ALMA for Everyone

The North American ALMA Science Center
Education & Public Outreach Strategic Plan

October 15, 2010

The National Radio Astronomy Observatory is a facility of the National Science Foundation
operated under cooperative agreement by Associated Universities, Inc.

Table of Contents

NAASC EDUCATION & PUBLIC OUTREACH STRATEGIC PLAN

I. Foreword

The NRAO is the most capable radio astronomy organization in the world, the primary U.S. national observatory for this astrophysically-important wavelength regime, and a premier resource for innovations in radio astronomy. It has provided state-of-the-art radio telescope facilities for the scientific community for over 50 years, transforming our understanding of the universe and enabling scientific discovery. These facilities offer capabilities that are unique in the radio regime but complementary to those of optical, infrared, and X-ray telescopes, so that astronomers can attain a comprehensive view of complex cosmic processes. One of its newest facilities is the Atacama Large Millimeter/submillimeter Array (ALMA).

The Atacama Large Millimeter/submillimeter Array (ALMA) is one of the major new observatories most eagerly anticipated by professional astronomers this decade. ALMA is a joint collaboration between Europe, North America, East Asia and the Republic of Chile to build the largest astronomical project in existence. NRAO is the North American partner and participates in ALMA operations and development through the North American ALMA Science Center (NAASC).

ALMA's fundamental purpose is to satisfy scientific curiosity about how nature works on the grandest scales of space and time. It will equip professional astronomers to probe previously inaccessible realms of astronomical discovery space, tackling unsolved problems and attacking stubborn mysteries.

But ALMA is not only for the sliver of the populace who are professional astronomers. Curiosity about the universe, and about the great causal chain that leads back to our origins, is shared by millions of people; indeed, the entire astrophysical enterprise is but an elaboration upon a theme that even preschoolers grasp: *Twinkle, twinkle, little star. How I wonder what you are.*

It is thus appropriate that the NAASC conduct an education and public outreach (EPO) program, enabling the United States' component[1] of the international ALMA project to achieve the broader impacts mandated by the National Science Foundation (NSF).

II. NAASC Education & Public Outreach (EPO) Mission

Consistent with the NRAO EPO mission and the NRAO Strategic Plan, the NAASC's EPO mission is to engage the American public, including students, in the adventure and fruits of ALMA astronomy, the wonder of the natural phenomena that ALMA reveals, and the role that mm/submm astronomy plays in the larger multi-wavelength context.

[1]The North American ALMA Science Center represents the contributions of both the United States and Canada to ALMA operations. However, by agreement Canadian funds cannot be used to fund NAASC EPO activities. Therefore the formal intent of the NAASC's EPO program is to benefit residents of the United States. Naturally, our Canadian neighbors, and others as well, will have access to many of the resources developed under NAASC EPO, particularly those that are posted on-line.

III. NAASC EPO Vision

The NAASC's EPO vision is to serve as a dependable, authoritative source of engaging, accurate, informative, and educational resources about ALMA for the science-interested American public and students; to lead efforts nationwide to promote public awareness of ALMA's science results (including their broader meanings) and amazing technologies; to reach and inspire diverse people groups in so doing; to promote STEM (science, technology, engineering, and math) learning and careers among students; and to contribute to the sustaining of public support for continued American participation in the ALMA project.

IV. NAASC EPO Guiding Principles

Know and respect its audiences. Millions of people are interested in science, by which they mostly mean the *results* of science (that is, an understanding of natural phenomena and their contexts). Most do not aspire to be scientists, any more than most restaurant patrons aspire to be chefs, and so they mostly do not seek to acquire the specialist's vocabulary and deep knowledge of technique; nor do they benefit from being burdened with such things. But they do often enjoy opportunities to relate to human adventure, even in the context of a story about the struggle to overcome technical challenges or resolve scientific mysteries. They enjoy pondering the vastness and beauty of universe, and learning about extremes of scale, energy, and instrumental precision. The intensity of their interests lies on a continuum from casual (image gallery browsers) to intense and sustained (Facebook fans), with far greater numbers on the casual end of the spectrum[2]. They have a variety of learning styles, ranging from media watchers and readers to discussion group participants and simulation role-players; such preferences are broadly correlated with age. They have other interests, and thus appreciate economy of expression that demonstrates respect for the value of their time. Yet they will often attend to a sustained argument or explanation if it is presented entertainingly, with evidence of some passion, and with an effort to express ideas in common language. Many potential members of the NAASC's audience have never heard of ALMA, so they must be actively cultivated.

Prioritize activities in principled ways that maintain excellence. In the event that funding does not enable activities to be undertaken with excellence in support of all aspects of the EPO Vision, choices will be made about which aspects of the EPO Vision will be implemented and which deferred or pursued via avenues of additional funding. This idea is akin to an aspect of the development of ALMA itself, in which not all receiver bands could be afforded in the initial construction phase, but those that were built are of highest quality.

Broadly, the NAASC's EPO activities can be described as fitting into one of two categories: *News & Public Information* and *K-12 Education*[3]. The former entails activities that inform the

[2] Although relatively small in number, the NRAO/NAASC's social media audience can have a disproportionately large positive impact when they respond to something "cool" and alert *their* networks in viral/chain-reaction fashion.

