

NASA EXPLORER INSTITUTES' FOCUS GROUP - FINAL REPORT

SEEING THE UNIVERSE

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American Museum of Natural History, New York, NY

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The vast quantity of high-quality space science data acquired by NASA's missions and scientists is providing revolutionary new understandings of our Earth and sky. At the same time, advances in computational power allow us to depict current astronomical discoveries with unprecedented fidelity, providing audiences with an opportunity to experience the universe as never before. **SEEING THE UNIVERSE** brought together visualization providers, users, commercial vendors, and NASA scientists and mission personnel to identify the next steps in coordinating efforts to bring superior visual experiences to NASA's audiences. Informal science education venues represented ranged from living room television sets and pages on the World Wide Web to fully immersive, real-time visualization theatres. Planetaria, screens, and kiosks in museums and science centers, educational multi-media, IMAX, television, news media, the Web, games, and feature films have all made use of visual representations of NASA data in an effort to share space exploration with general audiences. Beyond informal science education, NASA visualizations have been an important and effective communication tool for formal education, the news media, congressional briefings, and other important NASA audiences. **SEEING THE UNIVERSE** assessed the present state of scientific visualization of NASA data and identified strategies for the future that maximize the quality and efficiency of visualization production and dissemination.

A full list of participants and materials resulting from **SEEING THE UNIVERSE** can be found at <http://haydenplanetarium.org/workshop>.

Most significant best practice: The team approach that combines scientists, artists, animators, programmers, and end users from the informal education community has led to the most successful, high-quality visualizations.

Most significant lesson learned: Tremendous opportunities exist to expand the reach and power of NASA data visualization by organizing the community to assess and develop appropriate strategies for advancement; we can make a big difference with a few simple next steps.

Most significant accomplishment: The astronomy and space science visualization community has not met before on this scale. Our most significant accomplishment was the development of a true community identity with a commitment to working together to advance astronomy visualization for all audiences.

Most significant unanticipated outcome: All those involved in scientific visualization comprise a distinct community, apart from other scientific or informal education communities, with common goals and unique needs.

* will attend the NEI Planning and Evaluation Meeting, March 15-18, 2005

II. Summary and Recommendations

The visualization of scientific information is a powerful tool in communicating NASA's accomplishments and discoveries to a wide range of audiences. NASA should **establish an organized, coherent program across NASA to coordinate and support scientific visualization that serves the full range of NASA's audiences and needs.** A coordinated program would enhance and streamline NASA's educational and outreach activities while leveraging valuable resources to provide the greatest reach to NASA's audiences. Such a program can (1) establish, disseminate, and implement standards and best practices related to scientific accuracy, educational efficacy, technical excellence, and production values and aesthetics; (2) insure the equitable availability of data and other NASA resources to the community; (3) foster communication within NASA on how to access emerging visualization capabilities across the country; (4) build alliances between NASA and informal science education organizations; (5) provide for professional development and training of informal science education professionals, visualizers, and others engaged in the delivery of visualized information to the public; (6) develop and disseminate standards in evaluation; (7) promote research into visualization and learning; and (8) help set priorities for the creation of visualizations that best serve the community's and NASA's needs. Such a program would require new models of partnership between government, academic, and private sector, but would enhance NASA's ability to communicate in a potent new medium.

Scientific visualization includes a wide range of products, from simple, aesthetically pleasing images (such as the Hubble Heritage program or other widely viewed images like the M16 "Eagle" Nebula) to fully interactive, 3-D, and/or time-evolved data or numerical model animations for fully immersive, domed theatres (such as the Orion Nebula fly-through sequence in the AMNH planetarium show *Passport to the Universe* or the galaxy evolution sequence in *The Search for Life*). Visualizations also include diagrams and animations of concepts, independent of specific data, which aid in understanding astronomical objects and processes. Visualizations are those applications of NASA's data for which the primary goal is not to extract quantitative information — the goal of scientific research — but to enhance the understanding of and provide an immediate connection to the universe around us through visual means. Because of their accessibility, visualizations can reach a broader audience than is typical of much scientific research; indeed, for many Americans, visualizations provide a primary experience of NASA's science and achievements.

Participants in SEEING THE UNIVERSE represented all professions involved in bringing superior visualizations to the public, including mission personnel, scientists, visualization producers, vendors, program producers, and a wide range of informal science education professionals from museums, science centers, planetaria, television, and other informal science education venues. Out of this mix emerged a new community: the visualization community. Indeed, perhaps the single greatest achievement of the workshop was the interdisciplinary conversation that identified common goals and needs, and the discovery that great advances can be made in increasing the quality and quantity of visualizations by coordinating our efforts and improving communication.

For the remainder of the report the term "visualization community" refers to the interdisciplinary group of people and institutions representing all roles required in developing and disseminating visualizations, i.e., the group who participated in the workshop and their peers and colleagues elsewhere who were unable to attend. **Overall, our primary recommendation is that the communication and work initiated at the workshop needs to continue and expand.** Future task forces, workshops, and working groups are needed to assess the overall state of the field and chart a course for future work that will lead to a greater flow and increased exposure of high-quality visualizations that are of the greatest educational and inspirational value.

