltering Mac support" which is currently being corrected). Five respondents were *unsure* about different uses, with one explaining that it depends on unknown "involvement in relevant projects."

When asked to think **further into the future,** over the next twelve months, respondents shared some bigger dreams.

SMEs cited a variety of long-term ways they would like to use OpenSpace (n=19) *

7	As support for new or existing projects
6	A new aspect of educational outreach
5	To create new visualizations
3	To enhance the software itself

*Answers do not add up to sample size because respondents could select multiple answers.

Using OpenSpace **for support for projects** in the longer-term future included visions of collaboration, creating a new, personal science communication project, and even incorporating OpenSpace into art projects in the SME's museum (n=7).

> *Our project would like to continue to work with OpenSpace to share data and explore interesting work that two projects can implement collaboratively.*
>
> *To record videos for my own Science Communication projects.*
>
> *I'd like to use OpenSpace more in exhibits and combinations with art installations.*

Examples of SMEs using OpenSpace **to expand educational outreach** included grade school, museum, and public education (n=6).

> *OpenSpace would be an incredible tool for teaching K-12 (or honestly anyone). Set up OpenSpace on a school computer and let the student sit there and explore the solar system.*
>
> *It would be nice to be able to use it in the hyper-wall of my institution for educational purposes.*
>
> *I'd like to use OpenSpace as a tool teaching the public about eclipses, transits, and occultations.*

New visualizations from SMEs covered a variety of ground (n=5).

> *I could potentially see using OpenSpace to visualize NASA constellation missions around distant planets and moons in our solar system, not to mention other solar systems.*

> *Visualizing error ellipsoids along the path of an asteroid, especially as the ellipsoid intersects with the Earth.*

> *I would love to be able to use it for generating contextual information for other visualization projects. Examples might include flying to other exoplanet systems to show proximity to Sol.*

Respondents also wanted to make time in their future schedules **to support the augmentation of OpenSpace** (n=3).

> *I'd like to use OpenSpace to present non-space content by utilizing it to, for example, play/render various online 360 videos, more user-friendly controls/instructions/tutorials for importing custom 3D models and environments, native.BLEND file format support, etc.*

> *Would like to work toward OpenSpace being able to pull science data from additional sources.*

Barriers to Adoption

Most SMEs (n=17) shared what they think is holding OpenSpace back from being more widely adopted.

Lacking Awareness of OpenSpace and its Complexity Stood Out as Barriers (n=17) *

6	Lack of awareness
6	Complexity, steep learning curve
4	Mac, web, or cloud compatibility**
2	Lack of updated tutorials

*Answers do not add up to sample size because respondents could select multiple answers.

** Responses about the lack of compatibility for Mac, a web-based version, or a cloud-based version are mostly obsolete with the new 0.19 updates.

The comments about **lack of awareness** range from focusing on online education to NASA (n=6).

> *I think OpenSpace needs to be more well-known. I highly doubt getting it integrated into K-12 is an option... But there are plenty of online education sites that I'm sure could use it.*

I'd say it still isn't commonly known among NASA employees.

Two respondents felt the problem was that the marketing approach was unclear.

Not clear who OpenSpace wants to be adopted by. Planetariums? Then make it drop dead easy to do a basic night sky show. Scientists? Commit to Mac and make it clear it's something that is worth learning.

I believe it's misunderstanding what it is used for.

The same number of respondents wrote that the **software's complexity** was likely a main barrier to adoption (n=6).

In general, steep learning curves tend to discourage all but the most dedicated individuals for whom it solves a specific, critical problem. For a larger audience there needs to be very casual, easy ways to play through scenarios and to have a UI that allows for intuitive exploration.

It is complicated to use and needs quite a bit of data and computer power to operate well.

I think the user interface is a bit too involved for most (e.g., teachers) to use without extensive training.

The responses about the need for updated tutorials included a lengthy explanation about the details of what is desired. It is copied here in an edited version, with the full version reported to the project team.

The lack of video tutorials and detailed, updated user/builder/developer documentation. One thing that contributes to many open-source softwares' success is how accessible it is for people to get started utilizing it for their own complex projects/uses. While simply installing OpenSpace and flying around couldn't be simpler (as long as everything is working) and it's awesome to do that in OpenSpace for a few minutes, I need more.
I completely realize that such documentation and tutorials is not trivial to create. However, if/when your goals are shifting, even slightly, from simple development of the product (I know it's still technically in beta), to actually growing the community, then I would suggest shifting your resources, in equal measure, from development to documentation/tutorials.

We always ask whether there's anything respondents would like to add at the end of the survey. The following response speaks to the barrier of being "tightly focused on specific use cases", without recommendation of how to correct this.

*I really appreciate what the project is doing and do want to help expand awareness of it in the visualization community. But I also realize it is kind **of tightly focused on some specific use cases** that make it harder to use in novel situations (e.g., I'm aware that attempts to incorporate exoplanet systems are burdened by object lighting being hard-wired to Sol, so bodies don't reflect the light of the star they orbit).*

Support Needed for Future SME Use

We wanted to know what changes would most help the respondents achieve the futures they see with OpenSpace. We offered five choices, and they could select as many as they wanted.

SMEs Want Easy Access and Easy Use (n=19) *

9	**Simplify the interface: make it easier to use.**
8	**Offer a lightweight version.**
5	Support large-scale datasets.
4	Increase the number of data formats.
3	Incorporate more Earth-based content.

*Answers do not add up to sample size because respondents could select multiple answers.

Under half of the respondents also added in their own ideas in *other* responses. These responses sometimes furthered the ideas behind closed-ended options.

Goes along with interface, but having offline/caching mode be more easily accessible, and producing more documentation/tutorials on coding sequences/buttons/custom JavaScript interfaces. [Also selected *Simplify the interface; Increase the number of data formats.*]

Focus on educational usage which can run on lower power computers. [Also selected *Offer a lightweight version.]*

Offer a web-based interface. [Also selected *Simplify the interface; Offer a lightweight version*]

There was one new idea in this section:

A Python 3D version would be very cool -- or how about the new language "Mojo" when it comes out! Google it! It is supposed to be a superset of Python that is as fast as C++ for real!!! Include some content specific visualizations. [Selected no other options.]

A few wrote of the desire for Mac availability and support (n=3), which has already been addressed since the release of version 0.19 on June 27, 2019. One of these three mentioned Linux support as well which has been in existence since the project's inception.

Appendix: Instrument

OpenSpace SME Survey- 2023

Introduction

Thanks so much for your time with this survey! We are excited to learn about your use of OpenSpace. Your honest answers are critical for determining the next steps for the program.

We are asking for your name so that we can follow up with you individually if needed. Your answers will remain confidential, and will only be used for the purposes of this study. Names will not be shared with the team. No individual will be directly or indirectly identified, and all results will be presented in aggregate. The data collected for this survey will be destroyed upon the conclusion of the study. Please email Madeleine at madeleine@hgandco.com if you have questions.

The survey should take no longer than 15 minutes to complete. Your time and effort is deeply appreciated, and will support the continued evolution of OpenSpace!

* 1. Your name:

* 2. Your institution:

* 3. Your role in that institution:

* 4. In the past 12 months, how did you use OpenSpace? *Select the frequency that you did each activity in the past year.*

	Never	Once or twice	3-4 times	More than 4 times
I worked with interns, mentees, or students.	○	○	○	○
I presented live to the public.	○	○	○	○
I presented live to colleagues or students.	○	○	○	○
I presented stills or videos to the public.	○	○	○	○
I presented stills or videos to colleagues or students.	○	○	○	○
I furthered research or visualized data.	○	○	○	○

* 5. What's the most interesting thing you did with OpenSpace in the past 12 months?

* 6. In the next 12 months, how are you likely to adjust the **frequency** that you use OpenSpace?

I will **decrease** the frequency	The frequency will **stay the same**	I will **increase** the frequency
○	○	○

Why will you adjust this frequency of use (or not adjust it) in the next 12 months?

* 7. In the next 12 months, will you use OpenSpace **differently** than you have to date?

Definitely not	Probably not	Unsure	Probably	Definitely
○	○	○	○	○

Why or why not?

* 8. Thinking longer term, what are any other ways you'd like to use OpenSpace?

* 9. What changes to OpenSpace would most support your work? *Select up to 3 choices.*

- [ ] Offer a lightweight version.
- [ ] Increase the number of data formats.
- [ ] Support large-scale datasets.
- [ ] Incorporate more Earth-based content.
- [ ] Simplify the interface: make it easier to use.
- [ ] Other (please specify)

* 10. How did you learn how to use OpenSpace? *Select all that apply.*

- [ ] I taught myself.
- [ ] I learned from a colleague.
- [ ] I learned from someone on the OpenSpace team.
- [ ] Other (please specify)

* 11. Please rank your ability to fly (operate) OpenSpace.

I cannot fly.	I am learning to fly.	I fly ok.	I fly well.	I fly with total ease.
○	○	○	○	○

* 12. In the next 12 months, how likely are you to learn (or continue learning) how to fly?

Highly unlikely	Somewhat unlikely	Somewhat likely	Highly likely	N/A
○	○	○	○	○

* 13. Why or why not are you likely to learn (or continue learning) how to fly within the next 12 months?

* 14. Have you ever visualized new data or created new assets for OpenSpace?

- ◯ No
- ◯ Yes (please describe)

* 15. What do you value most about OpenSpace? *Please rank in order from most to least valuable.*

Its ability...

- To combine datasets.
- To interact with data in real time.
- To visualize multi-dimensionality.
- To create high-quality visuals.
- To communicate research to the public.

16. Is there anything else that you highly value about OpenSpace?

* 17. In your opinion, how important is it that OpenSpace is open-source software?

Unimportant	Somewhat unimportant	Neutral	Somewhat important	Very important
◯	◯	◯	◯	◯

Why is it important, or not important?

* 18. How **interested** are you in contributing to the open-source development of OpenSpace?

Not at all interested	Somewhat uninterested	Somewhat interested	Highly interested
◯	◯	◯	◯

If interested, in what ways would you want to contribute to the open-source development of OpenSpace?

* 19. How **likely** are you to join OpenSpace's open-source community?

Not at all likely	Somewhat unlikely	Somewhat likely	Highly likely
◯	◯	◯	◯

Why or why not?

* 20. Why or why not are you (or will you become) part of OpenSpace's open-source community?

* 21. Please share any thoughts on how we could support the growth and evolution of our open-source community.

* 22. What, if anything, do you think holds OpenSpace back from being more widely adopted?

23. Is there anything else you would like to tell us about OpenSpace?

24. We're interested to learn who else is using OpenSpace. Please list any other OpenSpace users (individuals or institutions) whom we might not be talking to yet.

Name:	
Email:	
Other type of contact information:	

25. If you would like receive an OpenSpace t-shirt mailed to you, please complete the following information in full.

Size *(Small, Medium, Large, XL, XXL)*:	
Name (to address the package):	
FULL mailing address:	
Country:	

OpenSpace Year 8:
Funded Partner Survey Evaluation Report

October 30, 2023

VISITOR-CENTERED PLANNING, STRATEGY, AND EVALUATION

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OpenSpace Year 8:
Funded Partner Survey Evaluation Report

October 30, 2023

VISITOR-CENTERED PLANNING, STRATEGY, AND EVALUATION

Summary of Findings

OpenSpace's ISI and development partners experience a variety of benefits from the software. In responses to this survey, we saw lots of excitement and plans for creative future uses. Respondents are hopeful that they and their institutions will continue to use, augment, and evolve OpenSpace into the future.

- The majority of respondents said that their institution seemed "highly likely" to continue to use OpenSpace beyond the current NASA funding. Four more respondents said that it was "somewhat likely."
- Most of the ISIs are currently developing uses of OpenSpace to reach new audiences, in new locations, and/or with new content.
- Almost all ISIs are planning on increasing frequency of OpenSpace use in the next year.
- The current use of OpenSpace for ISI and development partners scans a variety of audiences and activities, from new types of public programs to internships to research to conference presentations. OpenSpace is often featured both as the focal point and in smaller ways throughout the museums or planetariums.
- It is extremely important to the partners that OpenSpace is open-source software. They see this quality as a benefit to not only the software itself, but the field of Space and Earth Science learning overall.

Study Overview and Goals

In the past years of evaluation for OpenSpace, HG&Co has reported on the health of team collaboration by surveying funded Informal Science Institution (ISI) partners and funded software development partners about areas of growth and of strength which provided useful input to the project leadership team to support the growth of the project over time. We pivoted in Year 8 to explore the ways in which funded partners, all who have been involved with the project since Year 1, are currently using the software and how they view its potential impact within their institution and for their own personal and professional growth moving forward. This approach achieved the year's evaluation goal of exploring a breadth of uses to demonstrate the flexibility of OpenSpace.

In that light, this survey looked at the following themes, referencing two different units of analysis:

- **Current Uses** *(institutional)*
- **Future Uses** *(institutional + individual)*
- **Beyond Current Funding** *(institutional + individual)*
- **Thoughts on Being Open-Source** (*individual)*

The goals of the survey included exploring:

→ The ways in which funded partners are using OpenSpace,
→ Individual uses of OpenSpace and intended future uses,
→ The growth of use over time,
→ Integration of OpenSpace into the museums' activities, and
→ Funded partners' connection to the project's open-source community and what they think it needs for growth.

Sample & Methods

In April and May of 2023, nineteen core team members from six ISIs and two universities (where development partners are housed) completed a 28-question online survey which was a mix of open- and closed-ended questions (see Appendix). Of these nineteen individuals, two groups of two colleagues completed the survey together, so we received a total of seventeen completed surveys.

The ISIs represented in this report and the number of surveys returned from each follow:

- **Adler Planetarium**: 3 responses
- **American Museum of Natural History**: 2 responses
- **California Academy of Sciences**: 5 responses
- **Denver Museum of Nature & Science**: 1 response
- **Houston Museum of Natural Science**: 2 responses
- **New York University, Tandon School of Engineering**: 2 responses
- **North Carolina Museum of Natural Sciences**: 1 response
- **University of Utah, Scientific Computing and Imaging Institute**: 1 response

Current Institutional Uses for OpenSpace

The survey asked each respondent to select how their institution used OpenSpace in the past twelve months. Respondents each chose multiple activities within three categories: informal education (mostly within museums), education within the field of space science (such as presenting at conferences or sharing renderings with other users), and formal education settings. All institutions used OpenSpace in all three settings except two museums, which did not use it in formal education this past year.

All but Two ISIs used OpenSpace in Each of Three Settings (n=8) *

8	Informal education
8	Education in the space science field
6	Formal education

*Answers do not add up to sample size because respondents could select multiple answers.

Respondents identified the types of activities for which their institutions used OpenSpace over the past 12 months. Every institution presented in an informal learning environment, which is unsurprising as these partners are mostly housed in museums. All ISI partners (n=6) hosted public programs and presented at conferences using OpenSpace. All but one ISI (n=5) and one development partner rendered and disseminated media and presented at a demo.

Most Institutions Used OpenSpace for Presenting and Sharing Media. (n=8) *

Activities	Number of Institutions
Presented in an informal learning environment	8
Hosted a public program	**6**
Rendered and disseminated media	**6**
Presented at a conference	**6**
Presented at a demo	**6**
Trained another peer how to use OpenSpace	5
Trained students how to use OpenSpace	5
Hosted an internship	4
Used in a classroom	4
Presented in the institution, but outside the classroom	3

*Answers do not add up to sample size because respondents could select multiple answers.

Looking at a selection of the most frequent activities alone, the focus audiences range from everyday museum visitors to professionals to potential users of OpenSpace.

Many Types of Audiences Reached by Most Frequent Institution Activities. (n=8) *

Activities	Focus Audience	Number of Institutions
Hosted a public program	**Museum visitors**	6
Rendered and disseminated media	**Space enthusiasts**	6
Presented at a conference	**Conference attendees**	6
Presented at a demo	**Potential users**	6
Trained students how to use OpenSpace	**Students**	5

*Answers do not add up to sample size because respondents could select multiple answers.

OpenSpace Integration Supports ISI Programming and Engagement

We asked two open-ended questions intended to understand the ease of using OpenSpace within pre-existing institutional infrastructure:

> *How does OpenSpace integrate into your institution's current **activities**?*
> *How does OpenSpace integrate into your institution's current **technical infrastructure?***

The respondents mostly interpreted the first question, about activities, by writing about how OpenSpace increased access of science learning to certain audiences.

OpenSpace Creates Access for Institutional Audiences. (n=8) *

5	**Augments in-person engagement**
2	**Brings in online audiences**
2	Create internships
2	Supports school-age audiences
2	Aids in teaching classes

*Answers do not add up to sample size because respondents could select multiple answers.

For five institutions, integration of the software supported in-person audiences:

> *OpenSpace has slowly become our first-choice platform when creating new content for planetarium shows, lectures, and shows [in a] small flat-screen theater… We use OpenSpace every day!*

We use it to showcase astronomy and space missions in my lab, and we have our exhibit content in our kiosks and lunar display on the floor. I also use OpenSpace in many public programs and events as well.

We use OpenSpace in our planetarium, and with some of our kids' education programs. It is used in live programs monthly as well as various education programs for middle and high school students, as well as the MAT [Master of Arts in Teaching] training.

For two of those five institutions who saw increased in-person audiences with OpenSpace, remote audiences were also supported:

Used every day in our planets shows, used daily for our widescreen video presentations, used for our weekly "simulcast" program, used monthly for our astronomy lecture series, used regularly for other planetarium programs, online programs, etc. OpenSpace has become our core software platform for real-time content delivery.

One institution's respondent explained that OpenSpace was simply **not** integrated into their ISI.

Looking at responses to the second question, it's unclear how OpenSpace integrates into the institutions' technical infrastructures. This question saw a range of answers, implying that some respondents read the question differently than others. Nevertheless, the answers give an impression of the visibility of OpenSpace within the institutions.

OpenSpace is Featured Prominently in Most ISIs (n=6) *

5	**Used in the main audience space**
5	**Installed in a variety of places throughout the institution**
2	Integrated well and is easy, generally

*Answers do not add up to sample size because respondents could select multiple answers.

Four of the six ISIs feature OpenSpace as part of the main audience area and use it throughout their institutions.

Installed pretty much everywhere—on multiple clusters for the planetarium, on the panoramic theater system, on numerous laptops and personal computers.

The two remaining ISIs feature it either throughout the institution or in their main space. One of the two uses OpenSpace throughout the museum "easily," and will use it in their new theater once development is completed.

> *Integrates well into new theater upgrades, which we have used in one of the upgraded systems, but the larger theater is not yet ready... Other uses easily work with OpenSpace.*

The other ISI features OpenSpace in a planetarium, even though it's not regularly used in general.

> *It's still a somewhat experimental software that is not generally supported by our IT department. However, through the OpenSpace grant support, it is installed and being used in our planetarium for special programs.*

The development partners answered this question by explaining that OpenSpace is used for research and is not part of their technical infrastructure (n=1), or by saying that it is integrated "seamlessly" (n=1).

New Uses are In Development

We asked respondents if there was anything new about their institutional uses of OpenSpace in the last 12 months. Of the six ISIs, four explained that they have been developing and exploring new uses.

Most of the ISIs are Using OpenSpace for new audiences, new outputs, and new locations. (n=6) *

3 Institutions used OpenSpace with **new audiences**	• *Professional scientists* • *External researchers* • *Internal ISI researchers* • *Blind and low-vision audiences*
3 Institutions generated **new outputs**	• *Adult lectures* • *Rendered video content* • *Interactive games* • *Live segments of planetarium shows*
2 Institutions used OpenSpace in **new locations**	• *A dome after upgrading a computer cluster for a professional conference* • *A newly-built theater in a free, non-ticketed venue* • *Public touchscreens and kiosks*

*Answers do not add up to sample size because respondents could select multiple answers.

Future Uses for OpenSpace

When asked about the upcoming twelve months, five of the ISIs (n=6) expect to use OpenSpace more frequently next year. Selecting from a list of four responses ranging from "definitely not" to "definitely," respondents said their institutions "probably" (n=10) or "definitely" (n=2) will use OpenSpace more

often than it has to date. Of the twelve individuals who expect their institution will use OpenSpace more frequently next year, seven said it was because they have plans for new programs or new exhibitions.

> *We are working on a new planetarium show based on the "Rare Earth" hypothesis.*
>
> *With the new theater we have more opportunity.*

Four respondents (from different institutions) explained that there will be more use simply because they are focused on improving and continuing to explore OpenSpace.

> *We're always trying to find new ways to use OpenSpace in our various venues and presentations, so I expect we'll find even more in the next year.*
>
> *We remain uncommitted to any of the existing software vendors in the marketplace and prefer to concentrate our development efforts on OpenSpace.*

One respondent mentioned that they will likely increase use because they have more people to fly OpenSpace now.

> *We have more venues and opportunities to create programs as well as more educators trained to fly OpenSpace.*

ISIs Likely to Use OpenSpace Differently Next Year

The majority of respondents representing ISIs (10 of 14) expect their institution to use OpenSpace in a different way next year. These responses were similar to those explaining what new uses are currently in development but read as somewhat of a wish-list.

A Quarter of Respondents Expect ISIs to Create Different Content Next Year. (n=14)

5	Mentioned **different content** for existing audiences	• *We will likely have more Earth-oriented content in the dome, and we're particularly excited about GeoJSON functionality.* • *We will use the new panorama in the Learning with Data Lab and create OpenSpace rendered content for a large screen in the Hall of the Universe.*
4	Mentioned content for **different audiences**	• *If the night sky view in 0.19 covers our needs, we will convert our school shows to OpenSpace.* • *We are expanding how we use OpenSpace for climate science education.* • *We would like to increase the research use for OpenSpace.*

3	Mentioned content for **different spaces**	• *We may want to create a short display to run in our new theater, similar in idea to a screensaver which would be seen by a large number of visitors.*

Some respondents who answered that they were "unsure" that their ISIs would use OpenSpace differently still shared ideas about possible institutional uses.

> *We'd love to use OpenSpace in our school shows too, but we can't with the current version since there isn't any night sky mode.* [Note that this feature is available as of June 2023].

The two respondents representing development partners had mixed feelings about different uses in the future. One said that they were unsure, but "We would like to increase the research use of OpenSpace." Another representing a different institution said they would probably find different uses but did not explain further.

Individuals Planning their Own Uses

We also asked respondents to think more personally and long-term about different ways they would like to use OpenSpace, perhaps separate from their institutions. Almost two-thirds of the respondents (11 of 17), both from ISIs and development partners, have plans for their own use of OpenSpace in the future, one saying that increasing their role with adding to OpenSpace content sounds "fun."

> *It would be fun to be more of a builder and create content.*
>
> *More Earth stories!*
>
> *As a research tool: explore how it could be used in place of GIS tools.*
>
> *Rendering out 360 frames/videos.*
>
> *My hope is to continue to build a more sophisticated interface for adding buttons and text as a narrative experience for users.*
>
> *I want to distribute profiles to other institutions.*

When asked what would be needed to make these plans possible, the same eleven respondents explained that these uses would require technical support, as well as time and money.

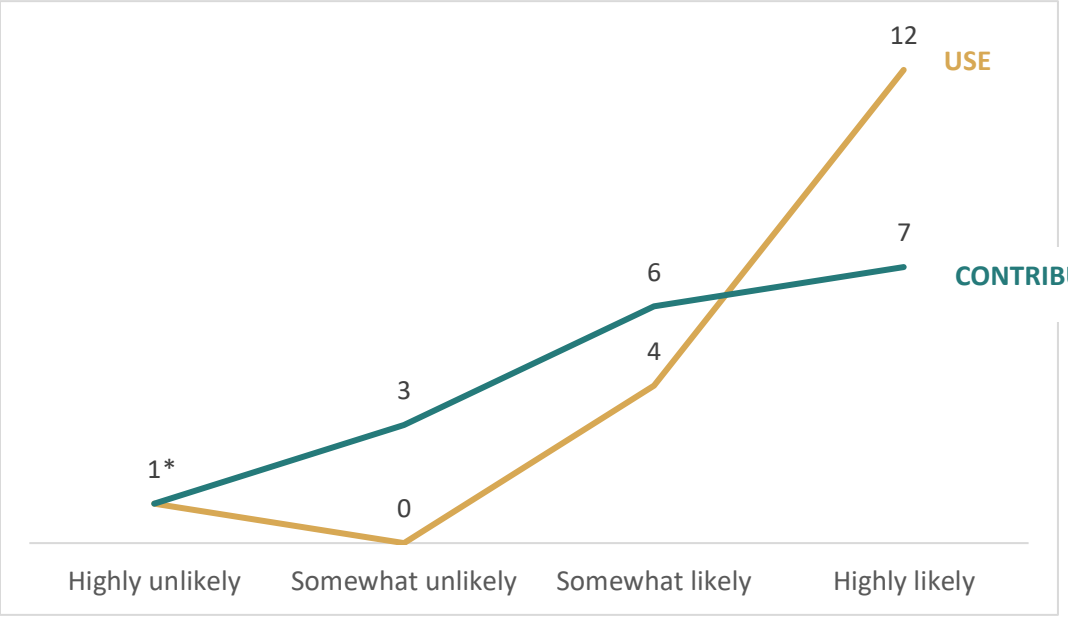
Technical Support Desired for New Ideas to Lift Off. (n=11)

6	Technical Support	• ***A really easy to use GUI.*** • *More Earth functionality!* • *VR/360.* • *Night sky features to use in our school shows.* • *Ongoing development of the relevant globe-browsing/ data tools.* • *More documentation of code to help figure out how to build on existing code.*
3	Time	• *I need to find the time to try out my ideas.*
3	Money	• *Money to go to conferences.* • *A dedicated budget to create the hardware infrastructure from AMNH.*

Beyond Current Funding for OpenSpace

The majority (n=12) of the seventeen respondents said that their institution seemed "highly likely" to continue to use OpenSpace beyond the current NASA funding. Four more respondents said that it was "somewhat likely." But when we asked about the likelihood of institutional contribution to OpenSpace after current funding ends, respondents were slightly less assured.

Institutions More Likely to *Use* OpenSpace Than To *Contribute* (n=17)



* This respondent rated both use and contributions as "highly unlikely," but their colleague at the same institution rated both as highly likely. This may be because the former being less involved with planning than the latter.

Individuals who think institutional contributions are *likely* (13 of 17) wrote of the unique nature and embedded use of the software.