[3] At the NAASC, and elsewhere within the NRAO, "education" activities undertaken beneath the EPO banner are principally K-12. The observatory's Office of Science and Academic Affairs oversees educational programs for students in college and beyond; those activities are outside the scope of this document.

science-interested public about ALMA and its results (and which are of course, by nature, inherently *educational*), while the latter typically entails activities conducted in support of STEM education in formal learning environments. In the event that available EPO funding in ALMA's early years of operation is insufficient to support excellence in both areas, *News & Public Information* should take precedence over *K-12 Education*, because, while hundreds of billions of public dollars are already expended annually in support of K-12 education, the NAASC alone bears responsibility for providing the American public with a share of the fruits of its investment in ALMA. As ALMA matures, the apportionment of EPO resources should be periodically re-evaluated.

Additional, carefully considered arguments in favor of this approach are provided in Appendix C.

Maintain a grasp of ALMA's major science and technology themes, potentials, and results. The preponderance of NAASC staff members are scientists, with NRAO engineers and technicians also contributing to ALMA operations. Those people constitute the NAASC's principal repository of scientific and technical knowledge about ALMA, and are available "just down the hall" for consulting with their EPO colleagues. Because their time is valuable, it is best used in helping the EPO staff refine details and explain new findings, not in continually re-introducing the EPO staff to basic concepts. Therefore, the EPO team will take steps to maintain a descriptive-level understanding of "ALMA basics."

Employ a core EPO team having expertise in the essential crafts of contemporary science communication and education. In today's world of fast-paced, highly visual communication, how a message is conveyed, and how effectively it is disseminated, is easily as important as the significance of the information it contains. The NAASC EPO team will include (subject to funding) professionally trained specialists in science education, curriculum tool development, science writing, scientific illustration, animation, visualization, video production, astronomical image processing and meta-tagging, and press/public relations. The team will be equipped with the necessary tools and trained in their use.

Equip K-12 STEM educators with tools they can use. There are roughly 50 million students enrolled in grades 1-12 in the United States. In fiscal year 2010 federal, state, and local governments spent some $634 billion on K-12 education, with untold millions more spent by private- and home-schooling families. Obviously, any impact to which the NAASC may aspire in this realm must be carefully targeted to have noticeable impact. A promising approach is to create targeted curriculum support materials that help teachers teach more easily, entertainingly, and effectively those subjects that they have to teach anyway.

Millimeter/submillimeter astronomy itself is not typically among those subjects, nor is astronomy as a whole in most schools. But students do have to learn about the dual wave/particle nature of light, about forces such as gravity and magnetism, about colors and spectra, about estimation and order-of-magnitude, and about the graphical representation and meaning of data. ALMA is a gold mine for exciting ways to present such ideas to students interactively, and then they'll learn about ALMA too along the way. Having significant impact via ALMA-themed curriculum support tools entails development of the activities themselves,

creation of teacher support materials, training workshops for teachers, and extensive promotion of the activities for adoption by school districts. The NAASC will need to partner with organizations having the means to carry out such campaigns if it is to be a player. Local schools in Charlottesville could serve partially as development and test partners.

Be appropriately entertaining. Entertainment is not the opposite of education. Entertainment is hospitality. We acknowledge, welcome, and make comfortable each guest. This is conducive to effective communication.

Pursue efficient, leveraged methods to achieve meaningful, large-scale impacts. To have a quantitatively significant impact, the NAASC simply must, in cost-effective ways, leverage networks and audiences developed by others. Such opportunities are readily available on the national scale in the form of established news dissemination networks (television, traditional print press, web-based news aggregators, specialty sites, etc.), established cultural enrichment networks (ViewSpace[4], museums, planetariums, libraries, large-format cinema theaters, documentary television networks, etc.), established and growing social discussion and media networks (Facebook, Twitter, Youtube, podcast distributors, etc.), established curriculum support tool and informal learning tool networks (Amazing Space, Family ASTRO, Hands-On-Universe, Astronomy from the Ground Up, GEMS, etc.), and established instructional supplement networks (Night Sky Network, Project Astro, Solar System Ambassadors, etc.). A number of these networks were developed via NASA funding, and so it will require a diplomatic approach to secure access. The NSF's Office of Legislative and Public Affairs (OLPA) has also developed a portfolio of science communication networks, which will welcome ALMA content.

The NAASC's EPO partners at the European Southern Observatory (ESO), National Astronomical Observatory of Japan (NAOJ), and the EPO office of the Joint ALMA Observatory (JAO), can also represent opportunities for EPO resource leveraging.

Seek nationwide impacts that avoid geographic favoritism. ALMA is in Chile. The NAASC is in Charlottesville. Taxpayers in Boise are paying for both, and there are students in Akron curious about astronomy. In an approach that reflects the spirit of the NSF's "Open Skies" policy, by which astronomers everywhere enjoy equal opportunities to compete for access to NSF telescopes, the NAASC's EPO effort will endeavor to serve equitably its entire national constituency, favoring outreach projects and programs that are accessible from anywhere (or from many places) in the country to those that require the beneficiary to be present at some particular geographic location. It should be no more necessary to visit or live in Charlottesville or Chile to benefit from ALMA than it is to visit Baltimore or low earth orbit to enjoy the results from Hubble.

