Association of Universities for Research in Astronomy

Management of Astronomical Observatories
A Partnership between the National Science Foundation and AURA

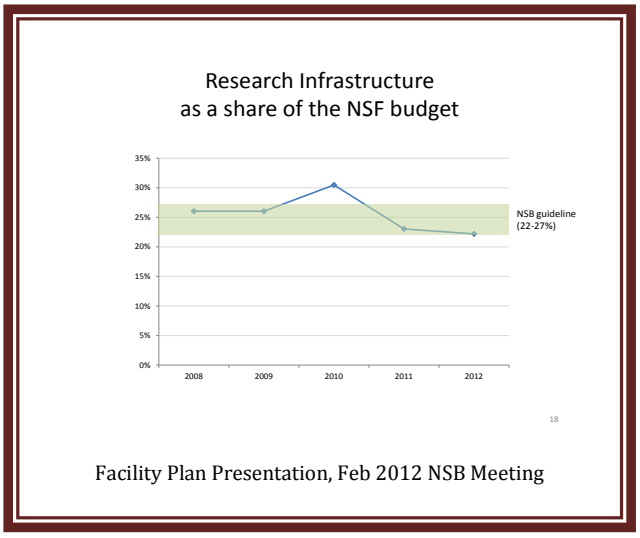
The Association of Universities for Research in Astronomy (AURA) is a consortium of universities that manage the National Optical Astronomy Observatory (NOAO), the National Solar Observatory (NSO), the Gemini Observatory, and the Large Synoptic Survey Telescope (LSST) project. AURA has managed and nurtured such public observatories from their original formation, some going back 50 years. This statement lays out why the NSF provides funding for AURA managed observatories, the return on this investment, and how AURA assures that taxpayer dollars are spent effectively.

Also addressed, are specific issues faced by AURA as well as other managing organizations.

- The goal of building effective national organizations should be the highest level objective by the NSF. Other administrative goals such as recompetition, are a means, but not the only means, to achieving this central goal. A wide range of factors should be considered in making a decision to recompete.
- Decommissioning is an essential element of the evolution of scientific facilities but costs should be included in an NSF-wide budget such as MREFC.
- International collaborations and other forms of partnership in many cases call for governance structures that could be complex. It is crucial that the US community perceive that scientific return and management control are commensurate with the US investment.

Introduction

The Association of Universities for Research in Astronomy (AURA) is a consortium of universities and educational institutions that operates world-class astronomical observatories on behalf of the National Science Foundation (NSF). Our aim is to act on behalf of the science communities that are served by these facilities, and as trustees and advocates for their missions. AURA was founded in 1957, with the encouragement of the National Science Foundation, by a group of U.S. universities with a common interest to create astronomical observing facilities that would be available for use by all qualified researchers from U.S. institutions and universities on the basis of scientific merit. Today, there are 37 U.S. Member Institutions and 7 International Affiliate Members which comprise the Member Institutions of AURA. AURA's mission is "*To promote excellence in astronomical research by providing access to state-of-the-art facilities.*"



Facility Plan Presentation, Feb 2012 NSB Meeting

In its organic act, Congress restricted the NSF from directly managing facilities[1]. Thus, from the outset, the NSF has contracted with managing organizations such as AURA. All of AURA's awards take the form of a cooperative agreement in which AURA is expected to provide a service to the scientific community on behalf of the NSF[2].

Major, multi-user facilities, operated on a competitive peer review basis, has emerged as a major tool for advancing the state of knowledge in astronomy and astrophysics. Just as important, these facilities have been the training ground for students at all levels, providing early career research experiences, and enabling research for PhD students at academic institutions across the US and indeed across the world.

Research infrastructure funding within the NSF, which includes all AURA operated facilities, has declined since 2010. Although the National Science Board has recommended that this portion of the overall NSF budget be between 22-27%, it is now at the bottom of that range. AURA operated facilities have followed this trend. Significant reductions in personnel and functional roles are now being planned in response to fiscal limitations.

[1] 42 USC 1873(b), which states "The Foundation shall not, itself, operate any laboratories or pilot plants"

[2]This differs from the award vehicle for AURA's management of the Space Telescope Science Institute. That contract is based on the presumption that AURA provides a service to the Government.

Although precise, specific correlations are not possible, research infrastructure is a fundamental part of the nation's R&D portfolio, which stimulates innovation, and ultimately economic growth. Astronomy has played a major part in this overall picture because advances in this field are largely driven by improvements in technology. The effort to compete scientifically has inspired technological breakthroughs in detector development, cyber-infrastructure, optics, and a host of other frontier applications.

AURA applauds the efforts of the Committee to examine the general area of facility management by the NSF and its managing organizations. This has been a valuable and evolving partnership. The nurturing of strong national organizations that can support the NSF mission and enable the scientific community to fulfill its potential is a mutual goal of the NSF and its managing organizations.