Specific recommendations from the workshop include the following:

- 1. Visualization of NASA's data, simulations, and other relevant assets should be made a priority throughout NASA.** Each mission and program can benefit from the power of visual language to communicate its activities and achievements to wide audiences. A review of all missions (current and future, and including those housed outside NASA Centers) should be conducted to assess what visualization is currently being done or planned, and what opportunities exist to enhance current activities. As appropriate, a small amount of mission time should be given to creating imagery optimized for public enrichment (rather than scientific analysis), such as the Hubble 15th anniversary image. Visual assets from prior missions should be archived and made available in formats compatible with present display and storage technologies, ensuring the preservation of "legacy visualizations" such as the

Apollo landings or the Voyager missions. Visualizations have the power to inspire and inform, and studies show that visualization dramatically enhances learning. NASA data and other imagery should not just be for scientists, but for all citizens; visualization should not be an occasional by-product of scientific research but should be planned for on its own merit.

2. Enormous leverage can be gained by multi-purposing visualizations to serve a wide range of audiences.

The user community is wide and varied within informal education and extends beyond that to formal education and public affairs. While they have much in common, each community also has unique needs, practices, and infrastructures. NASA's emphasis should be placed on providing assets, building blocks, tools, access, and capabilities that empower the visualization community to support a range of needs rather than one-off products for specific audiences. A strategy should be developed and implemented for re-purposing visualizations and visualization elements for different user groups (e.g., full-dome, high definition video, 3-D stereoscopic, on-line interactives, and many more) that is built into the visualization production process from the start.

3. Content is king – context is key. Continue and expand efforts to provide interpretation of data and scientific results through alliances between scientists, informal science educators and NASA. A visualization by itself has value, but its value is enhanced immeasurably when it is used as a tool to tell a broader story. Interpretive materials related to the concept, mission, or discovery at the heart of a visualization are required to give it meaning, and they should be developed and provided along with the visualizations. Partnerships between scientists, mission personnel, visualizers and informal science education professionals are essential and must be fostered to insure accuracy and to reap the greatest educational value from the effort put into a visualization. Educational materials, scientific content, professional development, access to scientists, and other support should be planned for and provided to informal science educators. JPL's Mars/Museum Visualization Alliance (facilitated by Anita Sohus) is an excellent model and should be supported and expanded to other missions and programs throughout the agency.

4. Continue and expand efforts to facilitate special events such as space mission landings, launches, and other major milestones. Mission milestones comprise an important subset of NASA's activities that provide an excellent opportunity to educate the public due to increased public attention and media coverage. In anticipation of major events, spacecraft models, trajectories, and other visualization components should be made available to the visualization community. Educational materials, scientific content, professional development, access to scientists, and other support should be planned for and provided to informal science educators. Again, JPL's Mars/Museum Visualization Alliance is an excellent model.

5. The current E/PO process can be improved. Linking science goals and E/PO plans *during the mission proposal process* may not lead to the best possible education and outreach program. Missions should be selected on the basis of their science, and institutions with strong research capabilities are not necessarily best suited to educational endeavors. Visualization producers must gamble on which mission will succeed, and some of the best visualization capabilities may go unused if they are attached to missions that aren't selected. Mission E/PO programs should be encouraged to partner with established visualization teams, and to budget adequate funding for high-quality work. Similarly, the small (\$10K - \$20K) E/PO grants that are competed broadly are not large enough to undertake high-quality visualization projects. NASA should articulate a high-level list of educational products, resources, and visualizations needed for each mission and program and compete those separately from the mission teams, while ensuring linkages to the scientists and mission planners. Finally, significant confusion remains within the visualization community over the broker/facilitator role.

6. Enhance communication about currently available products. Tremendous leverage of existing resources can be gained by facilitating the search for and retrieval of what already exists. NASA should support the creation of a database, registry, or other directory of visualizations that pulls together existing high-quality work and helps users find what they need. The directory should be user-friendly (some existing databases are very hard to navigate), include meta-tagging appropriate to users' searches (e.g., audience, pedagogical goal, etc.), build on and link to (i.e. supplement but not supplant) directories that already exist, adapt/migrate with changing technology and other standards, and contain visualizations of sufficient scientific content and visual quality in as many formats as possible for a wide variety of uses. It should also include directions to historical footage and imagery (e.g., Apollo footage, Voyager images, etc.). The adopted strategy should be in concert with the work of the Virtual Repository Program Group under the IAU Working Group Communicating Astronomy with the Public. A one-stop shop would

be invaluable to visualization users who currently must search several sites (centers, missions, and even separate instruments on missions) or be “in the know” about whom to contact to find what they need.

7. Identify and fund an individual at each NASA center whose job it is to interface with the visualization community. This simple first step can lead to tremendous gains in efficiency in the short term by providing a one-stop first contact for visualization producers and users. Visualizers tend to need lower-level information such as spacecraft models, trajectories, and raw data that is generally not well provided by a standard public affairs office. This person must be a technical person (rather than an educator, E/PO program officer, or PAO officer, which NASA already provides) who understands the specialized needs of the visualization community and can quickly identify and acquire assets at the Center. Ideally, this individual would have enough authority within the organization to insure visualization-related requests are acted upon in a relevant and timely manner.

8. Support the advancement of future capabilities through technology and software development. The revolution in technology over the past decade has created unprecedented opportunities for learning. This trend can continue to push the envelope in what NASA has to offer the public. Research and development into improved visualization tools and cutting edge technologies that permit interactivity, networking, and real-time experiences (among others) should be supported.