Anticipate unanticipated opportunities for impact. Experience has shown repeatedly that success in EPO is predicated on a combination of preparation for likelihoods and adaptability to the unexpected. Much of the EPO group's practical work is driven not by its own

[4] As an example of the leveraging that's possible by connecting to established astronomy EPO networks, a description of the ViewSpace program is given in Appendix B.

planning, but by rational response to unforeseen opportunities that simply arise as a consequence of what others are doing. All EPO "plans" must thus be amenable to flexible adjustment to take advantage of opportunities for impact as they arise.

Foster success of the international ALMA EPO effort. ALMA is an international effort among the scientific communities of North America, East Asia, and Europe in cooperation with Chile. The cost savings that each community enjoys (versus building the entire array by itself) are a result of cost-sharing, not of efficiency.

By international agreement, the regional executives (NRAO, NAOJ, and ESO[5]) are responsible for their own EPO programs and are not obligated in any way with respect to one another; ALMA's "founders" wisely recognized that EPO is an area profoundly susceptible to subjective cultural and political influences in which rational argument cannot necessarily drive consensus the way it can among scientists and engineers in the objective domain.

Despite the intentional, and internationally agreed-upon, independence of the executive EPO groups, the EPO leads have met (initially at NRAO's suggestion) semi-formally as the International ALMA EPO Working Group (WG) to discuss areas of common interest and to explore ways in which they might *voluntarily* cooperate to mutual benefit. This collaboration continues in what the JAO calls the ALMA EPO Integrated Product Team (IPT). The NAASC is an active member of this WG/IPT and will persevere to foster mutual trust and collaboration where possible among the partners, even amidst cultural and competitive forces that can sometimes mitigate against unity.

Assess impact. The NAASC will assess the effectiveness and impact of its activities by collecting data about the reach and appeal of its communication products and services. For educational activities, appropriate evaluation techniques will be employed. These techniques are described in Appendix A.

V. NAASC EPO Organization

Education and Public Outreach is an important activity for the NRAO. The EPO organization therefore reports through the Director's Office on all EPO activity for the Observatory. The NAASC's EPO group is a subset of the NRAO's EPO office. The NAASC's EPO staff is headquartered in Charlottesville to be close to the NAASC and have access to the NAASC scientists and NRAO ALMA engineering and technical staff.

VI. NAASC EPO Strategic Goals

Serve as a dependable, authoritative source of engaging, accurate, informative, and educational resources about ALMA for the science-interested American public and students.

- Build, equip and train the NAASC EPO team.
- Create vibrant, appealing, inspiring, educational, accurate materials that communicate vital and interesting information about ALMA, its science promise, its results, the

[5] There is also an ALMA EPO effort in Chile, comprised of EPO staff from the JAO, ESO, and NRAO.

context of its results, and the fundamental physics that underlie the observed phenomena in space. Various materials will be appropriate for reception by various target audiences (including students).

Lead efforts nationwide to promote public awareness of ALMA's science results (including their broader meanings) and amazing technologies.

- Pursue and implement effective nationwide promotion, amplification, and dissemination processes and networks to increase the reach and impact of NAASC communication and education materials

Reach and inspire diverse people groups.

- Make special efforts to reach out to audiences traditionally underserved by NRAO outreach programs
- Depict diversity within the practice of ALMA-related science and engineering

Promote STEM (science, technology, engineering, and math) learning and careers among students.

- Create and shepherd-to-adoption by schools educational curriculum support materials that infuse ALMA- and STEM learning into school curricula
- Create opportunities for students to meet and interact with NAASC scientists and ALMA engineers in real and virtual social settings; inspire such students with a positive vision of a life dedicated to a STEM profession, and offer opportunities for further engagement

Contribute to the sustaining of public support for continued American participation in the ALMA project.

- Generate positive publicity in US media about ALMA triumphs, and help American public understand the vital contributions of US science and engineering to the success of the international ALMA project
- Support ALMA outreach in Chile. As possible, contribute to the success of collaborations among the EPO representatives from the ALMA Executives and the JAO

VII. NAASC EPO Strategic Initiatives

Build, equip, and train the NAASC EPO team.

- Hire key staff members (see Appendix D for a description of the complete NAASC EPO skill set

- Equip and train the team in skills such as HD video production, ViewSpace production (see Appendix B), photography, astronomical visualization, live multicamera webcast production, interactive multimedia "web feature" programming, 2D & 3D animation, graphic design and manipulation, press release writing, audio/podcast production, media asset archiving & meta-tagging, and astronomical public release image production and meta-tagging

Create vibrant, appealing, inspiring, educational, accurate materials that communicate vital and interesting information about ALMA, its science promise, its results, the context of its results, and the fundamental physics that underlie the observed phenomena in space.

- Cultivate story leads, develop press release and media text, and define comprehensive media packages, press/public events, and public/press awareness campaigns

- Create photo-realistic "artist impressions" of astronomical phenomena associated with ALMA observations, and for drawings and diagrams that explain the working of phenomena and technology

- Create scientific and technical 3D visualizations and animations associated with stories about key ALMA science discoveries and techniques

- Implement and maintain overall design of the NRAO/NAASC public web site

- Carry out graphic design of web and other media elements, exhibition panels, and 2D motion graphics production

- Shoot, edit, produce, and render video products for the web, exhibition, and broadcast.

Pursue and implement effective nationwide promotion, amplification, and dissemination processes and networks to increase the reach and impact of NAASC communication and education materials.

