**21 April 2014**

# AURA in 2014 and Beyond:

## An Ongoing Strategic Plan

### Association of Universities for Research in Astronomy


**Revision History**

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| 21 April 2014 | Revisions from the AURA Board of Directors in April 2014 |
| 11 April 2014 | Revisions by Dan Clemens |
| 8 April 2014 | Revisions by Dan Clemens, Timothy Heckman, and Heidi Hammel |
| 20 March 2014 | Acronym list added as second appendix by Heidi Hammel |
| 12 March 2014 | Revisions from the AURA Board of Directors in February 2014 |
| 14 February 2014 | Revisions by Dan Clemens and Heidi Hammel |
| 5 February 2014 | Revisions by William Smith, Dan Clemens, and Heidi Hammel |
| 21 January 2014 | Revisions from the AURA Board of Directors in October 2013 |

# Introduction

This document describes the rationale for AURA, and provides a framework for fundamental decisions and actions that shape and guide what AURA is, what AURA does, and why AURA does it. Its primary focus is on the decade 2014-2024, but it also sets the stage for decades beyond. This document identifies the following for AURA:

**MISSION/ROLES:** WHAT AURA DOES

**CUSTOMERS:** PEOPLE AND/OR ORGANIZATIONS TO WHOM AURA DELIVERS BENEFIT

**CONTEXTS:** WHY, HOW, AND WHERE AURA OPERATES

**ACTIONS AND TOP-LEVEL GOALS:** AURA ACTIVITIES AND HOW THEY ARE PRIORITIZED

**GOALS:** EFFECTIVE MEASURES OF AURA SUCCESS IN BOTH THE SHORT AND LONG TERMS

AURA's Corporate Office and Centers developed this document in conjunction with the AURA Board of Directors. Each Center establishes and pursues its specific role in supporting AURA's activities (synopses provided in the Appendix).

# AURA MISSION/ROLES

AURA's mission, which guides all AURA activities including those of its Centers, is:

> "*to promote excellence in astronomical research by providing access to information about the universe from state-of-the-art facilities, surveys, and archives*."

The role of the AURA Corporate Office, aided by AURA's Governance structure, is "*to establish, operate, and promote public access observatories and science institutes that serve the astronomical community*."[1] In so doing, AURA and its Governance achieve the top-level goals of its Centers (see Appendix). The AURA Member Institutions[2], through representation at the Annual Meeting and on the various Management and Governance Councils, constitute a forum for review of, and advisory comment upon, the activities of AURA, as well as other issues that Member Representatives deem worthy of consideration in the management and governance of AURA and the advancement of astronomical sciences. The Representatives from the Member Institutions also recommend membership for all Boards and Councils, and effectively represent the moral authority for AURA. The AURA Board of Directors sets policy, oversees the operations of the Corporation, and is responsible for execution of AURA's contractual and financial obligations. The Board delegates oversight/administrative responsibilities for the Centers to its Management Councils and subsidiary bodies.

[1] http://www.aura-astronomy.org/about.asp

[2] http://www.aura-astronomy.org/membership.asp?memberType=institutions: 39 US institutions and 6 international affiliates as of early 2014.

# AURA CUSTOMERS

As the steward of observatories operated under contracts and cooperative agreements for the National Science Foundation and NASA, AURA recognizes that the fundamental customers for the AURA Corporate Office and Governance activities are the funding agencies, as influenced by, and on behalf of, the astronomical community and the public. At the same time, AURA recognizes that scientific effort, findings, and initiative all flow from the astronomical community. AURA's customers must also include the astronomers, and the public, who use the astronomical information from AURA facilities, surveys, and archives to discover and publicize the nature of the universe.

# AURA CONTEXTS

## Core Principles

AURA was founded on, and continues to support, the following principles for advancing scientific discovery in astronomy and astrophysics.

• ***Merit-based access to information about the universe maximizes scientific return on investments in astronomical facilities, surveys, and archives.***

The opportunity to conduct world-class astronomy and astrophysics should be available to all, regardless of institutional affiliation. It is through merit-based competition for public access to information from the universe that AURA's Centers help ensure the best possible astronomical science. Open merit-based access to world-class astronomical data is provided on public telescopes, as well as through initiatives on private ones, and through participation in major astronomical surveys. Because of AURA and the leadership it provides, the scientific return on public investment is excellent. Merit-based science using AURA facilities has led to paradigm-changing breakthroughs.

• ***Forefront innovations in facilities, technology, and data science drive discovery in astronomical sciences.***

World-class facilities are often the largest, newest, and best instrumented. Innovative instrumentation also transforms older or smaller telescopes into world-class performers. World-class science answers the important questions we ask today, challenges old paradigms, and leads to tomorrow's key questions. It drives outward the boundaries of the known, often in quantum leaps as new telescopes and/or new instrumentation are brought to bear on difficult problems. Inherent in astronomical science is a natural tension between the need to develop new facilities and instruments, and the desire to exploit the stable and reliable performance provided by existing facilities and instruments. Both are vital to scientific success, and AURA has long understood and helped manage this tension. AURA empowers its Centers, via community-led Management Councils and User Committees, to constantly assess the appropriate balance in this tension. AURA also acknowledges that limited resources demand tough choices, and AURA has

over 50 years of experience in working closely with the astronomical community and their funding sources in making difficult decisions.