9. Evaluate and publish such evaluation of visualizations. The evaluation community has the tools to determine whether or not the ultimate outcome – improved understanding and appreciation of science in general and NASA’s activities in particular – is being achieved. Evaluation should be conducted, on a small scale at first to develop appropriate tools and mechanisms, and evaluation results should be published and incorporated into best practices and standards for visualization production and use.

10. Create and provide data for visualizations that do not fall under government or mission restrictions. For many spacecraft, the computer design models are restricted by the International Traffic in Arms Regulations (ITAR) for security reasons. For visualization work, less detailed models that would not be subject to ITAR restrictions would be sufficient, but such models are rarely made available. In a similar vein, missions that provide scientists with extended or unlimited proprietary access to data inhibit the use of such data in visualizations. As visualization use of data does not threaten or compromise potential scientific findings (indeed, one would argue that visualization acts as advertising for the mission/scientist), NASA should encourage sharing of data for visualization, while retaining proprietary restrictions on its use for scientific publication.

11. Give visualizers credit for their work. Visualizers find NASA's policy of not providing credits is not only disappointing but also financially burdensome to the growth of their business. Since visualization production is a small field of small businesses, exposure can be critical to the survival of these companies. NASA may want to develop a policy towards credits that helps foster the growth of this emerging field, without, of course, appearing overly commercial.

12. Recognize and support existing infrastructures. Informal science education venues, and planetaria in particular, which *each year* reach close to 100,000,000 people world-wide (roughly 30,000,000 in the United States alone) provide ready access to the audiences NASA seeks to serve. NASA’s efforts can be leveraged by establishing alliances with professional organizations such as IPS, regional planetarium associations, SIGGRAPH, ASTC, and others.

13. Support the development of the fledgling visualization community. Although all of the professionals who participated in the workshop have communities and professional societies to which they belong, no single entity serves the need of this diverse, interdisciplinary group. Participants expressed enthusiasm over developing this nascent visualization community further, holding future meetings and perhaps establishing a society dedicated to the visualization of scientific data. A list-serve has already been established — initially to facilitate communication between workshop participants — that will be opened up to the broader visualization community after the focus group work is completed. NASA should support these community-building activities, as appropriate to its budget and goals.

14. Establish a Visualization Working Group at NASA to advise and coordinate the next steps in the development of the visualization capability. An advisory and/or coordinating committee made up of NASA and

non-NASA personnel can help steer future activities and opportunities for the visualization community, streamline efforts, and coordinate activities with NASA's goals and plans. It can both help get the word out to the visualization community about NASA's activities and resources, and to help NASA understand the needs and priorities of the community outside NASA. A Visualization Working Group can also assist in supporting the organizational efforts undertaken by the emerging visualization community (as described in Recommendation 11 above), though it does not replace their independent activities.

15. Keep in mind the big picture. In an era of digital data and its representation, other means of visually communicating NASA's science to intended audiences should not be overlooked. Traditional analog planetarium projectors, dioramas, as well as paintings and other artwork — and even data representation for the visually impaired — hold an important place in touching informal science education audiences. In addition, informal science learning takes place in a wide range of venues that may not traditionally have been considered within the realm of NASA's activities, such as in National Park Visitor Centers, and other popular locations. Innovative strategies to reach new audiences should be explored. Finally, astronomical research and space science is conducted by other agencies and organizations in the public and private sectors; strategies should be identified which make linkages outside of the NASA organization. Beyond missions, beyond NASA, and even beyond astronomy, visualization is a powerful tool can break new ground in learning and experiencing the universe around us as never before. NASA's leadership can pave the way for new learning experiences in a wide range of endeavors that will have a lasting impact.

16. Promote the ethic throughout NASA that visualization is more than “pretty pictures.” Many participants expressed frustration over the lack of support, follow-through, communication and priority given to their requests in support of visualization production and programmatic use. A common perception was that educational visualization activities were deemed superfluous, or in some cases, even frivolous. We argue that the broad public reach of scientific visualizations and the power of their ability to communicate play an essential role in NASA's overall mission. Science is one goal but not the only goal: we believe a mission is not complete until it has been shared with the public. Through policy and leadership, NASA management can promote the importance of visualization for education and other communications needs. Visualizers are willing and able to help the science community and NASA, but we can not do it alone.

1. Results from the NEI Focus Group

Needs of the informal education and visualization communities and design solutions/best practices that can be used to address them

All members of the visualization community need:

- Improved communication
 - Community communication tools like list-servs, the continuation of meetings like this one, etc.
 - Means to “publish” results and lessons learned from visualization projects
 - Training in vocabulary and practices of other disciplines involved in visualization
- Access to NASA assets
 - Help in navigating through NASA
 - Directory/registry/database of available visual assets
 - One-stop “shopping” for the entire visualization community
- Evaluation of the effectiveness of visualization programs and products
 - Partnerships with evaluators and educational researchers to conduct evaluations
 - Publication and other dissemination of evaluation results
 - Specific studies on interactivity; real-time experiences; visualization and cognition/learning
- Continued community building and sharing of experiences/information
 - Continue meetings, workshops, and other community building activities
 - Work closely with NASA through representation in Visualization Working Group
- Continued growth in visualization production and display technologies
- Standards and best practices in formats, technologies, production standards