- Establish targeted email lists for educators, writers, and other interested parties

- Through effective programming, grow the NRAO/NAASC social network audience

- Collaborate with the NSF's Office of Legislative and Public Affairs (OLPA) and AST divisions to publicize science results and promote educational and informational opportunities

- Catalyze production and nationwide broadcast of an HD documentary about ALMA Construction and Science Promise

- Handle image, footage, and interview requests from outside documentary producers

- Tie-in to established science news dissemination networks

- Tie-in to established cultural enrichment networks
- Tie-in to established social discussion and media networks
- Tie-in to established formal and informal education and educator networks
- Work with ALMA partners on effective cross-promotion of activities and resources developed by the partners
- Seek opportunities for commercial sponsorships and promotions

Make special efforts to reach out to audiences traditionally underserved by NRAO outreach programs.

- Solicit advice for appropriate communications vehicles from organizations of minority scientists and engineers
- Conduct special programs to offer underserved students and families exposure to and experience in the world of ALMA science and engineering

Depict diversity within the practice of ALMA-related science and engineering.

- Feature minority and women staff members in EPO communication products and role modeling events

Create and shepherd-to-adoption by schools tested/evaluated educational curriculum support materials that infuse ALMA- and STEM learning into school curricula.

- Pursue funding sponsorship for creation of educational role-playing simulations
- Pursue partnerships with established curriculum developers having established networks. Develop and propagate STEM-educational activities, laboratory experiences, teacher resource guides, and workshops for students and teachers
- Seek opportunities to update STEM textbooks with ALMA-themed information

Create opportunities for students to meet and interact with NAASC scientists and ALMA engineers in real and virtual social settings; inspire such students with a positive vision of a life dedicated to a STEM profession, and offer opportunities for further engagement.

- Develop and pilot-test a middle school "meet the NAASC" program within Charlottesville

Generate positive publicity in US media about ALMA triumphs, and help American public understand the vital contributions of US science and engineering to the success of the international ALMA project.

- Create new ALMA content for a new NRAO/NAASC Public Website – With the NASSC site for the science community now unambiguously established as http://science.nrao.edu/alma/index.shtml, the NAASC can move forward with redesign of its home in the http://www.nrao.edu domain, as part of a larger redesign of that site that will be tailoring it specifically as a place for the public to come and enjoy the ALMA experience. Full links to partner and JAO websites will be available.

- Stage media events, and workshops for the US press and documentary media

- Create and disseminate professional media resources, such as stock footage, illustrations, and background information

Support ALMA outreach in Chile. As possible, contribute to the success of collaborations among the EPO representatives from the ALMA Executives and the JAO.

- Collaborate on joint outreach projects with the JAO and other ALMA executives.
- Provide materials for the JAO website.
- Support JAO and executives by publicizing their ALMA outreach offerings to NRAO audiences via NRAO social networks.
- Elevate Chilean public awareness of US contributions to ALMA via interactions with Chilean press and educational system.

Appendix A. Assessment of NAASC EPO Educational Programs/Products

For curriculum support tool development projects, a multi-phase process of evaluation will be used. During the Formative Evaluation phase, local teachers will be consulted to discuss the usefulness of the proposed tool, and alignment of the proposed tool to applicable national teaching standards, such as the National Academies' *National Science Education Standards*, the AAAS' Project 2061 *Benchmarks for Science Literacy*, and the National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* will be carried out. Also during the Formative Evaluation phase, the science accuracy of the proposed activity will be certified through consultation with subject matter experts, and the appropriateness of the vocabulary employed in the tool and its associate teacher support materials will be assessed. The services of an external educational consultant/evaluator having *specific experience related to the grade level and/or subject matter of the development project* may be utilized – and will be when NAASC education staff lack the requisite experience. Such consultants/evaluators may be drawn from academia (for example, the University of Virginia's Curry School of Education or the University of Wyoming's Cognition in Astronomy, Physics, and Earth Sciences Research Team), from private science curriculum development organizations (for example, TERC or McREL), or from the ranks of private consultants/evaluators with prior experience in curriculum or standards development.

Following the Formative Evaluation phase, the first iteration of the curriculum support tool will be subjected to Field Testing (and subsequent revision) with teachers in a variety of educational settings, both public and private. The goal of this phase will be to polish the product into something ready for dissemination.

During the final phase, Summative Evaluation, a report will be created that summarizes lessons learned and best practices from the development experience, that describes the effectiveness of the tool as appraised by teachers in the Field Test phase, and that communicates early usage statistics and comments from early adopters.

For informal education development projects (such as museum exhibits or planetarium shows) of significant scope, a multi-phase process of evaluation will be used that is similar to the one described above for curriculum support tool. During the Formative Evaluation phase, surveys will be conducted of typical audiences (e.g., museum visitors at the Science Museum of Virginia) to assess public awareness and knowledge of, interest in, and misconceptions associated with the proposed topic. In addition, informal education practitioners (e.g., museum exhibit department heads or planetarium directors) will be surveyed to assess their interest in hosting the proposed exhibition or program. Surveys will be designed and conducted by an external evaluator having considerable experience in evaluation of informal education projects; typically active membership in the Visitor Studies Association will be a requirement.