How AURA Manages

AURA's fundamental structure includes two major parts: first the employee-based management structures for our observatories; and, second, the community-based governance structures that oversee and guide our activities. AURA employs nearly 900 staff. Of these, between 120 and 130 are scientists. AURA provides tenure to those scientists on tenure track in a manner comparable to academia.

Direct community involvement is achieved through governance. Although AURA does not purport to **represent** the community, AURA is **representative** of the community and its interests. At the core of AURA governance are the 44 Member Institutions, but community involvement goes far beyond this. Over the past five years, in excess of 200 individuals drawn from the community have been involved in AURA related activities including standing oversight committees and special purpose committees and groups.

AURA's traditional governance philosophy includes:

- Maintaining strong links to the community: AURA has sought to maintain active links to its Member Institutions and, through the member representatives, an active link to the broader community. Membership on all AURA bodies is elective and rooted in the most democratic and inclusive process possible.
- Heavy reliance on oversight: AURA provides its own community-based oversight and relies on this as a part of its management approach. AURA evaluates the performance of its own staff, establishes metrics for its observatories, and includes feedback as an integral part of its

process. In addition, oversight mechanisms put in place by the NSF have served as an external check[3].

A crucial component of management for AURA, as well as other NSF funded facilities, is the conduct of independent reviews. The following represents some reviews that are now in place:

AURA Management Oversight Councils—as stated above, AURA has established an oversight committee for each major observatory. The members of these councils are drawn from the community and elected by the AURA member institutional representatives. These councils meet at least twice per year and examine every aspect of the observatory.

Visiting Committees—AURA requires periodic independent reviews of the performance of the staff and facilities by visiting committees. Visits are conducted about every two to three years for NOAO and NSO. For Gemini, the Gemini Board itself charters the visiting committee.

Program Review Panel—for NOAO, the NSF has established a special Program Review Panel that meets at least once per year and reports its findings to the NSF. The primary purpose is to review NOAO's annual program plans and to make independent recommendations to the NSF.

NSF Management Reviews—NSF conducts mid-term management reviews of all observatories including NOAO, NSO, and Gemini. These Review Panels report to the NSF on the progress and performance under the cooperative agreements.

Business Systems Review—the NSF Large Facilities Office conducts periodic reviews of the financial management systems and policies for all observatories.

Other NSF Reviews—the Astronomy Division within the NSF conducts major community based reviews of its portfolio in order to align its overall budget and priorities and balance of investments. These have included Senior Reviews and Portfolio Allocation Reviews. A Portfolio Review is now under way.

AURA Managed Observatories

Our facilities serve as the primary observational facilities used by the general astronomical community for ground-based, solar astronomy and for night-time optical and infrared (O/IR) astronomy. Comparable managing organizations are similarly responsible for radio-astronomy.

In the fields of O/IR and solar astronomy in the US, there has also been a healthy development of privately and State funded and operated telescopes. These usually serve specific communities--normally the faculty of the home institutions.

NSF and AURA partnered in the late 1950s to provide an alternative to privately operated facilities to ensure broad community participation and access. This decision and the result have been fundamental to the development of astronomy in the US. The NSF funds these observatories because they provide the primary access to observing facilities for most of the community. They are the only publicly funded publicly available telescopes.

Public observatories, with access determined on a pure merit basis, have been responsible for many of the major scientific breakthroughs over the past several decades. These include:

- The discovery of "dark matter" that is responsible for the rotation of observable galaxies, and dominates the dynamics of the universe (NOAO)
- The discovery of the accelerating universe that has recently been recognized for a Nobel Prize (NOAO)
- The detection of black holes at the center of galaxies and their effect on galaxy evolution (NOAO)
- The first reported spectra of arcs caused by gravitational lensing (NOAO)
- The detection and measurement of solar oscillations (sound waves below the surface of the sun) that lead directly to sunspot activity. (NSO)
- Discovery of the solar filigree (small bright points associated with strong magnetic fields). These measurements were the first showing that features existed at much smaller scales than the granulation and that they were associated with strong magnetic fields. (NSO)
- The development of the first adaptive optics for low contrast, extended objects, for the Advanced Technology Solar Telescope. This has practical uses in retina imaging, satellite identification and a whole host of applications. (NSO)
- First direct images of extra-solar planets; the multiple-planetary system around HR 8799 (Gemini)
- Observation and measurement of the most distant gamma ray bursts, providing evidence for the formation of the first stars following the Big Bang (Gemini)
- Measurement of super-massive black hole growth and the linkage to the chemical enrichment of the early universe (Gemini)

The return on investment for the NSF has been substantial. In 2011, a typical year, 965 US investigators were awarded observing time on NOAO and Gemini telescopes. This represented 180 academic institutions in the US from 41 states. Of these, 80 PhD students and 106 non-thesis students were awarded time.