In addition, Informal Science Educators and Vendors need:

- Superior visualizations in a wide variety of formats
 - Multi-purpose existing and new visualizations
 - Adapt/migrate formats and other standards as technology evolves
 - Don’t forget small “classic” planetaria
- Scientific accuracy, context, and interpretation
 - Include scientists and content specialists in multi-disciplinary production teams
 - Professional development on content
- Pieces and building blocks, not just finished products
 - Informal educators know their audiences best and can customize content for their needs
 - Educational “tool kits”
 - Small venues often do not have the internal resources to customize and can form partnerships with other providers to meet their needs
- Resources that are affordable
- Visualizations that support basic concepts as well as missions or discoveries

In addition, Vendors need:

- Superior visualizations in specific, compatible formats
- Insight into the newest, most interesting new discoveries
- Clear guidelines on use policies for private sector and public domain

Visualizers need:

- Credit for their work
- A point of contact at each NASA center (or in each mission) with technical proficiency to respond to their needs
- Unrestricted data for visualization
- Visualization software tools

Scientists and mission personnel need:

- To inform the education community of their activities and data
- To understand the education communities needs better
- Help in visualizing their data
 - Continued community building, meetings, opportunities for collaboration
- Visualization software tools
 - Cross-fertilization of software tools between visualization, scientific communities
- Recognition, even reward (not scorn!) for engaging in visualization, education
 - Visualizations “count” as a publication
- Comprehensive and intelligent data tagging

Relevant NASA assets and effective mechanisms to access/leverage the resources;

Leveraging NASA’s assets requires coordination within NASA (across multiple missions, centers, and programs; and across Education, Public Affairs, Science, and other offices) as well as coordination between NASA and informal science education outlets. The emerging visualization community provides the needed linkages and coordination and should be supported.

asset: data

leveraging/access strategy:

search and retrieval

simple search capability across missions, centers, NASA (one-stop shop)

format standards

uniform metadata

software tools

standards should adapt/migrate with changing technology

identify technical personnel responsible at each center to interface with visualization community

remove or find workarounds for restrictions (e.g., ITAR, proprietary rights)

that which has already been done / available needs to be communicated

asset: in-house (internal to NASA) visualizations

leveraging/access strategy:

registry/directory/database to find visualizations that have already been created

re-purpose as needed to address wide variety of formats, productions practices

provide components/pieces, not complete productions (to customize to different venues, audiences)

asset: missions in space

leveraging/access strategy:

mission achievements and activities should be visualized to share with wide audiences

acquire data, as appropriate, optimized for visualization (e.g., Hubble 15th anniversary)

highlight and support informal education community in celebrating events

(i.e., landings, milestones, discoveries) to draw public, media attention

asset: scientific, technical expertise

leveraging/access strategy:

share content knowledge through workshops, professional development

technology, software development support

asset: public funding for informal education

leveraging/access strategy:

complete visualization projects independent of mission science

establish and enforce standards of excellence for selection criteria

develop programs and share resources across other areas of NASA

includes formal education, PAO, missions and science

Partnership with private sector; cost sharing

asset: “meatball,” that is, its reputation

leveraging/access strategy:

NASA’s panache draws audience

NASA’s “stamp of approval” draws other funders, resources

Mechanisms to engage the informal education community with NASA science and technology staff and resources:

The visualization community *is* a link between NASA and the informal education community; through its activities provides the desired mechanisms to connect NASA science and technology to informal education audiences. Supporting the development of the visualization community achieves multiple linkages, and creates an environment for new partnerships, projects, and alliances to be born, thrive, and grow.

Each of the communities involved in delivering astronomical visualization to the public have their own professional societies and communications infrastructures such as meetings, list-servs, web sites and so on. Organizations such as ASTC, AMA, IPS, regional planetarium associations, NSTA, SIGGRAPH, AAS, ASP, AGU, AAAS all have programs and partnerships of their own which should be identified, evaluated and linked to, as appropriate. Members of the visualization community should participate in meetings of these organizations to disseminate information about visualization activities and seek input and collaboration.

All members of the visualization community are members of one or more of the organizations listed above, but no single organization addresses the needs and interests of the visualization community. Further development of the nascent visualization community, who act as a link to engage the informal education community to NASA, should be supported.

For the most part, NASA should not put too much effort or public funding into individual partnerships with specific informal education venues or projects, but instead should support the overall infrastructure and needs of the visualization community to maximize the achievement of NASA’s visualization goals. Individual groups within NASA should certainly compete for resources to do individual projects or programs, much as a scientist at STScI competes for Hubble Telescope time. NASA’s resources should be directed to activities unique to its capacity as a federal agency acting in the public trust.

Instructional materials needed that reflect NASA research and scientific activities and meet the needs of the informal education community:

The need is not so great for fully-produced instructional materials so much as for data, information, and access for visualizers and the educator user community to develop their own customized instructional materials appropriate for the audiences they serve.

Instructional materials associated with professional development (PowerPoint presentations, dedicated servers providing high-definition or high-resolution data and images, etc.) are highly desired.

Recommendations that will help NASA broaden the diversity of organizations that that it might partner with in the future:

Taken on its own, the visualization of data is not specific to any one audience. Promoting and strengthening visualization activities supports diversity because the visual language is immediate and effective for all audiences, is relatively free of cultural or other biases and interpretive roadblocks, and can be employed in a wide range of products and venues that serve a wide range of audiences. The essential key is to ensure equitable access to visualizations for diverse informal education (and other) outlets that touch broad and diverse audiences.