The evaluator will bring the results of the Formative Evaluation to the development of the prototypes for the Field Testing phase. During this phase, prototype "samples" of the entire experience will be tested before typical audiences, with the evaluator gathering via survey and focus group discussions information on the effectiveness of the prototypes, data which will feed into improvements and fine-tuning. Meanwhile, the entire development team will evaluate the

entire proposed exhibition or program via the framework for assessing exhibition excellence from a visitor-experience point of view developed by Serrell and Associates via an NSF Small Grant for Exploratory Research (SGER).[6]

During the final phase, Summative Evaluation, the evaluator will create a report that summarizes lessons learned and best practices from the development experience, that describes the quality of the exhibition or program per the Serrell framework, and that tabulates comments received from hosting institutions.

[6] Serrell, Beverly, *Judging Exhibitions: A Framework for Assessing Excellence,* Left Coast Press, 2006.

Appendix B. ViewSpace: An Example of Leveraged EPO Impact

Over the past decade the Space Telescope Science Institute (STScI) has built up an enormous network of over 220 science museums, planetariums, observatory visitor centers, nature centers, libraries, NASA visitor centers, colleges, universities, and other venues frequented by the public. Collectively these places draw some 10+ million science-attuned visitors annually. Each site is equipped with a high-resolution display screen in its exhibit area or in a mini-theater, and each receives continuously-refreshed (typically multiple times daily) multimedia display content about astronomy and (NASA) earth science. The program is described here: http://hubblesource.stsci.edu/exhibits/self-update/viewspace/.

The growing ViewSpace network represents hundreds of thousands of dollars in private-sector investment (subscribers pay for their display hardware), and millions of dollars in cumulative expenditures by STScI, which maintains a staff of 5-6 FTE for this program alone.

The NAASC could never aspire to create something comparable, but has made an agreement with STScI for providing ALMA-related content, which will then play across the network. (Of course, it takes time and effort to create the content, but it takes roughly the ***same amount of time to create material for a high-leverage use like this as it does to create material for a much lower-leverage use***.)

This is just one example of how "plugging in" to an appropriate network can greatly amplify an otherwise weak signal. A list of ViewSpace venues as of October, 2010, sorted by state (with international venues listed at the end), is shown below. It reads as a veritable "who's who" of astronomy outreach venues.

Imaginarium, Anchorage AK
US Space and Rocket Center, Huntsville AL
Samford University Planetarium, Birmingham AL
Lowell Observatory Visitor Center, Flagstaff AZ
Arizona Science Center, Phoenix AZ
Challenger Space Center, Peoria AZ
National Optical Astronomy Observatories, Kitt Peak AZ
National Optical Astronomy Observatories HQ, Tucson AZ
Chabot Space and Science Center, Oakland CA
Explorit Science Center, Davis CA
Palomar Observatory, Palomar Mountain CA
Reuben H. Fleet Science Center, San Diego CA
Columbia Memorial Space Science Learning Center, Downey CA
California Academy of Sciences, San Francisco CA
Los Angeles Valley College Planetarium, Valley Glen CA
Lawrence Hall of Science, Berkley CA
Lick Observatory, Mt. Hamilton CA
Bakersfield Community College Planetarium, Bakersfield CA
California State University-Sacramento, Sacramento CA
Museum of Science & Natural History, Fresno CA
Castle Science and Technology/Challenger Center, Atwater CA
West Valley College, Saratoga CA
NASA Ames Exploration Center, Moffett Field CA
The Tech Museum of Innovation, San Jose CA
Sonoma State University, Rohnert Park CA
Radio Astronomy Laboratory, Berkley CA
Kolligan Library, Atwater CA
DeAnza College Planetarium, Cupertino CA
Denver Museum of Nature & Science, Denver CO
The Children's Museum, West Hartford CT
Yale Peabody Museum of Natural History, New Haven CT
Connecticut Science Center, Hartford CT
Discovery Museum and Planetarium, Bridgeport CT
Smithsonian National Air and Space Museum, Washington DC
AURA HQ, Washington DC
Astronaut Hall of Fame, Kennedy Space Center FL
Orlando Science Center, Orlando FL
Museum of Science and Industry, Tampa FL
Brevard Community College Planetarium, Cocoa FL
Hallstrom Planetarium, Fort Pierce FL
Fernbank Science Center, Atlanta GA
Georgia Southern University Planetarium, Statesboro GA
Coca-Cola Space Science Center, Columbus GA
Elachee Nature Science Center, Gainesville GA
Fernbank Museum of Natural History, Atlanta GA
Mark Smith Planetarium, Macon GA
Bishop Museum, Honolulu HI
Imiloa Astronomy Center of Hawaii, Hilo HI
Putnam Museum of Natural History and Science, Davenport, IA
Science Center of Iowa, Des Moines IA
Effigy Mounds National Monument, Harpers Ferry IA
Eastern Iowa Observatory & Learning Center, Cedar Rapids IA
Discovery Center of Idaho, Boise ID
Faulkner Planetarium, Twin Falls ID
Adler Planetarium, Chicago IL
Decatur Astronomy Club, Cerro Gordo IL
Lakeview Museum of Arts & Science, Peoria IL
Waubonsie Valley High School Planetarium, Aurora IL
Schouweiler Planetarium, University of St. Francis, Fort Wayne IN
Merrillville Community Planetarium, Merrillville IN