For National Solar Observatory facilities, typically researchers from 30 to 40 academic institutions per year conduct observing programs studying the Sun. Two to three PhD students are in residence at any given time.

Because NSF telescopes are operated on an "open skies" basis (i.e. our facilities also open to non-US users), a substantial number of non-US observers and students were also awarded time. Maintaining leadership through open access to the best minds, wherever they are, has been a hallmark of NSF funded facilities.

The appendix to this statement provides a description for each AURA managed observtory, its management structure and a historical summary. Present facilities managed by AURA on behalf of the NSF are as follows:

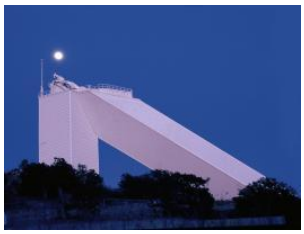
Gemini Observatory is an international partnership to operate twin 8.1-meter telescopes, one on Hawaii's Mauna Kea and the other on Chile's Cerro Pachon. The partners include the United States, United Kingdom, Canada, Chile, Australia, Brazil, and Argentina. AURA manages Gemini under the auspices of the International Gemini Board and the U.S. National Science Foundation as its executive agency.

Today, Gemini has over 200 staff. However, due to the recent withdrawal of the UK from the Gemini partnership, staffing will be reduced to less than 170 by 2015. The present contribution from all Gemini partners is about $37M of which $19 M is from the US.

National Optical Astronomy Observatory (NOAO) - NOAO operates telescopes for night-time astronomy. These telescopes are located on Kitt Peak in Arizona and Cerro Tololo and Cerro Pachon in Chile, and are used by approximately one thousand professional astronomers and students each year. NOAO is also designated as a Federally Funded Research and Development Center. This provides a substantial advantage in long term planning and commitments.

NOAO is comprised of about 350 staff distributed between its two sites and the Directorate in Tucson, Arizona. Although past funding levels have been over $29M, the present request is $25.5 M, necessitating a reduction of about 30 staff over the next year. NOAO serves over 1300 users from 350 institutions world-wide.

National Solar Observatory (NSO) - The mission of the National Solar Observatory is to



advance our understanding of the Sun in its astrophysical context as a star, as the driver of conditions in interplanetary space, in its influence on the terrestrial atmosphere, and in its role in long-term climate change. NSO provides observing facilities for use by the nation's solar and solar-terrestrial physics community. NSO conducts research at Sacramento Peak in New Mexico and at Kitt Peak in Arizona. Its current major initiative is the Advanced Technology Solar Telescope (ATST).

Currently, NSO has about 100 staff members and receives about $9 M per year from the NSF. When the ATST begins operations, however, the budget and staffing will increase. Presently operated NSO facilities in Kitt Peak and Sac Peak serve about 100 users per year[4].

Large Synoptic Survey Telescope (LSST) - The LSST is a public-private partnership to operate an 8.4-meter telescope on Chile's Cerro Pachon. The partnership includes NSF and DOE, private foundations, LSST Member Institutions, and international collaborators. The LSST is a wide-field telescope facility that will add a qualitatively new capability in astronomy. For the first time, the LSST will provide time-lapse digital imaging of faint astronomical objects across the entire sky. It will make fundamental contributions to the understanding of dark energy, dark matter, Earth crossing asteroids and other high priority topics. The LSST emerged as the highest priority in the most recent astronomy and astrophysics Decadal Survey.

LSST is presently in its final design and development phase. It is anticipated that a new construction start can be established as early as FY14. It is anticipated that LSST will begin operations in 2021.

Issues Addressed by Managing Organizations

Recompetition

The February 7, 2008 resolution by the National Science Board stated that the Board "..*endorsed strongly the principle that all expiring awards are to be recompeted, because rarely will it be in the best interest of U.S. science and engineering research and education not to do so*." This position was based on the conviction that peer-reviewed competition is the process most likely to assure the best use of NSF funds for supporting research and education. This premise has been further examined by the NSF in community-based workshops, in particular whether there are other factors in the interest of research and education that should also be considered.

[4] Solar and night-time observations differ substantially. A night-time observation may take one to three nights, a solar observation typically requires several weeks.