Planetaria reach diverse audiences. Nearly 30 million Americans visit planetaria *each year*. Located in all corners of the country, planetaria understand and serve the needs of local and regional audiences and they often have educational partnerships with school districts and institutions of higher learning in their communities. Inflatable domes can go anywhere, for example, reaching even the poorest communities. Supporting the planetarium community, particularly in efforts to serve local and underserved audiences, can broaden NASA's reach.

Venues other than planetaria (or full-dome visualization theatres) also have a wide and unbiased reach. Television is a pervasive medium and can reach nearly every audience. The special needs of the television production community should be evaluated and incorporated into NASA's planning.

Working with the informal education community, NASA can examine the roadblocks to reaching underserved communities. An up-front investment to build capacity (e.g., to support hardware investment, technical consulting, and professional development addressing content and production excellence) can help build an audience and establish a presence in the community that can provide a means that enable self-sustainability. For example, what would one inflatable dome per school district/county do for astronomy and science education? How might such a program be undertaken? What are other strategies that can serve communities in need of assistance?

Partnerships based on new models between federal, state, and local government, the private sector, and private donors need to be explored. The limited funds available through the public sector should leverage broader activities rather than be used on individual partnerships with isolated, though diverse, communities.

Partnerships with new venues (such as libraries, national park visitor centers, and even commercial sites like shopping malls and amusement parks) should be explored.

Professional development opportunities that should be provided to members of the informal education community at NASA facilities:

Each community involved in the production and dissemination of astronomical visualizations can benefit from professional development and training, including, but not limited to:

- Content training (in science, engineering, and missions) associated with the release of visualization pieces, perhaps in topical or mission-related workshops. The Mars Visualization Alliance at JPL or the University of Chicago workshops provide excellent models that should be supported and expanded.
- Training for the informal education community on the technical aspects of the data and their visualization, formats, players and projectors, and other related technologies.
- Training for scientists, missions, and visualizers related to audience, story-telling, and educational needs
- Training for visualizers on best practices in production ("Production 101").
- Evaluation training for all involved in the visualization community.

Training needs to stay practical to inform and improve communication, process and product among all those involved in visualization. Given the diverse professions involved in visualization production and dissemination, care should be taken to tailor professional development activities to enhancing efforts across different groups, not teach them another profession from the ground up ("we go to a restaurant to eat a good meal, not to become master chefs," according to one workshop participant).

University campuses, museums, and other non-NASA facilities are important sites for content dissemination and training and should be considered in the planning.

Other non-NASA facility related professional development:

Digital, interactive planetaria provide new opportunities for formal education (which makes up an important audience for informal education venues) to inspire and educate students. Teachers and planetarium professionals should partner to develop and disseminate curricula appropriate to the needs of the formal education community. Workshops training other teachers on how to use new planetarium curricula should be supported. Planetaria might

also work with local teachers' colleges and education schools to develop a course to train pre-service teachers on the curricula as well.

The profession is in need of a journal or other means for publication of *practical* informal education practices, evaluation results, audience studies, research, curricula, and other valuable information. Many excellent programs and products are developed and evaluated around the country to meet NASA's educational goals, but the information is not well disseminated. While NASA is not a publishing house, it can support the launch of such a journal. Given the nature of the field, such a journal should have an on-line component. An intermediate step might be to publish a newsletter with links to sites distributed around the country rather than establish a journal web site.

Evaluation strategies and mechanisms that could be used to measure the effectiveness of the NEI Program

Evaluation of the effectiveness of astronomical visualizations in informal education programs and products:

The subject of evaluation stimulated lively debate in the NEI focus group workshop. Issues under consideration included:

- Should NASA follow NSF's model and require evaluation?
- Can the various communities involved in visualization production and dissemination agree on goals and metrics for evaluation?
- How can we evaluate outcomes that may not become evident for years after the experience?
- How can we evaluate more elusive outcomes related to aesthetics and inspiration?

It was agreed that there should be better understanding of the tools and goals of evaluation for all involved in producing and disseminating visualizations. Professional development, review articles or talks, or other means to help bridge the gap of understanding are needed. Experts in education research and evaluation point out that there are decades of experience in evaluating related educational products (if not visualization of digital data, specifically) and the profession has the tools to address the challenges that were raised. It was also observed, however, that educational evaluation has its own specialized vocabulary and practices that make it difficult for non-professionals to comprehend.

Evaluations should be made available to the community as a learning tool. Several instances were reported of evaluations that were done but then withheld by the funding agency. Agency goals, public relations, and politics should not prevent evaluation outcomes from feeding back into the community.

A commitment to evaluation should not be so strict that it inhibits the power of the individual artists' vision. This is true for both visual artists and performance artists: one of the most powerful tools for learning is through the inspired instruction of an excellent teacher. Positive outcomes should not be identified solely by what can be agreed upon "by committee" but should be in balance with an approach that allows for artistry and individuality.

Strategies for next steps might include:

- Select three specific projects to evaluate then disseminate/publish the results from these case studies to illustrate evaluation "done right."
- Start capturing lessons learned from past experiences. Even anecdotal information at this point can be very informative about what works and what does not.
- Conduct and disseminate a literature review. Educational evaluations that are published are usually found in journals that are unfamiliar to most members of the visualization community and a guide to "evaluation for dummies" would be helpful.