Ball State University Planetarium, Muncie IN
Carmel High School Planetarium, Carmel IN
Neils Science Center, Valparaiso University, Valparaiso IN
Exploration Place, Wichita KS
Kansas Cosmosphere and Space Center, Hutchinson KS
Gheens Science Hall & Rauch Planetarium, Louisville KY
Louisville Science Center, Louisville KY
Space Science Center, Morehead KY
Irene W. Pennington Planetarium, Baton Rouge LA
SciPort Discovery Center, Shreveport LA
Charles Hayden Planetarium, Boston MA
Springfield Science Museum, Springfield MA
Ecotarium, Worcester MA
Deerfield Academy Planetarium, Deerfield MA
NASA Goddard Space Flight Center Visitor's Center, Greenbelt MD
Maryland Science Center, Baltimore MD
NASA Goddard Earth Observation System Project Office, Greenbelt MD
Space Telescope Science Institute, Baltimore MD
NASA Goddard Space Flight Center (traveling), Greenbelt MD
NASA Goddard Space Flight Center (traveling 2), Greenbelt MD
Hickory Environmental Education Center Planetarium, Accident MD
NASA HST/Control Center System (STOCC), Greenbelt MD
NASA Goddard Space Flight Center - Building 32,Greenbelt MD
Benjamin Banneker Historical Park & Museum, Oella MD
Maynard F. Jordan Planetarium, University of Maine, Orono ME
Longway Planetarium, Flint MI
Kingman Museum, Battle Creek MI
Alden B. Dow Museum of Science and Art, Midland MI
Dennos Museum Center, Traverse City MI
New Detroit Science Center, Detroit MI
Abrams Planetarium, East Lansing MI
Public Museum of Grand Rapids, Grand Rapids MI
Cranbrook Institute of Science, Bloomfield Hills MI
DeGraaf Nature Center, Holland MI
Pine River Nature Center, Marysville MI
Air Zoo, Portage MI
Impression 5 Science Center, Lansing MI
Sarett Nature Center, Benton Harbor MI
Ann Arbor Hands On Museum, Ann Arbor MI
Exhibit Museum of Natural History, Ann Arbor MI
St. Cloud State University Planetarium, St. Cloud MN
SMSU Planetarium, Marshall MN
St. Louis Science Center, St. Louis MO
Linda Hall Library, Kansas City MO
University of Missouri-Columbia, Columbia MO
Museum of the Rockies, Bozeman MT
North Carolina Museum of Natural Sciences, Raleigh NC
Ingram Planetarium, Sunset Beach NC
Cumberland Public Library & Information Center, Fayetteville NC
Catawba Science Center, Hickory NC
Elizabeth City State University Planetarium, Elizabeth City NC
Mueller Planetarium, University of Nebraska, Lincoln NE
Fontenelle Nature Association, Bellevue NE
McDonald Planetarium, Hastings Museum, Hastings NE
University Library, Omaha NE
Newfound Audubon Center, Hebron NH
See Science Center, Manchester NH
McAuliffe-Shepard Discovery Center, Concord NH
The Newark Museum Dreyfuss Planetarium, Newark NJ
Raritan Valley Community College Planetarium, Somerville NJ
Ocean County College Novins Planetarium, Toms River, NJ
New Mexico Museum of Natural History, Albuquerque NM
Museum of Space History, Alamogordo NM
Las Cruces Museum of Natural History, Las Cruces NM
The Bradbury Science Museum, Los Alamos Nat'l Lab., Los Alamos NM
NRAO Very Large Array Visitor Center, (outside of) Socorro NM
Robert H. Goddard Planetarium, Roswell NM
Fleischmann Planetarium, Reno NV
Space Science for Schools, Incline Village NV
New York Hall of Science, Corona NY
Buffalo Museum of Science, Buffalo NY
Milton J. Rubenstein Museum of Science and Technology, Syracuse NY
Waterman Conservation Center, Apalachin NY
Suits-Bueche Planetarium, Schenectady NY
Suffolk County Vanderbilt Museum & Planetarium, Centerport NY
Shafran Planetarium, Cleveland Museum of Natural History, Cleveland OH
COSI, Columbus OH
Cincinnati Museum Center, Cincinnati OH
Ward Beecher Planetarium, Youngstown OH
Trailside Nature Center, Cincinnati OH
Ritter Planetarium, Toledo OH
NASA-Glenn Research Center, Cleveland OH
Marietta College Physics Department, Marietta OH
Clark Planetarium, Portsmouth OH
The Imagination Station, Toledo OH
Martin Park Nature Center, Oklahoma City OK
Museum of the Great Plains, Lawton OK
Sun Valley Planetarium, Ashton PA
North Museum of Nature and Science, Lancaster PA
Franklin Institute Science Museum Philadelphia PA
Da Vinci Discovery Center, Allentown PA
Eastern University Observatory & Planetarium, St. Davids PA
Reading Public Museum Planetarium, Reading PA
East Stroudsburg University Observatory, East Stroudsburg PA
H.W. Ray Special Experience Room, Warminster PA
Villanova University Astronomy Department, Villanova PA
Carnegie Science Center Planetarium, Pittsburgh PA
Planetarium at The State Museum of Pennsylvania, Harrisburg PA
Eastern University Planetarium (2nd location), St. Davids PA
School of Science, The Behrend College, Erie PA
University of Rhode Island, Kingston RI
Sharpe Planetarium, Memphis TN
Adventure Science Center, Nashville TN
Anderson Planetarium, Jackson TN
Chattanooga-Hamilton County Bicentennial Library, Chattanooga TN
Vanderbilt Dyer Observatory, Nashville TN
Brazosport Nature Center and Planetarium, Clute TX
Gene Roddenberry Planetarium, El Paso TX
Lynx Exhibits, El Paso TX
Houston Museum of Natural Science, Houston TX
Space Center Houston, Houston TX
Fort Worth Museum of Science & History, Fort Worth TX
International Museum of Art & Science, McAllen TX
Texas A&M International University, Laredo TX
Angelo State University Planetarium, San Angelo TX
University of Texas at Arlington Planetarium, Arlington TX
McDonald Observatory Visitors Center, Fort Davis TX
Texas A&M-Commerce Planetarium, Commerce TX
Westcave Preserve, Round Mountain TX
Don Harrington Discovery Center, Amarillo TX
Mayborn Planetarium and Space Theater, Killeen TX
Museum of Texas Tech University Association, Lubbock TX
Clark Planetarium, Salt Lake City UT
Brigham Young University, Provo UT
Thomas Jefferson High School for Science & Technology, Alexandria, VA
Virginia Living Museum, Newport News VA
Science Museum of Virginia, Richmond VA
National Radio Astronomy Observatory HQ, Charlottesville VA
Science Museum of Western Virginia, Roanoke VA
James Madison University Planetarium, Harrisonburg VA