For AURA operated facilities, the following cooperative agreement expirations will occur:

Gemini: 9/30/2015
NOAO: 3/31/2014
NSO: 3/31/2014

AURA recognizes that a recompetiton can have a positive effect in reinvigorating the management of NSF facilities. This can be accomplished either by selecting a different managing organization who can manage more effectively or by effecting changes in the incumbent managing organization by virtue of the competitive process. In the period 2000-2002, the NSF undertook a recompetition of the National Optical Astronomy Observatory and the National Solar Observatory[5]. This recompetition was based on the concern that NOAO, under AURA management, should become a more effective national organization and extend its mission beyond the operation of its own telescopes at Kitt Peak, and in Chile. AURA strongly internalized this criticism and undertook a fundamental redefinition of the mission and purpose of NOAO. AURA also undertook an effort to separate NSO as a stand-alone organization so that it could pursue the development a new generation of ground-based solar telescopes more efficiently.

The result was that the AURA proposal, which included a vision of NOAO as a national leader promoting a "system" of US observing capabilities, was successful and has been pursued since 2003 as the mission of NOAO. This expanded mission includes a mandate to achieve access to private and independent telescopes. It is clear that this recompetition was an effective exercise for the NSF and for AURA in re-focusing the NOAO mission.

Although the recompetition in context was successful, AURA recommends that the primary emphasis be placed on building effective national organizations and enabling the community to conduct transformative science. A recompetition is one tool for accomplishing this, but there are others that must also be available. Some examples of alternatives to recompetition include the following:

- Recently a major redirection in the Gemini Observatory has been carried out through a close working collaboration between AURA, the managing organization, the Gemini Observatory management, and the Gemini Board and NSF. This redirection was made necessary by the withdrawal of the UK from the international partnership and the resulting dramatic decrease in financial contributions. It is doubtful that this change, which includes more efficient observing modes and staffing strategies, could have been accomplished through a recompetition. It required the development of a strong consensus among all of the

[5] Up until that time NSO was a division of NOAO.

stakeholders. The National Science Board recognized these circumstances and agreed to extend AURA's cooperative agreement to allow this transition to proceed smoothly.

- The US Decadal Survey for Astronomy and Astrophysics, *New Worlds, New Horizons*, has recommended that a common management structure be considered for NOAO and Gemini in order to achieve cost savings and to put in place a stronger US national observatory. However, such a merger would strongly affect the conduct of recompetitions for NOAO and for Gemini as separate organizations. The Decadal Survey recommended that the benefits of building such a strong consolidated organization should be the primary consideration by the NSF. However, it is clear that the entanglement of NOAO and Gemini would be an impediment to recompetition. Thus, currently the NSF is not considering any such structural changes that would complicate a recompetition. AURA accepts the NSF position at this time but clearly this deserves further examination in the future.
- For Gemini, regardless of whether any major consolidation with NOAO takes place, the Gemini Partners have strongly suggested that their continuing participation in Gemini should be predicated on a governance change of some sort in 2015 when the present International Agreement expires, which overlaps the expiration of the cooperative agreement. Such a governance change would in turn strongly affect the role of the managing organization and hence the guidelines for a recompetition. It is unlikely that a mutually agreeable governance change for the Gemini partnership will be in place at that time.
- The National Solar Observatory represents a case that is common within the NSF. NSO, under AURA management, undertook a strong community leadership role to define and promote the Advanced Technology Solar Telescope which achieved a new start within the NSF. It is crucial to continue this management arrangement throughout construction. Major procurements and agreements exist between AURA and the vendors that would be extremely difficult to novate or re-negotiate. The National Science Board has recognized that the policy should be transparent to the research community such that after construction of major facilities is completed, an appropriate time period to bring the facility to sustainable operations will be needed before a full and open competition. Thus a recompetition in 2014 would be highly disruptive for AURA and for the community.
- All AURA observatories have established strong scientific collaborations in order to enhance and leverage their scientific programs. These collaborations have required nurturing over many years, and in many cases formal agreements. Collaborating partners have made significant commitments on their own part, such as matching funds and, in the case of NSO, faculty lines. A recompetition could have a severe detrimental effect on science itself if these factors are not considered.

Unlike DOE facilities, many of which are Government owned/Contractor Operated, NSF facilities have a more complex ownership, many times involving the contractor itself. Astronomical facilities are unique in that they must be sited in locations that are remote and in

many cases only accessible to not-for-profit organizations like AURA. AURA owns the land in Chile on which NOAO and Gemini telescopes sit. Other sites include tribal lands, and lands managed by other Federal agencies such as the Forest Service. The transfer of ownership or operating authority to another organization as a result of recompetition is not straightforward.

Furthermore, some of the most advanced telescopes in operation today are the result of many years of strong advocacy and technical development by the managing organizations themselves. Gemini, for example, was created as a result of decades of work by AURA itself.

Each facility recompetition may involve factors that are unique to that community and how it interacts with that facility. A recompetition is justified when the managing organization is inefficient, not performing in an effective manner, when it is not responsive to the community, or when it is unable to evolve to respond to changing needs. The community itself should have a role in making this judgment.