These two core principles define AURA tenets, and help guide AURA's paths forward. Notable by their absence from the list of principles are "new business for the sake of business," and "growth for the sake of growth." AURA seeks new business only when those opportunities are aligned with the principles listed above.

## AURA's Internal Strengths

AURA has a wealth of internal strengths that it calls on to advance its mission and operate its astronomical Centers.

*Extensive managerial experience with ground-based astronomical observatories*. AURA has managed astronomical facilities for over 50 years. AURA is recognized as an established institution with a credible track record, excellent operating policies and practices, and a reputation as a good managing entity. In the northern hemisphere, AURA's NOAO operates telescopes at Kitt Peak National Observatory near Tucson, AZ; AURA is consolidating the National Solar Observatory (NSO) in Boulder, CO; AURA's Gemini Observatory operates the Gemini North telescope on Mauna Kea (island of Hawaii); and AURA is building the Daniel K. Inouye Solar Telescope (DKIST) on Haleakala (island of Maui). AURA also has over five decades of experience in the southern hemisphere as an effective juridical presence in Chile, where Gemini operates the Gemini South telescope, NOAO operates Cerro Tololo Inter-American Observatory (CTIO), and AURA is building the Large Synoptic Survey Telescope (LSST).

*Strong managerial experience with Hubble Space Telescope*. AURA's Space Telescope Science Institute (STScI) manages all science with Hubble and has a well-demonstrated role as a community-based science management center. This sets the stage for a strong role in the James Webb Space Telescope and other future space facilities.

*Deep engagement of the community in its Center management*. AURA's core strength is its strong roots in the astronomical community and its fundamental decision to draw on those roots to populate its Centers' Management Councils. This directly embeds the community in AURA Center management.

*Community dialogue*. AURA Centers play unique roles in leading community-wide discussions about current facilities, future needs, and innovative science areas. AURA Centers lead through workshops and meetings, and through discussions of coordinating federally- and privately-funded facilities.

*Ground-based solar astronomy*. AURA's National Solar Observatory (NSO) has decades of experience with facilities in Tucson and New Mexico. NSO is entering an exciting new era with DKIST on Maui and the relocation of NSO facilities to Boulder.

*Awareness of and engagement with external factors that affect funding sources*. AURA recognizes that federal funding levels are affected by the views and priorities of a diverse array of stakeholders, including individual members of Congress, the Administration, the agencies themselves, and many others. AURA maintains an awareness of, and linkages to, all of these stakeholders.

*Significant experience with international observatories and institutions*. In addition to AURA's experience in Chile, AURA has international member institutions, and facilitates interactions with other nations through AURA's management of observatories such as Hubble (with its European partnership) and Gemini (Canada, Chile, Argentina, Brazil, Australia, and, formerly, the United Kingdom). AURA also participates in development of facilities such as the James Webb Space Telescope (a NASA-led collaboration with Europe and Canada) and LSST (which in the process of developing international affiliations).

*Powerful scientific and technical workforce*. Through its Centers, AURA's combined employee base of almost 1,000 dedicated individuals represents a technical, operations, and scientific powerhouse within the astronomy community. AURA develops, trains, and advances its workforce.

*Scientific information management and data discovery*. AURA is a scientific leader in data management protocols (e.g., the original prototype for the FITS image format arose in part from a collaboration within AURA's Kitt Peak National Observatory) and community-wide data processing tools (e.g., the NOAO developed IRAF data processing package and the IRAF-based Space Telescope Science Data Analysis System, STSDAS). Modern innovations at AURA Centers include Barbara A. Mikulski Archive for Space Telescopes (MAST) operated by STScI, as well as various Virtual Observatory (VO) tools and services developed via the Virtual Astronomical Observatory (VAO) project (in collaboration with the Associated Universities, Inc.) in conjunction with NOAO and STScI.

*Incubation of astronomical innovation*. AURA Centers play important roles in the development of future astronomical facilities. NOAO played a key technology development role in the recent generation of large aperture telescopes (especially primary mirror technology), created the project that ultimately led to Gemini, and today plays a leadership role in the development of LSST. Both Gemini and NOAO made contributions to the initial design and development for the Thirty Meter Telescope (TMT) project. NSO is the driver behind DKIST. STScI is deeply engaged in JWST and in ideas for future space facilities.

*Management of government workforce requirements*. AURA's strong administrative team continually tracks and addresses federal requirements for funding administration.

*Diversity and outreach*. At the Corporate level, AURA pursues diversity of the AURA workforce as a strategic priority; AURA works to enable education and public outreach; and AURA promotes to society the broader benefits that accrue from accomplishing our mission.

## Opportunities

Today, AURA faces opportunities for growth, change, and new directions.

*Evolution in the astronomy funding base*. There is a growing recognition that ground-based astronomy is, in fact, more finely nuanced than "public" versus "private," or "federally-funded" versus "non-federally-funded." Participants in astronomical research now include: the traditional federal organization, i.e., NSF; non-traditional federal organizations, i.e., the Department of Energy and NASA (to a limited extent for ground-based facilities); private universities and institutions (e.g., organizations that buy Keck time or build large private facilities); truly private donations from non-astronomy Foundations (Moore, Allen, Keck, etc.); and foreign institutions and/or countries. AURA Centers are keenly aware of this change, and are actively working within these new funding paradigms via a variety of partnerships and consortia.

