PROVISIONAL PROGRAM PLAN
FY 2001

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NOAO Provisional Program Plan FY 2001: Table of Contents
The NOAO Program Plan for FY 2001 outlines plans for initiating work on the major projects recommended by the Astronomy and Astrophysics Survey Committee; ramping up user support for Gemini North and South; and continuing operations of the major telescopes at KPNO and CTIO, including developing a new wide-field IR imager and a wide-field high efficiency multi-object spectrograph.

More specifically, in FY 2001, NOAO will:

- Work with the community to define the scientific requirements for a 30-m Giant Segmented Mirror Telescope and let study contracts to identify the key technical challenges in optical design, structures, and controls. We will work closely with Gemini staff to coordinate studies of technical issues and Adaptive Optics (AO) requirements.

- Work with the community to develop a proposal for a Large Synoptic Survey Telescope.

- Work with the community to prepare and update road maps for AO, the National Virtual Observatory, IR detector array development, and other activities where multiple institutions must work together to achieve a common set of goals.

- Sponsor a workshop, co-chaired by Alan Dressier (who chaired the OIR panel of the AASC), to explore the implications of the Survey recommendation that the US ground-based observatories, federal and independent, should constitute an “observing system.”

- Support US users of the Gemini facilities by reviewing observing proposals, assigning instrument scientists to help US users to optimize their observing strategies, and providing assistance with data reduction software. We will also enable “one-stop shopping” for observing time for the SIRTF First Light Survey and Legacy programs, for some selected portion of the Chandra programs, and for HST programs that require ground-based data—with the goal of optimizing a single-proposal observing system.

- Provide management oversight of the several Gemini instruments being built in the US (a mid-infrared imager/spectrometer, the near-infrared coronagraphic imager, and a wide-field near-infrared imager/multi-object spectrometer) and continue construction of the Gemini Near-Infrared Spectrometer.

- Establish partnerships with universities to provide access to wide-field near-IR imagers north and south and to build a wide-field optical spectrograph, with these instruments to be shared between the Mayall and Blanco telescopes; complete work on other instruments for the NOAO 4-m class telescopes, including the WIYN Tip/Tilt System and the Blanco Infrared Side-Port Imager.

- Support the 10 groups conducting surveys with NOAO facilities and ensure that the data sets are made available to the US community through suitable archiving arrangements.

- Support the installation of SOAR at Cerro Pachón.

A description of these activities and a more detailed list of milestones for FY 2001 are given in the plan that follows.
The following plan describes in detail what NOAO proposes to accomplish in FY 2001 with funding of $22.0M, which is the amount allocated to the nighttime program from the combined NSO and NOAO budget request submitted by the President to Congress.

This is the first NOAO Program Plan to be submitted after publication of the Astronomy and Astrophysics Survey Committee report on priorities for the first decade of the new century and is designed to begin implementation of the AASC recommendations.

Perhaps the most significant of the AASC recommendations is that the independent observatories and NOAO must work together in new ways to develop a single, integrated, observing "system" that makes effective use of both federal and non-federal funding sources. Implementing this observing system will require: (1) strategic planning to guide the development of the system; (2) funding for that development; and (3) mechanisms to provide broad community access to the system and its components.

The AASC also recommends federal investments in: (1) a 30-m class telescope (the Giant Segmented-Mirror Telescope or GSMT); (2) a Large Synoptic Survey Telescope (the LSST); (3) the National Virtual Observatory (NVO); and (4) facility class instruments at the independent observatories. The first three initiatives transcend the capabilities of any single institution. In this plan we outline the requirements for initiating these ambitious programs, both in terms of funding requirements and community involvement.

The fundamental principle that underlies NOAO program planning is that the telescopes we operate, the capabilities that we offer to the community, and the facilities that we plan to build must play a vital and complementary role in the national observing "system"—which also includes the Gemini telescopes, the independent observatories, and NASA missions. The observing system concept is reflected in our choice of instruments, in new approaches to telescope scheduling, and in our reliance on community partnerships to develop new telescope concepts, data management and data mining tools, and innovative instrumentation.