However, the timing of a recompetition may not be best aligned with the expiration of a cooperative agreement if larger changes within the landscape are taking place. AURA advocates a process that considers community input in the decision to recompete. The community is well able to judge the more subtle factors that need to be weighed.

AURA recommends that NSF Management Reviews include as part of their charge an explicit requirement to make recommendations on whether it is appropriate to recompete in specific expiring cooperative agreements. Although the NSF is free to make a different decision, it is crucial that the user communities be fully engaged as a part of this process, and clear benefits of recompetition should be evident.

Lifecycle Planning

Lifecycle Planning should include the costs of construction, instrumentation and operation, and decommissioning. Currently the NSF has clear policies and mechanisms for construction planning in the MREFC budget, and instrumentation and operations in the base budgets of the facilities. However, decommissioning costs are not as well addressed.

Ideally, life cycle planning should anticipate the decommissioning of facilities as they become obsolete or when resources must be freed up to allow new facilities to come on line. For many astronomical facilities, their scientific utility and competitiveness are dominated much more by the instrumentation rather than the telescope itself. Thus it is clear that telescopes such as the 4 meter Mayall and Blanco telescopes operated by NOAO can remain among the most competitive in the world for many decades even as 8 meter and 30 meter class telescopes emerge.

However, there is no question that a process must be in place to make major transitions to new facilities when transformative science can be done. Some challenges in making such transitions include the following.

- Economics: In most cases, the one-time cost of decommissioning a major facility vastly exceeds the annual operating cost of that facility. Thus, it is frequently more affordable in the short term to continue its operation. For example, the National Solar Observatory plans to divest the current operation of its facilities in Sac Peak, New Mexico as the Advanced Technology Solar Telescope (ATST) comes on line in 2017. Clearly ATST will offer transformative scientific capabilities over what is presently available. The cost of operating existing facilities at Sac Peak is about $1 M per year[6]. However, the range of costs associated with decommissioning and shutting down those facilities is at least $7 M and possibly up to $30 M. Thus, it is implausible to finance the decommissioning through savings from the operations budget alone.
- User Impacts: Many long term astronomical facilities have developed strong, dedicated user communities which depend on these facilities for their science. Most scenarios for decommissioning imply a disruption or discontinuity in science unless other facilities are readily available. Such a disruption can have a devastating effect on a community as those researchers shift their scientific focus to other areas[7].

Both of these issues suggest that mechanisms must be found for lifecycle planning that can fit the NSF budget structure, and minimize impacts on the community. For example, it is possible to plan for decommissioning costs within the MREFC budget. The logic that led to the establishment of the MREFC budget—that construction costs were too large to be accommodated within an operating budget line—apply equally to decommissioning. This would help in overall budget planning and would minimize the disruption to the community.

For the present, AURA has surveyed the community to ascertain potential academic institutions and other entities that may desire to take over the operation of these facilities for their own purposes. Some of these, such as the Sac Peak facility, can be refurbished to provide for education and training, and even dedicated research for those institutions. It is unclear at this point whether this would be attractive to such institutions.

International Collaboration and Other Forms of Partnership

It is clear that the US community can achieve some of its more ambitious visions only through cost sharing with other international partners and other forms of partnership. In addition, it is

[6] The labor related costs of operating Sac Peak are an additional $2.8 M, however these personnel will be required for ATST.
[7] A well known case is the NASA decision to decommission the Kuiper airborne infrared observatory in order to create a funding wedge for the SOFIA observatory which would take its place. The two decade long interval between the two is widely believed to have adversely impacted the field of infrared astronomy.

AURA's experience that such collaboration enriches the scientific potential of shared facilities. It is important, however, that the US community perceives that its influence and role within an international project, as well as the scientific return to the community is commensurate with its investment.

The standard model for NSF facility management—that is, a managing organization working directly with the NSF through a cooperative agreement—does not fit the emerging complex partnerships which involve private entities, international partners, and other Federal Agencies.

There are many models for international collaboration and associated governance structures. Each has their advantages and disadvantages.

- Gemini Model—AURA manages the Gemini Observatory on behalf of the Gemini International Partnership. The NSF is both a partner and the "Executive Agent" for the partnership as a whole which operate through the Gemini Board. The governance is established and controlled by a Government to Government International Agreement. All partner funding flows through the NSF.

  Because AURA operates under a cooperative agreement, all guidance and direction come through the NSF. Although this provides NSF with direct oversight and control, it requires the other partners to subject their own investments to the policies and practices unique to NSF and the National Science Board. In many cases these are different than their own national practices. For example, the requirement to recompete the cooperative agreement for Gemini in 2015 limits the ability of the partners to examine other governance models.