> *OpenSpace is a unique opportunity to bring this powerful software into the dome and continue growing it, ideally in a user-driven way.*
>
> *OpenSpace has become embedded in our strategies for education and public programs.*
>
> *Museums are notoriously cash poor. If we have an interactive platform that continues to function, we'll use it as long as we can.*
>
> *Our staff are quite invested in the development of the software.*

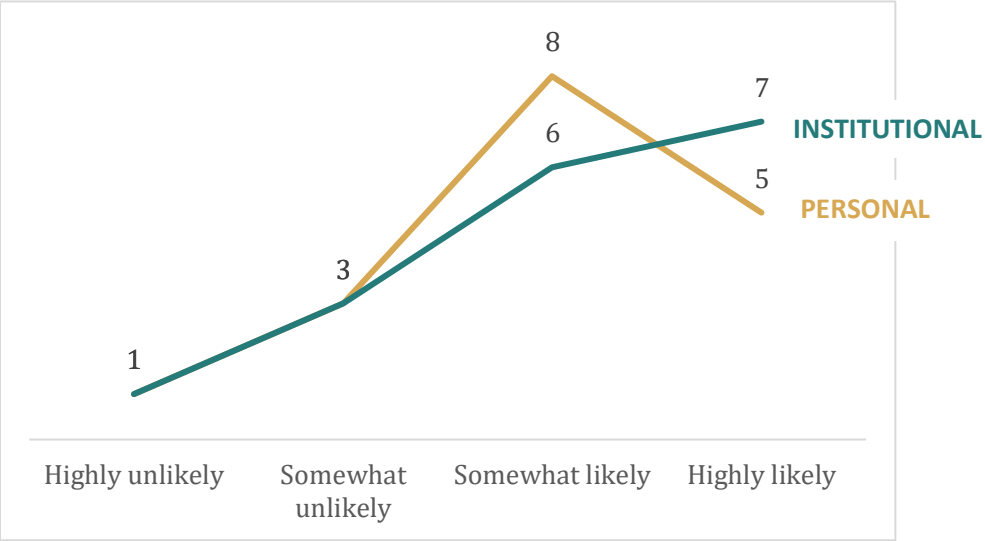
Individuals who think institutional contributions are *unlikely* (4 of 17) wrote that it is because of a lack of workers, time, or users.

> *We lost [an employee] during COVID and have not been able to replace his talents with software.*
>
> *Contributing back takes time and is harder to do without funding.*
>
> *There is not a significant user base of OpenSpace at my institution beyond myself who could continue to use and contribute to OpenSpace after the current NASA grant.*

Institutions Seem Able to Contribute More than Individuals

Individuals are slightly less confident that they will *personally* contribute to OpenSpace in the future (compared to their institutions), but a majority (13 of 17) believe it is likely. Because the answers are tied to job descriptions and responsibilities, the responses include guesses based on what they believe their institutions will choose.

More Confidence in *Institutional* Contributions than *Personal*, Post-Funding (n=17)



Those who said it was *highly likely* or *somewhat likely* that they would contribute (n=13) explained that they are personally or professionally invested in this useful tool.

> *The hope is that OpenSpace becomes a regular way to build interactive visuals and therefore, my use would continue on past the funding.*
>
> *As long as I'm using OpenSpace to support new and interesting public programs, I expect I will contribute to the knowledge base of how to use OpenSpace along with assets developed here that can be shared with the OpenSpace community.*
>
> *I would love to keep sharing media and program content, and continue using OpenSpace for my lab, exhibits, and programs. I would likely not have the paid student internships after funding runs out so the rate of developing new content will be slower, but we will use the software as much as possible.*

Those who said it was unlikely that they would contribute (n=4) explained that it is not their job to contribute, or that funding is their only doorway to contribution.

Partner Thoughts on OpenSpace Being Open-Source

It is clearly important to the partners that OpenSpace is open-source software. Nine respondents said that being open-source was *very important*, and eight said it was *somewhat important* (n=17). Nobody ranked the quality as "unimportant." The reasons given include the more obvious yet still important

points about increasing access, but also a recognition that OpenSpace can go further because of this quality.

Being Open-Source Benefits the Access, the Software, and the Field (n=17) *

10	**Allows broader access**
6	**Magnifies the growth of the software**
5	**Benefits the field and science learning**
4	Makes OpenSpace unique

*Answers do not add up to sample size because respondents could select multiple answers.

Over half of respondents wrote about open-source as vehicle for broader access to OpenSpace. These comments focused on the excitement of bringing in less typical users (n=10).

> *Being open-source enables anyone to try it for themselves, which even if they don't have high-end computers, they can at least try it and be "part" of the project.*
>
> *I am working on a planetarium in Bangladesh and want to share OpenSpace with them. Their funds are limited.*
>
> *It's important to attract new users, we're able to do stuff without budget considerations, and have the ability to share new science freely with the public.*

Over a third of respondents added that this access increases the growth of the software, as users become involved and on-boarded they can also augment the development (n=6).

> *That users can create or modify new features has helped spur the main development team to speed up development of the same or similar features in the main code.*

Beyond the developers and users benefiting, slightly less than one-third of respondents expressed the strong belief that being open-source makes OpenSpace more valuable to the field of science learning (n=5).

> *The prominent planetarium softwares on the market are all proprietary. Having an open-source option provides better accessibility to the industry.*
>
> *That it's also based on all real data is amazing and can help a lot of people educate their communities more easily.*

This is very important for getting the public excited about science and breaking barriers between tools for exploring and educating about science and people who generally do not have access.

A few respondents also mentioned that being open-source is unique for this field, which greatly adds to its value (n=4).

The fact that OpenSpace is free and accessible to anyone is something that makes it very unique and very valuable in the planetarium community.

Recommendations for OpenSpace

Respondents volunteered ideas to support OpenSpace's success into the future, which focused on funding and ways that funding could be used to increase the software's support networks. This is no surprise as time and money are always mentioned in annual surveys as needs to support the evolution of OpenSpace, but as partners are aware that NASA funding runs out in two years, this survey showed more focus on that particular desire with a tone of anxiety.

Partners Want Security in Funding, Support, and Community to Evolve OpenSpace (n=17) *

7	New types of funding
5	Increase communications & support
5	Expand community
2	Software adjustments

*Answers do not add up to sample size because respondents could select multiple answers.

Responses about new types of funding consider any approach that might help (n=7). The following examples are not quotes, but rather summaries of the ideas that respondents provided.

- → Expanding and diversifying funding sources (including private donors) to not rely solely on one backer.
- → Exploring government or corporate grants.
- → Welcoming smaller donations, including those from professional organizations.
- → Starting a non-profit that can fundraise for an endowment.

Partners believe that OpenSpace will benefit from increased communications and support for the software's users (n=5).

- → Increasing direct outreach to help users get comfortable with software.
- → Maintaining support networks, like Slack, as a priority.
- → Increasing documentation and making it easier to find information on how to add new data, what data is being used, and what functions are available.
- → Highlighting unique features (i.e., robust globe-browsing and ease of show-creation tool use).

→ Regular idea sharing sessions, continue Micah Mondays.

Respondents brainstormed ways to expand OpenSpace's community (n=5).

→ Creating OpenSpace Ambassadors who recruit users and lead trainings.
→ Suggesting/requiring institutional users to contribute resources.
→ Support it becoming a commercial product for support and production of other planetarium software.
→ The more OpenSpace simulations are incorporated into exhibits and non-planetarium experiences, the more ways it can be distributed both as software and as stand-alone exhibit product.

There were only two users who suggested some software adjustments to support OpenSpace's future (n=2).

→ Continuing to increase ease of install.
→ Dedicating resources to simplifying/stabilizing software to attract a variety of new users.
→ Introducing a user-friendly maintenance ability to help users trouble-shoot and monitor software stability (maybe a framework in Python or GitHub).
→ An asset-builder and built-out hub to support builders independently of the development team.

Appendix: Instrument

Funded ISI Partner Survey- 2023

Introduction

Thanks so much for taking this survey! We are excited to learn about your current uses of OpenSpace, as well as your vision for how you might use it in the future. Your honest answers are critical for determining the next steps for the program.
The survey should take no longer than 15 minutes to complete. We appreciate your time and effort!

We are asking for your name so that we can follow up with you individually if needed. Your answers will remain confidential, and will only be used for the purposes of this study. Names will not be shared with the team. No individual will be directly or indirectly identified, and all results will be presented in aggregate. The data collected for this survey will be destroyed upon the conclusion of the study. Please email Madeleine at madeleine@hgandco.com if you have questions.

* 1. Your Name:

* 2. Your Institution:

* 3. Your Role in the OpenSpace Project:

Funded ISI Partner Survey- 2023

Recent use of OpenSpace

* 4. What types of **informal education activities** (at ISIs, museums, etc.) did you do with OpenSpace in the last 12 months? Select all that apply.

- [ ] Presented in an informal learning environment
- [ ] Hosted an internship
- [ ] Hosted a public program (in-person or hybrid)
- [ ] Hosted an online-only public program
- [ ] Another informal education activity:

  [ ]
- [ ] None of the above

* 5. What types of **formal education activities** (at colleges, high schools, universities, etc.) did you do with OpenSpace in the last 12 months? Select all that apply.

- [ ] Used in a classroom
- [ ] Presented in the institution, but outside the classroom
- [ ] Trained students how to use OpenSpace
- [ ] Another formal education activity:

  [ ]
- [ ] None of the above

* 6. What types of **field education activities** did you do with OpenSpace in the last 12 months? Select all that apply.

- [ ] Presented at a conference
- [ ] Presented at a demo
- [ ] Rendered/disseminated media (videos, social media, screenshots)
- [ ] Trained another how to use OpenSpace
- [ ] Another field education activity:
- [ ] None of the above

* 7. Was there anything new about the ways in which your institution used OpenSpace in the last 12 months?

- ◯ Yes
- ◯ Our institution did not do anything particularly different or unusual last year.

Funded ISI Partner Survey- 2023

New ways of using OpenSpace

Tell us more about a new way your institution used OpenSpace in the last 12 months!

8. Name of activity:

* 9. Short description of activity:

* 10. What made that activity different from your institution's prior uses?

Funded ISI Partner Survey- 2023

Current use of OpenSpace

* 11. How does OpenSpace integrate into your institution's **current activities**?

* 12. How does OpenSpace integrate into your institution's **current technical infrastructure**?

* 13. In the next 12 months, will your institution use OpenSpace **more often** than it has to date?

Definitely not	Probably not	Unsure	Probably	Definitely
○	○	○	○	○

* 14. Why will your institution use OpenSpace more or less often? (write "n/a" if Unsure)

* 15. In the next 12 months, will your institution use OpenSpace **differently** than it has to date?

Definitely not	Probably not	Unsure	Probably	Definitely
○	○	○	○	○

16. If your institution has any plans for using OpenSpace in new ways, please describe them here.

* 17. Thinking personally and longer term, are there other ways **you** would like to use OpenSpace?

- ◯ Not at this time.
- ◯ Yes (please specify)

18. If yes, what needs to happen to make that possible?

* 19. Has OpenSpace changed the way your institution does things?

- ◯ No
- ◯ Yes (please explain)

* 20. In your opinion, how important is it that OpenSpace is open-source software?

Unimportant	Somewhat unimportant	Neutral	Somewhat important	Very important
◯	◯	◯	◯	◯

* 21. Why is being open-source important, or not, for OpenSpace?

* 22. How likely is it that your institution will **continue to use** OpenSpace beyond the current NASA funding?

Highly unlikely	Somewhat unlikely	Unsure	Somewhat likely	Highly likely
◯	◯	◯	◯	◯

* 23. How likely are you and your institution to **contribute** to OpenSpace beyond the current NASA funding?
(Contributions could look like working with code, communicating with the community on GitHub or Slack, sharing new media that you generate with others, etc.)

	Highly unlikely	Somewhat unlikely	Somewhat likely	Highly likely
You	◯	◯	◯	◯
Your institution	◯	◯	◯	◯

* 24. Why or why not are **you** likely to contribute to OpenSpace beyond the current NASA funding?

* 25. Why or why not is **your institution** likely to contribute to OpenSpace beyond the current NASA funding?

Funded ISI Partner Survey- 2023

Final thoughts

* 26. Do you have any thoughts on how our open-source community could be sustained beyond the current funding?

27. Is there anything else you would like to tell us about your use of OpenSpace, or your visions for its future?

28. We're interested to learn who else is using OpenSpace.

Are there any other OpenSpace users (individuals or institutions) that you know of whom we might not be talking to yet?

Name:	
Email:	
Another way to contact:	

OpenSpace Year 8: Network Survey Evaluation Report

October 30, 2023

VISITOR-CENTERED PLANNING, STRATEGY, AND EVALUATION

Table of Contents

OpenSpace Year 8: Network Survey Evaluation Report

October 30, 2023

Summary of Findings

The sampled network is a dynamic group of fifty-one OpenSpace users. These respondents are from around the world and use OpenSpace in a variety of settings: from museums and universities to at home, with friends and family. This report is a snapshot of users' excitement about the software's capacities, about a future of continued use, a willingness to engage, and desires for continued support through the community surrounding OpenSpace.

- Over half (58%) of respondents said their institutions will likely use OpenSpace more frequently in the upcoming twelve months.
- A total of 25% of respondents were using OpenSpace with friends or family, including seven respondents who used it with both (14% of the total sample).
- 45% of the respondents were one of multiple users of OpenSpace in their institutions.
- Almost all the respondents (91%) responded that they were *somewhat* or *highly likely* to continue learning to operate OpenSpace.
- When considering all roles with OpenSpace, over half self-identify as informal educators (55%), and over half as hobbyists or enthusiasts (51%).
- Three users (6%) volunteered that OpenSpace greatly supports their work, but voiced concern and hope that it will continue to exist and be improved on.

Study Overview and Goals

Year 8's OpenSpace evaluation focused on the breadth of use. To better understand the variety of users, we augmented last year's Network Survey (first used in Year 7 as a baseline study) to capture responses beyond SciAct-funded Informal Science Institution (ISI) partners, developer partners, and Subject Matter Experts (SMEs). The 51 respondents to this year's Network Study included twenty-six institutions that the OpenSpace Project Team previously did not know about, including users who do not receive NASA funding, or work in space science research or education. This is part of a suite of reports that, together, create a baseline understanding of how a widening span of user types are looking towards the future of OpenSpace.

This survey looked at the following themes:

- **Current Uses**, both institutional and personal;

- **Communication** between users and with the project team; and
- **Future Uses.**

Methods

In September and October of 2023, fifty-one OpenSpace users completed a 36-question online survey which was a mix of open- and closed-ended questions, taking an average of 23 minutes. The first twenty-five respondents were mailed an OpenSpace tee-shirt as an incentive; later respondents were sent OpenSpace decals. Responses were recorded from September to October of 2023.

Sample

The sampled population was OpenSpace Slack users, which number approximately 800 members, as Slack is the most-used communication method for the Network (see the section on Communication). The project manager posted directly in the General channel of the public slack workspace to invite users to complete the survey. This year's Network study doubled the sample size of last year's (n=51, compared to n=26 from last year), with many respondents introducing new user institutions to the OpenSpace team. Therefore, this approach not only increased the range of feedback providers beyond known users, but also provided valuable new user documentation for the team.

This study is not representative of the overall users of OpenSpace, as it was not a random sample, but rather a snapshot of a portion of the users who self-selected the survey.

The overall sample for the data gathered in this survey is n=51. Initially, the survey received a total of 70 responses, but sixteen of those respondents only filled in their name with no other data, and three others duplicated their responses, so the total respondent count is n=51. This may be due to the longer length of the survey.

Location

Over half of respondents' institutions completed our survey from across the United States. The institutions in the Tri-State area (New York, New Jersey, and Connecticut) made up 16% of the sample (n=8), and five of those institutions are in New York City.

Figure 1: Most Respondents Were Located Across the United States and Europe (n=51)

57%	United States
31%	Europe
12%	International, excluding Europe

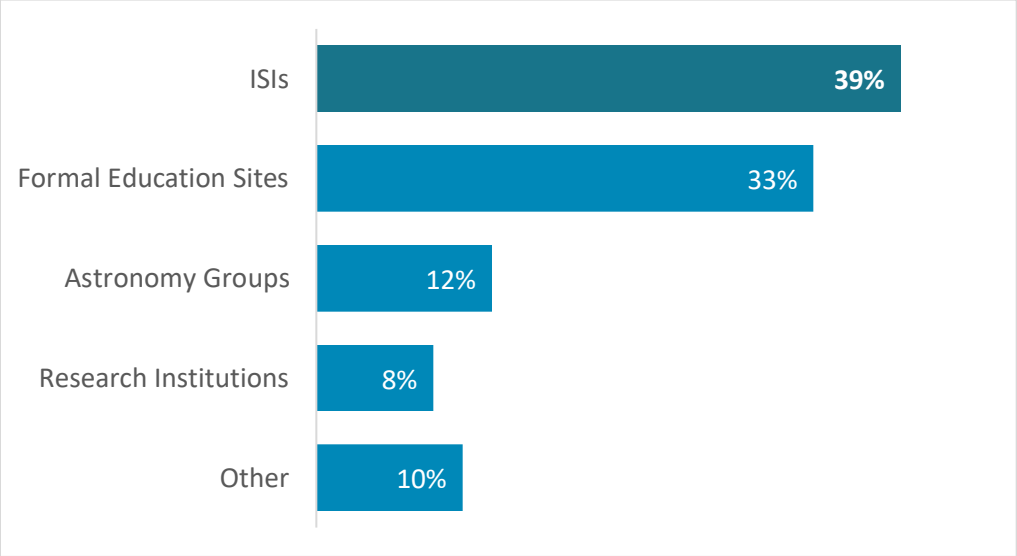
Almost one third of the representatives' institutions are in Europe. The country that was most represented was Sweden, with representatives from four institutions (*Universeum* in Göteborg; Umeå University in Umeå; and Stokholm University and The National Museum of Science, both in Stokholm).

Other international institutions were scattered across the globe, with two institutions in South Africa, and one each in Paraguay, New Zealand, and Thailand. The only non-European university was the University of Cape Town in South Africa.

Institutions by Type

We asked respondents for the institutions where they use OpenSpace the most. Throughout the report, we refer to this as their *primary institution*. This was important to delineate as nine respondents wrote about *secondary* institutions, and 14% mentioned using OpenSpace in their personal lives with friends or family. The listed institutions include Informal Science Institutions (ISIs), sites of formal education, astronomy groups and networks, and research institutions (see Appendix B for alphabetical list of all institutions represented and their locations).

Figure 2: Most Respondents Represented ISIs (n=51)



The plurality of respondents listed their institution as an ISI, including museums, planetariums, and observatories (39%). States in the United States or countries other than the U.S. are in brackets when unclear from the institution title.

The Admiral Vasile Urseanu Astronomical Observatory [Romania]

AMNH [American Museum of Natural History, New York] [1]
Anchorage Museum [Alaska]
Astrolab Iris [Belgium]
Connecticut Science Center
Curiosum science center, Umeå University [Sweden- also a Formal Education Site]
Exploratório - Centro Ciência Viva de Coimbra [Portugal]
The Lawrence Hall of Science (University of California, Berkeley) [also a Formal Education Site]
Michigan Science Center
Planetarium Spacedome [Switzerland]
Robeson Planetarium [North Carolina]
Seiler Planetarium [Missouri]
Sonnenborgh [The Netherlands]
Springfield Science Museum [Massachusetts]
StoryDome [Washington state]
Tekniska Museet (National museum of science) [Sweden]
Towson University [Maryland- a planetarium open to the public as well as for private classes]
Universeum [Sweden]
University of Nebraska State Museum
Wonderdome [England]

More than a third of respondents listed formal education sites like universities, colleges, and grade schools (33%). Schools serving children under age 18 are marked with "+".

Austin Community College [Texas]
+ Bromsgrove School [England]
+ Brooklyn Technical High School [New York]
City College of New York
Columbia University [New York]
Curiosum science center, Umeå University [Sweden- also an ISI]
+ Hubble Planetarium/ Edward R Murrow High School [New York]
+ Paterson Public Schools [New Jersey]
Southwest Minnesota State University
Stockholm University [Sweden]
Technical University of Munich [Germany]
The Lawrence Hall of Science (University of California, Berkeley) [also an ISI]
Towson University [Maryland- also an ISI, planetarium open to the public]
Universidad de Córdoba [Spain]

[1] Unlike the other respondents, AMNH houses the funded project group, however the respondents to this survey work outside of the OpenSpace project group.

University of Cape Town [South Africa]
University of Groningen [Netherlands]
Versant Power Astronomy Center - University of Maine

A little less than a quarter worked for astronomy-specific programs, groups, and networks (12%).

Astro Group, South Sardinia [Italy]
Mochileros Astronómicos, Planetario Canopus, Experiencia Planetaria [Paraguay]
NASA Solar System Ambassadors
NASA/JPL Solar System Ambassador Program
New Zealand Astrobiology Network
The Human Space Program [international]

Four respondents represented research institutions, all of which are federally funded (8%):

Brookhaven National Laboratory [New York]
IMERSS [Institute for Multidisciplinary Ecological Research in the Salish Sea, Canada]
NASA Jet Propulsion Laboratory [California]
NASA GSFC [Goddard Space Flight Center, Maryland]

The five institutions that did not fit within the prior categories were two design groups (*One World Immersive* based in Colorado, and *Spherical* based in California), the *African Circular Business Alliance* based in South Africa, a software library called *Nyx Space*, and an institution called *Travelling Universe* in Chiang Mai, Thailand.[2]

We asked respondents to add names of secondary institutions or organizations that they may use OpenSpace with, in addition to the primary locations above.[3] Nine respondents answered. The plurality of these (n=6) were located across the United States:

Elumenati [an OpenSpace vendor]
International Dark Sky Association
Saint David's School [a private school located in the Upper East Side of Manhattan]
Solar System Ambassador programs [NASA-funded public outreach]
University of Texas at Austin

---

[2] The respondent representing *Travelling Universe* was contacted for further information but did not respond in time for submission of this report on October 31, 2023. He reported using OpenSpace as a hobbyist, weekly via projector, has presented to the public once or twice in the past year, and uses OpenSpace mostly for research and visualizing data with the goal to "teach the general public about the known universe." Carter Emmart reported that "there was a big orange bus doing mobile, operated by the National Astronomical Research Institute of Thailand (NARIT), with special royal support by Princess Sirindhorn. I showed them OpenSpace years ago on an official visit after meeting the director at NAOJ."

[3] These are not included in the count of primary institutions above, as most of the follow-up questions in the body of this report revolved around the primary institution.

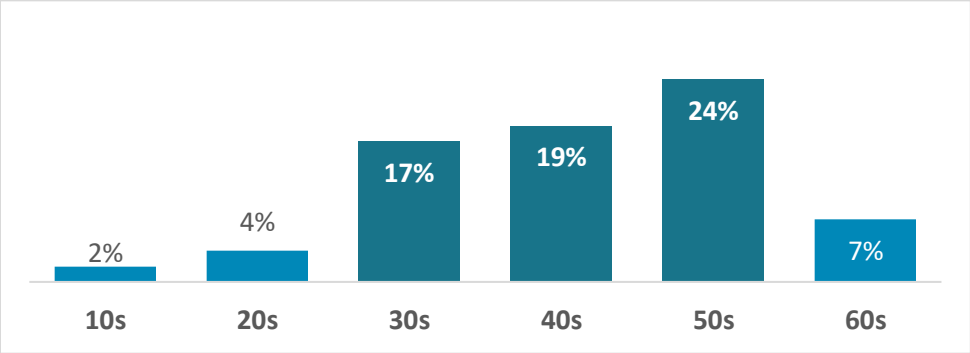
WISDOME [an event venue in Los Angeles]

Other secondary institutions were in England (*Bromsgrove Astronomical Society*), The Netherlands (*Dot Live Planetarium*), and Portugal (*Alpha-Centauri Astronomy Association)*.

Demographics

Respondent ages ranged from nineteen to sixty-seven, with an average age of forty-five and a median age of forty-six. Only one respondent was in their teens, and most respondents were in their fifties.

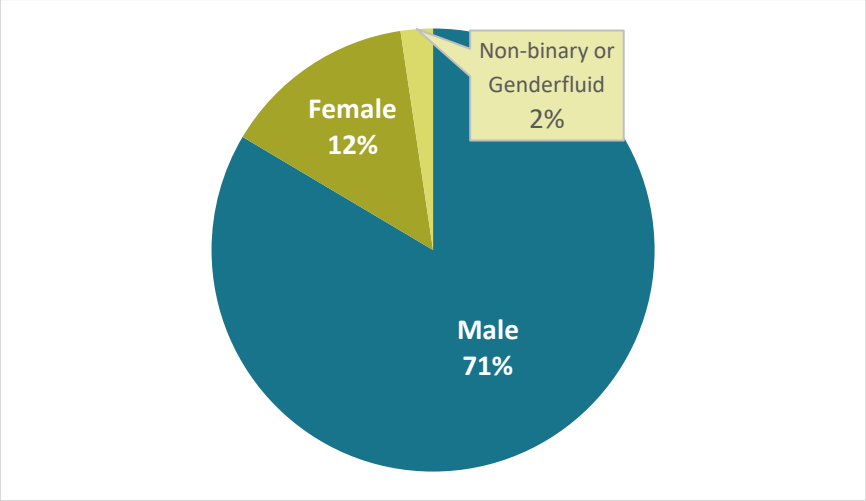
Figure 3: Respondents to this Survey Mostly Ranged from 30-59 (n=51)



These results trend older, with the plurality in their fifties. These percentages are unsurprising as many respondents held leadership positions within their institution, but we were interested by the responses of the nineteen-year-old. He is a student at Columbia, uses OpenSpace every day for mostly "Astronomy meetings, displaying structures," and flies *okay* but wants to improve.