*Big Data*. This area is a burgeoning field in all areas of science, and LSST is positioned to lead in astronomy. Through the LSST construction project, and through other initiatives being considered jointly by LSST and NOAO, AURA has the opportunity to advance Big Data astronomical science initiatives that will benefit the entire astronomical community. Other initiatives being carried out by NSO and by STScI will also be a part of this overall progress.

*National Solar Observatory in a new university environment*. The NSO's transition to Boulder provides an excellent opportunity to further many of NSO's goals by building new university ties and developing the future workforce. It is also an opportunity to explore deeper connections with the many institutions and facilities in the Boulder area, including the High Altitude Observatory. Beyond that, NSO will play an influential role in reinvigorating solar astronomy more broadly across US academic institutions.

*Existing ground-based facilities*. NOAO has been exploring opportunities to partner with the Department of Energy to bring innovative technologies such as DECam and DESI to its existing telescopes. Gemini has also recently seen first light by the Gemini Planet Imager, a world-class technological tool for exoplanet studies. These world-class instruments will keep these facilities at the forefront of astronomical science for some time. AURA has the opportunity with its southern facilities (CTIO, Gemini South, LSST) to achieve future synergies.

*Future ground-based facilities*. AURA is constructing two major ground-based facilities, LSST and DKIST. At least three extremely large telescopes (ELTs) are also under development around the world. AURA's NOAO is involved in one of those projects (TMT). AURA will continue to explore how best to strengthen and/or broaden connections to ELTs and what roles merit-based public access to the ELTs will have in the future.

*Space facilities*. AURA's Space Telescope Science Institute established Hubble as the premier space-based astronomical facility, and is working closely with Goddard Space Flight Center and industry partners on the James Webb Space Telescope. STScI is also exploring partnerships and leadership roles in space facilities within the Explorer class of NASA missions. The stage is being set now for the space-based astronomical facilities of the next decade and beyond.

*Optical, infrared, and ultraviolet astronomy*. AURA's ground-based facilities have traditionally focused on telescopes that sense optical and infrared light, and expanded into ultraviolet with the Hubble Space Telescope. In the future, there may be opportunities to expand AURA's wavelength portfolio.

## Continuing and Future Challenges

At this moment, AURA also faces a variety of challenges. AURA's ability to navigate these challenges will depend critically on the pursuit of priorities as expressed through strong leadership.

*Resource challenges*. AURA is being called upon to carry out its mission within a federal budget that is highly constrained. AURA must ensure that the operating plans of its Observatories establish clear priorities to effectively carry out their core activities and to reduce those activities deemed to be of lesser priority to the funding sources and to the astronomical community.

*Recompetition*. In recent years, the NSF has embraced the notion that facilities should be regularly recompeted in order to maximize the scientific return on federal investment. In many of these recompetitions, the desire for "fresh ideas" and "innovative operating models" is being weighed carefully against AURA's long-established management values based on community oversight, strong science staff, and optimizing community access. In some cases, such competitions hinder the development of unified strong national organizations and impede changes that could aggregate existing management structures more efficiently. To remain competitive, AURA constantly solicits feedback on its performance; explores new and alternative approaches to accomplishing its mission; and has built a diverse, agile, results-oriented management and workforce team. AURA will maintain a competitive posture for its core observatories and seek additional such work as fits our mission and strengths.

*Increasing management and oversight complexity*. Increasingly, external circumstances force the management structures of emerging major projects to be more complex than the simpler model that characterized AURA's legacy observatories, NOAO and NSO. New structures involve private, international, and other agency participants that require AURA to form more flexible and innovative management relationships. Future opportunities may also involve "teaming" with other managing entities. In addition, federal oversight and audit compliance has increased in scale, bringing concomitant complexities to facility management.

*Science and science staff at National Centers*. In this era of constrained resources and recompetition, the value added by science staff relative to their incremental cost must be convincingly demonstrated to our federal sponsors. A National Academy committee examined "best practices" at NASA science centers in 2007, noting: "The committee viewed the presence of research scientists and visiting scientists at the NASA astronomy science centers as enhancing the role of those centers and their ability to provide exciting and intellectually rich environments

for the research scientists they employ."[3] AURA concurs: the hiring, development, and retention of science staff have traditionally been and continue to be core AURA management principles.

# AURA TOP-LEVEL ACTIONS AND GOALS

Pursuit of the following goals guides the AURA Corporate Office and AURA Governance.

## AURA Corporate Office

The AURA Corporate Office continually strives to maximize AURA's management effectiveness through the following activities.

**Ensure Center accountability.** Hold AURA Centers accountable for executing their missions on behalf of the funding agencies and the astronomical community. The Centers' Management Councils, reporting to the AURA Board of Directors, are the primary means for assuring accountability.

**Coordinate effectively across all AURA activities.** Continually strive for a unified and coordinated suite of observing assets and a management structure that optimizes the community's use of, and influence over, these assets. AURA's consolidation of its business services and HR activities represents a major step in this direction. Closer coordination of AURA activities in Chile may be an evolving area of interest.

**Manage federal relations.** Enhance relationships with key policy making organizations such as Congress, the Office of Management and Budget, and the Office of Science and Technology Policy, as well as the funding agencies.