- SOAR Model—AURA is a partner in the Southern Observatory for Astronomical Research (SOAR) located in Chile. This observatory is a partnership between NOAO, Brazil, the University of North Carolina, and Michigan State University. It is managed through an independent corporation and a managing Board. All partners provide resources and participate in decision making. This model and others like it, have proven to be very flexible in accommodating the needs of the partners. However there is no Government-to-Government agreement, nor a specific cooperative agreement. It is likely that for large scale projects this lack of a direct NSF involvement would not be acceptable.

Although cost-sharing is accepted as a highly desirable feature of any major new facility, it is not straightforward that all funding should flow through the NSF and that an NSF administered cooperative agreement will be appropriate in accommodating partner needs.

In the future, the ATST and LSST will involve international partners in some way. However, the form of the governance is not established. Although for Gemini, the NSF was directly involved

at the outset in soliciting partnerships, and a substantial amount of work went into building these Government-to-Government relationships, ATST and LSST are proceeding now only at the project level in developing the international roles.

Managing Tax Payer Dollars Effectively

It is a major objective of all NSF facility operators to maximize the return on investment in terms of science per dollar. AURA, like many other NSF managing organizations, is a not-for-profit entity that operates on a very low overhead. Of AURA's current award total, only about 0.6% can be attributed to a management fee. The bulk of the awards are used for operating the facilities themselves.

AURA, like other managing organizations, has an obligation to proactively seek out waste, fraud, and abuse, and any wasteful practice. AURA has put in place a number of mechanisms to ensure a high level of fiduciary responsibility and integrity. Some of these include:

- Maintaining a standing Audit Committee appointed by the AURA Board;
- The appointment of an external independent audit firm, presently Clifton Larson Allen;
- The establishment of an independent corporate internal auditor;
- Participation in NSF organized Business Systems Reviews (BSR);
- Strong Fraud and Ethics Practices policies; and
- Whistle blower protection policies, and in the near future a whistle blower "hotline."

In addition, AURA is audited by the Defense Contracts Audit Agency on a regular basis. Because Federal policies and guidelines for grant holders are constantly evolving, the BSRs are particularly important in identifying needed changes in policy and improvements in accounting standards and financial systems.

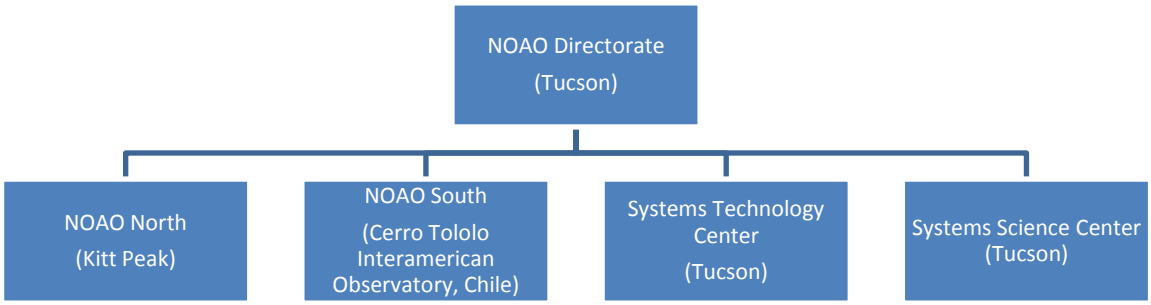
Conclusion

AURA has acted as a partner with the NSF and as steward of the preeminent public observatories that have influenced the development of astronomy within the US. Our observatories are among the most competitive and productive in the world. The return on investment for the NSF and the taxpayer has been substantial.

AURA looks forward to working with the Committee to strengthen NSF's research infrastructure to maximize the ability of our observatories to serve the community.

Appendix

National Optical Astronomy Observatory



NOAO is located at two sites, in Tucson Arizona and nearby Kitt Peak, and at the AURA site in Chile near La Serena. In Chile, AURA operates the Cerro Tololo Interamerican Observatory (CTIO) near La Serena. (AURA also operates the Gemini Observatory and the SOAR telescopes on Cerro Pachon, and soon will operate the LSST there.)

NOAO divisions include NOAO North for Kitt Peak, NOAO South for CTIO, a Systems Technology Center in Tucson for instrumentation development, and a Systems Science Center which provides access to other telescopes including Gemini.

NOAO was established as AURA's initial public observatory. Prior to the 1950s, research astronomers only had access to the scientific facilities available through the particular institution with which they were affiliated. Therefore, a faculty member teaching at a major university might be able work with a more powerful, better equipped telescope than a colleague at a smaller school. There was no equal access to the best research facilities.

Following World War II, the United States entered the Cold War with the Soviet Union. The successful launching of the first satellite, Sputnik, in 1957, by the Soviets, was a major catalyst for the formation of a national space program, and its obvious partner, astronomy research.