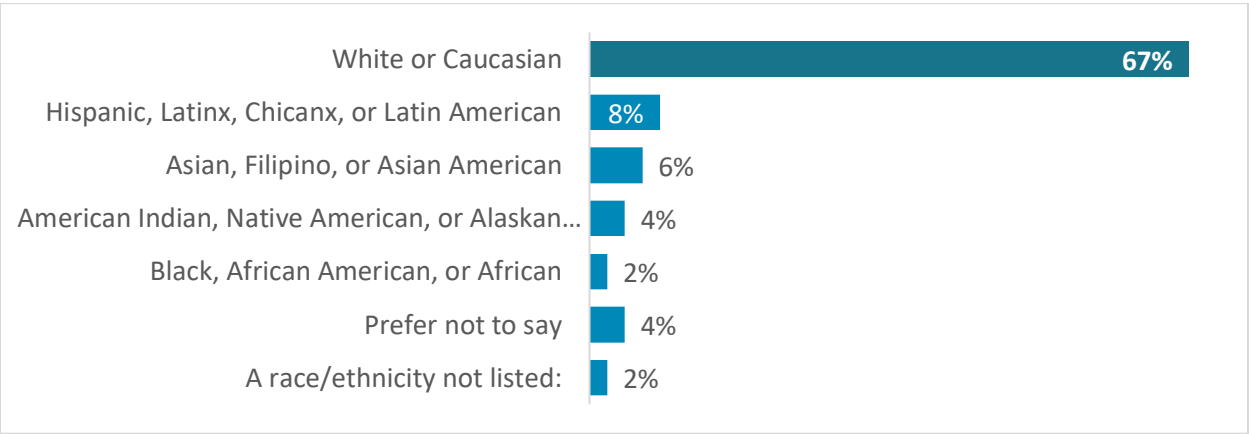
Moving to genders of the sample, the majority of respondents identified as male (71%). Six respondents identified as women and one respondent identified as non-binary or genderfluid.

Figure 4: Almost Three-Quarters of Respondents Were Male (n=51)



Regarding race and ethnicity, the majority of respondents to this survey identified as white. Of the 7% that identified as Latinx, one was in the United States (and two in Europe and one in South America), signifying a small sample of Latinx Americans. It is also notable that only one Black/ African/ African-American person responded to the survey, and they responded from the U.S. A reminder that this survey is not representative of overall users of OpenSpace, but new methods may need to be considered when sampling the network in the future.

Figure 5: Over Two-Thirds of Respondents Were White (n=51)



Current Uses of OpenSpace

Primary Institutional Use

For the first section of the survey, we asked respondents to consider one institution where they use OpenSpace as their primary institution. The data in this section refer to that one location of use and the respondents' roles there. In the following section, we ask about use beyond this one institution.

We asked respondents to write in their title or role within their primary institutions. Almost half of respondents had titles that signified leadership or founding positions in their institutions, including directors, founders, or co-founders.

Figure 6: Almost Half of Respondents Held Leadership Positions (n=51) *

47%	**Leadership / Founding positions**
18%	Educators
12%	Researchers / Academics
8%	Communication / Ambassadors
8%	Scientists / Developers
6%	Planetarium workers
8%	Other

*See Appendix C for full list of respondent titles/roles. Percentages do not add to 100% because respondents could select multiple answers.

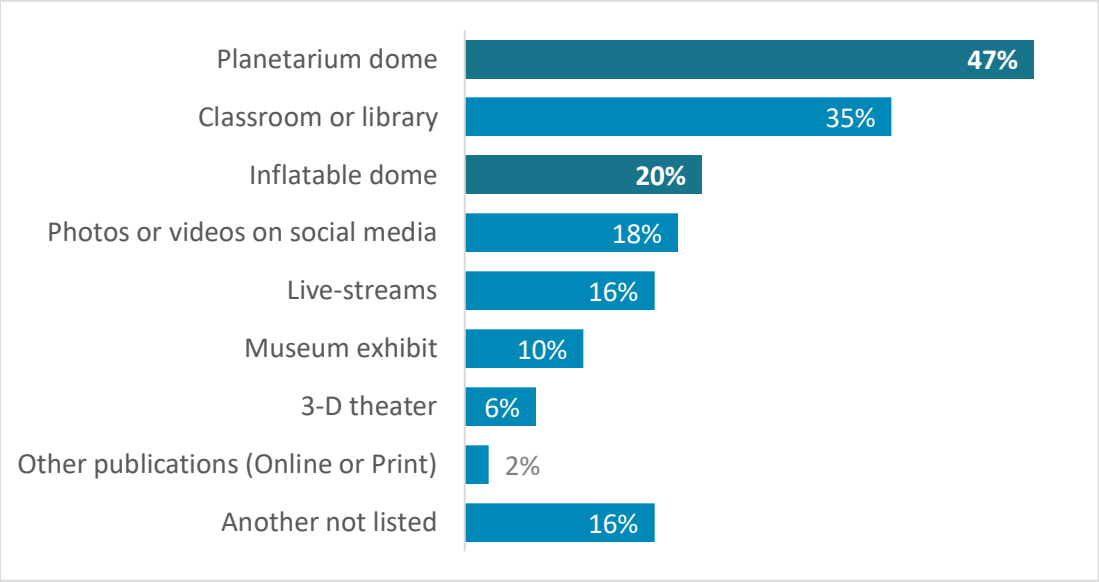
Following the leadership category, educators from formal and informal education settings were the most common (18%). There was overlap for three of the nine, who identified leadership positions in addition to their educator role, like "Director/Teacher" and "Professor of Physics/Planetarium Director." The Scientists/Developers category was varied, with responses like IT Assistant, Developer, Astronomer, and "Scientist/Software." As these titles were varied and included degrees of nuance at times, we included the full list of titles in Appendix C.

OpenSpace is Often Displayed on Domes and In Classrooms

The majority of respondents said their institutions are displaying OpenSpace on either a planetarium or inflatable dome (63%), with almost half of all respondents using a planetarium dome specifically (47%).

More than one third of institutions used OpenSpace in classrooms or libraries (35%), and less than one-fifth (right?) used OpenSpace for outreach and educational content on social media (18%).

Figure 7: Almost Half of Institutions Displayed OpenSpace in a Planetarium Dome (n=51) *



* Answers do not add up to sample size because respondents could select multiple answers.

Those who wrote in *Other* types of OpenSpace displays (16%) detailed different types of screens, formats, and uses, two mentioning Virtual Reality (VR).

> *R&D VR environment [The Human Space Program]*
>
> *Special events on flat screens; also exploring VR [National Museum of Science in Stockholm]*
>
> *Cobra Curved Display [University of Cape Town]*
>
> *Visualization of ADCS simulation [Technical University of Munich]*

Those who mentioned VR above, and three other respondents, later voiced their desire to see that prioritized by development (n=5):

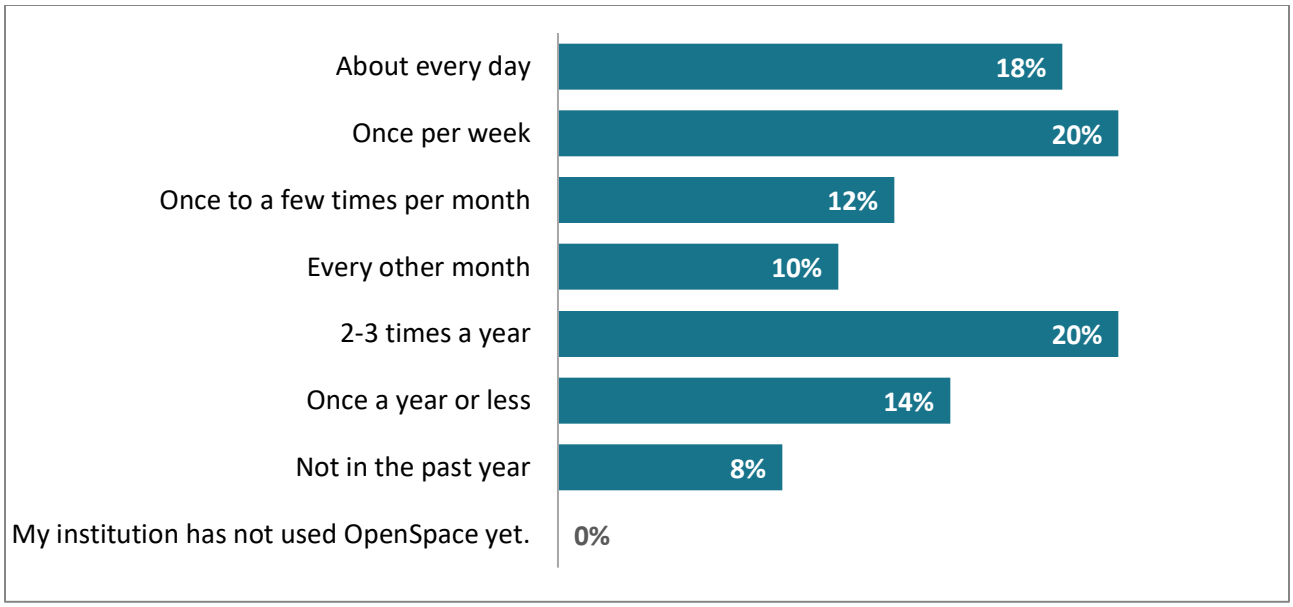
> *As I suggested before, support for VR headsets, Oculus/Meta or other brands should be your first priority.*
>
> *Keep it up, and get VR working, and if it were multi-user, it would be fantastic.*

Others explained that their display was for individual use, like "Internal Office" (*African Circular Business Alliance)* or for "Scientific and engineering analysis" (*Nyx Space*).

Use Frequency Varies Greatly Between Respondents

There were no trends to the frequency of institutional use in this group of respondents, which may have to do with the variety of use types and role types in the sample. That said, exactly half of the sample reported using OpenSpace at least once a month, only a few did not use it in the past year (8%), and nobody said that their institution had *not* used the software yet.

Figure 8: All Had Used OpenSpace, but Frequency of Use Varied Greatly (n=51)

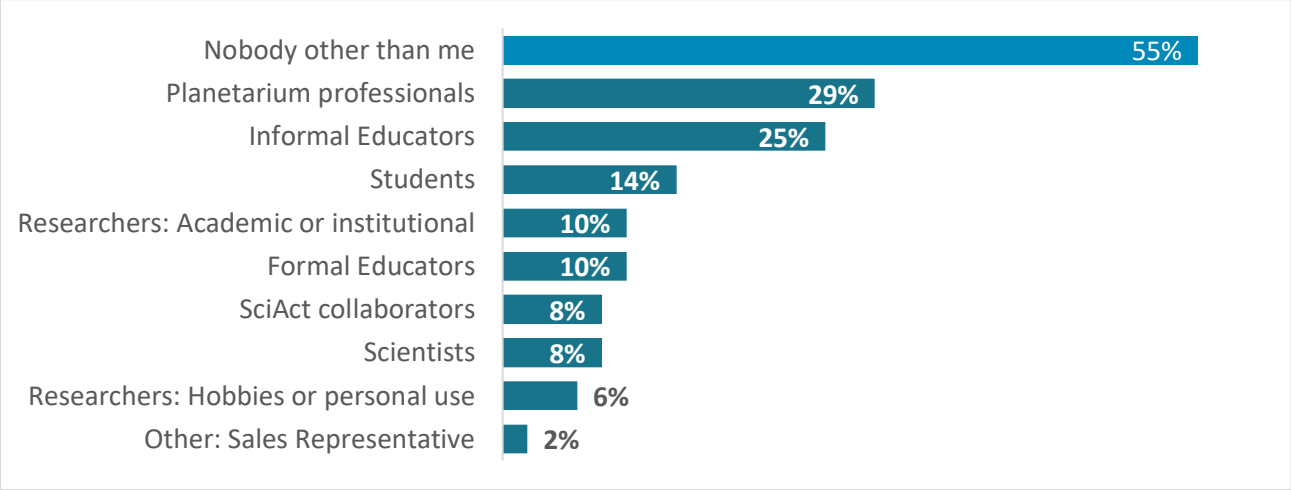


We asked the four respondents who reported *not* using OpenSpace in the past year why they had not used it more frequently. Three answered, explaining reasons that could have been more the responsibility of the institution than the individual: lack of training, lack of time, and incompatibility with their computer system.

OpenSpace is Used by Multiple People in Primary Institutions

We wanted to know who else was using OpenSpace within the respondents' primary institutions. More than half said that they are the only ones (55%), which also means that 45% of respondents were using OpenSpace with colleagues.

Figure 9: In Primary Institutions, Almost Half of Respondents Use OpenSpace With Others (n=51) *



* Percentages do not add to 100% because respondents could select multiple answers.

Of those twenty-two respondents who were using OpenSpace with colleagues in their institutions, 50% were from ISIs. In other words, a little over half (52%) of the museums and planetariums sampled (n=21) have more than one OpenSpace user in the institution. Almost half (44%) of the formal education sites (n=18) had multiple users. Half of the astronomy groups (n=6) and half of the research institutions (n=4) had multiple users.

We also asked about who respondents use OpenSpace with directly, within *all* roles and institutions (as opposed to only the primary institution in the question above). We confirmed the same result as above: 45% are using OpenSpace with coworkers or colleagues, though when thinking about *all* institutions, fewer are using it alone (22%) than in their *primary* institution (55%), implying that uses outside primary institutions are more social or shared in OpenSpace use. Answers that fell into other categories included more nuance. See Personal Use section for details about who else respondents are using OpenSpace with.

OpenSpace Is Relied On for Work

In the final section of the Instrument, we asked respondents to add any insight or thoughts that were not covered by other parts of the survey. Half responded to this question, with three speaking specifically about the importance of OpenSpace for their work:

> *OpenSpace enables me to run a robust planetarium outreach program that is highly featured on a shoestring budget. I don't know what I'd do without it!*

Two of these respondents linked this importance to a lack of confidence that it will continue to be around for them to rely on.

Since I rely much on OpenSpace, I would like to know that the project has a strong foundation and will be supported for a long time. The project has a very strong scientific side. Me, as an amateur, I would like to see the ease of use being developed more strongly.

It's been a big part of my life, professionally and personally. I invested myself fully in the software, and it's been a good time, but I'm having doubts that it will be a stable choice going forward. I understand the technological reasons why it is difficult to make it work cross platform, but somehow, other software manages to keep up. OpenSpace is mature now, and people rely on it for their work. It's not just an academic lab experiment, but a product (free, but still a product). It deserves the support a real product would have.

Barriers to Use Include Software Concerns and Desire for Training

We asked what limits respondents' institutions from using OpenSpace with more frequency. Many institutional limits were remarked on, which the OpenSpace team has little control over. But other comments focused on software limitations (including some erroneous perceptions) and the desire for more training.

More than two-fifths of respondents (41%) mentioned **institutional limits** that prevented them from adopting OpenSpace more widely. These types of limits most commonly were incompatible institution priorities, technology restraints, and programming requirements.

Old hardware, little interest in Astronomy by management.

Educational priorities

Computer and personnel resources

Updating our programing, developing new curriculum

Field trip constraints-mostly time.

Less than a quarter of the responses (22%) detailed **issues with the software itself.** These varied from problems that are solvable, that are not resolvable, and that have already been resolved. For example, "the demanding graphics capabilities" inspired the OpenSpace Cloud and will be addressed with that upcoming augmentation.

The difficulty in plotting spacecraft trajectories from SPICE files.

External control (via TCP/Websockets is brittle), no sufficient documentation of the LUA interface and console commands.

OpenSpace has a bit of a problematic control, and it crashes sometimes.

Installation procedure on PC laptops

It also doesn't have an easy way to disconnect from the dome to update the scene on our Preflight computer and then smoothly transition to the updated settings on the dome.

Wanting pre-programmed shows is a barrier that has been brought up in other studies, with SMEs and the previous Network survey.

Have a more flexible tool for making preprogrammed "shows". The action buttons are nice but would benefit if they could be more finetuned.

As in the SME survey, desires for night sky programming were raised. This request was completed with the most recent update (version 0.19 was released on June 27, 2023).

Missing essentials for night sky programs: star trails, zoom-ins on planets while staying "on the ground." Lack of development expertise and time for possible but currently laborious builds (custom constellation lines and art, custom GUI for student presenter use)

It cannot properly display night sky and standard planetarium views from Earth very well. It doesn't simulate diurnal motions, celestial coordinates, etc.

Out of those that detailed **time** to be one of their constraints (18%), they referred to lack of their time to develop new programs and to implement it to the institution's existing software as well as lack of time with certain audiences.

The learning curve for the software was also a barrier for 14% of respondents. These comments focused on a desire for training directly, or an observation of the complexity of learning how to operate OpenSpace.

The skill curve for anyone that isn't in the software all day every day makes it hard to use and understand some of the underlying features and tools provided.

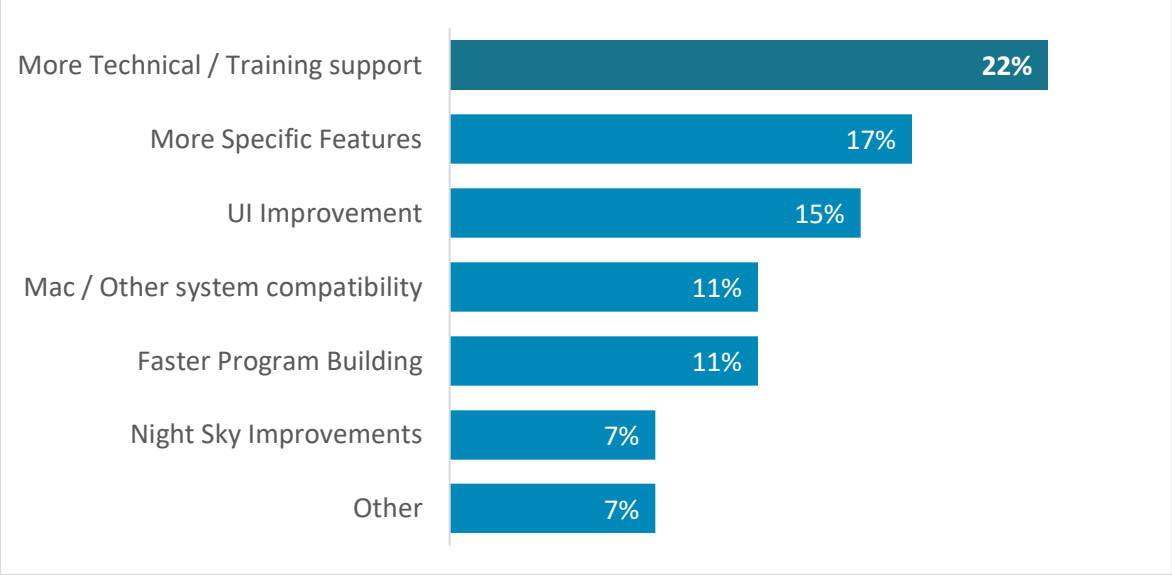
General unfamiliarity with this type of software and what a modern planetarium is capable of. Austin is still the largest city in the US without a planetarium :-(

Complexity of the use for our educators.

Limitations of software download, constant upgrades and lack of support from OpenSpace to deliver content in a non-planetarium setting.

When we asked the same question about use beyond the primary institution, we saw similar themes without the institutional limits.

Figure 10: Respondents want Training as a Priority for All Uses (n=51) *



* Percentages do not add to 100% because respondents could select multiple answers.

One response to the final survey question ("Do you have any final thoughts about OpenSpace?") commended the new update and voiced the desire for training.

> *0.19 was a great leap! Even though I haven't tried it yet, the easier caching and video implementations are going to be really helpful in my next project. I'm hoping you all start doing video tutorials and improve the documentation.*

Personal Use, Beyond the Primary Institution

For the second half of the survey, we asked respondents to switch gears away from thinking only about their primary institution and consider all other uses. Respondents mentioned other organizations or secondary institutions, informal groups, friends or colleagues, and even use with their families.

OpenSpace is Praised for Enhancing Access

In general, respondents deeply appreciate how OpenSpace is a doorway to not only science learning but also direct research and engagement with science. In response to our open-ended "any other thoughts?" question at the end of the survey, respondents explained:

Thank you for OpenSpace, it is amazing and really wonderful. It has given so many of our young people the chance to see the universe in a way they would have never experienced otherwise. You are all outstanding!

OpenSpace is, in my opinion, a brilliant tool for story-based learning in groups in dome as well as exploring by yourself on a gaming laptop. The Open-Source model makes it extremely useable for a wide range of situations.

OpenSpace is a great planetarium software, a wonderful tool very useful for showing to common people the amazing of Universe.

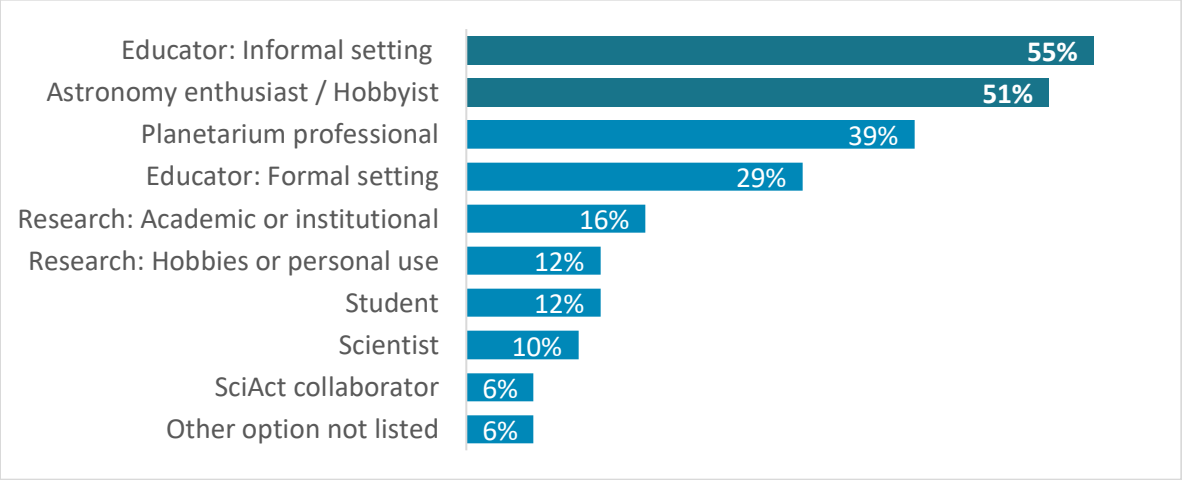
This is a remarkable software and even more so that it's free and available for the public to use! It is a visual masterpiece.

Over Half Use OpenSpace as Informal Educators and Space Enthusiasts

We first questioned respondents about their roles or titles in the primary institution with which they use OpenSpace in an open-ended question (Institutional Use), but we wanted to also capture the breadth of roles with which respondents engage OpenSpace in any setting. Later in the survey, we asked them to select from a list, considering any roles with which they *personally* engage OpenSpace.

With that expansion, more than half of respondents identified as informal educators using OpenSpace (55%, as opposed to 18% who have Educator in their title in their primary institution). We also see the more-than-half of respondents who identity as astronomy enthusiasts and hobbyists (one respondent had identified "Hobbyist" as their primary role with OpenSpace).

Figure 11: Most Respondents are Informal Educators and Enthusiasts with OpenSpace (n=51) *



*Percentages do not add to 100% because respondents could select multiple answers.

The rates of informal and formal educators for this section are interesting because only nine people had a title signifying Educator within their primary institutions, yet 59% of respondents personally identify as educators, either formal or informal. Some of institutional roles, like Science communicators/ Ambassadors, Planetarium workers, and Leadership positions, could fit under the educator categories for this question and influence these high percentages. This could explain the higher counts for educators, but respondents may also identify as educators in their personal life.

One comment in the final "any other thoughts?" section spoke to this role of informal educator that shares OpenSpace with their loved ones:

> *I think OpenSpace really drives my enthusiasm on the subject, and it has naturally engaged and caught the attention of anyone I have shown it to. I really believe in the team's overall goal. I would love to develop a learning plan, or if someone there created a learning plan/course for beginners with a possible capstone project to assess their development.*

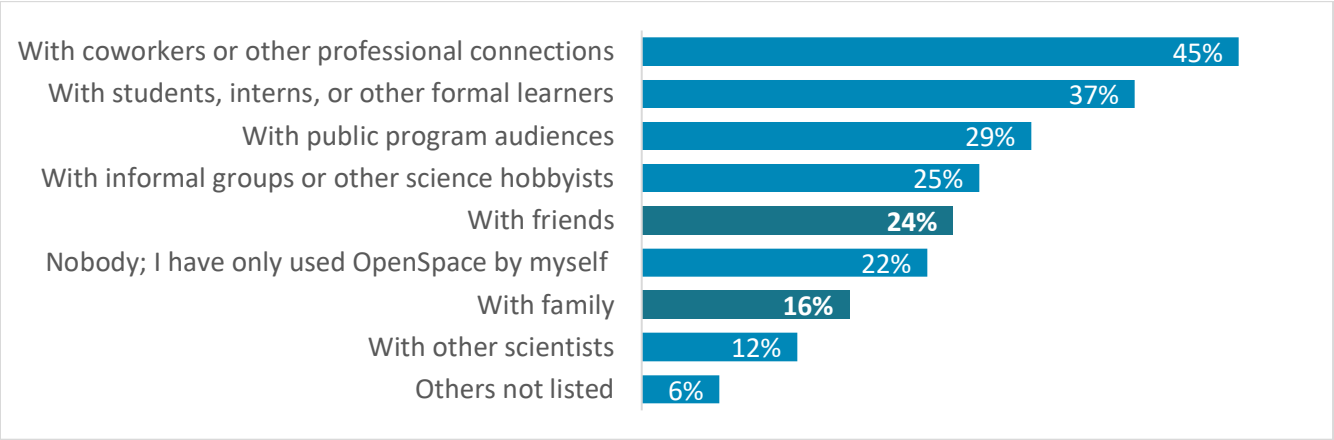
Only two respondents identified as students as their primary role, yet four other respondents personally identified as students apart from the institutional role they outlined.

OpenSpace is Used with a Variety of People, Including Friends and Family

As mentioned above in Institutional Use, respondents were asked twice about who they use OpenSpace with: once in their primary institution, and again for all uses. The plurality confirmed that they use OpenSpace alongside coworkers or professional connections (45%). Interestingly, reports of use with students, interns, or other formal learners increased to 37% (from 14% for the primary institution alone), demonstrating that more respondents use OpenSpace with students beyond their primary roles. In this question, about a quarter of respondents denoted audiences and other hobbyists, which is in line with other data about roles and settings.

Even more intriguing is that there is a somewhat high instance of using OpenSpace with friends (24%) and family (16%). A total of 25% of respondents were using OpenSpace with friends or family, including seven respondents who used it with both (14% of the total sample).