**Advocate for new construction projects.** Achieve success in ongoing and new construction projects such as DKIST and LSST, where success is jointly defined as facilitating the funding agencies to garner the necessary resources and bringing projects to completion on time and on budget.

**Enhance diversity in the workforce.** Be a national role model for diversity in leadership positions, and continually strive to diversify the current and future workplace through ongoing and new initiatives. Utilize the strengths embodied in AURA's Workforce and Diversity Committee to enhance current activities and develop new programs.

### Corporate Goals

- Fiscal responsibility for AURA centers and AURA programs.

- Recompetition wins in the coming decade: NOAO and Gemini.

[3] Portals to the Universe: The NASA Astronomy Science Centers, National Academy Press, 2007

• Construction projects completed on time and on budget in the coming decade: DKIST and LSST.

• Development of STScI segments of JWST operations completed on time and on budget.

• Coordination of AURA's existing facilities, e.g., for ground-based Centers, merging of the administrative and Human Resources services.

• Identification, assessment, and pursuit of new opportunities.

• Annual review of diversity metrics, application of both best practices and lessons learned, continuous improvement in diversity efforts.

## AURA Governance

Enable AURA's goals through execution of the following responsibilities.

**Engage stakeholders.** AURA must continue to be a proactive advocate for the interests of the broader observational astronomy community as well as the AURA Member Institutions community. AURA's governance model actively draws in community leaders, and puts them on the frontline of managing AURA's facilities. This strong linkage is unique, and reflects the core values of AURA.

**Identify new opportunities.** New scientific opportunities that take advantage of AURA's strengths and contribute to its mission will arise from formal competitions and from unsolicited proposals to funding agencies, as well as discussions with other entities and decadal surveys. Such new opportunities may emerge as consequences of the evolution of our existing Center missions, or may lead to the establishment of new Centers. Long-term business ideas should be continuously identified and discussed at the governance level.

**Governance Goals in the coming decade**

• NOAO participation in LSST, leading the "public astronomical community" perspective.

• STScI participation in a next-generation space telescope in the post-JWST era.

• NOAO participation in ground-based Extremely Large Telescopes (ELTs) for optical/infrared astronomy.

• NSO as focus for a robust solar physics academic and research community.

# Appendix A

Synopses of Center Activities (in alphabetical order)

# Gemini Observatory

## GEMINI MISSION/ROLES

**Gemini statement of purpose**. Exploring the Universe, Sharing its Wonders.

**Gemini mission statement**. To advance our knowledge of the Universe by providing the international Gemini Community with forefront access to the entire sky.

The specific requirements that determine Gemini's path forward, established by the Gemini Board, are:

- Deliver and operate high-quality instruments that represent the priorities of our community;
- Provide a high fraction of queue operations with appropriate data quality control, data products, and completion fraction;
- Have the ability to remotely operate the telescopes; and
- Better interface with the partner community.

Gemini will accomplish its mission by offering to its community a flexible observatory that supports state-of-the-art adaptive optics systems and reliable workhorse instruments covering a broad parameter space. Further, Gemini will provide easy access to more specialized instrumentation developed by its users.

Gemini will support flexible proposal opportunities aimed at enabling programs ranging from original ideas needing fast and flexible execution, to comprehensive studies requiring large amounts of time over long periods. The Observatory will offer a range of observing modes: visiting, queue, and remote observing, exploiting the full scientific potential of each.

Gemini will work to foster strong collaborations among the Gemini partner communities. By continuously evaluating the observatory efficiency and cost effectiveness, Gemini will maximize the value of this facility for its community.

## GEMINI CUSTOMER

The Gemini Observatory serves the Gemini funding agencies as influenced by the astronomical communities and the public through the Actions and Resolutions of the Gemini Board.

## GEMINI STRATEGIC ACTIONS

Maintain and enhance Gemini's performance and competitiveness as a world-class observatory through operational innovation, start-of-the-art facilities, and strong community engagement.

### Operations

Become the most flexible and scientifically productive optical-infrared ground based observatory.

Let the users' science drive the operational scheme, rather than the operational scheme constraining the users' science.

Offer multiple paths to apply for observing time (standard semester based calls; yearly call for large/long programs; fast turnaround proposals; and director's discretionary time).

Offer multiple modes of conducting the observations (queue mode opening the time domain and enabling targets of opportunity; classical mode allowing real-time decisions; priority visiting observing as a mix of both) supported by the best of each mode (eavesdropping on queue observations, remote observing in visitor mode, etc.).

Maintain a fully optimized operational model by being able to support multi-instrument observing every night.

Provide end-to-end science support to the community by maintaining a quality science staff able to execute the queue, optimize the instrument performance, and effectively manage the distributed support model in partnership with the National Gemini Offices.

**Instrumentation**

Provide facility class instruments from optical to near-infrared wavelengths, covering parameter spaces of both spatial and spectral resolving power as well as multiplexing capability.

Complement the facility class instruments with a vigorous visitor instrument program, enabling the community to conduct their own experiments on the Gemini telescopes.

Retain world leadership in the adaptive optics support of the scientific instruments.

Further optimize instrument and telescope performance to increase operational reliability and available science hours.

**Community**

Strengthen the Gemini partnership, allowing it to become more than the sum of its parts; enable long-term scientific collaborations between partners centered on Gemini's scientific strengths.