University of Virginia Brown Science & Engineering Library, Charlottesville VA
University of Virginia Leander McCormick Observatory, Charlottesville VA
Virginia Beach Public Schools Planetarium, Virginia Beach VA
Montshire Museum of Science, Norwich VT
Middlebury College, Middlebury VT
Pacific Science Center, Seattle WA
NRAO Green Bank Science Center, Green Bank WV
Barlow Planetarium, University of Wisconsin Fox Valley, Menasha WI
Charles Horwitz Planetarium, Waukesha WI
Great Lakes Aerospace Science & Education Center, Sheboygan WI
Benedum Planetarium, Oglebay Park, Wheeling WV
Casper Planetarium, Caspar WY
Australia Telescope National Facility, Marsfield, NSW, Australia
Sir Thomas Brisbane Planetarium, Toowong, QLD, Australia
Rio de Janeiro Planetarium, Rio de Janeiro, Brazil
Manitoba Museum, Winnipeg MB, Canada
Science East, Fredericton NB, Canada
TELUS World of Science Edmonton, Edmonton AB, Canada
H. R. Macmillan Space Center, Vancouver BC, Canada
Northern Lights Centre, Watson Lake YK, Canada
Telus World of Science Calgary, Calgary AB, Canada
Orion Planetarium, Rødding, Denmark
Steno Museum, Århus, Denmark
Planetarium Hamburg, Hamburg, Germany
Kerala State Science & Technology Museum, Trivandrum, India
Blackrock Castle Observatory, Blackrock, Ireland
Liceo Scientifico Lazzaro Spallanzani, Tivoli (Rome), Italy
PETROSAINS Discovery Centre, Kuala Lumpur, Malaysia
Planetario Luis Enrique Erro, Mexico City, Mexico
Auckland Observatory & Planetarium, Auckland, New Zealand
Ferrymeade Heritage Park, Christchurch, New Zealand
Science Alive!,Christchurch, New Zealand
Armagh Planetarium, Armagh, Northern Ireland
Taipei Astronomical Museum, Taipei, Taiwan
Singapore Science Centre, Singapore
Iziko Planetarium, Cape Town, South Africa
Museum of Science and Industry, Manchester, UK
South Downs Planetarium, Chichester, West Sussex, UK
Yorkshire Planetarium, Leeds, UK
Bishop's Stortford College, Hertfordshire, UK

Appendix C. Carefully Considered Arguments in Favor of Programmatic Priorities (that can evolve with time)

A fundamental decision, when faced with a modest EPO staffing level, is whether to focus efforts on *News & Public Information*, or *Education*, or both.

The NAASC believes that, assuming funding is not available to support both, it is appropriate during ALMA's early years to focus most (though not all) of its modest EPO resources toward *News & Public Information* rather than toward *Education*. Several carefully considered reasons inform this decision:

1. The fundamental end of science is the attainment and diffusion of new knowledge. The fundamental purpose of the NAASC is to enable the North American science community to effectively use ALMA toward that end. Therefore, the fundamental purpose of the NAASC's EPO effort is to participate in the scientific process by "publishing" the knowledge of the universe gained by North American scientists to interested parties among the science-interested, and science-funding public. While many, many billions of dollars are spent annually on STEM education, there is nobody else in North America equipped and specifically commissioned to convey ALMA news and information (much of which will be inherently e*ducational*) to the public.

2. The NAASC does not believe it can operate a viable News and Public Information program with fewer resources than currently anticipated.

3. Supplemental grant funding for education programs from private- and public-sector sources are much more readily available than is supplemental funding to carry out our core responsibilities.

4. Opportunities for educational research projects using data in the ALMA archive will be far more viable when there is a data-rich ALMA archive, a few years after science operations begin.

5. Opportunities for educational impact will likely be greatly enhanced when ALMA is, to be blunt, "famous." Thus, the NAASC should focus its efforts on those activities that will give ALMA the kind of well-earned reputation that opens doors[7].