Evaluation of products and programs should also consider what might *not* be best communicated through the language of visualization.

Evaluation of the NEI SEEING THE UNIVERSE Focus Group Workshop

Evaluation of the focus group workshop itself was also carried out. The report from the evaluator can be found at <http://haydenplanetarium.org/workshop/survey>. In general, the feedback on the conference was very positive. The key result was that participants felt the workshop provided a valuable opportunity to bring together this community and would like to do another three-day gathering in a year. In summary, it was agreed that a coordinated community of this sort will broaden NASA's reach significantly with less effort and duplication.

2. SEEING THE UNIVERSE and the Goals of the NEI Program

Improving the public's understanding and appreciation of Science, Technology, Engineering and Mathematics (STEM) disciplines to enhance their scientific and technological literacy, mathematical competence, problem-solving skills, and desire to learn:

Visualization has been shown to be a powerful language in communicating the results and excitement of NASA's enterprise to a wide range of audiences. A visual representation of an object, concept, or idea provides an important cognitive pathway to learning and understanding. Studies show increased student performance in the continued use of visualizations to teach a particular concept. The sheer beauty of an aesthetic visualization inspires, attracting people to the field and drawing a larger audience into awareness of the world and the universe around them. The entire educational enterprise devoted to STEM education, including literacy, skills, and desire to learn, is lifted by visualization, and even more so if a visualization is done right. The results from the SEEING THE UNIVERSE focus group workshop will help to enhance the quality and facilitate the delivery of the best possible visual experiences to accompany and enhance the understanding and appreciation of STEM disciplines. A coordinated effort to promote excellence in visualization can take STEM education in the United States to a whole new level.

Establishing linkages that promote new relationships between providers of formal and informal education resulting in improved and creative STEM education in all learning environments:

SEEING THE UNIVERSE was proposed as a workshop between the scientists, visualizers, and vendors who produce and disseminate visualization and the informal science education community who reach our audiences. The universality of the visualization approach allows for significant repurposing of such visual media in formal-education materials and settings. Furthermore, most informal science institutions, such as museums and planetaria, have extensive programming for formal education audiences so the potential for linkages is great. Future meetings that specifically address the connections to formal education should be held.

Exciting youth, particularly those who are underrepresented and underserved, about STEM disciplines;

Expanding STEM informal education programs and activities to communities/locations that have been traditionally underserved by such opportunities:

Can there be any doubt that superior visualization of data – virtual reality rides to space, interactive computer programs that employ engagement strategies from the gaming world, well-designed multimedia educational resources that facilitate their inquiry-based learning – can excite youth?

Underserved groups are often the same as those who are under-represented. Further, underserved groups are often economically or culturally separate from previous "mainstream" audiences. SEEING THE UNIVERSE has helped to develop and strengthen the visualization community, which in turn supports diversity and equity because well-crafted visual language is immediate and effective for all audiences, is relatively free of cultural or other biases and interpretive roadblocks, and can be employed in a spectrum of products and venues that serve a wide range of audiences.

In addition, the informal education user community that employs visualizations in their products and programs have a broad and diverse reach. Museums and planetaria can be found throughout the country specializing in providing material appropriate to the local audiences they serve. Empowering them results in a greater service to the broader community.

Stimulating parents and others to support their children’s learning endeavors in formal and informal settings and to become informed proponents for high-quality, universally available STEM education in the home and elsewhere:

The informal education outlets that employ NASA data visualization are primarily those that serve family audiences: museums, planetaria, television programs, and so on. The higher the quality of the visualization products, the more successful those outlets are at engaging families and encouraging them to spend their precious quality family time experiencing a NASA adventure. In turn, greater parental involvement in their children’s STEM education may be stimulated by a positive family experience in an informal education setting.

Encouraging and implementing innovative strategies that support the development of a socially responsible and informed public who can make responsible decisions about STEM policy issues affecting their everyday lives.

The enhanced quality and availability of compelling informal education programming is a powerful pathway to enlightening the public. Criteria for evaluation can include metrics that steer products and programs to include content that makes linkages to STEM policy and the issues affecting their everyday lives.

3. Where Do We Go from Here?

We have just begun to organize! Perhaps the greatest discovery at the workshop was how much we had in common and how strong was the desire to put processes in place that enable the visualization community to provide quality visual experiences of NASA science to the public. The conversations were all too short, but indicated that much more could be done to streamline and coordinate our activities and that some simple next steps could reap great benefits. One three-day meeting showed us the enormous potential in coordinating the community, but it was just a start.