Figure 12: A Quarter of Respondents Use OpenSpace with Friends, Family, or Both (n=51) *



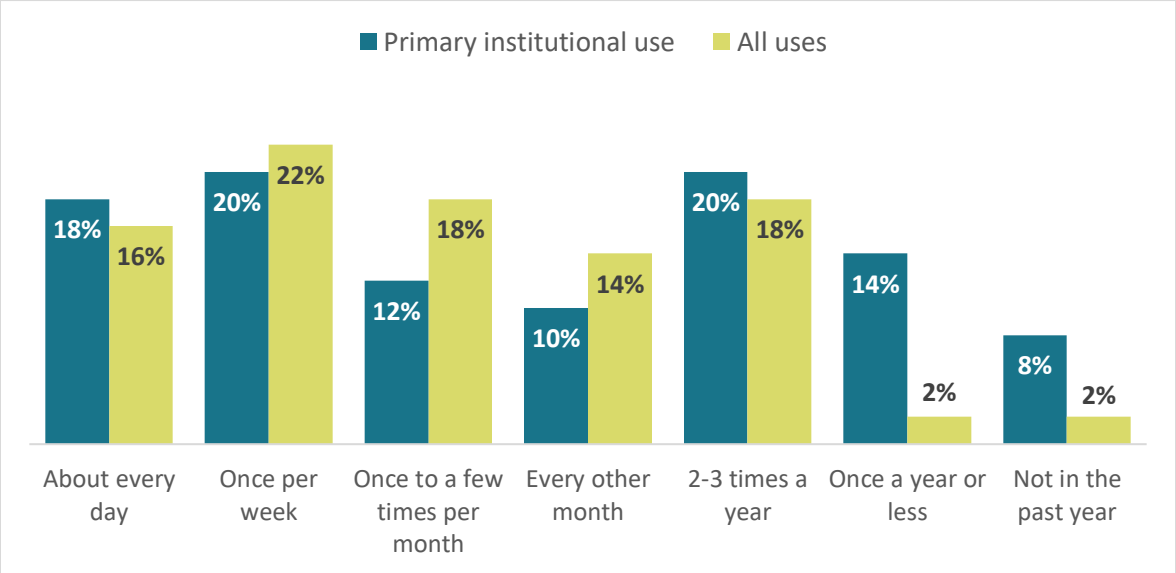
* Percentages do not add to 100% because respondents could select multiple answers.

This means that OpenSpace users share the software not only within their work, but with their loved ones in informal settings as well.

Frequency of Use Varies When Considering All Roles

We asked again about frequency of use for each role the respondents have for OpenSpace, removing the limitation of the primary institution as in the question before. Once again, the responses were varied, with a slight trend towards more frequent use when all roles were considered.

Figure 13: Slightly More Use of OpenSpace When All Uses Considered (n=51)

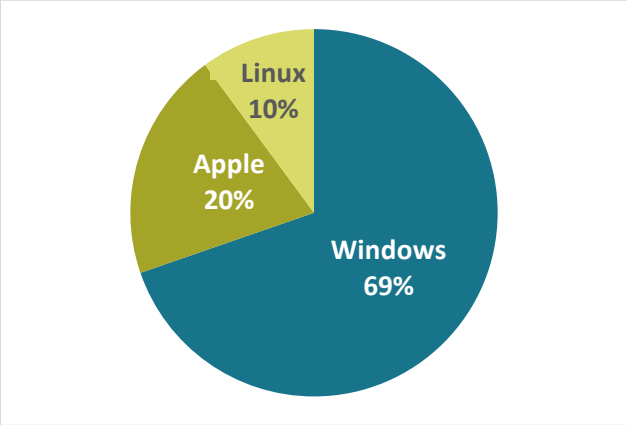


Similar to previous questions, the main limitations for the one respondent who used OpenSpace *once a year or less* was lack of time and funding; this person is a director of strategy for an international

astronomy group. The other respondent who hadn't used OpenSpace in the past year is a founder of a design firm, and said it was due to having a Mac computer. These respondents answered the same way for both the *primary* institutional frequency of use and *all* use.

That user is not alone in using Mac: over two-thirds of respondents run OpenSpace on Windows systems, but 20% use Mac systems. While OpenSpace is available for Mac computers since the recent update to version 0.19 in June this year, it is not yet able to run on Apple M1 and M2 processors, which may be the cause of the complaints.

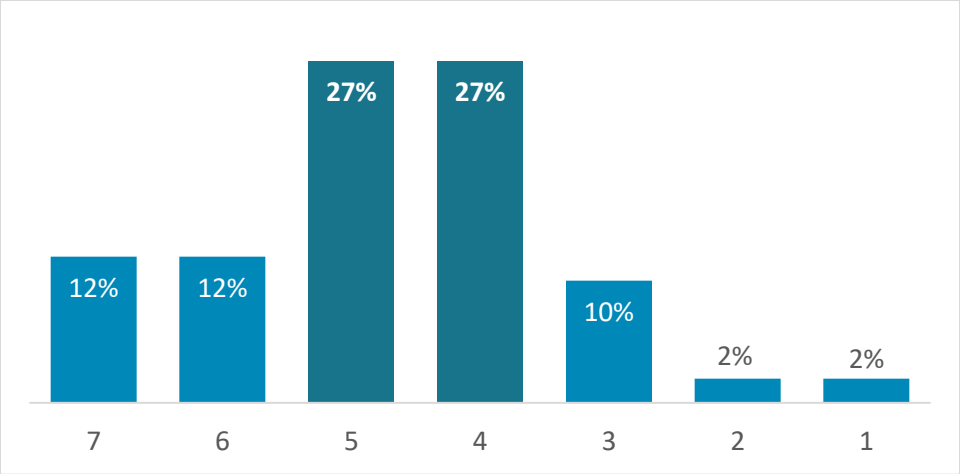
Figure 14: Majority of Respondents Runs OpenSpace on Windows (N=51)



Network Users are Moderately Comfortable with the Software

We asked respondents to rate their comfort with OpenSpace on a scale from one to seven, where one was *not comfortable at all* and seven was *totally comfortable*. More than a quarter of respondents identified having average comfort with OpenSpace, with a trend towards more comfort.

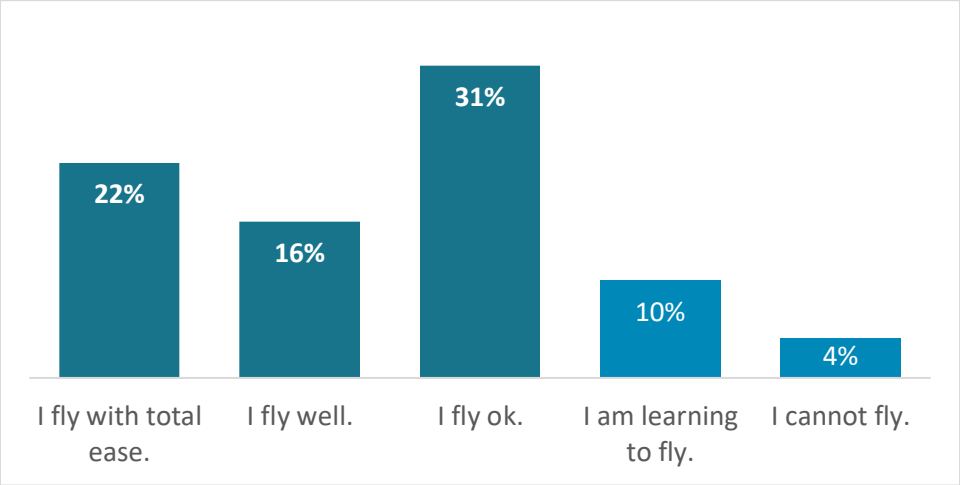
Figure 15: Most are Moderately Comfortable with OpenSpace (n=51)



Most have Some Flying Ability and a Lot of Flying Interest

We asked respondents to both rank their own ability to fly (operate) OpenSpace, as well as their interest in learning. This data trends positive, with 69% saying that they can fly at least *ok* or better. Only 14%, or seven respondents, are just learning or say that they cannot fly. These data are supported by the number of respondents requesting more tutorials and documentation for the software; many have the basic skills down but need support to acquire more complex skills.

Figure 16: Most have Some to Advanced Flying Capability (n=51)



Almost all the respondents (91%) responded that they were *somewhat* or *highly likely* to continue learning to operate OpenSpace. Over half of respondents that answered this question selected that they were *highly likely* (52%) to continue learning how to fly.

Of the 4 respondents that responded with either *somewhat* or *highly unlikely* to improve their flying ability, three explained that it was due to software limitations.

Communication

For both primary institution uses and broader uses that include more informal exploration of the software, communication with other users, developers, and the OpenSpace team are desired by the survey respondents. This section outlines how respondents have been receiving communication, choices about updating software, and suggestions for the team.

Most Learn about OpenSpace Updates Through Colleagues and Presentations

About the same number of respondents learned about OpenSpace first though professional connections (27%) or a presentation (25%). Professional connections were made through colleagues in their

institutions or in the broader space science field. Some were exposed through the institution they work at since their institution was adopting OpenSpace.

The remaining respondents first learned about OpenSpace through the internet (18%- many described happening upon it while looking for other things or seeing online videos) or AMNH, either via presentations, workshops, or connecting with the OpenSpace team (12%).

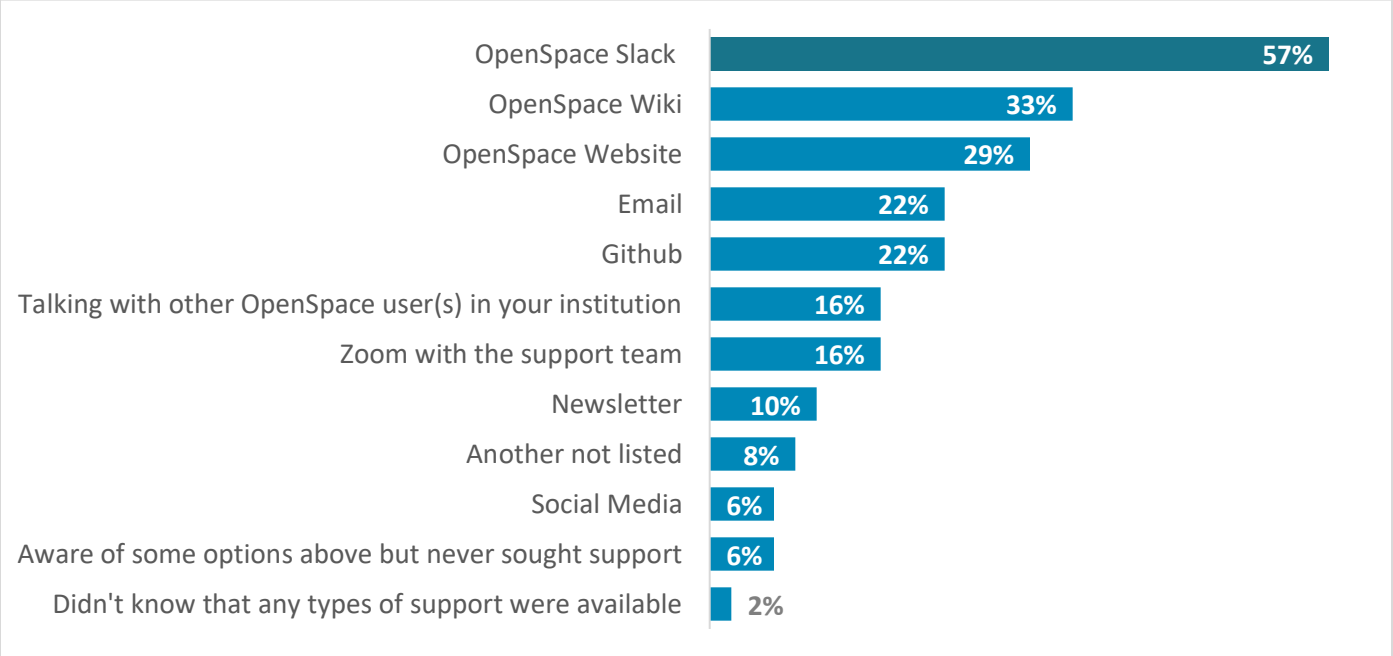
Users Access Support through Online Networks and Emailing Most

When asked to select three types of support that are most helpful to the respondents, more than half selected the OpenSpace Slack workspace (57%). The OpenSpace Wiki or website, emailing with the team, and GitHub also ranked highest for most useful types of support.

Although not among the most frequently chosen (16%), it is worth noting that discussions among coworkers within the same institution are incredibly helpful for OpenSpace. It doesn't just help by exposing more people to this software and knowing about updates, but also for those seeking support.

Nobody found any of these options unhelpful. Most (n=3) of the *Other* responses mention some sort of direct contact with the OS team.

Figure 16: Respondents Found the OpenSpace Slack as the Most Helpful Type of Support (n=51) *



* Percentages do not add to 100% because respondents could select multiple answers.

Users are Grateful to the Team

When asked to explain anything they had not said earlier in the survey, five respondents specifically mentioned the support that they receive from the team.

> *I am grateful to the OpenSpace team. They are helpful and highly competent. I appreciate that they take every question seriously regardless of if it's a trivial matter or an "in the weeds" question.*
>
> *A great strength is the access to developers and their friendliness and dedication to helping end users.*
>
> *Everyone who has worked on this project is very nice and welcoming. Keep up the good work.*
>
> *I love working with OpenSpace and am very grateful to be part of a welcoming community of developers, users, and associates. Thanks for all the support!*

Software Updates Unavailable or Unappealing to Some

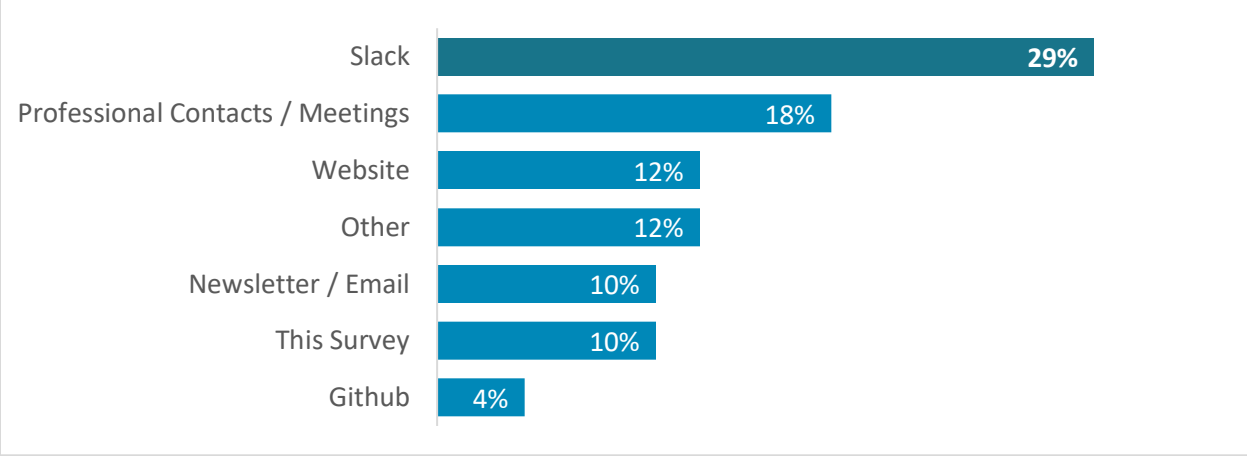
When asked whether respondents had updated their version of OpenSpace, a little more than two-fifths of the respondents said they are using the most recent software update-- version 0.19 (43%). Slightly fewer said their version is not updated (37%). When asked what prevented them from updating the software, 40% (or n=8) of that group said that it was due to infrequent use or lack of time.

> *Lots of new staff starting and just trying to get caught up with other projects.*
>
> *No mac version since 18.1.*
>
> *[What has prevented you from updating the software?] Bandwidth space on Operating System. OpenSpace downloads, upgrades continued to crash my system. These laptops are my personal devices, and I cannot afford to suffer the loss of another computer due to software upgrades, bugs, fixes, complications that generate a virus and/or crash my personal devices on an open-source network without any technical support from OpenSpace staff members.*
>
> *My next project will use the latest software. I haven't used it in earnest in a while.*

A few respondents (n=5) said that their resistance to updating to the most recent version was because of problems with their computer, or that they believed Mac updates were not available. Five respondents (9% of the total respondents) said they were not aware of the update until answering that question in the Network survey itself.

When asked how they knew about the recent update, more than a quarter of respondents said they learned about it through the OpenSpace Slack channel (28%). Other respondents said they learned about it from professional contacts or meetings (17%), or from the OpenSpace website (13%).

Figure 17: Most Respondents Learned about the Update through the OpenSpace Slack (n=54) *



* Percentages do not add to 100% because respondents could select multiple answers.

The responses in the "other" category included learning about it in a conference (n=2), checking OpenSpace resources regularly (n=2), and OpenSpace's Facebook account (n=1).

Future Uses of OpenSpace

We asked respondents how their primary institutions would use OpenSpace in the future. Only two respondents said they would be using it the same way as they are now.

Aspired use in planetariums and portable domes made up one-third of the replies (33%). Some mentioned the creation of new shows, and some mentioned increased levels of interaction.

Slightly less than one-fifth of respondents wanted more development of content (18%). Some mentioned new programs, along with the necessary expansion of staff familiarity to do so, and one respondent mentioned using OpenSpace in a museum installation.

14% of the respondents envisioned new modes of outreach.

Another 14% wrote about using OpenSpace with more formal education locations and students.

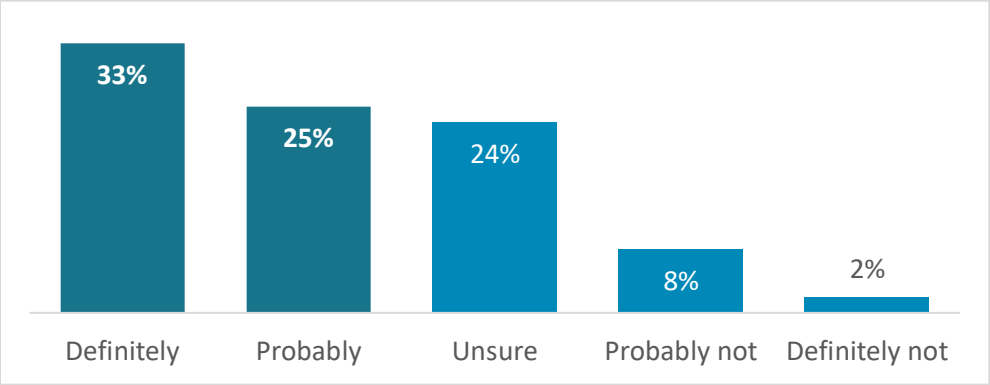
Of those that answered within the Other category, most mentioned using OpenSpace along with other software (*API Interconnect*, *Digistar*, or *Unreal Engine*). Two said that their institution will not be using

OpenSpace in the future due to transitioning roles and one indicated a lack of flexibility in OpenSpace compared to other software.

Frequency To Increase, Variety Less Predictable

When asked if their institutions will increase frequency of OpenSpace use in the upcoming year, one-third of respondents selected *Definitely*. In this chart, we see a strong trend towards the positive: 58% expect an increase in use, and only 10% of respondents expected no increase.

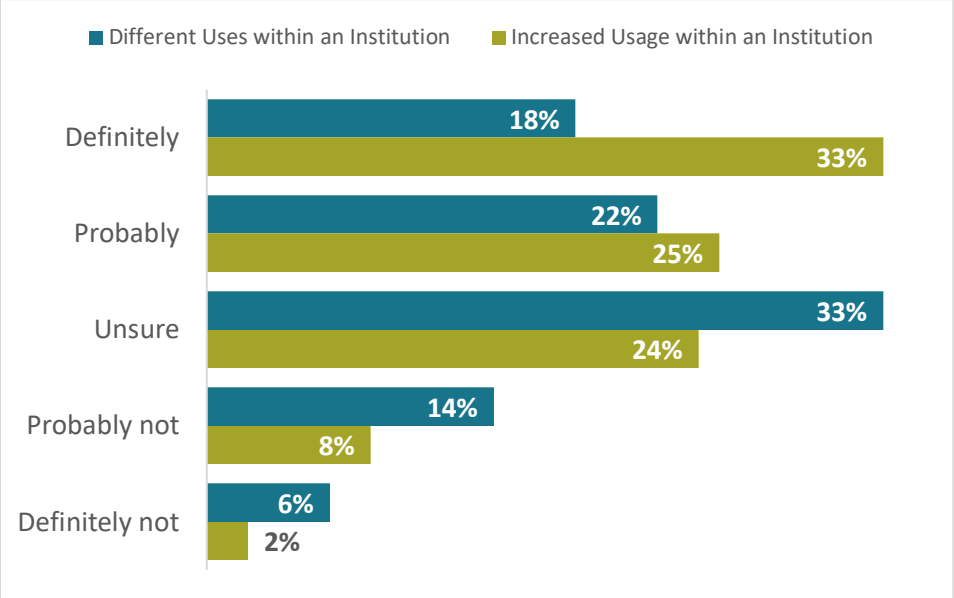
Figure 18: Over Half of Institutions Expecting Increase in OpenSpace Use (n=51)



When asked whether institutions will use OpenSpace differently than it has been in the next year, the plurality of respondents were unsure (33%). Looking beyond those who were unsure, responses still trend positive, with 40% of respondents expecting a different use and half of that (20%) expecting no new uses.

Comparing these ratings with those for frequency of use, respondents were *more* confident in increasing OpenSpace use, but in the ways that their institution had already been using it.

Figure 19: Respondents Surer About Increased Frequency than New Institutional Uses (n=54)



Network is Excited to Continue Use, Wants Assurance

Comments for the final "what else?" question at the end of the survey included thoughts from eight respondents about their use of OpenSpace in the future. Many of these were fully praise and excitement.

> *I really like this system and I am very grateful for everything I have learned because I have been able to personalize and show the universe to others from a very dynamic and modern perspective. I want to keep learning and contribute as much as I can.*
>
> *AWESOME product, with many future capabilities. Looking forward to actually start plugging in additional satellite data.*
>
> *I think it is really cool and look forward to integrating it more into our workflow.*

There was also a desire to find more ways to use it.

> *OpenSpace is an incredible piece of software. I just need to find better ways of incorporating it into my work.*

And, like those who rely on the software for their primary institution, an "amateur" also felt a longing for a stronger foundation of support for their own personal work.

Since I rely much on OpenSpace, I would like to know that the project has a strong foundation and will be supported for a long time. The project has a very strong scientific side. Me, as an amateur, I would like to see the ease of use being developed more strongly.

Appendix A: Instrument

OpenSpace Network Survey: 2023

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. Each of these questions is optional, but highly useful for the team to improve the use of OpenSpace. The data collected for this survey will be destroyed 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)*

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:

* 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

Infrequent Users

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

Institutional Use (continued)

* 9. In the next 12 months, will your institution **use OpenSpace *more often*** than it has been?

- ◯ Definitely not
- ◯ Probably not
- ◯ Unsure
- ◯ Probably
- ◯ Definitely

* 10. In the next 12 months, will your institution **use OpenSpace *differently*** than it has been?

- ◯ Definitely not
- ◯ Probably not
- ◯ Unsure
- ◯ Probably
- ◯ Definitely

11. What limits your institution from using OpenSpace more than it does, if anything?

12. How do you anticipate your institution will use OpenSpace in the future, if at all?

13. 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.

Your Use of OpenSpace

Now we're going to switch gears to think about your personal experiences with OpenSpace.

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

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

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

* 16. 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.

Infrequent Users

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

Personal Use (page 2)

* 18. In the past 12 months, **how did you use OpenSpace**? *Select the frequency that you did each activity in the past year.*

	Never	Once or twice	3-4 times	More than 4 times
I worked with interns, mentees, or students.	○	○	○	○
I presented live to the public.	○	○	○	○
I presented live to colleagues or students.	○	○	○	○
I presented stills or videos to the public.	○	○	○	○
I presented stills or videos to colleagues or students.	○	○	○	○
I researched or visualized data.	○	○	○	○

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

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

* 20. In what context(s) do you use OpenSpace? Please include contexts for **all roles and institutions** that you may use the software with.

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

* 21. 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:

* 22. Please rank your ability to fly in OpenSpace.

I cannot fly.	I am learning to fly.	I fly ok.	I fly well.	I fly with total ease.
○	○	○	○	○

Learning to fly

* 23. In the next 12 months, **how likely are you** to learn (or continue learning) how to fly?

Highly unlikely	Somewhat unlikely	Somewhat likely	Highly likely	N/A
○	○	○	○	○

Why is that?

Versions

* 24. OpenSpace version 0.19.0 was released on June 27, 2023. Is this the version that you're currently using?

- ○ Yes
- ○ No

Personal Use (page 3)

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

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

- [ ] Windows
- [ ] Apple
- [ ] Linux or Unix

* 28. 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 Slack workspace
- [ ] 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:

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

* 25. What has prevented you from updating the software?

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.

* 30. 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:

* 31. 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:

32. In what year were you born? *(optional)*

Final Thoughts?

33. **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.