6. While not strictly germane to the NAASC viewed in utter isolation, it is nevertheless worth mentioning that the NAASC's EPO program will not exist in a vacuum. The NRAO's EPO program focuses a very sizable percentage of its resources on K-12 and informal education via in-depth programs conducted in Green Bank, WV and Socorro, NM (see list at the end of this appendix). While mm/submm astronomy is not identical to longer wavelength radio astronomy, the basic concepts are not radically different as they'd be presented to school-age students. Thus, many ALMA-themed education projects could be considered as being roughly "more of

[7] The Space Telescope Science Institute's successful *Amazing Space* education program (staffed by a team of about 6-7 FTE) didn't get started until after Hubble had made a name for itself. Indeed, Hubble's fame attracted both the funding and the end-users to a program that is now formally adopted by school districts in all 50 states, and which is used by some of the largest science teacher training colleges and universities as well.

the same thing" that the NRAO is already doing. More education is a good thing, but not as a substitute for a one-of-a-kind ALMA News & Public Information program.

7. The NRAO conducts grant-funded education programs, such as Research Experiences for Undergraduates (REU), that are completely agnostic as to the flavor of involved NRAO scientist. Indeed, NAASC scientists do participate in such existing programs.

8. There is certainly precedence within NSF-funded national observatories for choosing to emphasize a particular aspect of an EPO program. At present, the NOAO devotes virtually all of its EPO resources to education and very rarely distributes a science result press release. There is no *a priori* reason why all possible forms of outreach must be simultaneously implemented by all organizations, especially when funding to do both with excellence is not available.

Formal/Informal STEM Education Programs Conducted by the NRAO (some with NAASC involvement)

Green Bank Science Center: A wonderful science museum for radio astronomy, and a great bus tour through the 2700-acre complex. Draws 42,000 visitors annually, including many school and scout group visits.

Pulsar Search Collaboratory: High School students make genuine astronomical discoveries by learning how to search through archived data from the Robert C Byrd Green Bank Telescope, the largest steerable astronomical telescope in the world. The first student discoverer of an intermittent pulsar, Lucas Bolyard, was honored by President Obama at a White House party held in honor of the 400th anniversary of Galileo's first use of a telescope.

West Virginia Governor's School for Math & Science: A two week Science Camp in Green Bank with 56 rising high school freshmen, who get observing time on research-grade telescopes.

National Youth Science Camp Tour: 120 rising college freshmen from every state in the US, plus Puerto Rico visit Green Bank for an intensive educational experience.

Educational Research in Radio Astronomy Camp: Organized by the University of North Carolina (UNC) Chapel Hill, 20 college and high school students visit Green Bank for a one-week residential research camp.

Radio SkyNet Robotic Telescope: With stimulus funding obtained through the NSF in cooperation with UNC, the NRAO will be renovating its 20-meter telescope and automating it so that students across the country can have a hands-on educational experience with a radio telescope without leaving home.

J Term / May Term Science Institutes for Undergraduate Students from Minority Serving Institutions: With NSF funding NRAO has carried out a pilot test for an intensive 11-day saturation experience that brings undergraduate students (freshmen and sophomores)

from minority-serving colleges and universities to the observatory for an authentic taste of the research life. Students conduct research and engineering projects and spend long hours in the company of NRAO staff scientists and engineers.

VLA Tour Program: Offered on site 361 days/year, at NRAO's Very Large Array facility outside of Magdelana, New Mexico

Appendix D. Building the NAASC EPO Team

Areas of professional staff expertise needed to execute all aspects of the EPO Vision are shown below. (Functions shown in **bold** are budgeted as of the date of this document.) Efforts will be made to cover non-budgeted functions where possible via dedicated existing personnel and through outside services where feasible and affordable:

EPO Head – Part time for NAASC. Responsible for formulating a vision, staff hiring, staff nurturing and leadership, resource management, program planning, budgeting, reporting, and for soliciting outside participants and partners in the EPO program. Participates in a "hands on" manner in many EPO activities.

Public Information (Press) Officer (PIO)[8] – Part time for NAASC. Responsible for cultivation of story leads, developing press release and media text, and defining comprehensive media packages, press/public events, and public/press awareness campaigns.

Web Developer – Part time for NAASC. Responsible for implementing and maintaining overall "look" of public web site, and for programming, posting, and maintaining content as developed by the EPO team.

Science Writer - Responsible for crafting of informative articles and scripts for media experiences, including background articles that accompany news releases.

Multimedia Designer – Part time for NAASC. Responsible for graphic design of web and other media elements, exhibition panels, and 2D motion graphics production (for example Adobe Flash and Apple Motion).

Video Producer / Editor - Responsible for shooting, editing, producing, and rendering video products for the web, exhibition, and broadcast. Also handles footage requests from outside documentary producers.

Image Processor - Responsible for creation of color composite press release images from pipeline-generated FITS files (including multiple-source, multi-wavelength composites), and for other photo processing.

Science / Technical Illustrator – Part time for NAASC. Responsible for creation of photo-realistic "artist impressions" of astronomical phenomena associated with ALMA observations, and for drawings and diagrams that explain the working of phenomena and technology.

Science Animator / Visualizer - Responsible for creation of scientific and technical 3D visualizations and animations associated with stories about key ALMA science discoveries and techniques.

[8] The currently-hired Science Writer will transition to this position in 2011, leaving the Science Writer position vacant.

Education Officer – Part time for NAASC. Responsible for development and effective propagation of STEM-educational activities, laboratory experiences, teacher resource guides, and workshops for students and teachers.

Curriculum Development Specialist – Responsible for creating and effectively propagating accurate, relevant curriculum support materials that infuse mm/submm astronomy concepts into adopted school curricula.