The implementation of this plan requires new modes of working with the community. In particular, we are basing our approach to the next generation of large ground-based telescopes on the model used in the early 1980s for development of mirror technologies for 8-m class telescopes. In this model, NOAO will serve as facilitator and coordinator of the overall effort, which will rely primarily on placing study contracts with university groups and industry. NOAO will conduct in-house technical programs only in those areas either where we are best qualified to do the work or where external options are not available.
INTRODUCTION

Initiatives in data management are central to addressing large-scale scientific problems, such as the origin and evolution of galaxies and structure. Again, we see the techniques for data mining and tools for sophisticated querying of multiple databases of ground-based observations being developed in the community, with NOAO providing the structure that ensures common standards, optimization of multiple distributed efforts, and community access to the results.

The instrumentation program presented here is designed to complement what will be available at the independent observatories. The instrumentation for Gemini North and South emphasizes narrow field diffraction-limited imaging and spectroscopy in the near-infrared in order to take advantage of the Gemini design, which is optimized for this type of science. The optical instrumentation for Gemini is complementary to what is available on other large US telescopes in each hemisphere. We estimate that at least one-third of the NOAO and Gemini instruments—and possibly considerably more depending on our success in finding capable external groups—will be built outside NOAO.

We have also worked with Chandra, SIRTF, and HST to enable “one-stop shopping” for observing time for the SIRTF First Light Survey and Legacy programs, for some selected portion of the Chandra programs, and for HST programs that require ground-based data—again, to realize the advantages of an observing system. The goal is to ensure that all of the observations, both ground- and space-based, required to solve a scientific problem can be obtained through a single proposal process.

The changing emphasis of the NOAO program requires a change in the administrative structure of NOAO. To this end, we have established a new project group. Under the leadership of Steve Strom, the Planning and Development Office (PDO) is focused on strategic planning, initiatives, and development. Within PDO, the two major programs are (1) Surveys and Data Management (SDM), which is responsible for supporting science of scale, with emphasis on data pipelining, archiving, and data mining; and (2) early development of the GSMT, with emphasis on defining a design reference mission, establishing the flowdown from science goals to design requirements, and formulating a plan for technology studies. We will also undertake analogous set of tasks for the LSST.

The FY 2001 program proposed here is divided into two broad components: (1) programs that will provide new capabilities, including telescope initiatives and new instrumentation, to the community and (2) programs that support principal investigators and their access to existing facilities. In order to keep this plan to a readable length, we describe the major program components briefly, emphasizing key issues and changes in program content relative to last year. An extensive science justification is prepared before new projects are included in the Program Plan, and those justifications can be made available on request.
**NEW CAPABILITIES**

This section highlights the new capabilities being developed at NOAO on behalf of the community. First we describe work on the major initiatives recommended by the AASC. Then we outline plans for the SOAR telescope. The Gemini and NOAO instrumentation programs are described in the subsequent section.

**Giant Segmented Mirror Telescope (GSMT)**

With the start of science operations at Gemini North and the imminent completion of Gemini South, it is time to begin planning for the next major ground-based telescope. ESO and Caltech have already begun planning for 100-m and 30-m telescopes, respectively. If the US national community is to have significant input into the next generation of large telescopes, it is clear that we must begin now to make some investment in defining the scientific requirements for a major new facility and initiating the technical studies needed to ensure that such a facility can be built with confidence in terms of both cost and budget.

Working closely with the staff of the International Gemini Project, NOAO has taken the lead in establishing a New Initiatives Office (NIO) charged with exploring these issues. Several workshops have already been held to address both scientific and technical issues, and an approximate budget for the studies required in the early phases of this project has been developed (see Appendix F).

We understand that issues relating to ALMA must be clarified before a proposal for significant funding will have any chance of success at the NSF. However, we want to point out the following. The GSMT is likely to be built in partnership with either US universities and/or independent observatories and/or other countries. In order to be an attractive partner—as well as a "smart buyer"—NOAO must make some investments in formulating the science requirements and evaluating key technical issues on a time scale that is commensurate with other initiatives. These costs are relatively modest: about $1.5M/year for the first three years.

Appendix F summarizes what would result from this investment. In general, we expect to focus initially on defining a design reference mission and examining systems issues relating to the design of the telescope. As a result of these studies, we would expect to develop the following:

- The proceedings of a workshop defining science programs/opportunities;
- A flowdown from science requirements to requirements for telescope system, AO, and site selection;
NEW CAPABILITIES

- Point optical designs that would provide for diffraction-limited imaging with multi-conjugate AO and for reasonable fields of view (up to about 20 arcmin).