35. **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:

36. **We really value your opinions as we continue improving the software.** If the evaluation team can contact you with further questions, please let us know how below. *(optional)*

Email address:

Phone number:

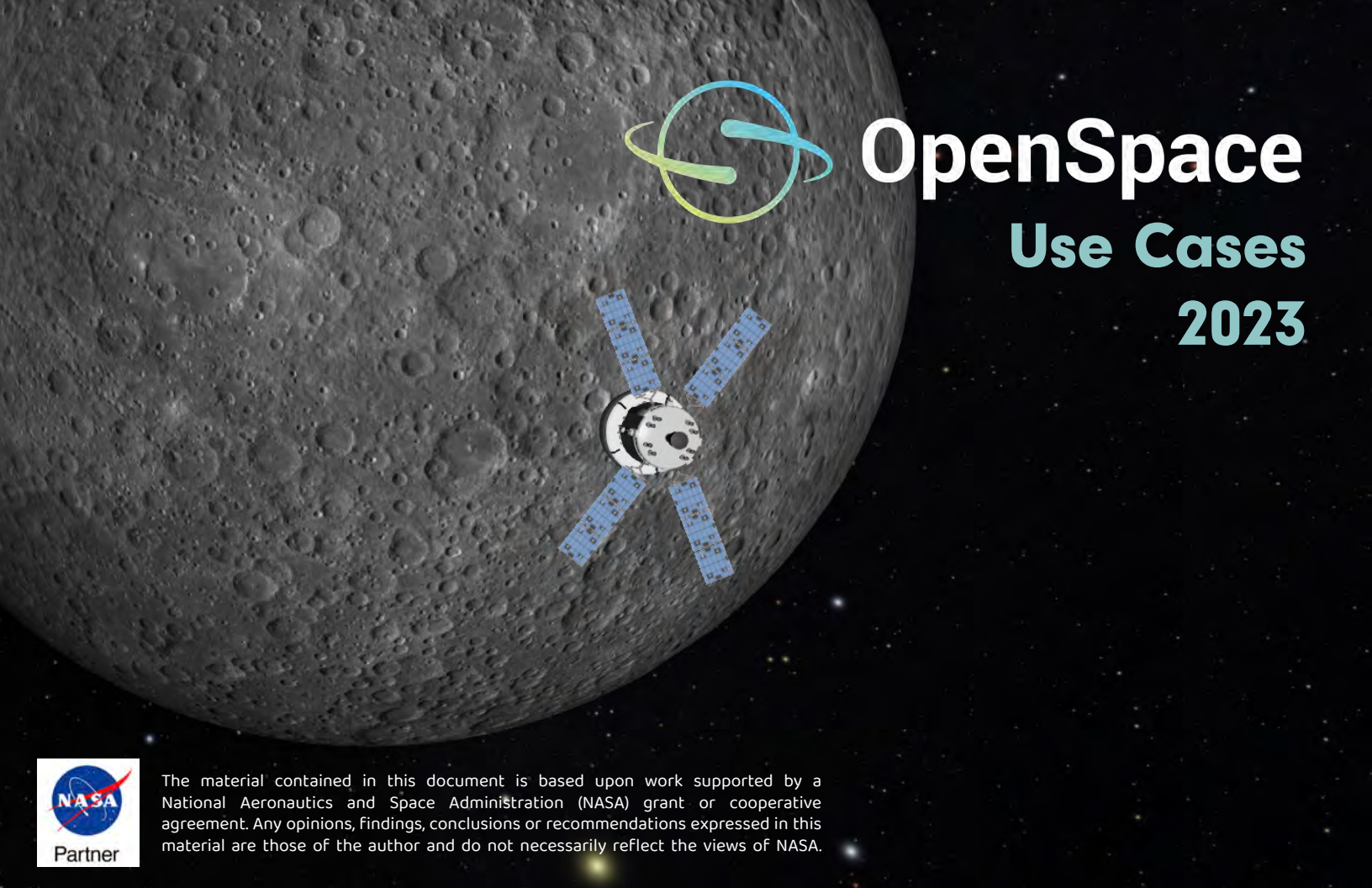
Appendix B: Institutions Represented in Sample

Institution	City	State	Country (if not USA)
African Circular Business Alliance	Cape Town	Western Cape	South Africa
AMNH	New York	NY	
Anchorage Museum	Anchorage	AL	
Astro Group South Sardinia	Castiadas	Sardegna	Italy
Astrolab Iris	Leper	WVL	Belgium
Austin Community College	Austin	TX	
Bromsgrove School	Bromsgrove	Worcestershire	United Kingdom
Brookhaven National Laboratory	Upton	NY	
Brooklyn Technical High School	Brooklyn	NY	
City College of New York	New York	NY	
Columbia	New York	NY	
Connecticut Science Center	Hartford	CT	
Exploratório - Centro Ciência Viva de Coimbra	Coimbra		Portugal
Hubble Planetarium/ Edward R Murrow High School	Brooklyn	NY	
IMERSS	Galiano Island	BC	Canada
Jet Propulsion Laboratory	Pasadena	CA	
Michigan Science Center	Detroit	MI	
Mochileros Astronómicos, Planetario Canopus, Experiencia Planetaria	Asunción	Asunción	Paraguay
NASA GSFC	Greenbelt	MD	
NASA Solar System Ambassadors	Lincoln	NE	
NASA/JPL Solar System Ambassador Program	Charleston	SC	
New Zealand Astrobiology Network	Carterton		New Zealand
Nyx Space	Golden	CO	
One World Immersive	Denver	CO	

Paterson Public Schools	Paterson	NJ	
Planetarium Spacedome	Zürich	Zürich	Switzerland
Robeson Planetarium	Lumberton	NC	United States
Seiler Planetarium	St. Louis	MI	
Sonnenborgh	Utrecht		Netherlands
Southwest Minnesota State University	Marshall	MN	
Spherical	Oakland	CA	
Springfield Science Museum	Springfield	MA	
Stockholm University	Stockholm		Sweden
StoryDome	Langley	WA	
Technical University of Munich	Munich		Germany
Tekniska Museet (National museum of science)	Stockholm		Sweden
The Admiral Vasile Urseanu Astronomical Observatory	Bucharest	Bucharest	Romania
The Human Space Program	Natick	MA	
The Lawrence Hall of Science (University of California, Berkeley)	Berkeley	CA	
Towson University	Towson	MD	
Traveling Universe	Chiang Mai		Thailand
Umeå University	Umeå		Sweden
Universeum	Göteborg		Sweden
Universidad de Córdoba	Córdoba	Andalusia	Spain
University of Cape Town	Cape Town		South Africa
University of Groningen	Groningen		Netherlands
University of Nebraska State Museum	Lincoln	NE	
Versant Power Astronomy Center-University of Maine	Orono	ME	
Wonderdome	Sheffield		U.K.

Appendix C: Self-identified Respondent Titles or Roles

Adjunct Professor
Astronomer
Biodiversity Informatics Lead
Chief Executive Officer
Co-Founder
Creative Director
Developer
Director
Director of Planetarium
Director of Planetarium and Discovery Center
Director of Policy and Strategy
Director of Science and Theaters
Director of Simulation Innovation Strategy
Director/Teacher
Education Specialist
Educator
Founder
Founding Member
Head Netherlands Euclid Science Data Centre
Hobbyist
IT Assistant
Lecturer and Planetarium Director
Manager
Member
Owner
Planetarium Coordinator
Planetarium Lead Educator
Planetarium Manager - Science Educator
Planetarium presenter
Postdoctoral Research Fellow
Professor of Physics/Planetarium Director
Research Assistant
Research fellow
Science communicator
Science communicator/explainer
Scientist/software
Senior Educational Programs Representative
Senior Manager of Youth Learning and Teaching
Senior research fellow
Solar System Ambassador
Solar System Ambassador, Science Communicator
STEM Curator
STEM Educator
Student
Teacher of Physics
Tech Lead
Volunteer



OpenSpace

Use Cases 2023

The material contained in this document is based upon work supported by a National Aeronautics and Space Administration (NASA) grant or cooperative agreement. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of NASA.

OpenSpace

More information at OpenSpaceProject.com

@OpenSpaceProj

Our Mission:
OpenSpace is an open-source interactive data visualization software designed to visualize the entire known universe and portray our ongoing efforts to investigate the cosmos.

Dynamic Data Exploration:
OpenSpace supports interactive presentation of dynamic data from observations, simulations, and space mission planning and operations. The software is compatible with multiple operating systems, from laptops to planetarium domes.

The following pages are nine examples showing the broad range of uses.

Real Time Planet Exploration at Full Tilt

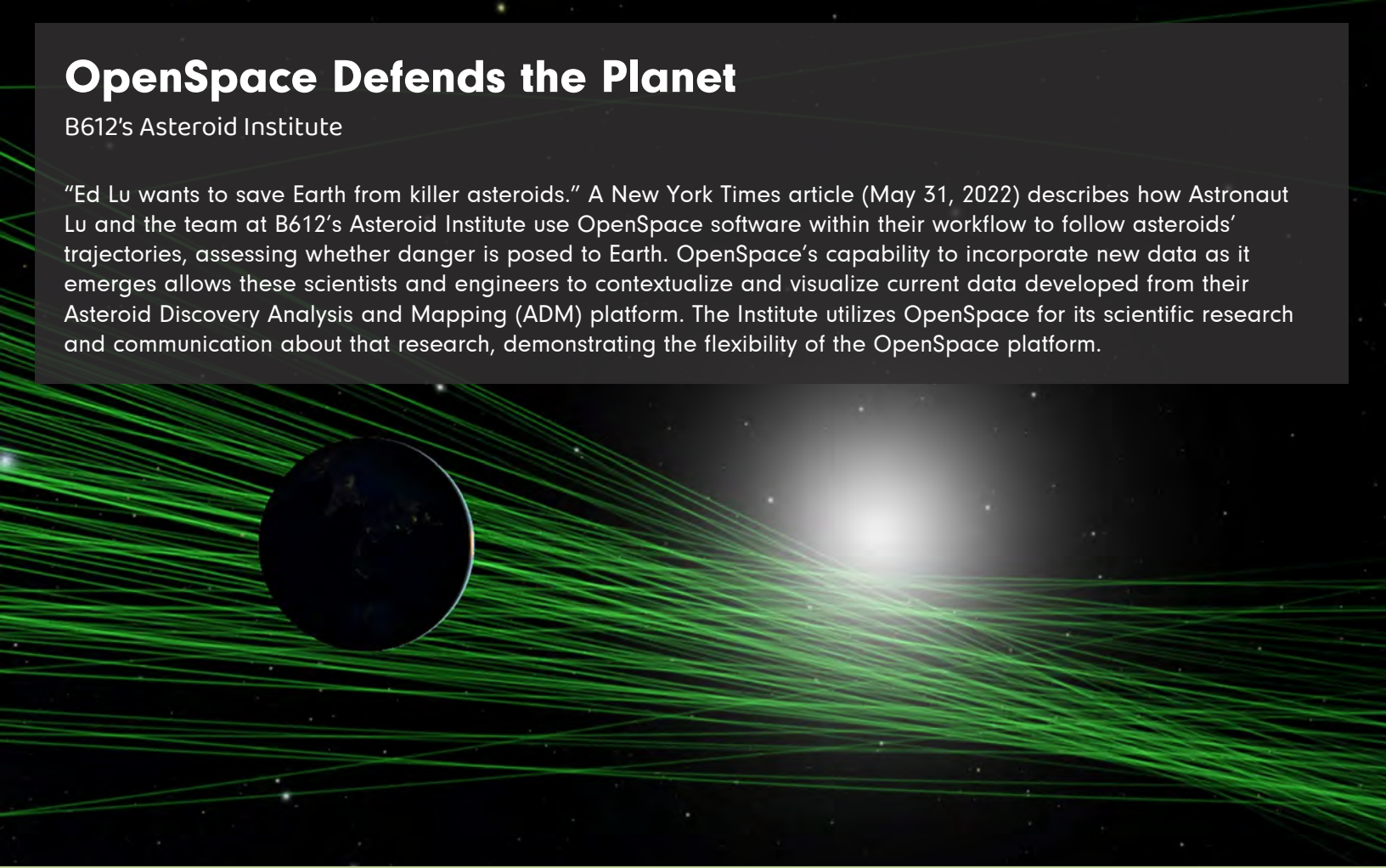
Museum of Life & Science
Durham, North Carolina

Live OpenSpace visuals shift and rotate on this tilt table, so museum visitors can explore a planet from all directions with just the flick of a wrist. This hands-on design allows individuals to steer around the surface of the Earth with the speed and focus of the visitor's choosing. OpenSpace delivers near real-time views of our dynamic and changing weather systems. (Available as a prototype now with a completion target of Spring 2024).

OpenSpace Defends the Planet

B612's Asteroid Institute

"Ed Lu wants to save Earth from killer asteroids." A New York Times article (May 31, 2022) describes how Astronaut Lu and the team at B612's Asteroid Institute use OpenSpace software within their workflow to follow asteroids' trajectories, assessing whether danger is posed to Earth. OpenSpace's capability to incorporate new data as it emerges allows these scientists and engineers to contextualize and visualize current data developed from their Asteroid Discovery Analysis and Mapping (ADM) platform. The Institute utilizes OpenSpace for its scientific research and communication about that research, demonstrating the flexibility of the OpenSpace platform.



OpenSpace Gives Visitors Control of the Planetarium Dome

The Lawrence Hall of Science — Berkley, California

OpenSpace began by focusing on enabling live presentations by professionals in planetarium domes. Now a new program at The Lawrence invites anyone to become "Planetarium Pilots." No experience with the software is needed. By tapping on a tablet, visitors can take themselves (and everyone watching) to the moon and back, all over the universe, or anywhere in between. Voice-overs explain the space science behind the visuals as visitors fly around space.

Gaming with OpenSpace

Houston Museum of Natural Science
Houston, Texas

In Texas, OpenSpace videos and photos form the backbone of HMNS's space science game lab. The lab has a family focus, fostering increased social engagement through the room's fifteen-plus stations and seating. In addition to families, the lab attracts visitors of all ages looking for a quiet space of collaborative learning in the clamor of the busy museum. For kids and by kids, high school interns programmed the games using content they captured themselves within OpenSpace. The OpenSpace Lab contains other games, including one that utilizes sonification software called "Seeing with Sound," and a large monitor where interns present live tours.

OpenSpace Takes Audiences from Sunrise to Sunset

The Towson University Planetarium
Baltimore County, Maryland

What do kids from Title One schools, scout troops, older adults with dementia and their caregivers, and the state Higher Education Commission all have in common? These are all audiences at Towson University's planetarium. The planetarium director chooses to use OpenSpace for planetarium talks and shows, as it "gives a better viewing experience and uses real data." As this director points out, the growth of OpenSpace users increases growth in both the software and in new content areas, creating a more powerful system over time.

Passers-By Fly High in OpenSpace

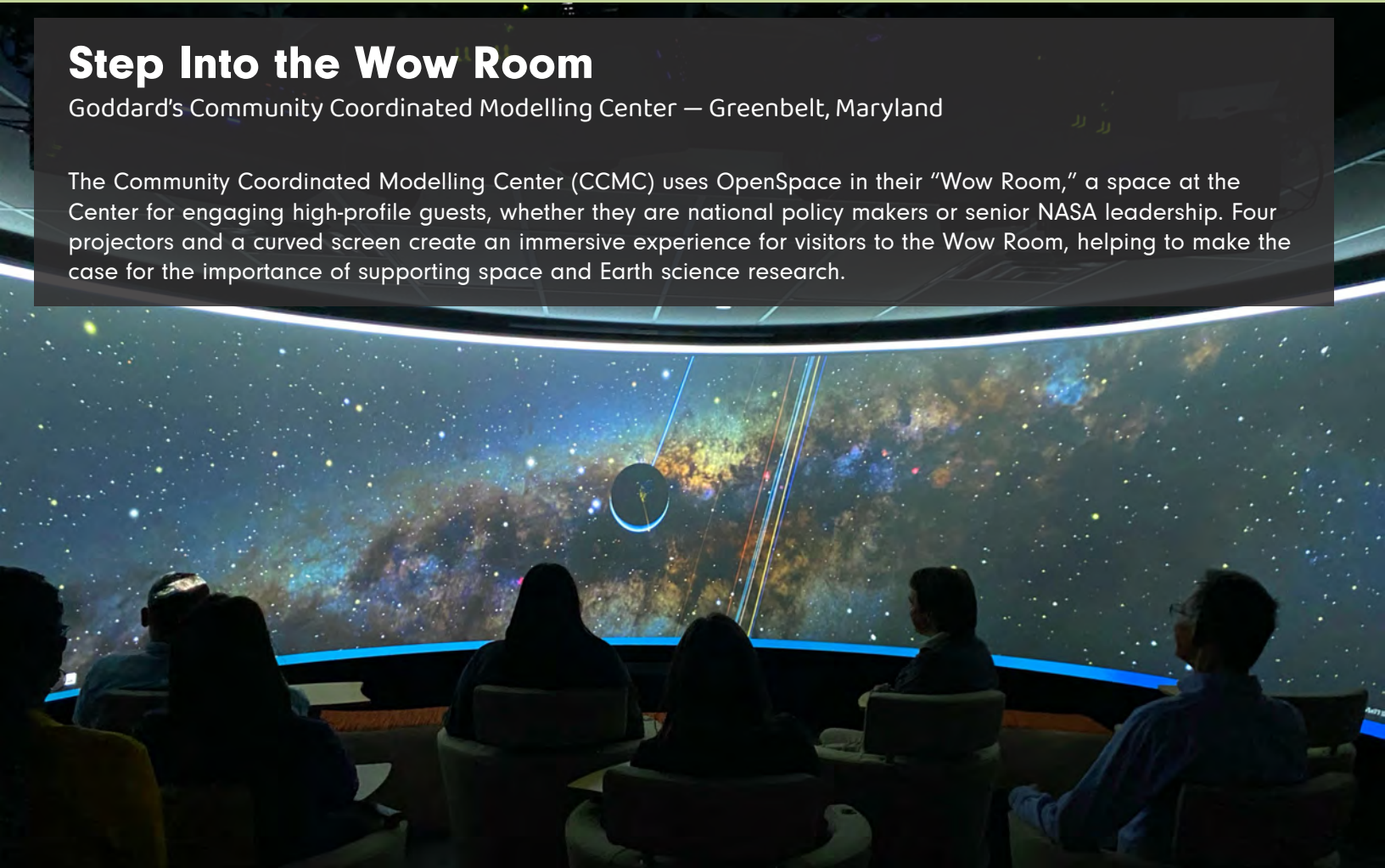
The Marston Exploration Theater at Arizona State University — Tempe, Arizona

In the queueing area for the ASU's Exploration Theater, visitors will soon be able to do more than watch a tour of the universe—they'll pilot it. The Interactive Immersive Educational Experience (I2E2) is a panoramic display controlled by the visitor who wants to explore space and Earth in their own way, and has room for 20 other students or family members. This implementation of OpenSpace in this public area makes it easy for untrained pilots to fly, hover, and dive into the planetary or geological body of their choosing. (Open to the Public Soon.)

Step Into the Wow Room

Goddard's Community Coordinated Modelling Center — Greenbelt, Maryland

The Community Coordinated Modelling Center (CCMC) uses OpenSpace in their "Wow Room," a space at the Center for engaging high-profile guests, whether they are national policy makers or senior NASA leadership. Four projectors and a curved screen create an immersive experience for visitors to the Wow Room, helping to make the case for the importance of supporting space and Earth science research.



To Infinity and Beyond! OpenSpace as a Powerful Outreach Tool

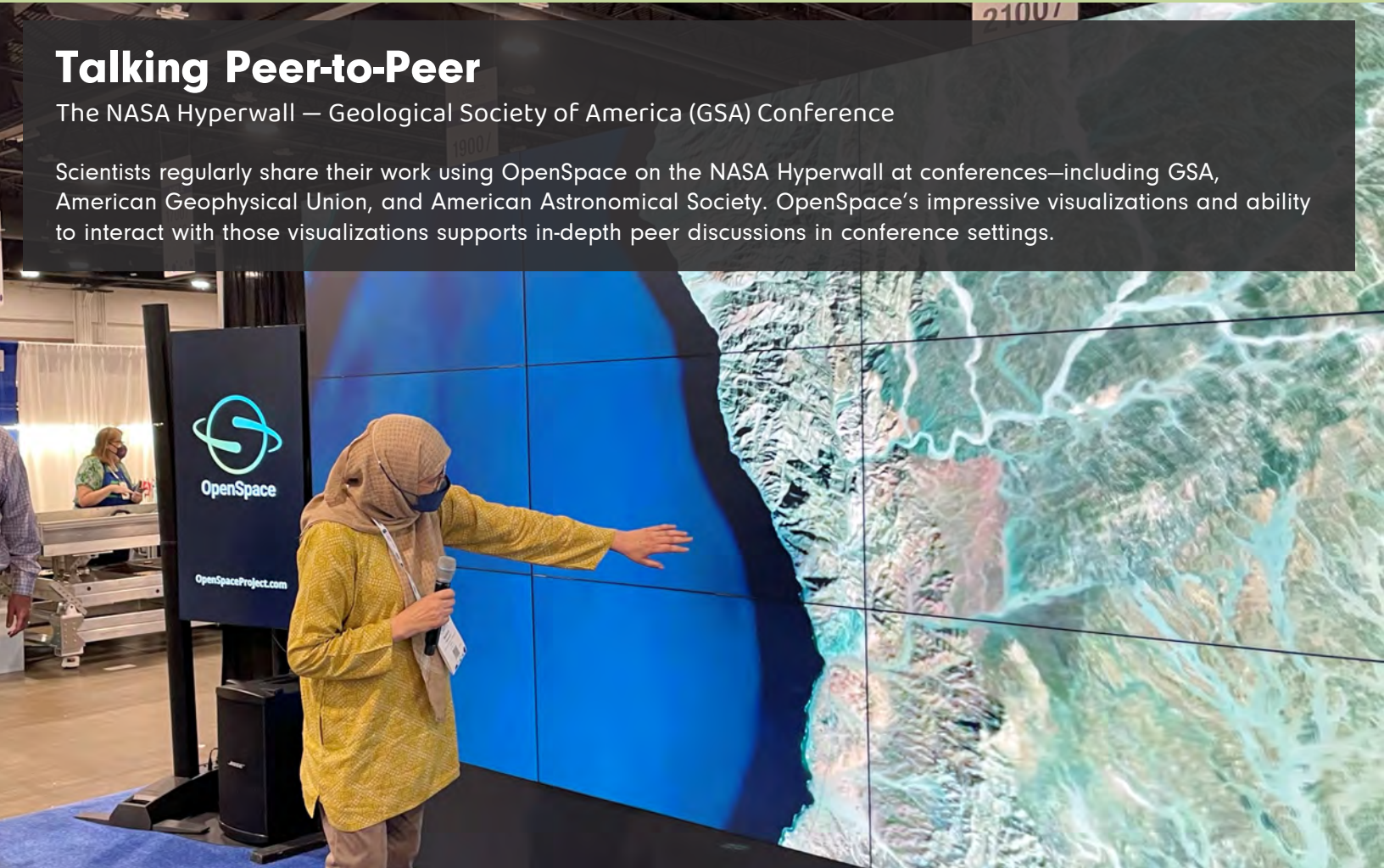
Rachel Smith, Super User
Raleigh, North Carolina

Dr. Rachel Smith uses OpenSpace in research, teaching, and museum exhibitions. OpenSpace's data-rich visualizations enable Dr. Smith's compelling outreach to a wide variety of audiences including retirement communities, science conferences, and public policy groups.

Talking Peer-to-Peer

The NASA Hyperwall — Geological Society of America (GSA) Conference

Scientists regularly share their work using OpenSpace on the NASA Hyperwall at conferences—including GSA, American Geophysical Union, and American Astronomical Society. OpenSpace's impressive visualizations and ability to interact with those visualizations supports in-depth peer discussions in conference settings.



American Museum of Natural History

SCI www.sci.utah.edu

NYU TANDON SCHOOL OF ENGINEERING

Adler Planetarium

the Houston Museum of natural science

North Carolina Museum of Natural Science

LINKÖPING UNIVERSITY

Community Coordinated Modeling Center

CALIFORNIA ACADEMY OF SCIENCES

DENVER MUSEUM OF NATURE & SCIENCE

HG &CO

IX. Appendix C: Attached Information

OpenSpace Version 0.18.1 Changelog

OpenSpace Version 0.18.2 Changelog

OpenSpace Version 0.19.0 Changelog

OpenSpace Version 0.19.1 Changelog

OpenSpace Version 0.19.2 Changelog

Prime Access Consulting Batch 01 OpenSpace Web UI Spot Checks

Prime Access Consulting Batch 01 Launcher Accessibility Overview

OpenSpace Developer Meeting Agenda

OpenSpace Funded ISI Partner Meeting Agenda

0.18.1

Compare

alexanderbock released this Nov 22, 2022 · 1318 commits to master since this release releases/v0.1... 0a6aa29

Fixes to existing assets

- Use the new ESRI WorldImagery URL
- Use the new CelesTrek URL for all satellites fixing an issue where satellites would no longer appear due to a change in the CelesTrek API (#2135, #2146)
- Fix the Mars profile so that Perseverance and Insight do not land inside Mars anymore and stay there as well (#2049)
- Update OsirisREx kernels to include a missing kernel file that would prevent the profile from loading correctly (#2177)
- Reorganized the assets for the NASA Treks values to make it less likely to end up with too long file paths on Windows when installing OpenSpace in a nested folder (#2311)
- Fixed issue with Show All Trails / Hide all Trails when executed in a profile that did not have `*trail` and `*Trail` scene graph nodes
- Updated the bounding spheres for Vesta and the Orion Nebula to make it possible to use the Fly-To feature with these objects (#2259)
- Fixed a typo in the reset_loop_action.asset that prevented the asset from being able to be included
- Fixed spelling mistakes in the Andromeda constellation image (#2129)
- Fixed spelling mistake in Voyager focus action
- Fixed missing GuiPath for Jupiter approach in Voyager profile
- Update the descriptions for the Open Star Cluster Digital Universe asset

Bug Fixes

- Fix issue where parts of a globe would disappear when the settings of a heightlayer change (#2096)
- Fix an issue where it was not possible to drag the SkyBrowser window in fisheye rendering mode (#2093)
- Fixed an issue where executing a SessionRecording containing a wildcard character `*` in the property name fails to load (#2121)
- Provide a better error message when failing to load a dataset for GlobeBrowsing layer
- Fixed an issue where ScreenSpace images would be too dark by adding a gamma correction slider
- Various compilation and UI fixes for Linux (#1479, #2111, #2123, #2163)
- Fixed an issue where the conversion of a preexisting profile from version 1.0 to 1.1 would not rename the keypad numbers correctly, causing the new profile to fail to load (#2138)
- Fix issue where the first row in the ScriptsDialog of the Profile Editor would be automatically selected (#2282)
- Fixed an issue where the navigation state was not loaded correctly from a profile (#2143)
- Fixed an issue where exporting the camera position to a Navigation State would lose precision
- Provide a better error message when trying to edit a profile that does not exist (#2224)
- Fixed an issue where special characters would not show in the keybinding panel correctly

- Fixed issue that prevented the full range of values for the field-of-view slider in the SGCT configuration editor from being used(#2148)
- Place some stricter limitations on the field-of-view settings in the SGCT Configuration editor (#2156)
- Fixed an issue that what cause a SkyBrowser display copy from being removed properly (#2200)
- Fixed an issue that would occur when the camera's focus node was removed (#2196)
- Correctly use the default position of display copies of the SkyBrowser
- Fixed an issue where the time component in the WebUI would flicker as time is progressing
- Fix an error where the interpolation parameter for a camera path was out of range causing the Fly-To to fail occasionally (#2211)
- Fixed issue where an asset in the Profile Editor would be selected if there wasa folder with the same name as the asset (#2154)
- Fixed an issue that would prevent multiple files from being synced in a UrlSynchronization
- Updated SGCT configuration files that where using a legacy user position

Breaking Changes

- The height offset of a GlobeBrowsing height layer was calculated incorrectly before, causing a flip in the sign. Before, an offset of 1000 would cause the terrain to be *lowered* by 1000m, not *raised* by 1000m as expected. With this version, this bug is fixed, but it might require some adjustments in existing profiles. **Fix**: Invert the sign of all `*.Settings.Offset`s in scripts that apply to Height Maps
- The organization of the NASA TREKs asset files has changed as the old method caused many users to get "too long path" errors on Windows. **Fix**: Any user-created profile that uses the NASA Treks files needs to be manually updated.