Short and long term objectives for the program

Short term

- Finish the web site for the workshop (<http://haydenplanetarium.org/workshop>) according to the original plan. Although the outline for the workshop report to NASA (i.e. this report) was changed in response to the format requested by NASA, the original plan and the associated website contains numerous resources such as the original source materials, break-out reports, summary chapters, a list of participants and their bios, and other materials relevant to the SEEING THE UNIVERSE workshop. That work should be completed and made available to the visualization community at large.
- With only about an hour on the agenda for each break-out discussion, several break-out groups were only able to provide a start and set direction to accomplishing the task at hand. Small groups should be convened to further the work on several topics, including:
 - Visualization and informal science education: literature review and rationale.
 - Educational “tool kits” desired by informal education professionals to permit customization to their own institutions and audiences.
 - A straw-man priority-ranked list of desired visualizations based on current drivers and capabilities for science visualization.
 - A summary of best practices and standards to date and evaluation criteria and recommendations,
 - Professional development and training within and between communities,
 - New technologies and capabilities on the horizon.
- Make the presence of the visualization community and its efforts known at meetings of the numerous professional societies to which they belong. Be sure that all our professional society meetings hold appropriate sessions (such as the “Gadgets and Gizmos” sessions at the AAS, and others) where visualization experiences can be

shared with the broader community. Because many visualization experiences require specialized equipment or venues, NASA can assist this activity with support and coordination.

- Establish a Visualization Working Group at NASA-HQ that can provide coordination between the visualization community and NASA. The Working Group's on-going activities will be to address and revise as appropriate recommendations related to the topics in this section (e.g., establishing and maintaining the coordination, collaboration, and partnerships between NASA and the visualization community, identifying and addressing roadblocks and barriers, developing follow-up goals and strategies, etc.).

Long term

- Establish a fully coordinated program for visualization of NASA science of the sort described in the recommendations section of this report. A coordinated program would reach across different areas of NASA (i.e. Formal and Informal Education, Public Affairs, Legislative Affairs; Science, Exploration, missions and programs) and enhance and streamline NASA's educational and outreach activities while leveraging valuable resources to provide the greatest reach to NASA's audiences. In its first year, the Visualization Working Group can help develop a plan for this ambitious undertaking, serve as advocates within and outside NASA, and help bring new partners and organizational models to the way in which NASA does business with the visualization community.

Facilitating coordination and establishing and sustaining collaborations, partnerships, and other relationships among various communities including NASA

Rather than develop individual partnerships for specific projects or products, NASA should foster an environment for the *on-going* development of collaborations and partnerships by helping to establish the visualization community as a link between NASA science and the informal education community.

Other immediate steps that can be taken to facilitate coordination and promote sustained relationships include:

- Review and revise E/PO policies and practices to insure maximal use of the visualization capability available (Recommendation 3).
- Create a database, registry, or other directory of visualizations that are available (Recommendation 4)
- Identify and fund an individual at each NASA center whose job is to interface with the visualization community (Recommendation 5).
- Preferentially provide resources to those programs and projects that employ a team approach that includes participation from all the disciplines involved in ensuring high-quality products (scientists, visualizers, educators and other end users, etc.).
- Support another meeting, one year from now, of the visualization community convened for this workshop, to assess the progress being made and support the development of new collaborative relationships.

Identifying roadblocks/barriers

As part of its routine work, the recommended Visualization Working Group would naturally lead to the identification of barriers that impede progress to the goal of providing more high-quality visualizations to our audiences, as well as address recommendations to overcome them.

Current roadblocks that were identified at the workshop included:

- Restrictive policies on the access to and use of NASA data
- Inadequate communication about existing resources and activities
- Difficulty navigating the complex maze of NASA centers, programs, missions, etc.
- Difficulty getting appropriate technical and other assistance from NASA centers, missions, etc.
- Ineffective distribution of E/PO resources to maximize visualization capability
- Lack of access to NASA scientists and other content specialists
- Barriers to for-profit entities for partnering in grants and contracts

These (and other) roadblocks were considered during workshop deliberations; recommendations for improvement are provided elsewhere.

Evaluating program impact – short and long term

Evaluations of existing visualization projects should be gathered and disseminated so that lessons learned and best practices can be established. More specific recommendations regarding visualization *project* evaluation can be found elsewhere in the report.

It is too early to determine the *program* impact as a coordinated visualization program is not yet underway. Establishing means for evaluating the program impact should also be an activity of the Visualization Working Group.

Developing follow-up strategies

Together, the establishment of a Visualization Working Group, facilitation of its work, and a follow-up workshop one year from now will help insure that progress has been made. Many participants expressed the desire to move beyond the study phase and into concrete actions that help facilitate the growth and improvements of visualization activities. The highly motivated group of attendees made it clear that they are willing to offer any assistance required or requested by NASA to help bring these changes about, and that they will communicate openly with NASA their appreciation (or disappointment) over the progress (or lack of progress) being made.

Identify required resources to support all aspects of the program

Public funding from the Informal Education office at NASA is limited and should be focused on coordination and communication activities. Funding from other areas within NASA should be sought as appropriate in a coordinated effort across the agency. The envisioned program is broad enough that it can serve the goals of other federal agencies beyond NASA. Resources should be sought from those sources (such as the NSF, NOAA, Department of Education, Department of Energy, etc.). In addition, museums and planetaria play an important role in their local communities; state and local funds should be sought where appropriate.

In order to provide the substantial flow of high-quality visualizations envisioned by the workshop participants, new sources of funding will need to be identified. A more detailed analysis is required, but a quick look at the “customer base” for visualizations suggests that there are opportunities to tap into resources through effective public/private partnerships. Television, video, film, textbooks, amusement park rides, and other for-profit venues can be potential sources of cost-sharing if effort is put into marketing NASA’s visual resources and capabilities. New policies and practices will need to be considered to work with private entities in areas such as proprietary ownership, credit, value-added work, profit, and production schedules and timing, to name a few.