Nurture the relationship with neighboring observatories by exploiting opportunities that enhance the scientific potential of the Gemini Observatory; these may include sharing of time, instruments, development capability, or other resources.

Maintain an effective Public Information Office in the arenas of news, informal outreach, and informal education.

# Large Synoptic Survey Telescope

## LSST Mission

The mission of the LSST Project Office is to complete the construction and commissioning of the Large Synoptic Survey Telescope, which was the highest-ranked new ground-based project of the 2010 decadal survey[4].

## LSST Customer

The LSST Project must meet the science requirements, which were determined after consultation with the community of potential scientific users, while at the same time meeting the requirements of the two sponsoring agencies—the National Science Foundation and the Department of Energy—for completing the project within budget and schedule.

## LSST Context

**Approval/funding status**. At the time that this strategic plan is being written, the LSST Project has: 1) submitted a construction proposal to the NSF and project plans to the DOE; 2) successfully completed all agency reviews scheduled to date; 3) received approval from the National Science Board for inclusion of construction funds in a future NSF budget request; 4) been included for a new construction start in the President's FY 2014 proposed budget, which was submitted to Congress in April, 2013.

The integrated construction schedule assumes that NSF/MREFC funds will be authorized and available by July 1, 2014 and that the first article sensor contract can be issued in early calendar year 2014. With these assumptions, the camera will be completed and available on Cerro Pachon in mid-2020, at which point commissioning of the entire LSST system can begin. Full survey operations would then begin in October 2022 if all of the budgeted contingency time is used. Lack of timely approval of the annual required budget within the US federal funding system is one of the major threats facing this project.

**Key Personnel**. The Director for the construction phase of the project formally assumed his position effective July 1, 2014. A search for a Deputy Director is underway, and when that appointment is made all of the key senior personnel will be in place and ready to initiate construction.

**Preparatory work complete**. In advance of authorization of federal funding, private funds have been used to prepare the site on Cerro Pachón for the telescope and conduct geotechnical tests; acquire the secondary mirror substrate; and complete the fabrication and polishing to final figure of the primary/tertiary monolithic mirror.

[4] New Worlds, New Horizons in Astronomy and Astrophysics, 2010, National Academies Press, Washington, DC. http://www.nap.edu/catalog.php?record_id=12951.

**LSST Actions**

The key near-term actions are **successful completion of the NSF Final Design Review and the DOE CD-3a Review** in early FY 2014. Successful completion is a necessary (but not sufficient) condition for authorization to proceed to construction.

**Staff to support the construction phase of the project must be hired**. This will require hiring 20 additional staff in Tucson and 7 in Chile during the first 18 months of construction. Contracts that support a ramp-up at partner institutions, particularly in the area of data management, will also be required. The challenge of achieving this ramp-up is partially mitigated by the fact that we will convert some positions that are currently half-time to full-time.

The agencies have asked the project to **identify about one-third of the operations funding** from sources other than the NSF and DOE. We have received Letters of Intent from international institutions that would meet this goal, and the LSST Corporation will begin detailed negotiations in late CY 2013. Payments will be scheduled to begin two years before the start of survey operations.

Work with the science community in the U.S. and in partner countries is necessary to **ensure that researchers are prepared to use LSST survey data** effectively and efficiently as soon as it comes on line. The construction project does not include specific funding for this effort, but it does include funding for testing and validating data management products. Validated products and documentation will be made available to the community. The LSST Corporation, partner institutions such as SLAC and NOAO, and the LSST science collaborations will play an essential role in engaging and supporting the community in working with these early data products. The LSSTC has established a task force to develop a strategic plan for how the corporation will work with the science community to prepare to use the survey data. This plan with metrics and milestones will be completed by the end of CY 2014.

# National Optical Astronomy Observatory

## NOAO MISSION/ROLES

NOAO is a national center for research in ground-based, nighttime, optical and infrared (O/IR) astronomy. Its core mission is to facilitate access for all qualified professional researchers to state-of-the-art O/IR observational capabilities and data products as well as tools for data processing, data access and data mining. Through such access, NOAO enables world-leading research programs that address a broad range of modern astrophysical challenges from small bodies in the Solar System to first stars in the early universe to the nature of dark matter and dark energy and how they have shaped cosmic evolution.

## NOAO CUSTOMER

NOAO serves the U.S. astronomy and astrophysics community of research scientists and their international collaborators within a programmatic and financial framework established by NSF. The NSF framework is often extended by partnerships with DOE and NASA, or the centers and projects they sponsor.

## NOAO CONTEXT

**Science Leadership**. The NOAO user community and NOAO scientists are leaders in many research fields, with particularly high impact in the areas of:

- Dark energy characterization
- Time-domain exploration and characterization
- Galactic archeology
- Resolved stellar populations
- Near Earth Object (NEO) detection, characterization, classification
- Demographics of supermassive black holes
- Galaxy formation and evolution in the early universe

**O/IR System Leadership**. The US O/IR System is the ensemble of all U.S.-led ground-based optical-infrared observatories. NOAO fosters System operation, development and coordination in the following ways:

- Organizes broad, inclusive virtual and face-to-face public discussions of topics such as LSST follow-up plans, instrumentation and AO development roadmaps, and at-large involvement in new, international mega-projects;
- Operates that physical infrastructure (e.g. roads, grounds, buildings, IT, power, water) on Kitt Peak, Cerro Tololo, and Cerro Pachón that is the critically enabling foundation for a broad range of university, national, and international research facilities;
- Operates and/or provides high-impact research capabilities and tools such as: Mayall and Blanco 4-m telescopes; IRAF; wide-field near-IR and optical imaging systems (Mosaic, DECam, NEWFIRM, soon LSST); wide-field optical spectroscopy (Hydra, soon DESI);

- Trains future leaders in O/IR research and technology; many past NOAO employees are key leaders at front-line universities, facilities, and projects;
- Retains critical management and technology knowledge that is called upon regularly by the federal agencies as well as institutions throughout the U.S. O/IR System.