▼ Assets 2

0.18.2

Compare

alexanderbock released this Jan 2 · 1318 commits to master since this release releases/v0.1... 7b09d1a

Bugfixes

- Fix to a problem that caused the Mars profile to not load correctly
- Fix for an issue that made the some of the options of the configuration helper functions in the openspace.cfg file unusable (#2364)
- Fix to an asset dependecy issue that prevent the JWST asset from being included outside the JWST profile (#2378)
- Fix to an issue that would prevent the FOV slider from working in a rendering+GUI window setup
- Fix to prevent invalid entries for actions and keybindings in the Profile Editor (#2362)
- Fixed and issue where it was possible to interact with a joystick during a camera path or a session recording
- Fix problem with the interaction sphere of scene graph nodes without renderables being unused (#2399)
- Fix issue where the explicit bounding sphere was being ignored (#1899)
- Fixed a typo in the documentation for the RenderableTimeVaryingSphere

▼ Assets 2

Source code (zip) Jan 2

Source code (tar.gz) Jan 2

0.19.0

Compare

alexanderbock released this Jun 26 · 138 commits to master since this release releases/v0.1... f6e2cd8

Features

- Add the ability to customize the complexity of the user interface by choosing the visibility level of settings to determine how many of the properties are visible. The visibility settings can be set from the `openspace.cfg` file or by specifying an environment variable `OPENSPACE_LEVEL`. (#166)
- Toggling objects in the scene menu will now fade them in and out over a given time, rather than toggling them instantaneously. The default duration can be changed in the Setting / OpenSpace Engine / Fade Duration (#1827)
- Add the ability to add videos to globes, sphere, and planes. The videos can be played back at their native speed or stretched to cover arbitrary time ranges. The `data/asset/examples/video` asset files include examples of how to use this feature. (#2608)
- A complete redesign of the documentation generated by OpenSpace. The new documentation now includes more information, is a lot easier to navigate, and includes links to other important sources of information. It can be found in the same location as before under `documentation/index.html` (#2604)
- Include a new technique to display GeoJSON files on globes. This feature can be used to render line strips and polygons onto the surface of any planet. (#2595)
- Add a new GUI for ongoing missions that provides information about mission duration and milstones. This is a first step towards making mission profiles more accessible to users without prior knowledge (#2603)
- Add a new user interface that can be toggled through the ... menu in the bottom right that is a Getting Started Tour to teach new OpenSpace users how the navigation system works and how to operate the different settings in the menus (#2189)
- Replace the previous caching method for GlobeBrowsing layers with an MRF-based cache. This allows the caching of any remote layers locally on the computer. (#929)
- Fade out stars and other objects in atmosphere during daylight (#1148)
- SkyBrowser
  - Add the ability for the image inset to have both sharp or rounded corners (#2029)
  - Add the ability to the Skybrowser to drag and drop images to change their order in the viewer
  - Add the loading of a hash for WWT image files and automatically force a redownload of the files if the hash has changed
  - Move the wwtdataimages location into the sync folder (#2115)
- Various performance optimizations
  - Move calculations for bounding sphere to only be executed during a full sweep, which improves overall performance (2726)
  - Switch multiple OpenGL calls to a single call for increased efficiency in the asteroid rendering (#2724)
  - Improve the performance of the SkyBrowser for both rendering and image loading
  - Add a property to make it possible to set if the browser display copies should animate while the target is moving (#2773)
- Add the ability to instantaneously jump to the end point of a path (#2568)
- Add the ability to fade out a model that consists of multiple components (#2550)
- Add the ability to provide both minimum and maximum distances in which the camera can be relative to the current focus node. This also adds the ability to disable the limit entirely (#2570)
- Add the ability to select individual constellations (#1682)

- Add support for other file formats for general pertubation information, in particular OMM KVN style (#1778)
- Add the ability to disable the automatic slowdown when the camera approaches the surface of a planet in order to provide a flight that has a constant linear velocity (#2150)
- Add the option to invert the direction of the camera during an idle behavior. This can be achieved both through a separate property that inverts the direction and also by allowing negative speed factors (#2379)
- Add new configuration file that also adds 3D graphics to the UI window (#2530)
- Enable highlighting of lines in grids (#1683)
- Automatically abort an ongoing shutdown when interacting with the mouse or the keyboard (#2393)
- Add the ability to disable mouse input (#2361), zoom and roll for touch interaction, and keybindings (#2238)
- Expose the ambient intensity lighting value for globes as a property
- Add the ability to configure the Console key through the openspace.cfg (#2573)
- Add an enable/disable property to toggle the use of a TimelineRotation (#1607)
- Expose the SGCT statistics information through a property in the RenderEngine (#2195)
- Update Spice repository

Launcher

- Add info tooltips to profile dropdown
- Add the ability to edit previously created configuration files through the editor (#2574)
- Changes to the configuration editor with regards to the behavior of the GUI portion of the window and the 3D rendering. There is now a combobox in the editor to specify how the different windows should behave (#2531)
- Option to specify a scene graph node in profile editor camera dialog to start the camera at the given scene graph node (#2227)
- The properties panel now makes use of the script log dialog (#2253)
- Allow the script log dialog to return multiple scripts
- Replace profile actions/keybind editor button with single close button (#2497)
- Rename "Keybindings" panel to "Actions & Keybindings" (#2363)
- Add the ability to open a different scriptlog file when changing the additional scripts (#1545)
- Reduce the forced height of the asset editor, making it possible to resize the editor to increase legibility on low resolution displays (#2547)
- Remove explicit specification of read-only profiles and read-only configuration files. Now every profile and configuration file that is not in the `user` folder is read-only
- Increase the size of the configuration boxes in the launcher to make files with long names easier to read (#1785)
- Add a display of the version number in the bottom right of the launcher (#2365)

Content

New Assets/Profiles

- Add layer files that use the new AMNH-based WMS server (#2451)
- Add objects that can be used to show the scale of other objects, for example the Eiffel Tower, the Statue of Liberty, the Golden Gate Bridge, etc (#2273)
- Add new offline profile that can be used without internet access (#1714)
- Add top dwarf planets (#1712)
- Add Ceres in dwarf planet folder (#2260) (#2261)
- Add assets for the Shepherd moon group of Saturn system (#2157)
- Update existing outer planets SPICE Kernels and adding new moons to outer planets (#2556)
- Add Itokawa model (#1264)
- Add v3 WAC layer for the Moon (#886)

- Add a new empty profile "empty.profile" that can be used as a starting point for custom profiles

New Profiles

- Add a new profile showing ESA's JUICE mission (#2155)
- Add new profile to show the Artemis-1 mission (#2597)

New Maps

- Add new 99.5% coverage CTX layer for Mars
- Add new layer for the moon of Triton using Voyager2 information (#2198)
- Add new Mosaic layer from the Lunar Orbiter Mosaic
- Add a new combined clouds-magellan layer for Venus (#1534)
- Add a combo layer that shows the NOAA20 VIIRS layer and transitions to the ESRI ground layer (#2538)

Updates to existing Assets/Profiles

- Data Updates
  - Update the data from the exoplanets archive (#2450)
  - Update Digital Universe catalogue (#2729)
  - Update small solar system body assets to use updated Horizons data (#2614)
- Action updates
  - Harmonize capitalization of action names (#2579)
  - Move actions defined in profiles into assets to increase their reusability (#2408)
  - Add actions for minor moons (#2476)
  - Add new actions to show the zodiac constellations (#2272)
  - Add action to control the global lighting of all globes (#2494)
  - Add new action to toggle dwarf planet visibility (#2674)
  - Add new actions for hiding/showing major moons and their trails (#2675)
- Rename ISS scene graph node and remove the previous ISSPosition node (#2245)
- Create labels for all moons and grids (#1486, #1244)
- Create a better organization for moons of gas giants by introducing subgroups #2609
- Add lighthour grid to Digital Universe, and light minute and light second grids to Earth (#2439)
- Move Gaia and JWST from `missions` to new `telescopes` folder
- Update all assets to a new consistent coding style (#2713)
  - Moves `default_actions` and `default_keybindings` asset file locations
  - Change procedural globes to explicitly specified globes
  - Remove unused asset files, `asset_helper`, `script_scheduler_helper`, `testing_keybindings`, and `procedural_globe`
- Move the Milky Way Image and arm labels from `/Universe/Galaxies` to `/Milky Way`
- Some simplifications to joystick assets and enable reversal of axes
- Show animation in example asset `modelshader.asset`
- Set default settings for blue marble height to make it look similar to the ESRI terrain layer (#891)
- Change layer name/description to match image cloud image for the BlueMarble clouds (#2285)
- Update the Ipac example asset
- Remove luastatemachine example asset as it was superseded by the new native statemachine introduced in 0.18.0 (#2193)

Profiles

- Asteroids
  - Disable most objects in the asteroids profile at startup (#2477)
- Bastille Day

    - Add more explanation about the static magnetosphere
    - Resetting the CME loop also sets the delta time to 1 in the bastille profile (#2516)
- Juno
    - Update Juno kernels
- JWST
    - Add trail that co-revolves with L2 around the Sun (#2220)
    - Change terra layer to viirs20 in the jwst profile (#2631)
- Messenger
    - Switch MessengerTrail to RenderableTrailTrajectory in order to match start/end times, and add corresponding sample interval (#2292)
    - Remove camera lighting from Messenger spacecraft
- New Horizons
    - Update sample interval for New Horizons trail
    - Disable New Horizons labels by default (#2743)
- Rosetta
    - Add scheduled scripts to enable shading outside of image acquisitions for the rosetta profile (#2514)
- Voyager
    - Add tags to Voyager models in assets

Content creation

- Add the ability to start a profile paused (#2228)
- Add new dashboard item to show elapsed times (#2234)
- Move the keybindings out of the `base.asset` and the specific label keybinding out of the `default_keybindings`
- Remove the exoplanets and skybrowser module specifications from `base_blank`. Add the skybrowser and exoplanet module specifications to `base` asset
- Add events when paths are started or finished (#1834)
- Add events for when renderables are enabled/disabled that can be used to link renderables together (#2132)
- Add a new portrait window config (#2383)
- Add a new dashboard item that shows the state of input devices (#2415)
- Make the argument in `asset.localResource` optional. If nothing is provided, then the path to the current directory that the asset is located in is returned
- Make the numeric value of the model scale a property allowing the size of models to be adjusted at run-time
- Add the ability to use integer NAIF IDs in a `SpiceTranslation`
- Add the ability to pass a boolean value into the `asset.require` function that gets passed into the loaded asset as a `enabled` property (#1279)
- Add property that contains the list of all compiled modules (#1021)
- Make it possible to individually set the base radius for `RenderablePrism` shape which can be a cone, a pyramid, or any other shape
- Add new property to the `IndexSequenceTileProvider` that shows the number of available images in a sequence (#2688)
- Add a missing dimensions property to the screenspace browser
- Add option to specify an offset distance for the start and end points of the `RenderableNodeLine` (#2483)
- Remove unused Roll Y movement for camera
- Add the ability to provide a random background image to the `TileIndexTileProvider`
- Add an option to the HttpSynchronization to automatically unzip downloaded files (#1852)

Lua

- Add the ability to pass a script to the `setPropertyValue` function that is called after interpolation has finished
- Make it possible to trigger camera path with zero duration

- Add function that creates a valid identifier from any string
- Add function to load CSV file, utilize new function to correctly load bookmark values (#2124)
- Update documentation for `setPropertyValueSingle` with all available easing functions
- Add the ability to move globe layers based on their name (#2411)
- Changes to the `addCustomProperty` function to restore functionality and make it more useful (#2433)
- Add function to target the previous and next interesting focus node
- Add function to return a list of all defined tags
- Add function that returns information about the current OpenSpace version (#2136)
- Add some helper scripts to modify property values (`appendToList` , `add` , `invertBoolean`)
- Add functions to get distance to bounding and interaction sphere
- Add function to get the current distance to the focus object
- Add function that resets the screenshot index of the current session back to 0

Bug Fixes

- Fix for the issue that prevented inputting underscores and period characters in the WebUI (#853, #896)
- Fix an issue that caused a subsampling of the height map on planets (#2472)
- Correctly show all points, including the proper end point for a `RenerableTrailTrajectory` (#2540)
- Fix a bug that would cause 8 bit grayscale images showing up in red colors (#2330)
- Fix an issue that caused the adding and removing of assets to happen in different orders on Windows and Linux (#2513)
- Fix an issue where the behavior for a GUI window and a separate render window was causing the UI to disappear (#2372)
- Use correct FOV calculations to handle portrait or landscape windows (#2546)
- Disable too aggressive culling of `RenderableTrail` s that caused some trails to not render at all (#2653)
- Move model loading code to initialiseGL which caused models to sometimes load without textures (#1838)
- Prevent crash when moving to an early date in the JWST profile (#2617)
- Fix issue where whitespaces in bookmark locations would cause a loading failure by replacing them with underscores
- Properly report an error when an `.info` file is missing the identifier, preventing the addition of a layer without one (#2490)
- Fix an issue that caused multiple viewports and stereo rendering to not render correctly and prevent overlays on windows and viewports (#2542, #1645)
- Make the local bookmarks file print their error message if they fail and continue evaluating the file (#1483)
- Only reject major version changes in the JPL Horizons interface and allow minor version changes (#2507)
- Fix an issue where property owners would show the identifier and not their name in GUI (#2521)
- Check for invalid indices in the Gaia stars to prevent crashes in the gaia profile (#2495)
- Prevent an infinite loop when extracting invalid commandline arguments when starting OpenSpace from the commandline (#2349)
- Fix bug where triggering an action via keybinds would not work
- Do not crash when trying to add assets with invalid path (#2299)
- Fix issue that would cause actions in the Action panel to not be sorted based on their name or identifier
- Make the travel indicator take floating point length values smaller than 1 (#2459)
- Fix a bug in the gamma correction of dark screen-space renderables (#2776)
- Fix issue that would cause some GlobeBrowsing Lua functions to not be documented correctly (#2732)
- Fix an issue where it was not possible to set the WebGUI port from the `openspace.cfg` file (#2279)
- Fix issue that caused a mask file in SGCT config to not load correctly (#2370)
- Fix crash when calling `openspace.getProperty()` with only a tag
- Remove unintentional default value for skybrowser/exoplanet module enabled property that would cause them to show in the UI even though they are disabled #2464
- Fix an issue where the Constellation selection did not apply to labels (#2382)
- Fix drag-drop error for the interesting nodes panel when trying to rearrange the list in the profile editor (#2346)

- Correctly parse SSSB files that use an integer, rather than a floating point, epoch (#2551)
- DashboardItem now listens to parameter 'enabled' in constructor
- Fix issue where the GUI allows, and then crashes, when a numeric input field has NaN value (#2452)
- Fix issue with some action folders in the Action panel not being clickable (#2467)
- Fix issue where we would use the SSB position instead of the Sun position in light sources (#2223)
- Add special case to the string tokenizer for "Keypad +" which caused an issue binding an action to that key (#2358)
- Do not render `RenderableTrailTrajectory` if the time is *exactly* the start time, which causes a crash (#2314)
- Prevent a crash in the SGCT Editor when trying to add more than 2 windows on a computer with only 1 monitor
- Various precision fixes for camera paths that caused erratic behaviors (#2212)
- Move the Lua Console updating into the actual `postSyncPreDraw` function so that it gets called accurately when GUI windows are present (#2141)
- Fix crash when a profile would contain an empty profile line
- Remove the flickering that would occur during TileIndex tile provider loading
- Check for illegal keywords in the header of Speck files to detect invalid files (#2549)
- Provide a proper error message when trying to overwrite a hidden profile (#2575)
- Add more description to the --config command when starting OpenSpace on the commandline
- Provide informational text in the actions panel if the user tries to create an illegal identifier (#2289)
- Show error message when trying to save navigation state to an invalid file path rather than failing silently (#2508)
- Provide error message when running OpenSpace from a folder containing a ', ", [, or] rather than providing obscure error messages (#2563)
- Fixed bug where Lua function `openspace.pathnavigation.isFlying()` returned an unexpected value
- Fix an issue that would cause a failure to download when providing a URL that ends in `/` in a UrlSynchronization (#2435)
- Fix collision between rendering of the native ImGui and the WebGui
- Remove legacy geometry specification from `RenderablePlanetProjection` (#1967)
- Fix issue with the ImGui GIBS panel where it did not create the new tileprovider format (#2108)
- Fix broken ImGui time picker unit dropdown (#2639)
- Do not crash when trying to access a module folder that does not exist (#2703)
- Prevent Lua error when trying to load a constellations file that does not exist
- Fix for preventing adding property from scriptlog if already in add mode (#2735)
- Remove check for boundingsphere among child nodes when flying to small objects that could cause issues if a child has a bigger bounding sphere than the parent (#2257)
- Fixes line ending problems with horizons vector files on Linux (#2588)
- Remove the registered actions before updating the delta time keybindings that prevented the rebinding of delta times at runtime (#2764)
- SkyBrowser
  - Ensure all nodes in a cluster load the image collection in the sky browser (#2313)
  - Fix issue with the sky browser space craft pointing where it would not point correctly under some circumstances
  - Fix bug where some channels in a cluster do not set the field of view to the same value after animating (#2425)
  - Fix a crash that could occur in the screenspace sky browser scaling (#2280)
  - Fix bug that caused the master node to have no rendering output
  - Fix issue where the scale sometimes did not update the border radius in time (#2266)
  - Ensure browser is initialized properly before executing JavaScript
  - Make it harder to input wrong values in the interface
  - Disable hover circle per default when setting renderable and show a warning if setting to non-existing node (#2153)

Breaking Changes

- Make the check for whitespaces and dots in identifiers fatal also in non-Debug builds

- Provide error message if a GuiPath does not start with `/` ; Automatically add / in the Profile editor. Default initialize all paths to `/` (#2318)
- Remove Earth layers that no longer work

▼ **Assets** 2

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0.19.1

Compare

alexanderbock released this Sep 21 · 138 commits to master since this release releases/v0.1... cf04d6c

Features

- Add the ability to show a border around ScreenSpaceRenderables
- Add a trigger property to delete a GeoJSON component
- Added the option to disable roll and zoom for during interaction (#2866)
- Add the ability to specify the angular size of the Sun in the atmosphere
- Add the ability to fade in and out RenderableFieldLinesSequences

Launcher

- Update example in openspace.cfg to use correct `pos` instead of `windowPos`

User interface

- Prevent checkbox from shrinking for profiles with long name (#2804)
- Fix issue where user interface icons would not show up when starting OpenSpace without an internet connection (#2794)
- Fix issue so that objects are only disblaed on fade to 0 if the checkbox was actually clicked (#2873)
- Revert the accidental style change of the settings buttons causing them to be darker

Content

New Assets/Profiles

- Add mission file for the JUICE mission (#2823)
- Add a new asset showing the eclipse shadow cone in the Earth/Moon system
- Add "mission" file giving access to all eclipses between 1900 and 2100
- Add new asset showing a text marker for the Moon (#2831)
- Add radial grids showing a comparison between the Earth ecliptic plane and the Moon's orbital plane
- Add GeoJSON files showing the paths many eclipses of this century
- Add an asset that shows the corona of the Sun during the last US eclipse in 2017

New Profiles

- Add a new eclipse profile with new assets

Updates to existing Assets/Profiles

- Update faulty tags for Charon and update other Pluto Moon tags for consistency

Content creation

- Add a new Renderable to show the shadow cone between two celestial bodies

Lua

- Add new function that resets the camera back to the start position (#2825)
- Add new function to remove all loaded assets (#2812)

Bug Fixes

- Fix issues that would prevent scripts from being executed twice in a dome environment, that would break stateful actions (#2872)
- Fix an issue where the start time would not be set correctly when starting a profile paused (#2826)
- Fix crash when trying to start a profile with a navigation state camera settings
- Fix issue where scripts from the Additional Scripts dialog would not be added in the order of the list, but in selection order instead (#2862)
- Fix issue where the Sun and Moon were not layered correctly during an eclipse
- Fix issue where the Apollo 17 insignia would not show up correctly
- Fix issue with fisheye configurations created through the window configurator (#2818)
- Fix issue where a non-square image would be shown at a wrong aspect ratio (#2815)
- Prevent crash on AMD cards when trying to upload textures with MipMapping enabled (#2843)
- Fix potential crash in the RenderableShadowCylinder
- Fix issue that would ping the camera to infinity when trying to jump to an object with a bounding sphere of 0
- Fix issue that prevented the action to hide all constellation lines from working
- Improve quality of error messages when loading illformed GeoJSON file
- Fix issue where trying to include an invalid image as a screenspace image would produce infinite error messages
- Fix issue where transparency for movies would not work (#2792)
- Fix issue that would cause GeoJSON rendering from not working on some graphics cards
- Make the loading of GeoJSON files more flexible by allowing .json files (#2797) and allowing null geometries that will no longer fail, but instead produce an error (#2811)
- Update offline Mars map to fix 180 degree offset
- Fix potential crash when no shadow caster was specified in an eclipse scenario
- Fix issue that would cause many scene graph nodes from now being deinitialized correctly (#2851)
- Fix crash when flying to navigation state with non-existing anchor
- Prevent crash when the `cache` folder is left in an inconsistent state after the application closes (#2850)
- Prevent rendering errors in the galaxy rendering when minimizing the window (#2852)
- Fix crash that would occur when trying to delete an asset that is also a root asset
- Fix issue that prevented the Voyager 1 and 2 trails from showing up
- Fix issue where the educational asset of the Statue of Liberty was located at the wrong place (#2787)
- Fix issue that would be raised when trying to create an identifier from non-ASCII characters
- Allow negative values for KeplerTranslation that wrap around correctly (#2784)

▼ Assets 2

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Releases / releases/v0.19.2

releases/v0.19.2

Latest

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alexanderbock released this 2 weeks ago · 138 commits to master since this release releases/v0.1... b368116

Content

- Use the local image layer for Europa by default
- Add the ability to specify a custom shader for the RenderableGalaxy class

Bugfixes

- Temporarily fix disappearing tiles on globe surfaces by disabling frustum culling
- Fix naming mixup between umbral and penumbral shadow
- Fixed an issue with the atmosphere shader code on Mac platforms

▾ Assets 2

Source code (zip) 2 weeks ago

Source code (tar.gz) 2 weeks ago

Prime Access Consulting, Inc.
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AMNH: Batch 01 OpenSpace Web UI Spot Checks

May 19, 2023

This document forms part of the accessibility spot checks package prepared by Prime Access Consulting, Inc. for the American Museum of Natural History.

Introduction

This document enumerates the results of a series of accessibility and usability spot checks carried out against the OpenSpace Beta-11: Version 0.18.2 web application. The aim was to identify problems which various groups of users may encounter, along with recommended remediation strategies.

The report has a section for each component. We may refer to components used within the product by name throughout. Where specific terms for these have not been previously communicated, they have been inferred from the mark-up or page content and therefore may not be consistent with those used by internal development and design teams.

Please also note that the environment under test may have undergone additional changes since the evaluation results in this report were recorded; the date on this document reflects its completion and delivery, and not the date(s) during which testing was carried out.

Severity Numbers

Each observation in this document has been assigned a severity level from 1 (most) to 3 (least). This is intended to indicate the likely impact on users, as follows:

- Severity level 1 represents behavior which will either prevent a user from carrying out a task, or drastically decrease the effectiveness with which are able to do so.
- Severity level 2 is applied to issues which are likely to cause significant frustration or confusion, but in a non-blocking fashion given enough time, experimentation, or assistance.
- Severity level 3 is reserved for aspects which are demonstrably problematic but will have the least noticeable impact on users. For example, this could be because a specific set of circumstances is required to trigger the behavior, or because users are likely to be well-versed in appropriate workarounds. However, it is critical to note that the presence of a high number of severity 3 items can substantially degrade a user's experience.

These levels do not take into account the amount of effort or development time required for remediation, but it is our hope that they will assist in the prioritization of resource allocation and scheduling.

Note on Mark-Up Validation

It is critical that all mark-up be validated against the W3C's HTML5 and ARIA-aware validator found at http://validator.w3.org/nu. Validation is critical because even if appropriate accessibility attributes are used and considerations taken, it is possible for them to have little or no effect if there are other parsing and related issues preventing the DOM from being constructed semantically per the design/development intent. This task should be carried out for all pages/components and must use the full rendering of each page rather than any base mark-up that is later hydrated via JavaScript. Problems must then be prioritized accordingly and addressed where they are determined to have an impact on the user. Errors take precedence over warnings.

Executive Summary

The web application follows some accessibility best practices, but it is currently inaccessible to users who do not interact with it via mouse input. Several improvements are needed to ensure that its content can be equally accessed and enjoyed by all users. Recurring issues include:

- Several controls lack a focus outline or any other indication when reached with the keyboard by pressing Tab or Shift+Tab. Combined with the fact that there are many controls that are not keyboard focusable, it is currently extremely difficult for keyboard-only users to track the focused element and navigate effectively.
- Many custom controls cannot be activated using the keyboard limiting user access to many features, while in other instances they do not properly convey their role, state, and value to screen reader users.
- Actionable elements either lack an accessible name or have an uninformative one, leaving screen reader users uncertain of how these controls are intended to function.
- In many instances, text and non-text elements are rendered with insufficient color contrast, which is problematic for many site visitors, including those with low vision.
- Information and relationships between elements which are visually evident are not conveyed in a programmatic manner so that they can be made available to screen reader users.
- From a usability standpoint, the application feels overloaded and complex, requiring significant time and experimentation to determine how to perform various tasks.