At that time, numerous astronomers petitioned the federal government for funds to build a research center available to the entire astronomy community, a National Observatory.

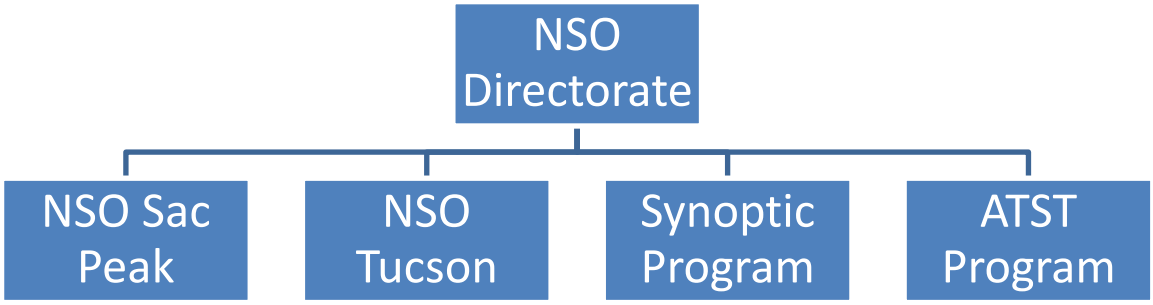
Over 100 mountains in the western portion of the nation were surveyed. From the narrowed list of eleven sites in California, Arizona and New Mexico, Kitt Peak was determined to have the greatest number of positive attributes. A comparable search took place in the southern hemisphere to provide US astronomers with full sky access.

For Kitt Peak, the National Science Foundation secured a lease from the Tohono O'odham Nation to use the chosen mountain on their ancestral homeland for the sole purpose of astronomy research.

By the early 1960s, the building of roads and such early telescopes as the 0.9-meter (36-inch) and 2.1-meter (84-inch) had begun across Kitt Peak, as well as the current Tucson-based headquarters of the National Optical Astronomy Observatories.

For its operations in Chile, AURA secured special legislation from the Chilean government that provided AURA with special juridical privileges and exemption from Chilean taxes. AURA has nurtured good relations with the Chilean government from the 1960s through turbulent times up to the present.

National Solar Observatory



The National Solar Observatory facilities are currently located at Sac Peak New Mexico and Kitt Peak Arizona. The Director spends his time between the two sites. NSO also operates a synoptic program consisting of the Global Oscillations Network Group (GONG) and the Synoptic Optical Long-term Investigation of the Sun (SOLIS) located in Tucson. The Advanced Technology Solar Telescope Program is primarily made up of personnel now located at Sac Peak who will transition to Maui Hawaii as ATST moves into construction and operations.

Some of the first facilities on Kitt Peak were solar telescopes. Until recently, NSO existed as a division of NOAO and it evolved along with NOAO. In the 1970s, the Air Force asked the NSF to take over the operation of their facilities at Sac Peak, and the NSF subsumed these into the NOAO management structure. At that time AURA initiated actions to separate out NSO as a stand-alone organization. By 2009, a separate cooperative agreement was awarded to AURA to operate NSO separately from NOAO.

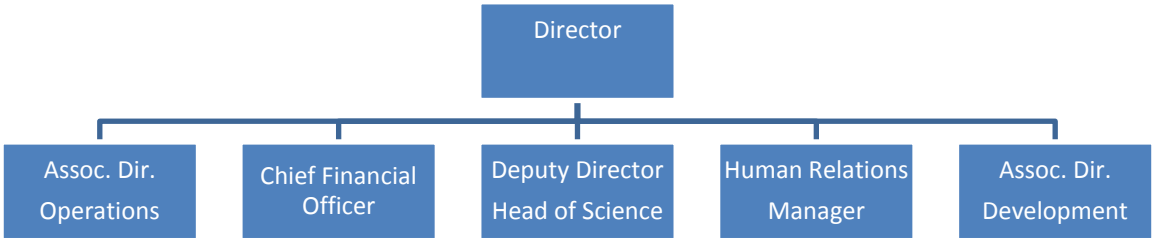
Some of the major NSO facilities include the following:

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 meters, is the premier facility for high-resolution solar physics. The evacuated light path eliminates the loss of image clarity due to distortions from the air. NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to ATST.

The McMath-Pierce Solar Telescope on Kitt Peak, at an altitude of 2096 meters, is currently the largest unobstructed-aperture optical telescope in the world, with a diameter of 1.6 meters. Thus, it is uniquely capable of panchromatic, flux-limiting studies of the Sun. In particular, it is the only solar telescope in the world on which investigations in the relatively unexplored infrared domain beyond 2.5 microns are routinely accomplished.