**Leadership in Innovation**. NOAO has a long history of innovation leadership in facilities, technologies, and data systems. Motivated in large part by our LSST user support mission, during the current survey preparation phase as well as the survey execution phase in the 2020s, NOAO is currently developing:

- Calibration pipelines for state-of-the-art wide-field imaging systems;
- Improved user interfaces for object catalogue exploration and data mining;
- Software systems for time-domain exploration;
- Operational concepts for spectroscopic follow up of time-domain phenomena.

**Leadership in Education**. NSF strongly encourages NOAO to promote public education, understanding, and support of astronomy, and NOAO has a strong track record of success in these areas. **Funding Outlook**. For the period FY16 – FY25, NOAO base funding from NSF is expected to be constant in terms of purchasing power. Base funding will be augmented by supplementary awards from NSF, DOE, or NASA for specific non-base activities. For example, DESI operations will be funded by DOE.

**NOAO ACTIONS AND TOP-LEVEL GOALS**

NOAO's scientific leadership will be maintained and extended over the next ten years through the deployment and operation of three world-class wide-field imaging and spectroscopy facilities:

- Dark Energy Camera (DECam) on the CTIO Blanco 4-m
- Dark Energy Spectroscopic Instrument (DESI) on the KPNO Mayall 4-m
- Large Synoptic Survey Telescope (LSST) System

Those three capabilities and the data they produce will be used by thousands of users in tens of countries in the pursuit of myriad PI-class "discovery" projects as well as many large national and international collaborations investigating key scientific frontier challenges such as the nature of dark energy over the last 10 billion years and how the Milky Way galaxy was assembled in the early Universe.

NOAO will remain the U.S. gateway to the Gemini Observatory as well as the point of public access to other world-class large aperture facilities (e.g. Keck, Large Binocular Telescope, Magellan, MMT) as NSF funding permits.

As anticipated by several recent high-level review panels, NOAO aspires to be the federal community gateway to TMT if and when a NSF/TMT partnership emerges. Towards that end, NOAO has established a US TMT Liaison office in order to engage the community in scientific and outreach planning.

In the realm of education and outreach, NOAO shall:

- Seek to offer unique undergraduate-level program opportunities in astronomy and in related STEM fields, in collaboration with partner colleges and universities
- Continue to focus on local engagement, especially with the Tohono O'odham Nation in Arizona, and with Chilean students in the Región de Coquimbo
- Continue internationally recognized dark skies educator development program
- Continue and extend mountain-based public visitor programs

**ACTIONS in 2020 and beyond.**

Looking towards 2020 and beyond, the highest priorities for NOAO are:

- Complete Dark Energy Survey, in concert with our DES Collaboration partners;
- Deploy and commission DESI, and initiate DESI Survey, in concert with our DESI Collaboration partners;
- Deliver and commission LSST System, in concert with our LSST partners.

In addition to steady-state operations & maintenance activities discussed above, other key NOAO deliverables in this period are:

- Complete 5-year program to develop framework for NSF/TMT partnership
- Tools and processes for efficient time-domain follow up of rare events (with emphasis on LSST event stream)

# National Solar Observatory

## NSO MISSION/ROLE

NSO will support and lead community research into the nature of the Sun by providing critical ground-based optical capabilities. NSO's unique facilities will include the world's largest solar telescope and a network of full-Sun imaging spectrometers to continuously observe the Sun's structure and evolution. A resident scientific staff will support both the development and exploitation of these facilities and a diverse community of users.

Through the development and operation of enhanced and new observing capabilities, NSO provides the space weather community with the data needed to monitor, model, and understand solar activity and variability.

## NSO CUSTOMER

As the National Observatory for Solar Astronomy, the NSO serves the science community and the public on behalf of the National Science Foundation as the primary funding agency, with contributions from NASA, DOD, and other US agencies.

## NSO CONTEXT

**Funding environment.** There is strong competition for project and operational resources at the NSF; multiyear operations and projects are challenging in the context of annual budget allocations; and the increasingly complex and sophisticated operations require enhanced funding. These challenges are not unique to the NSO, but NSO is directly affected by all of them.

**Scientific community environment**. The establishment of new domestic and foreign facilities dedicated to advancing our knowledge of the Sun is a positive development for the field of solar physics, and other closely related fields. The NSO encourages and supports these additions to the public and private capabilities in solar physics: for example, NSO collaborated with the privately-owned Big Bear Solar Observatory, which currently hosts the world's largest solar telescope, to enhance that facility's adaptive optics capabilities. The NSO adds complementary capabilities in solar astrophysics that are not within the plans or scope of other programs but are highly desired by the scientific community.