Components

Application-Wide Considerations

Problematic Usability of User Interface

Severity: 1

The application feels complex and difficult to use, for several reasons:

- The user is given too many options to choose from at various steps, and some may be duplicated in other areas of the application. For example, some items in the "Scene" menu have groups of controls which allow for detailed customizations, but some are listed again in an overlay triggered by pressing an icon in the shape of a "wrench".
- Many controls have only an icon as a visible label and their function can only be determined by experimentation.
- Many components require some knowledge or expertise to determine exactly what they should do and how they can be used.
- The language may be difficult to understand for users without an academic background in science and space exploration.
- The hover styles for toolbar controls are very subtle which may complicate mouse interaction with the toolbar buttons.
- Label text is small and the use of all-caps in labels and heading text significantly decreases their readability.

Suggested Solution

Simplify the UI and ensure that the primary use cases are evident and easy to perform. Provide text for controls whenever possible and include documentation to explain the meaning of icons in the application. Expand the tutorial collection to include all primary tasks and provide further guidance on more advanced features.

Missing Keyboard Navigation Mechanism

Severity: 1

The application has several main components, such as:

- The space viewer, taking up most of the screen, above the toolbar and to the right of the side panel when in view.
- A toolbar at the bottom of the screen with several controls:

    - A navigation region with the Menu button, "Scenes" and "Settings" controls.
    - Other custom buttons, e.g. Navigation, Select Date, Record Session, Screenspace Renderables, Actions, Flight Control and AAS Worldwide Telescope.
- A <section> with the "Scenes" or "Settings" left-side panel when in view.
- Other features in non-modal overlays.

There is no mechanism currently to allow users to move through the main sections of the application. Users must tab through the interface, which at the moment is prevented due to the inaccessibility of many controls. But such an approach is inefficient and time consuming for users that rely on keyboard navigation.

Suggested Solution

Provide common shortcuts, e.g. F6 to circle focus between main sections of the application while allowing users to tab or use Arrow keys within a group of controls. Further discussion with PAC is recommended.

Additionally, make the grouping of elements in a section programmatic and provide descriptive accessible names so that screen reader users are always aware of the current context.

Missing Focus Indicator on Many Controls

Severity: 1

While some buttons show the default focus outline when reached by pressing Tab or Shift+Tab, most interactive elements have the styling of "outline: 0" applied to remove the focus outline. The lack of a focus indicator along with the inaccessible implementation of many controls makes the page unusable for keyboard users as it is impossible to realize which element is currently focused.

Examples include:

- The three vertical dots menu button;
- The "Close" button in the "About OpenSpace" dialog;
- The "Scene" control;

- The "Search" input field in the "Scene" menu pane; note that the field relies only on its cursor as an indication that the field is reached, but this may be difficult to notice;
- The "Scene" custom menu items which expand or collapse additional options; and
- Color Picker buttons, sliders (See: Problematic Focus Indicator for Form Controls), dropdowns, etc.

Suggested Solution

Remove the styling of "outline: 0" and provide a highly visible focus indicator for all interactive controls.

For details about requirements and best practices, see the following resources:

- https://www.w3.org/WAI/WCAG21/Understanding/focus-visible.html
- https://www.w3.org/WAI/WCAG22/Understanding/focus-appearance.html
- https://www.w3.org/WAI/WCAG22/Understanding/focus-not-obscured-minimum.html
- https://sarasoueidan.com/blog/focus-indicators/

Missing Accessible Feedback When Viewer Content is Updated

Severity: 1

When space exploration is controlled using the web interface, changes are only reflected in the space viewer of the running application. This may not be evident to many users since the web interface shows a black screen for the viewer area. Additionally, blind screen reader users are not provided with any feedback to determine when these updates have occurred.

Suggested Solution

Inform all users of the current functionality when trying to perform the space exploration via the web UI, e.g. by including instructions in the "About OpenSpace" overlay, or the black screen area of the space viewer. Additionally, inform screen reader users when changes become effective in the running application via a live region facility.

Use aria-live="polite" and aria-atomic="true" on an appropriate container to communicate these changes in context to screen reader users, e.g. "Labels added in the running application" or "Adjustments are applied in the running application" or similar. If visible feedback will be added to the web UI, this should be wrapped inside the live region, with the note that the empty container must be present in the DOM on page load and then populated with the appropriate status message as needed.

If no visible feedback will be provided, the live region should be added at the bottom of the DOM, and then filled with the status message. This container should be hidden off-screen so that only screen readers can make use of it.

The following CSS declaration will create a class called "sr-only", which will position any element to which it is applied off-screen:

```
.sr-only {
        clip: rect(0 0 0 0);
        clip-path: inset(50%);
        height: 1px;
        overflow: hidden;
        position: absolute;
        white-space: nowrap;
        width: 1px;
}
```

For further details on off-screen text refer to: https://www.tpgi.com/the-anatomy-of-visually-hidden/.

Problematic Implementation of Landmark Region

Severity: 2

The Menu button, "Scenes" and "Settings" controls are wrapped in a <nav> with class="_16EbidWL9cgqVGI4etuXZF", but it is not necessarily a true navigation landmark, and no accessible name is provided for screen reader users to inform them on the purpose of the region.

Suggested Solution

A different grouping method may be more appropriate for the three controls instead of a navigation landmark, such as a toolbar. Refer to the ARIA APG Toolbar Pattern: https://www.w3.org/WAI/ARIA/apg/patterns/toolbar/.

Use an aria-label attribute on the widget container with a descriptive value to inform screen reader users of how are the items in the group related.

Incorrect Implementation of Icons

Severity: 2

Many icons throughout the application are rendered via an <i> tag with uninformative text, e.g. "more_vert" for the menu button, or "exit_to_app" for the icon accompanying the "Quit Openspace" menu item. The text is invisible as part of the "font-family: "Material Icons"" styling and it is communicated to screen reader users creating either incorrect or unnecessary text alternatives for such icons.

Suggested Solution

Apply aria-hidden="true" to the <i> tag to hide the icons from screen reader users.

More Menu

Applies to: content of with class="_3ywsxpHk291KvhpXBbWi7i" and the three vertical dots menu (in <nav> with class="_3-04obvW8f9tSfbFObAr-V").

Inaccessible Menu Component

Severity: 1

The three vertical dots menu button (<button> with class="_2ujwRWQn0SWTaB1uovviGA") and the controlled menu are incorrectly marked up preventing many users from interacting with the component while others cannot determine the information that is visually conveyed:

- When the button is activated, focus is lost, and users need to navigate backwards by pressing Shift+Tab to reach the menu button again and then the items in reverse order.
- Screen reader users are not informed of the presence of a menu when the button is reached. Additionally, there is no programmatic indication of the collapsed or expanded state of the button. For example, when the button is focused, the NVDA speech output is "more_vert button", then there is complete silence if Space or Enter are pressed to show the menu.
- The toggled menu is implemented as a set of buttons in an unlabeled navigation landmark, but the controls are not necessarily intended for navigational purposes.
- The buttons can only be reached using Tab which is not expected for sighted users who will see the menu and assume they can use the Arrow keys to move between menu items.

Suggested Solution

Implement an accessible menu widget which behaves like native operating system menus.

- When the menu button is activated, by pressing Enter or Space, focus should be sent to the first menu item in the list allowing users to move through options using the Arrow keys.
- When the menu is dismissed using Escape, focus should return to the menu button.
- When a menu item is activated, the menu should be dismissed, and focus should be sent to a meaningful location.
- Use menu semantics for the widget by adding role="menu" to the menu container and role="menuitem" to the menu items.

For more on accessible menu widgets, please see:
https://www.w3.org/WAI/ARIA/apg/patterns/menu-button/

Uninformative Name for Menu Button
Severity: 1

The three vertical dots menu button (<button> with class="_2ujwRWQn0SWTaB1uovviGA") is communicated with the accessible name of "more_vert" which does not describe the purpose of the control. This is implemented as invisible text wrapped in an <i> tag with the styling of font-family: "Material Icons". See: Incorrect Implementation of Icons.

Suggested Solution
Use the aria-label attribute on the <button> to provide an accessible name, e.g. "Utility Menu" or similar. Use the aria-hidden attribute on the icon to hide the non-descriptive text alternative from screen reader users.

Inaccessible "About OpenSpace" Dialog
Severity: 1

When the "About OpenSpace" button is activated, the overlay is displayed covering the space viewer. The required mark-up is not implemented to convey the container as a modal dialog, and interaction with the overlay is problematic for users of access technologies:

- The focus indicator is not visible once the dialog appears, and users must press Shift+Tab to reach the "Close" button.
- Screen reader users encounter complete silence in the speech output and the result of their action remains unclear. To access the overlay, users must navigate backwards and read through the items in reverse order.
- Both screen reader and keyboard users can move focus onto elements outside of the displayed content, and into the application toolbars which are now obscured.

Note that the dialog heading is correctly conveyed as a level 1 heading to emphasize the current context of a modal interface.

Suggested Solution

Implement an accessible modal dialog for the "About OpenSpace" overlay. Wrap its container in a native <dialog> element which comes with several built-in accessibility features:

- provides programmatic boundaries for the overlay;
- sends focus to the dialog when displayed on its first interactive element, the "Close" button;
- prevents users from reaching the dimmed main page content when in view; and
- returns the focus back to the triggering control when dismissed, with the note that in this case, focus should go back to the collapsed menu button.

As an additional adjustment, apply an aria-labelledby attribute to the <dialog> element, referencing the ID of the modal heading to provide an accessible name for the overlay.

Missing Indication for External Control

Severity: 2

The "Open Tutorials" button opens content in a browser window, but there is no visual or programmatic indication to warn users of this action.

Suggested Solution

Ensure that all users are warned about the functionality of the "Open Tutorials" control:

- Provide an icon positioned next to the control's text, inside the boundaries of the menuitem so that it is clickable and encompassed by the focus outline. The icon must have a color contrast ratio of 3:1 with its background and be hidden from screen reader users (via aria-hidden="true" on an SVG or empty alt attribute value on an <img>).
- Provide a text alternative for the icon as off-screen text inside the control, for screen reader users. This should be implemented as a span with the appropriate screen-reader-only class, with the text "(opens in new tab)" in parentheses. There should also be a non-breaking space before the left parenthesis, so that it does not become adjoined to the control's name.
- Optionally, when the link receives focus and mouse hover, you can show the off-screen text visually too (i.e. temporarily remove the sr-only class), as a sort of

accessible tooltip and additional reinforcement. This can be helpful but may not fit into the design.

Please find attached the icon we recommend using for opening new tabs: Opens in New Tab/Window Icon.

Problematic Toggle Controls

Severity: 2

The menu contains two buttons, "Toggle console ~" and "Toggle native GUI F1", which control the visibility of a specific feature and dismiss the menu. There are several usability and accessibility concerns:

- There is no visible indication in the controls appearance if they are pressed or not, to clearly convey that users must open the menu and press the button again to remove the feature.
- There is no programmatic mark-up for the state of the controls, so that screen reader users may be made aware if the feature is active or not.
- The Tilde symbol ("~") in the name of the "Toggle console" button is not communicated by some screen readers, e.g. NVDA at default punctuation settings.
- Once activated it is currently unclear where the focus is sent.

Suggested Solution

Once the menu widget is implemented as suggested a previous observation (See: Inaccessible Menu Component), use role="menuitemcheckbox" instead of role="menuitem" for "Toggle console ~" and "Toggle native GUI F1". Additionally:

- Indicate the state of the control via aria-checked with a value of "false" when the feature is hidden and a value of "true" when shown.
- Add a checkmark to precede the text of a control when pressed so that its functionality is clear for all users. Then, the word "toggle" may be removed from the text of the control.
- For "Toggle console ~" apply aria-hidden="true" to the element wrapping the symbol and instead provide off-screen text inside the button with the symbol's name, e.g. "Tilde".
- Once a control is checked, and the menu is dismissed, send the keyboard focus to the added feature.

- Once a control is unchecked and the menu is dismissed, send the keyboard focus back to the menu button.

Insufficient Contrast Ratio on Hover

Severity: 2

The menu items have white text (#FFF) displayed on a black background (#000) with the keyboard shortcuts displayed in gray (#999). On hover, the item's background color changes to blue (#3DBDEE) which has a contrast ratio of 2.16:1 against the white text and 1.31:1 against the gray keyboard shortcuts, below the 4.5:1 minimum contrast requirement for normal-sized text.

Suggested Solution

Either use a different hover indicator or a different background color that has a contrast ratio of at least 4.5:1 against the white and gray text. Note that darkening the blue color to achieve a sufficient contrast ratio will result in an undistinguishable hover indicator with low contrast against the surrounding black items.

Problematic Keyboard Shortcut to Quit the Application

Severity: 2

The "Quit OpenSpace" menu item has the Escape key assigned as a shortcut, but this may lead to accidentally closing the application when in fact the user intended to dismiss a menu or a tooltip.

Suggested Solution

Reserve the Escape key for in-app functions and provide a different shortcut for quitting the application.

Inclusion of Decorative Separator for Screen Reader Users

Severity: 3

The menu items are separated by horizontal rules <hr> which are announced by screen readers and cause unneeded speech/braille verbosity.

Suggested Solution

Add aria-hidden="true" to the <hr> elements.

Scene

Applies to: content of with class="_2z-xbL-rVC2gjadKRijaoR " and the "Scene" menu pane in <section> with class="_3_c3v9H3yafru05mCERRqx".

Problematic Implementation of "Scene" Control

Severity: 1

The "Scene" control triggers the display of a left-side panel with datasets and other elements. It is currently inaccessible to many groups of users:

- Keyboard-only users can reach the control due to the tabindex attribute, but they cannot activate it using Enter or Space.
- It has a partial tab implementation, just as the "Settings" custom control which has a similar functionality. However, this means that screen reader users will hear incorrect details about the component.
    - Although it has role="tab", it is not part of a tablist element, meaning that users are not informed of the number of items in the set.
    - The selected control is not communicated as such, although visually this is indicated using a blue bottom border and slightly lighter background color.
    - The controlled panel is not marked up as a tab panel.
    - The tabs keyboard navigation pattern is not implemented, and arrow keys cannot be used to navigate between different tabs.
- Note that although "Scene" and "Settings" are styled to look as tabs, they do not function as a Tabs widget since:
    - By default no tab is selected.
    - When a tab is selected, the panel is displayed, and the cursor can be noticed in the "Search" field to indicate that the field is active.
    - Users cannot activate a tab to close the corresponding panel.

Suggested Solution

Implement "Scene" using a native button element and remove role="tab" and tabindex="0". Use aria-pressed to communicate the state of the "Scenes"/"Settings" buttons, with a value of "false" when the corresponding menu pane is hidden and "true" when displayed.

Note that it has been previously suggested to group the buttons at the bottom of the screen in one or two toolbar components, depending on how they relate to each other. See:

- Missing Keyboard Navigation Mechanism
- Problematic Implementation of Landmark Region

Grouping only "Scene" and "Settings" may potentially be confusing since one is intended to make changes to the application in general while the second has an effect on the object in focus in the space viewer area.

Missing Programmatic Boundaries for "Scene" Menu Pane

Severity: 1

Some screen reader users can activate the "Scene" control and focus is sent to the "Search" field in the "Scene" menu panel. User are not informed of the new context and the boundaries of the component.

Note that the pane acts as a non-modal overlay inserted in the DOM in <section> with class="_3_c3v9H3yafru05mCERRqx" before the navigation region encompassing the menu button, the "Scene" and "Settings" controls. This means that blind screen reader users encounter it when present, as the first content on the screen.

Suggested Solution

Apply an aria-labelledby attribute to the <section> element encompassing the pane and reference the ID of the "Scene" visible heading.

Missing Heading Mark-Up for Visual Heading

Severity: 2

The "Scene" text acts as a heading for the following section but is only emphasized visually with no heading mark-up. Screen reader users will not be able to use heading navigation to reach this section.

Suggested Solution

Implement "Scene" as a level 2 heading.

Missing Focus Management for Overlay Dismissal

Severity: 1

When the "Scene" overlay is dismissed, by activating the "Close" ("x") button, the focus indicator is no longer visible, while screen reader users encounter complete silence in the speech output.

Suggested Solution

Manage keyboard focus to ensure that when the overlay is dismissed, focus reliably returns to the control that was used to open it.

Missing User Notification of Dynamic Search

Severity: 2

When a user starts typing into the search field, the displayed datasets are updated dynamically to reflect the search input. Screen reader users are not notified of the dynamically rendered datasets and when nothing matches the search query, the text "nothing found. Try another search!" is displayed but is not announced to screen reader users.

Suggested Solution

- Notify users of the dynamically updated datasets by providing off-screen instructions, e.g. "Datasets will update as you type", and use the aria-describedby attribute on the search input referencing the ID of the instructions container to announce them when the field is focused.
- Implement the status message "nothing found. Try another search!" as an assertive live region to be announced once it's displayed. Note that the with aria-live="assertive" and aria-atomic="true" should be present in the DOM when the page is loaded, and the text should be dynamically added when no results are available.

Inaccessible Hierarchical Structure

Severity: 1

The "Scene" menu is organized in an overly complex component that resembles somewhat a "treeview". The parent items may contain several controls on the same line:

- A chevron pointing towards the right which can be clicked to expand the second level items, or the available customization controls.
- A checkbox which may be clicked to show or hide an object in the space viewer.
- The textual label which also reveals or hides the second level items.
- A "compass" icon to bring the item into focus in the space viewer and a "wrench" and an "info" icon which may open an overlay in the viewer area (See: Inaccessible Icon Buttons).

These are all encompassed in <header> with class="_2aFJ5hI5gk9pAFhb4odhAM false" and role="button". Then tabindex="0" makes the group focusable but no action can be executed when Enter or Space is pressed by keyboard-only users. Arrow keys also do not have any action such as showing the next level items.

Screen reader users can expand or collapse these custom disclosure controls, but the remaining actions are unavailable. A sample speech output from NVDA when the "Milky Way Arms Labels" parent item is reached is:

> "chevron_right clickable check_box_outline_blank Milky Way Arms Labels clickable clickable build clickable help_outline button"

Once all tree items are expanded, there are groups of controls which include checkboxes, color pickers, sliders, spin buttons, dropdowns etc. with info tooltips for additional descriptions. No mechanism is implemented to explore the menu structure and reach these controls using the keyboard.

Note that the amount of options present in the "Scene" menu may feel overwhelming as mentioned in a previous observation (See: Problematic Usability of user Interface).

Suggested Solution

As a first step, further investigation is needed to determine which options must be present in the "Scene" menu and which can be reached by other means. Further discussion with PAC is recommended to determine the most appropriate pattern for the "Scene" menu to ensure it can be navigable using the keyboard. Care must be taken to

ensure that actionable elements are nested according to their specifications (See: Inaccessible Icon Buttons).

Inaccessible Icon Buttons

Severity: 1

Several items in the "Scene" menu are accompanied by one or more actionable icons, such as:

- A "compass" <svg> to bring the item into focus in the space viewer;
- A "wrench" icon (<i> with icon="build") which opens an "Asset Information" overlay in the space viewer area; and
- An "info" icon (<i> with icon="help_outline") with a question mark in a circle, which opens an overlay in the viewer area with the item's properties.

The controls are not keyboard focusable or operable and are incorrectly nested inside the parent menu item (<header> with role="button") as detailed in the previous observation (See: Inaccessible Hierarchical Structure). Also the accessible name of the control is either missing or provided using a non-descriptive text alternative for the icon.

Suggested Solution

Use native <button> elements for all icon buttons and apply an aria-label attribute on each button to provide an informative accessible name.

Problematic Clear Input Button

Severity: 1

When a user starts entering a search query, a clear input button is displayed. The button is implemented as an icon with role="button" and a tabindex attribute to make it focusable but keyboard-only users cannot press the Enter or Space to activate the button. Additionally, a title attribute with the value of "Clear input field" is relied upon to provide context for the control but this is not surfaced to many groups of users.

Note that the <i> tag holds the uninformative text of "cancel" which will make the purpose of the button unclear to screen reader users (See: Incorrect Implementation of Icons).

Suggested Solution

Implement the control as a native <button> element and use the aria-label attribute to provide it with an accessible name, e.g. aria-label="Clear input field" or aria-label="Clear search entry".

Inaccessible Checkboxes

Severity: 1

Several checkboxes are used in the hierarchical structure of the "Scene" menu. The checkboxes are implemented as icon elements with a text alternative of "check_box". With the current implementation, the custom controls cannot be focused by keyboard users, while the visual affordances that indicate the name, role and state of a checkbox are not conveyed to screen reader users.

Suggested Solution

Implement checkboxes as native <input> elements with type="checkbox" and associate the visible label with the checkbox using the for attribute on the <label> referencing the ID of the <input>.

Inaccessible Tooltips

Severity: 1

Several controls are followed by info icons which show a tooltip with additional information on mouse hover. These tooltips can only be triggered by mouse users and are not available for keyboard and screen reader users.

Additionally, the current tooltip interaction may be problematic for screen magnification users, since:

- there is no mechanism available to dismiss the additional content without moving the pointer hover; and
- the pointer cannot be moved over the additional content without causing it to disappear.

Suggested Solution

Implement the info icons as buttons, display the tooltips on focus and on hover, and use the aria-describedby attribute on the button referencing the ID of the tooltip container to announce it for screen reader users. This approach has the disadvantage that the tooltip text cannot be triggered on touch devices and with some speech input software.

Additionally ensure that the tooltips can be dismissed by pressing Escape and that they are hoverable.

For more information on implementing accessible tooltips, refer to https://inclusive-components.design/tooltips-toggletips/.

There are a few alternatives to the suggested remediation path, e.g.:

- Implement the info buttons as "toggletips" which require activation to reveal or hide the additional information.
- Ensure that help is always available in the label text by including more detail in the label wherever possible and providing a "toggletip" with the remaining information.
- Provide a link to a documentation page with explanatory notes for customization options.

Non-Dismissible and Non-Hoverable Tooltips

Severity: 2

Several controls are followed by info icons which show a tooltip with additional information on mouse hover. The current tooltip interaction may be problematic for screen magnification users, since:

- there is no mechanism available to dismiss the additional content without moving the pointer hover; and
- the pointer cannot be moved over the additional content without causing it to disappear.

Suggested Solution

Ensure that the tooltips can be dismissed by pressing Escape and that they are hoverable.

Problematic Custom Comboboxes

Severity: 1

Some customization options, e.g. "Render Option" under "Milky Way Galaxy Image", are provided via a custom combobox which has severe accessibility problems affecting many user groups:

- When reached by pressing Tab or Shift+Tab, screen reader users are not informed what is the field's label since the ID referenced in the value of the "for" attribute on <label> does not match with the assigned ID for the <input>.
- There is no indication that this is form control which has an associated list of options, for example both JAWS and NVDA communicate it as a simple "edit" field
- Its current value is inconsistently announced, e.g. NVDA conveys the field as "blank" while JAWS speaks the value as the field's label.
- While Down Arrow or Space expand the associated list of option, blind screen reader users may not be aware that one exists.
- If users start typing, the entered text is difficult to see, and it is overlapped by the visible label.
- Screen reader users hear the first option in the list, e.g.:

> "option Points focused, 1 of 2. 2 results available. Use Up and Down to choose options, press Enter to select the currently focused option, press Escape to exit the menu, press Tab to select the option and exit the menu."

Suggested Solution

Consider implementing the form controls as native <select> elements and associate each one with its visible label by ensuring that the referenced ID in the value of the "for" attribute on <label> and the ID of the <select> match.

If there is a high number of options in the list then an accessible design pattern known as Editable Combobox with List Autocomplete may be more usable. PAC can provide further guidance as needed.

Missing Visual and Programmatic Labels for Form Controls

Severity: 1

Some related form controls, e.g. the three "Multiply color" or "Rotation" spin buttons, share the same visible label which appears as left-justified above the first field. This is problematic for sighted users who may have difficulty determining the purpose of the remaining fields in the group, other than the first one. Due to the current focus styling, keyboard users cannot see any indication of when the form controls are reached.

Screen reader users hear a label announced only for the first input field, while the remaining ones in the group are unlabeled, since they are programmatically associated with a <label> element with no text.

Suggested Solution

Use a <fieldset> to group the control with the visible group label wrapped by the <legend>. Provide visible and programmatic labels for each <input> in the set to clearly identify their purpose.

Mismatched Visible and Programmatic Value for Sliders

Severity: 1

For all available sliders (<input> with type="range"), the displayed value does not match the programmatic value assigned using the value attribute.

Here is an example of the screen reader speech output for the following controls found in Moon Trail > Renderable > Translation:

- Opacity: the displayed value is "1" while the announced value is "100";
- Period (in days): the displayed value is "27" while the announced value is "666"; and
- Number of samples along the orbit: the displayed value is "1000" while the announced value is "1389".

Suggested Solution

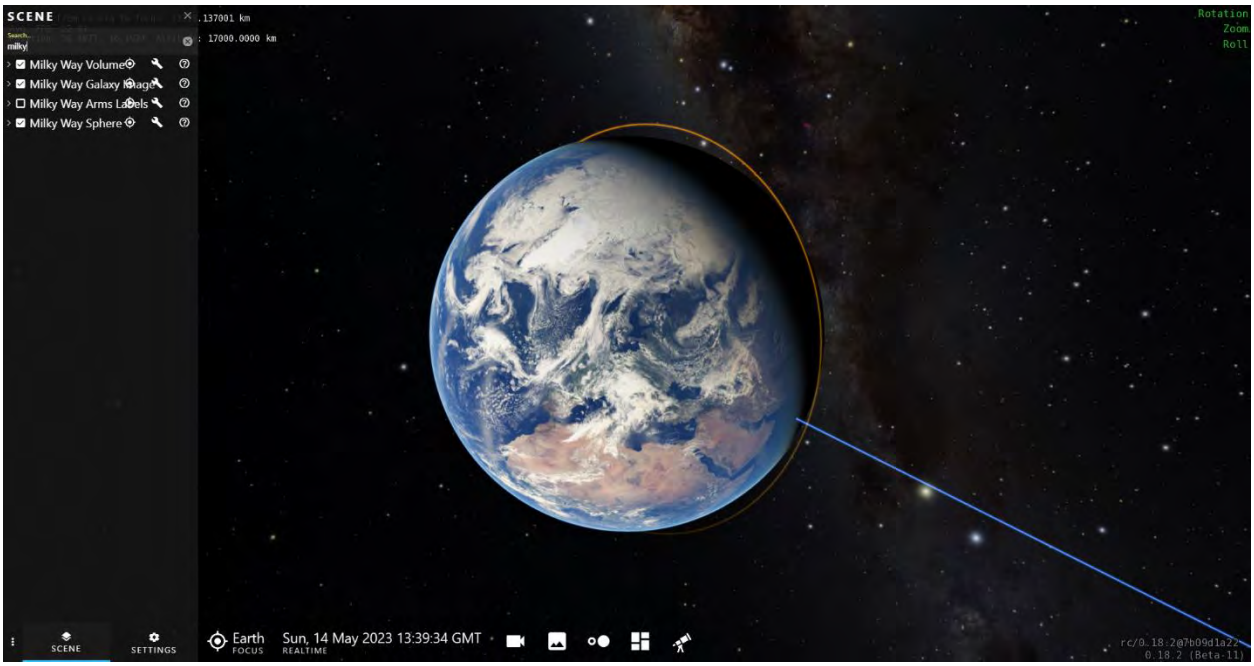
Update the programmatic value of each input to match the visible text.