The Global Oscillation Network Group (GONG) studies the internal structure and dynamics of the Sun by means of helioseismology - the measurement of acoustic waves that penetrate throughout the solar interior - using a six-station, world-circling network that provides nearly continuous observations of the Sun's "five-minute oscillations."

Gemini Observatory



Gemini telescopes are located on Mauna Kea, Hawaii, and on the AURA site near La Serena Chile. Gemini is operated as a single observatory located at two sites. This operating philosophy reduces operations costs.

The Gemini Observatory organization was restructured during 2011. One significant change was to consolidate all of operations activities, including engineering and science, into a single division. Within Operations, there is a Head of Science Operations for each site, and a Head of Engineering Operations for each site, all of whom report to the AD for Operations.

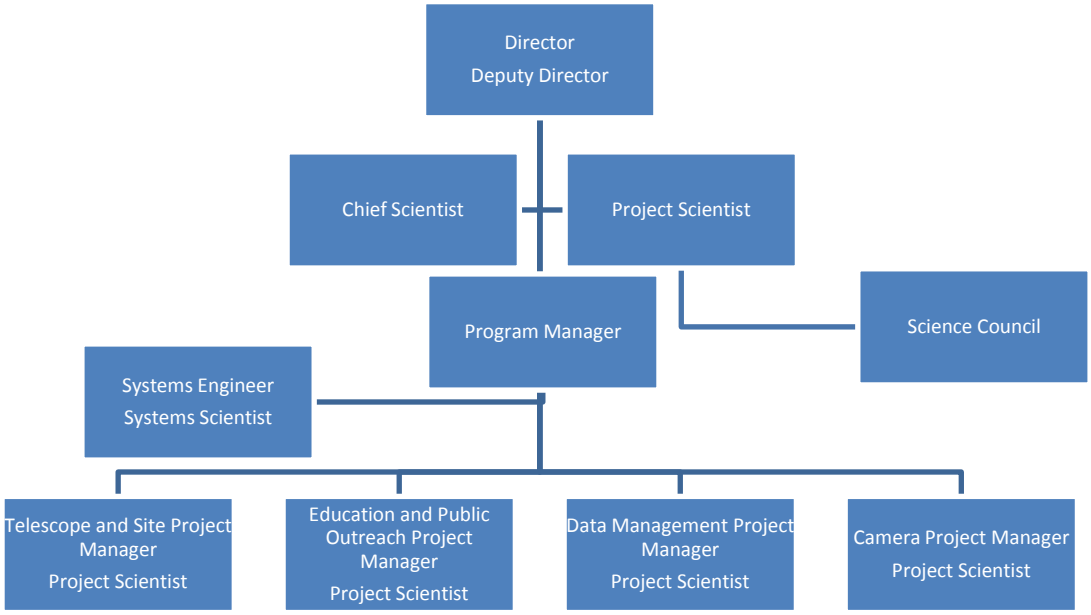
The Deputy Director provides leadership for the science staff and also heads the Public Information and Outreach activities.

The Development branch is organized largely according to key projects, each of which is led by a project manager. The Systems Engineering Group and Adaptive Optics are also part of this division.

The management structure also provides for independent direct reporting by the Human Relations Manager and Chief Financial Officer.

The Gemini Observatory was the NSF's entry into large aperture telescope astronomy. Recommended in the 1990 Decadal Survey, the NSF took the initiative to create an international collaboration including Great Britain, Canada, Australia, Brazil, Argentina, and Chile. Great Britain announced that it intended to withdraw from the partnership in 2012. Presently the US share of Gemini is about 65%.

LSST Program Office



The LSST Project Office is located in Tucson. It consists of a Director and Deputy Director, a Chief Scientist and Project Scientist, and a Program Manager who has purview of four major work packages. The work packages consist of a telescope and site manager in Tucson, an Education and Public Outreach manager, a Data Management Project manager and a Camera Project Manager located at the Stanford Linear Accelerator Laboratory.

The LSST was recommended in the 2010 Decadal Survey as the highest priority ground-based initiative. The LSST is a wide-field deep imaging facility that will add a qualitatively new capability in astronomy: *Wide-Fast-Deep.* LSST's field of view is 3100 times larger than the Hubble Space Telescope's wide-field Advanced Camera for Surveys. The final catalog will include twenty trillion measurements for 10 billion stars and 10 billion galaxies.

For the first time, the LSST will provide time-lapse digital imaging of faint astronomical objects across the entire sky. LSST's unique ability to go *Wide-Fast-Deep* will expand our window on the dynamical universe by a thousand-fold: from bursts of light caused by the extreme physics of rare objects, to unknown dark objects closer to Earth. The LSST will provide digital imaging of faint astronomical objects across the entire sky, night after night.

If construction for LSST begins in FY2014, it is anticipated that it will be fully operational in 2021.