**Strategic strengths of the current NSO**. A key strength of the NSO is its scientific staff that engages in frontier research, actively and visibly participates in the community, develops advanced instrumentation for the NSO's world class facilities, participates in educational outreach, and establishes new initiatives. Of equal importance is community confidence in the NSO as expressed in the Solar Physics Decadal Survey's[5] endorsement of the NSO organization and its proposed initiatives. A further strength is that, as a federally funded research and

[5] Solar and Space Physics: A Science for a Technological Society, 2013, National Academies Press, Washington, DC. http://www.nap.edu/catalog.php?record_id=13060.

educational institution, the NSO is able to provide leadership, continuity and stability for the conduct of long-term programs and projects that are a scientifically necessary component of solar and solar-terrestrial research. Finally, the interdisciplinary nature of, and multi-agency participation in, solar astrophysics enables the formation of productive partnerships with the NSO that result in a stronger and broader-based program.

**The needs of stakeholders other than the primary customer**. The NSO will be responsive to the space weather community in addition to the solar astronomy community. NSO receives funds from other (non-NSF) agencies for co-located scientists. This synergy enables a broader range of science in the NSO than would otherwise be possible. The NSO must be sensitive to the requirements of its partners and ensure that their objectives are compatible with the NSO mission. The NSO must also be sensitive to the quality of the scientific environment of its staff that, in turn, contributes to the quality of its interactions with the community.

NSO will actively **promote the creation of a university-level curriculum in Solar Physics** that helps to educate, empower, and inspire the future generations of researchers for the DKIST era. We envision a broad curriculum in Solar Physics that covers theory, observations, instrumentation, and space physics. This involvement is best materialized by close collaborations with universities to further expand the scope of NSO contributions in education. The NSO also trains high school teachers in current research topics through its participation in the Research Experience for Teachers.

**NSO ACTIONS AND TOP-LEVEL GOALS**

As top priorities, NSO will:

**Develop and operate the Daniel K. Inouye Solar Telescope** (DKIST) as the premier ground-based facility for high-resolution studies of solar magnetism and atmospheric dynamics.

**Engage the community in maintaining a Solar Synoptic network**; NSO's Integrated Solar Program (NISP) provides crucial insights about solar variability at all scales and its impact in the surrounding planetary environments.

Use the opportunities provided by DKIST and NISP to **promote a strong connection to university programs in solar physics** in order to leverage and further develop the future community of solar astronomers. Develop and strengthen connections with the university researchers and educators in solar physics; assist them in strengthening their programs through participation in the NSO program of research, education, and the implementation of new scientific capabilities. Promote NSO staff involvement in undergraduate and postgraduate university programs.

Develop the **NSO's Data Center** to effectively provide community access to the data acquired at NSO's facilities in an efficient and integrated manner that combines global observations and high-resolution data sets.

NSO will also:

**Increase diversity within the NSO** by recruiting minority and female candidates for openings as they occur. In collaboration with our institutional partners, ensure that the scientific staff directly involved in NSO research covers a wide range of aspects from theory to observations, and from numerical modeling to state-of-the-art analysis tools.

Partner with NASA and universities to **develop a Virtual Solar Observatory** (VSO) that provides community access to all aspects of solar data.

**Continue NSO scientific and instrumentation leadership** by balancing staff responsibilities, increasing staff opportunities for research and postdoctoral support, developing strong university collaborations, and strengthening partnerships with other solar organizations.

Maintain, upgrade, and/or divest existing facilities as needed to **ensure continued scientific productivity** until future equivalent assets (i.e., DKIST) are in place.

Through discussions with the funding agencies, proposals for new opportunities, and shared efforts with other solar groups, **advocate for an NSO budget** to sustain and enhance NSO operations and programs that support the solar and space science community.

# Space Telescope Science Institute

## STScI MISSION

Our mission is to enable excellence in astronomical research by optimizing the science from state-of-the-art observational instruments in space.

## STScI CUSTOMER

Our customer is NASA as influenced by the astronomical community and the public.

## STScI CONTEXT

**Funding changes or limitations**. Efforts are underway to extend HST's lifetime to overlap with JWST. Nevertheless, HST's lifetime is limited and the STScI staff size will diminish. There are no other missions on NASA's current planning horizon of a scale similar to Hubble and JWST. NASA's paradigm in the current budget environment is to operate fewer flagship missions of the type STScI operates.

**Competition**. There are Great Observatories that have science centers with their own operating models, and these have a similar outlook to STScI. Changes in accounting at NASA may also allow some NASA Centers to appear more competitive for science operations.

**Strategic Strengths:**

STScI runs HST, the most scientifically productive facility in astronomy; HST occupies an exceptionally broad observational capability space.

The HST TAC and GO grant processes and procedures are trusted by the community.

The STScI's Office of Public Outreach (OPO) is acknowledged as one of NASA's most successful outreach and education programs. OPO is a national center for astronomy education and outreach in astronomy.

STScI has a contract to run JWST, the highest priority mission in the National Academy of Sciences' Decadal Survey, Astronomy and Astrophysics in the New Millennium (2001).

The scientific and technical staff at STScI are consistently world-class.

**Current Opportunities:**

STScI is evolving into a multi-mission UV/Optical/IR science operations center.

STScI has attracted a high caliber of staff with the expertise to optimize JWST's IR performance and with a strong interest in exploiting and enhancing JWST's unique ability to contribute to a broad range of science.