Overlap of Elements at Default Side Pane Size

Severity: 2

In several instances the text of various items in the "Scene" menu pane is overlapped by one or more adjacent controls, in the form of a "compass", "wrench" or "info" icon. Once items are expanded, some controls become fully or partly obscured to the right.

Mouse users may resize the pane, but this feature only becomes noticeable on mouse hover over the right side of the pane (with style="position: absolute; user-select: none; width: 10px; height: 100%; top: 0px; cursor: col-resize; right: -5px;"). An accessible alternative for users of access technologies is not available, and resizing the pane does not seem to be listed as an option in the "Settings" menu.



A screenshot of the application UI with the "Scene" menu filtered by the search term "milky".

Suggested Solution

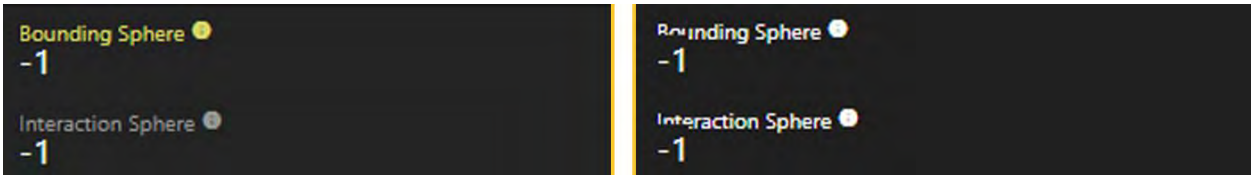
Review the sizing of the side pane and ensure that elements are not overlapped or obscured at any supported width. Provide an accessible option, e.g. in the "Settings" menu to adjust the pane width via an input field with a descriptive visible and programmatic label.

Problematic Focus Indicator for Form Controls

Severity: 2

The available sliders (<input> with type="range") rely on color only to indicate their focused state, when reached by pressing Tab or Shift+Tab. The label text updates its font color from gray (#999) to yellow (#D9DA6D). The change is subtle and may not be noticeable for many users, since the contrast ratio between the two colors is very low, at 1.48:1.

Additionally, such styling is not persistent when using Windows Contrast Themes and no other indication of the focus state exists.



A comparison of the focused state for the "Bounding Sphere" spin button without any contrast theme in the first image and with "Aqua" Theme applied in the second.

Suggested Solution

Restore the focus outline and ensure that a highly visible indication of the focused state exists. See: Missing Focus Indicator on Many Controls.

Insufficient Contrast Ratio for Gray Text

Severity: 1

Different shades of gray color are used for placeholder text, labels or entered text in an input. On several instances, the gray color has insufficient contrast ratio against the black page background or other gray shades, making the text hard to read for users with low vision.

Some examples are included in the following data table:

Element	Font Color	Background	Contrast Ratio
"Search" placeholder	#757575	#161616	3.9:1

Slider labels when placed on the bar for the selected value	#999	#3A3A3A	4.1:1
Text typed in comboboxes	#333	#222	1.3:1

A screenshot of the "Render Option" combobox with the letter "S" typed in.

Suggested Solution

Ensure a contrast ratio of at least 4.5:1 is achieved for all normal-sized text.

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AMNH: Batch 01 Launcher Accessibility Overview

July 14, 2023

This content was prepared by Prime Access Consulting, Inc. for American Museum of Natural History.

Introduction

This document enumerates the results of a series of accessibility and usability observations carried out against the "OpenSpace Launcher" window and the "Profile Editor" dialog in the QT6 OpenSpace Beta-11 (Version 0.18.2) application. The aim was to identify problems which various groups of users may encounter, along with recommended remediation strategies.

Additional screens, such as the Window Configuration Editor, were not assessed in this report. However, the included examples and advice should be used to address similar instances of problematic behavior elsewhere in the application to expedite any future evaluations and increase the accessibility of the application as a whole.

We may refer to components used within the product by name throughout. Where specific terms for these have not been previously communicated, they have been inferred from the mark-up or page content and therefore may not be consistent with those used by internal development and design teams.

Severity Levels

Each individual issue is preceded by "(sev N)", where N is a severity level from 1 (most) to 3 (least). This is intended to indicate the likely impact on users, and is assigned as follows:

- Severity level 1 represents behavior which will prevent a user from carrying out a task, drastically decrease the effectiveness with which they are able to do so, and/or disproportionately increase the time required for task completion.
- Severity level 2 is applied to issues which are likely to cause significant frustration or confusion, but in a non-blocking fashion given enough time, experimentation, or assistance.
- Severity level 3 is reserved for aspects which are demonstrably problematic but will have the least noticeable impact on users. For example, this could be because a specific set of circumstances is required to trigger the behavior, or because users are likely to be well-versed in appropriate workarounds. However, it is critical to note that the presence of a high number of severity 3 items can substantially degrade a user's experience, potentially to the same degree as the presence of one or more severity level 1 issues.

These level definitions do not take into account the amount of effort or development time required for remediation but are intended to assist in the prioritization of resource allocation and scheduling.

Executive Summary

The application launcher follows some accessibility best practices, but it is currently significantly inaccessible to users who do not interact with it via mouse input. Several improvements are needed to ensure that its functionality can be equally accessed and enjoyed by all users. Here are some of the most impactful problems:

- Controls either lack an accessible name to inform screen reader users of their purpose or have a non-unique, uninformative name. It is very difficult for screen reader users to find, apply and edit the customization settings present in the launcher UI as a result.
- While most interactive elements can be reached and operated from the keyboard, several controls either have no focus indicator, or have one which is very difficult to see. Additionally, controls are reached in an incorrect order, making the launcher dialog difficult to navigate for people who must rely on keyboard input or other assistive technology that simulates it.
- In some instances, text elements are rendered with insufficient color contrast, which is problematic for many users including those with low vision.

Components

Shared Observations

- (sev 1) Visible labels of UI components are not conveyed to screen readers when input fields are reached with Tab or Shift+Tab. For example, in the application launcher window, the "Choose Profile" dropdown is conveyed by the NVDA screen reader as "combo box default Down", and "Window Options" as "combo box sgct.config.single (from .cfg) Down". Similarly, in the "Profile Editor" dialog, none of the input fields have accessible names and it is impossible to determine their purpose using a screen reader.
    - Suggested Solution: Connect all text labels to their corresponding UI element using the Qt "buddy" pattern.
- (sev 1) The accessible names for certain buttons provide no context as to what the user is creating or editing. The names of buttons on the launcher are read out to screen readers, but labels such as "New" and "Edit" are not sufficient on their own to convey whether the user is creating or editing a window, a profile, a setting, etc. The "Edit" buttons found in the profile editor are also subject to this behavior.
    - Suggested Solution: Use Qt's setAccessibleName method to give a more descriptive name to each button for screen reader users, and include the visible text followed by the additional context. For example: "New Window", "New Profile", "Edit Modules", "Edit Simulation Time Increments (20)".
- (sev 2) The terminal/shell window remains persistently displayed behind the background of the application launcher, and may result in a confusing or distracting effect for both sighted and non-sighted users. Some screen readers, e.g. JAWS, speak its entire content when the program starts, leading to an overly verbose experience. Additionally, closing the terminal window will dismiss the entire interface of the application launcher.
    - Suggested Solution: Do not present a terminal window when the application is launched from the operating system's UI directly, e.g. from Windows Explorer. If information from the command line output is important to or required by users, consider adding the relevant context to the application's UI, and/or writing it to a log file. Note that if the application is started from the user's terminal/shell, presenting the output in the same terminal session is expected.

Application Launcher

Description: The window has the name of "OpenSpace Launcher" and shows its content on a different background image every time it is opened. The text has a white font color. The following elements appear from top to bottom:

- The logo with the text of "OpenSpace";
- The "Choose Profile" label;
- A dropdown with gray background and the value of "default";
- The "Edit" and "New" buttons, on the same line;
- The "Window Options" label;
- A dropdown with gray background and the value of "sgct.config.single (from .cfg)";
- Another "New" button;
- The "Start" button with large all-caps text on a light gray background.

Observations

- (sev 1) Actionable elements are focused in an order which is not meaningful. When Tab is pressed to navigate through the overlay, elements are reached in the following order: "Choose Profile" dropdown, "Window Options" dropdown, "Start" button, "New" button, "Edit" button for the profile section, and lastly the "New" button for "Window Options".
    - Suggested Solution: Ensure that the Tab Order matches the visual order of elements and follows a logical sequence in the launcher window, from left to right, top to bottom.
- (sev 1) The focus indicator is missing on the "combo box" dropdowns and the "Start" button. Meanwhile, a focus indicator is present on the "New" and "Edit" buttons, but the gray (#9F9F9F) 1 px dotted outline is extremely difficult to see. The resulting color contrast ratio is 2.38:1 against the gray (#606060) background for buttons, and 2.65:1 against their white (#FFF) border.
    - Suggested Solution: Review the current styling and use a prominent focus indicator via QPushButton:focus, such as a solid outline around the control that meets the minimum non-text contrast ratio requirement of 3:1 with all adjacent colors. Here are some additional considerations:
        - Changes in font/background colors and box shadows may be used, as long as they are accompanied by an outline to ensure that there is at least one indication of the focus state that persists in Windows Contrast Themes. Additionally, if the font/background color of the control is changed when focused, the text must still have a color

contrast ratio of 4.5:1 with its background for normal sized text, and 3:1 for medium/large font size (14 pt and bold or 18 pt).

- While consistency is encouraged, the styling of the focus indicator can be adjusted across components so that it remains highly visible and has sufficient color contrast, since different backgrounds may be used in different circumstances.
- Resources:
  - A guide to designing accessible, WCAG-compliant focus indicators: https://www.sarasoueidan.com/blog/focus-indicators/
  - Success Criterion 1.4.11: Non-text Contrast: https://www.w3.org/WAI/WCAG21/Understanding/non-text-contrast.html
  - Success Criterion 2.4.11 Focus Appearance: https://www.w3.org/WAI/WCAG22/Understanding/focus-appearance-minimum

- (sev 2) The two "New" buttons, single "Edit" button, and "Start" button can only be activated with Space, and not Enter. Users will expect both keys to trigger button activation. Note that the buttons in the "Profile Editor" can be activated using both the Spacebar and Enter keys.
  - Suggested Solution: Review the differences between the buttons in the application that do support activation on press of Enter, and those that do not, and reconcile the two so that all buttons in the application can be activated with both Enter and Space.
- (sev 2) The "Start" button has low color contrast for its hover style as the background updates to light gray (#969696) resulting in a 2.96:1 color contrast ratio with the white text (#FFF).
  - Suggested Solution: Update the hover style for the "Start" button and ensure that large text (at least 14 pt and bold, or 18 pt and larger) has a color contrast of at least 3:1 with its background, while the requirement for normal-sized text is 4.5:1.
- (sev 2) The overlay may have a different background image every time when opened. The text of the dropdown labels can be difficult to read when their text is positioned over lighter colors in the background image. Here are some examples where the white label text (#FFF) is difficult to read, and our suggested remediation path:

    - The entire "Choose Profile" label can be positioned over a satellite image of Earth with light colors, e.g. #BBB8A9 resulting in a color contrast ratio of 2:1.
    - The last letters of "Window Options" may appear over a beige (#7B7C74) shade of the Jupiter planet and the resulting color contrast ratio is 4.2:1.
    - When the background image shows a rocky surface, some letters in "Choose Profile" appear on a light gray (#9F9F9F) background and have a 2.6:1 color contrast.
    - Suggested Solution: Add a background color or drop shadow to the text content and ensure that normal-sized text meets the minimum color contrast requirement of 4.5:1.
- (sev 3) The "Choose Profile" and "Window Options" dropdowns are presented to screen reader users with confusing description text of "Down", resulting in overly verbose output, e.g. "combo box default Down" with NVDA or "Choose Profile combobox default, to change the selection use the arrow keys, Down" with JAWS.
    - Suggested Solution: It is believed that this text is being added by Qt, perhaps in reference to the fact that users can press Down Arrow to move through the dropdown options, and/or Alt+Down Arrow to fully expand the list of items. Exploration is required to determine if it can be removed in some way, e.g. by adding an empty string as the accessible description using Qt's setAccessibleDescription method, or alternatively to set the description to something more useful if an empty string is not an option.
- (sev 3) The "Start" button uses all-caps which drastically decreases readability for all visitors but poses a particular challenge for those with reading difficulties like dyslexia. It becomes impossible to identify and recognize individual words by their shape, as the uppercase styling causes all words to take on a uniform rectangular appearance. In addition to the visual impact, use of entirely uppercase text can also interfere with the output of screen readers, which may announce certain words as acronyms or abbreviations.
    - Suggested Solution: Instead of relying on all-caps text, consider using a different typeface, weight, and/or color to emphasize layout elements such as important call-to-action buttons. Note that in this case, the relevant label only uses a single word, and hence the decrease in readability Is minimal. However, this issue is included as a pointer to generally avoid all caps text in the interface, regardless of its length.
- (sev 3) There is no mechanism to close the launcher window for keyboard-only users other than pressing Alt+F4, which might be unfamiliar to less technical users.

    - Suggested Solution: Provide a "Cancel" or "Exit" button to abort the application launch if needed.

Profile Editor

Description: This screen can be reached by pressing "Edit" or "New" in the profile section. If "New" is used, then all input fields are blank. When the "Edit" button is used, fields may be pre-populated with values. The dialog name is "Profile Editor", it has a Close ("x") button, and contains the following elements from top to bottom:

- The "Profile Name" label, an input field and the "Duplicate Profile" button, all three on the same line;
- A gray horizontal separator;
- Two columns of content, with the left column being wider than the second.
    - The first column contains three vertically stacked large multi-row input area with their labels: "Properties", "Assets" and "Keybindings". When editing a profile, they may contain one or more values, each on a separate row, while the label shows the count, e.g. Assets (4)".
    - The second column has seven sections stacked vertically, each with a label text and an "Edit" button: "Meta", "Mark Interesting Nodes", "Simulation Time Increments", "Camera", "Time", "Modules", "Additional Scripts". A small horizontal separator demarcates each section.
- A gray horizontal separator;
- Two right-aligned buttons on the same line: "Save" and "Cancel". In the case of an error, a message is displayed in red font color, left justified on the same row with the two controls.

Observations

- (sev 1) Within the read-only inputs for "Properties", "Assets" and "Keybindings", Only the first value is communicated to screen reader users while the remaining values cannot be read at all.
    - Suggested Solution: Use list views in place of multi-line text fields to display available options. Potentially, accompany each list view with controls to edit the existing settings, such as "Add" and "Remove" buttons, as discussed in the last observation in this section.
- (sev 1) Screen reader and keyboard users focus the "Properties", "Assets" and "Keybindings" controls in an order which is not meaningful when pressing Tab

through the dialog. First the "Edit" button" is reached for each feature, followed by the read-only form control with the existing settings.

    - Suggested Solution: Update the order of elements in the code and the visual layout for each feature so that users first encounter the container for the existing settings and then the control(s) to change them.

- (sev 1) When screen reader users attempt to submit a profile without a "Profile Name", the keyboard focus remains on the "Save" button and the error message ("Profile name must be specified") is not communicated. The error text cannot be reached using a screen reader, and users cannot determine what problem has occurred or what information is missing.
    - Suggested Solution: Either present the error in an alert dialog, or send focus to the "Profile Name" field upon submission with incomplete data. In the second case, set an accessible description for the input that contains the error message, so that it is conveyed by screen readers once the field is focused, using Qt's setAccessibleDescription method.
- (sev 2) When a new profile is created, the only required data is the "Profile Name" while setting any other details is optional. There is no visual or programmatic indication to help users determine which fields are required and to prevent an invalid submission of the form.
    - Suggested Solution: Append the word "(required)" to the visible label of the field, e.g. "Profile Name (required)" and ensure it is programmatically associated with the input. See: Shared Observations.
- (sev 2) When returning to the launcher window, there is an announcement with the text of "--- User Profiles ---" communicated together with the value of the "Choose Profile" combobox which overlaps some of the relevant information needed to indicate the current context to screen reader users. Here are some examples of results, when the editor dialog for a new profile is dismissed by pressing Escape:
    - NVDA users cannot determine the name of the focused element, the "New" button, and the window name ("OpenSpace Launcher").
    - Using JAWS, the window name is not announced in the speech output.
    - Suggested Solution: Create new windows or dialogs for distinct views, rather than dynamically updating controls in a single one.
- (sev 2) All buttons in the dialog are conveyed to screen reader users with the string "Enter" appended which results in overly verbose output, e.g. "Edit button Enter" with NVDA or "Edit button to activate press Spacebar, Enter" with JAWS. This hint is unnecessary, as users expect buttons to be actionable with Enter anyway.

    - Suggested Solution: It is believed that this text is being added by Qt. Exploration is required to determine if it can be removed in some way, e.g. by adding an empty string as the accessible description using Qt's setAccessibleDescription method, or alternatively to set the description to something more useful if an empty string is not an option.
- (sev 2) Error messages, e.g. "Profile name must be specified", have red text (#DD1111) which has an insufficient color contrast ratio of 4.4:1 with the gray background (#F0F0F0).
    - Suggested Solution: Use a darker red color, e.g. #D90D0D which has 4.6:1 color contrast with the gray background.
- (sev 2) The "Save" button updates its border from gray to blue whenever the "Profile Name" text field or the "Properties", "Assets" and "Keybindings" read-only form controls are reached. Keyboard-only users may incorrectly assess the location of the focus indicator when pressing Tab or Shift+Tab through the dialog.
    - Suggested Solution: Remove the border update styling when the "Save" button is not in its focused state. Ensure that a highly visible focus indicator is provided for all controls as previously suggested. See: Application Launcher.
- (sev 2) When the "Duplicate Profile" button is activated, focus remains on the control and the value of the "Profile Name" input is appended with an Underscore character and the digit 1 ("_1"), e.g. "default_1". Screen reader users encounter complete silence and cannot determine the results of their action unless they navigate back to the field.
    - Suggested Solution: Send keyboard focus to the "Profile Name" field when the "Duplicate Profile" button is activated so that screen reader users are informed of the updated value.
- (sev 2) The "Profile Editor" dialog is overloaded with options and does not allow users to directly edit any of the profile details other than its name. The "Properties", "Assets" and "Keybindings" read-only form controls stand out as main features while "Meta", "Mark Interesting Nodes", "Simulation Time Increments", "Camera", "Time", "Modules", and "Additional Scripts" are displayed to the side with their names and a corresponding "Edit" button. Keyboard-only users have to encounter all these controls tabbing through the dialog to reach the "Save" button.
    - Suggested Solution: Further review of the intended design for the "Profile Editor" is recommended to make the interface easier to use. For example, only the key features could be listed with the option to directly edit their settings, while the remaining profile details could be collapsed under an

"Advanced Settings" controls and revealed on user-initiated action. PAC can provide further guidance if needed.

OpenSpace

OpenSpace Developer Meeting

May 1-5, 2023 | American Museum of Natural History

Monday and Tuesday connection:
Zoom - direct link*
Meeting ID: 988 8578 8889
Dial-in: +1 929 205 6099 US New York
+1 253 215 8782 US Tacoma
+46 850 539 728 Sweden
*Let Megan know if you plan on joining.

Monday, May 1: OpenSpace Development Forum

Join Zoom — Times in EDT
Room: Davis West Classroom

9:30 am	**Breakfast**
10:00 - 10:15 am	**Welcome, introductions, and agenda (15 min)** *Facilitator: Ro*
10:15 - 11:15 am	**Reviewing 2023 Software Features (60 min)** *Facilitator: Alex, Micah* Descriptions of what happened since version 0.18: Overall software development, features/assets that were developed by us and other scientific institutions, and highlighting new features. With a lookback at what we had planned and what we achieved.
11:15 - 11:30 am	**Vision for 1.0 December 2025 (15 min)** *Facilitator: Alex, Vivian* Mantras discussed last year and NASA grant deliverables.
11:30 - 1:00 pm	**Developer Presentations** ● **Community Hub (30 min)** ● **Accessibility (30 min)** ● **Improved Testing (30 min)**
1:00 - 2:00 pm	**Lunch Break (60 min)**
2:15 - 3:45 pm	**Developer Presentations cont'd** ● **Usability / Documentation (30 min)** ● **Domecasting (30 min)**

- **Dynamic Models at CCMC (30 min)**

4:00 - 5:00 pm **OpenSpace Children and Family Learning Dome Program**
Hayden Planetarium
AMNH Child and Family Learning (CFL) educators will fly graduating fifth graders through OpenSpace.

5:30 - 7:00 pm **Dome Time**
Facilitator: Micah

7:30 - 10:30 pm **Dinner at Bustan**
487 Amsterdam Ave, New York, NY 10024

Tuesday, May 2: OpenSpace Development Forum

Join Zoom — Times in EDT
Room: Davis East Classroom

9:30 am **Breakfast**

10:00 - 11:30 am **NASA & OpenSpace**
Facilitator: Ro
How do we strengthen our visibility and perceived value to NASA?
- Proposal deliverables
- Serving Mission Priorities for Education and Public Outreach
- Broadening participation

11:30 - 12:00 pm **WebRTC**
Facilitator: Alex

12:00 - 1:00 pm **Student Projects (60 min)**
Facilitator: Alex, Emma
Current and future of Master's student projects. How to improve how projects are chosen, conducted, and integrated. → opportunities for NYU grad students.
Internships
- Other internships (e.g. AMNH REU)

1:00 - 1:30 pm **Invisible Worlds Visit**

1:30 - 2:30 pm **Lunch Break (60 min)**

2:30 - 3:15 pm **Quarto Demonstration**

Facilitator: Claudio

3:15 - 3:45 pm **Show & Tell (30 min)**
Facilitator: Micah
Sharing of some of the best uses of OpenSpace by our users, along with a collection of images and video from projects/presentations in the last year. Everyone is encouraged to bring their own favorite image/video/link and/or add them to these slides.

5:00pm **OpenSpace in Big Bang**

Slack thread for discussions:
https://team-openspace.slack.com/archives/CBLM14A87/p1676451109267609

Wednesday, May 3: Developer Day
Room: Perkins

Thursday, May 4: Developer Day
Room: Perkins

Friday, May 5: Developer Day
Room: Perkins

OpenSpace

Annual ISI Partner Meeting
July 24-25, 2023
American Museum of Natural History

Monday, July 24
Join Zoom — Times in EDT
Room: Davis West Classroom

11:00-11:15 am	**I. Introductions** (15 min)* *Facilitator: Megan*
11:15-12:00 pm	**II. SciAct Grant 2.0 Progress** (45 min)* *Facilitators: Ro & Vivian*
12:00-1:00 pm	**Lunch**
1:00-2:00 pm	**III. Release Updates and Goals** (1 hour)* *Facilitators: Micah & Alex* ● Recap version 0.19.0 and look ahead for version 0.20.0 and OpenSpace Cloud
2:00-3:00 pm	**IV. ISI Partner Share Outs** (1 hour; 20 min per partner)* ● Adler, Cal Academy (annotated presentation here), DMNS ● 10 min presentation plus ten min discussion for each partner
3:00-3:15 pm	**Break**
3:15-4:15 pm	**IV. ISI Partner Share Outs Continued** (1 hour; 20 min per partner)* ● HMNS, NCMNS, AMNH
4:15-4:45 pm	**V. Non-Funded Partner Activity** (30 min)* *Facilitators: Megan & Micah*
5:00-5:30 pm	**VI. Big Bang** (30 min) ● NCMNS and AMNH to present in fish-eye
5:30-7:00 pm	**VII. Dome Show** (1.5 hours) ● Adler, HMNS, Cal Academy, DMNS to present on dome ● Version 0.19.0 highlights
7:30 pm	**Dinner** *Han Dynasty - 215 West 85th Street*

Tuesday, July 25

Join Zoom — Times in EDT

Room: Davis West Classroom

9:30-10:00 am	**I. Breakfast** (30 min)
10:00-11:00 am	**II. Evaluation Findings** (1 hour)* *Facilitators: Kate & Madeleine*
11:00-11:30 am	**III. Revisiting Mantras** (30 min)*
11:30-11:45 am	**Break**
11:45-12:45 pm	**IV. Advancing OpenSpace Adoption** (1 hour)* *Facilitators: Ro & Megan*
12:45-1:30 pm	**V. New Funding Opportunities** (45 min)* *Facilitators: Ro & Vivian*
1:30-1:45 pm	**VI. Wrap up discussion** (15 min)* *Facilitator: Ro*
1:45-2:00 pm	**Group Picture** *Wear your OpenSpace shirt!*
2:00-3:00 pm	**Lunch** *Restaurant at Gilder*
3:00 pm	**V. Gilder Center Tour** ● 3:00 pm Butterfly Vivarium ● 3:45 pm Invisible Worlds ● 4:30 pm Worlds Beyond Earth Planetarium Show

*Session available on Zoom: https://amnh.zoom.us/j/97785562218
Meeting ID: 977 8556 2218
Dial-in: +1 929 205 6099 US (New York)
+1 312 626 6799 US (Chicago)
+1 346 248 7799 US (Houston)
+1 669 900 6833 US (San Jose)

See Meeting Notes