Establishing realistic expectations

What is realistic? The workshop participants agree that there is tremendous potential in scientific visualization that is currently un-tapped. As a new endeavor, we can and must evaluate the overall balance between resources, capability, and priorities to determine what realistically can be achieved. There is a great deal to be done, but there is time to do it and a talented, committed community of professionals ready to work hard to achieve these goals. But a coordinated effort has not yet been undertaken and limits to what can be achieved have not yet been established.

Developing a wish list (blue sky)

During the break-out session on developing a rank-ordered list of priority visualizations, one participant said in all seriousness that he wanted a fully interactive and time resolved visual representation of all the objects and evolutionary processes from the creation of the Cosmic Microwave Background Radiation to modern-day galaxies and their stars and clusters; in other words, a completely virtual universe. While this is a massive undertaking, it serves as a goal of what can be done and what should be done — eventually. Even if it takes a decade or more, the capability to let all Americans — not just the lucky few who become astronauts — explore space (even if through virtual means) is within reach. NASA has set and attained decade-long goals before and has led the world in

dreaming big dreams and pushing back the horizon on what is possible to broaden the place of humans in the universe.

As we move forward in the coming months, we will be able to determine whether the current list of recommendations is already “blue sky” from NASA’s perspectives, or whether we will be able to move at a more aggressive pace at developing the visualization capability described in this report. Again, the Visualization Working Group can help set attainable goals while keeping the loftiest goals in sight.



Agenda for the NASA Explorer Institute (NEI) Focus Group on Science Visualization and Informal Science Education

American Museum of Natural History, February 2–4, 2005

Wednesday, February 2

- 9:00 Welcome; Review of workshop goals (Danly, Koke)
9:20 Setting the stage: What is Viz? (Wyatt, Danly)
9:45 Introduction of first 8 participants (participant self-introduction)
10:00 Review of literature: Visualization in Informal Education (Connolly; ch. 1)
10:15 Case Studies from the Community / Lessons Learned — Part One
10:45 Instructions to by-community (i.e., “birds-of-feather” or “BOF”) breakouts
11:00 Coffee and “BOF” breakouts (to draft ch. 2)
 scientists, mission managers
 visualization producers
 vendors
 users – museums/planetaria
 users – other
 other
- 12:15 Lunch (continuing “BOF” discussion as needed)
- 1:15 Introduction of next 8 participants
1:30 Reports from break-out groups and discussion (including a report from Jim Sweitzer on the GLPA NEI focus group and Judy Koke on Four Corners NEI focus group)
2:45 Case Studies from the Community / Lessons Learned — Part Two
3:45 Coffee Break
4:00 Introduction of next 8 participants
4:15 Uses of visualizations in programs
- Dinner (participants on their own)
- 7:30 3D – Dessert and Demos in the Dome

Thursday, February 3

- 9:00 Introduction of next 8 participants
9:15 Presentation and Discussion: Where is science visualization heading? (Emmart; includes report from Chabot focus group by Barnett)
10:30 Break-out groups
 opportunities and challenges for domed environments (ch 7)
 opportunities and challenges for non-theatre users (ch 8)
 professional development and training (ch 10)
12:00 Lunch

1:00 Space Show or demos
1:45 Introduction of next 8 participants
2:00 Report of morning break-outs and discussion
2:15 Break-outs
 priority-ranked list of visualizations (ch. 4)
 educational “tool kits” (ch. 3)
 guidelines for evaluating visualizations (ch. 6)
4:00 Introduction of next 8 participants
4:15 Report of afternoon break-outs and discussion

Dinner (participants on their own)

Friday, February 4

- 9:00 Introductions of remaining participants
9:15 Review of “roadblocks/concerns” list (ch. 9)
 Review of “best practices” (ch. 5)
11:00 strategies for facilitating coordination among communities and providing for sustainability (ch. 11, 13)

12:00 Lunch

1:00 Presentation from morning work; discussion; summary of next steps (ch. 12)
3:00 Adjourn

**Draft Outline of the Report to NASA by the NASA Explorer Institute (NEI)
focus group on Science Visualization and Informal Science Education**

Chapters include:

- Chapter 1. Visualization and informal science education: rationale
- Chapter 2. A summary of the current state of the field, including a description of the resources, capabilities, needs, and limitations of each community identified in Figure 1 and lessons learned from previous activities;
- Chapter 3. A description of the educational “tool kits” desired by informal education professionals to permit customization to their own institutions and audiences;
- Chapter 4. A straw-man priority-ranked list of desired visualizations based on an evaluation of the current drivers and capabilities for science visualization;
- Chapter 5. A summary of best practices and standards to date and areas where work must be done;
- Chapter 6. Recommendations for evaluating science visualizations in informal science education settings;
- Chapter 7. A summary of the opportunities and challenges unique to fully immersive (i.e., domed) environments;
- Chapter 8. A summary of the opportunities and challenges unique to venues *excluding* theatres;
- Chapter 9. A summary of current roadblocks or other issues of concern;
- Chapter 10. Recommendations for providing for training and professional development within and between communities;
- Chapter 11. Suggested strategies for facilitating coordination among various communities, including NASA;
- Chapter 12. A summary of next steps, both near-term and long-term;
- Chapter 13. Recommendations for sustainability
- Chapter 14. List of Participants