The combination of STScI's traditional strengths in UV/O astrophysics and our growing expertise in infrared, exoplanet, and optics research allows the Institute to provide unique leadership in future missions which synthesize these fields.

**External factors or trends affecting future levels of spending by funding agencies**

The United States is running a large budget deficit that puts downward pressure on discretionary spending for agencies such as NASA.

There exists a continuing uncertainty regarding NASA's mission.[6]

US investment in space science is unlikely to grow over the next decade, and any growth has shifted its strategic focus to Earth sciences.

Though the search for habitable exoplanets is of increasing interest to NASA and the community, this requires considerable investment in enabling technologies (large telescopes, high-contrast imaging approaches).

Theere is some uncertainty in the timescale for NASAs plan for developing large rockets that could launch a large (8-16m) telescope.

The NASA astrophysics program has no present plan for a future major UV/optical observatory.

**Government requirements and the organization's desire to meet the needs of stakeholders other than the primary customer**

Public education and stimulation of student interest in science, engineering and mathematics are high priorities of government programs.

Government places a high priority on developing and fairly employing a diverse national workforce.

Increased federal requirements for accountability, compliance and IT security have significantly increased the complexity of STScI's auditing and regulatory environment.

**STScI ACTIONS**

**1) Business Base Actions**

*Missions*

- Maintain HST as the world's leading observatory.
- Develop and support the mission operations and science program of the James Webb Space Telescope.

[6] See, for example, "Destination Unknown," a series of review articles by Washington Post writer Joel Achenbach in late 2013: http://www.washingtonpost.com/sf/national/collection/destination-unknown/.

- Operate a world-class archive and, in partnership with universities, AURA Centers and other institutions, maximize the science return of community-based astronomy projects.
- Stimulate astronomy education and public outreach in support of NASA's missions.
- Lead in defining and advancing the next major astronomical mission(s) and establish with NASA and the community why such STScI leadership and involvement is critical.

*Science*

- Maintain and enhance the strong science culture which infuses everything we do.
- Invest in science staff and science programs that will inform our future directions.

*Innovation*

- Pursue creative and innovative solutions to science operations challenges.
- Foster new instrumentation and new mission concepts.
- Use new technology to increase access to astronomy data and information.

*Workplace*

- Attract and retain outstanding staff.
- Provide an invigorating, inclusive and exciting work environment.
- Provide staff training and mentoring to better understand our strategy and values.

*Community*

- Serve as a trusted advocate of the astronomy community to NASA.
- Working with the community and NASA, provide leadership for the next the next major UVOIR mission(s).
- Maintain, enhance and create new partnerships with complementing institutions.
- Encourage public interest in science, technology, engineering and mathematics.
- Develop partnerships to expand astronomy outreach in the greater Baltimore area.

**2) Competitiveness Actions**

- Maintain the trust of the community through transparency and accountability.
- Enhance STScI cost effectiveness while preserving the scientific and technical excellence that gives us a competitive advantage for mission support.
- Support community-led astronomy programs, and enhance our core competencies and contributions.
- Support internal studies for the development of new technologies for planet detection and characterization, and for the next flagship mission to characterize planets and search for life.

# Appendix B

## Glossary of Acronyms

AO – adaptive optics

AUI – Associated Universities, Inc.

AURA – Association of Universities for Research in Astronomy, Inc.

CTIO – Cerro Tololo Interamerican Observatory

CY – calendar year

DECam - Dark Energy Camera

DESI - Dark Energy Spectroscopic Instrument

DKIST – Daniel K. Inouye Solar Telescope

DOD – Department of Defense

DOE – Department of Energy

ELT – Extremely Large Telescope

FITS –Flexible Image Transport System

FY - fiscal year

GO – Guest Observer

HR – human resources

HST – Hubble Space Telescope

Hydra – a multi-object, fiber-fed spectrograph, Cassegrain instrument

IR - infrared

IRAF – Image Reduction and Analysis Facility

IT – information technology

JWST – James Webb Space Telescope

KPNO – Kitt Peak National Observatory

LSST – Large Synoptic Survey Telescope

MAST - Barbara A. Mikulski Archives for Space Telescopes

MMT - 6.5-meter telescope on Mt. Hopkins (was "multiple mirror telescope")

Mosaic -an 8k x 8k pixel wide-field imager

MREFC – Major Research Equipment and Facilities Construction

NASA – National Aeronautics and Space Administration

NEO – near-earth object (comets or asteroids in the vicinity of Earth)

NEWFIRM – a near-IR imager with an 28 x 28 arcmin field of view

NISP – NSO Integrated Solar Program

NOAO – National Optical Astronomy Observatory

NSF – National Science Foundation

NSO – National Solar Observatory

O/IR – optical and infrared

OPO – STScI's Office of Public Outreach

SLAC – SLAC National Accelerator Laboratory (was "Stanford Linear Accelerator")

STEM – Science, Technology, Engineering, and Mathematics

STScI – Space Telescope Science Institute

TAC – Time Allocation Committee

TMT – Thirty-Meter Telescope

UV - ultraviolet

UV/O – ultraviolet and optical

UVOIR – ultraviolet, optical, and infrared

VAO – Virtual Astronomical Observatory

VO – Virtual Observatory

VSO – Virtual Solar Observatory