- An analysis of the requirements for the control system, including especially the requirements for maintaining diffraction-limited images;

- An assessment of competing conceptual approaches for the next facility (e.g., a scaled-up version of the HET; a Keck-like instrument; adaptive secondary and possibly primary, etc.).

A number of major issues must be resolved before we can decide what should be built by the US. ESO currently plans to proceed directly to a 100-m telescope because they wish to use natural guide stars for adaptive optics correction. Thus, very large aperture and a substantial field of view are required to access enough natural guide stars. The US community is focusing on 30-m class telescopes because we are more optimistic about the use of lasers for adaptive optics. A 30-m aperture would be extremely valuable for spectroscopy, particularly in support of NGST, and it could be built much sooner than a 100-m telescope. If we use technology in building the 30-m that is extensible to larger aperture, then we can also lay the groundwork for an ultimate 100-m telescope.

The two critical technical issues in moving to larger aperture are: 1) adaptive optics and 2) the control system. What kinds of controls on what part of the structure will be necessary to maintain image quality in the face of wind-buffeting and other disturbances? Other problems to be addressed concern the efficient manufacture of glass and optical surfaces, the control of the optical surfaces, and the feasibility of instruments, especially for those times when diffraction-limited performance is not possible because of atmospheric conditions. It is necessary not only to develop the requisite technological solutions but also to break the current cost curve. If we assume that an 8-m telescope costs $50M and use the usual scaling law that telescope costs increase with the 2.5 power of the aperture, then a 30-m telescope would cost nearly $1.5B. The goal is to cut this cost by about a factor of 3.

The GSMT must be placed at a superb site. The two most likely locations are Mauna Kea, which is already fairly well characterized, and northern Chile. Although excellent sites have already been identified in northern Chile (Tololo, La Silla, Pachón, Paranal, Chajnantor), we must identify the most suitable site based on the scientific priorities and technical attributes of the GSMT. CTIO has established a Site Working Group with participants from outside NOAO. In FY 2000, this group produced a detailed, costed, multi-year, site testing plan for both Mauna Kea and Chile. ESO participation in the working group has resulted from the recent informal agreement between AURA and ESO to collaborate on GSMT studies.
In early FY 2001 the results of an analysis of eight years of archival satellite cloud data will be completed via a contract with the leading expert in this field. Together with terrain analyses and modeling, and meteorological measurements where available, a short list of potential sites in northern Chile will be produced.

In FY 1999 and 2000 weather stations and Differential Image Motion Monitors (DIMM) were purchased and assembled, and additional equipment will be procured in FY 2001. CTIO will participate in Cornell-led site testing campaigns in the Chajnantor (ALMA) region in late FY 2000 and in FY 2001. General testing of the vertical structure of the atmosphere will begin in collaboration with Gemini, as the GSMT will be dependent on AO to correct the atmospheric wavefront, and possibly also the telescope structural deformation under wind-loading. Systematic testing of individual sites will begin when scientific and engineering studies better define the required site characteristics.

Large Synoptic Survey Telescope (LSST)
NOAO has joined with Steward and Lowell in exploring the feasibility of constructing an extremely wide-field 8-m class telescope for very deep imaging in the optical and non-thermal near infrared, and input on this possibility was provided to the OIR panel of the AASC. The field of view would be 3 degrees. NOAO and Steward have already sponsored a workshop to define the scientific goals, and the major theme that emerged from that workshop was mapping non-luminous matter in the universe from our solar system out to a redshift of \( z = 1 \). The decade survey highlighted the role of such a telescope in discovering Earth-crossing asteroids. In ten years, it would be possible to discover approximately 90 percent of the near-Earth objects to a diameter of 300 m—that is, the objects capable of doing significant damage. The operational mode would be to scan the entire sky every few nights with short exposures (20 to 100 s). This same observing strategy would make it possible to characterize the objects in the Kuiper belt, and thereby study the fossil remnants of the formation of the solar system.

As a follow-on to the AASC recommendation, NOAO, Steward, and Lowell will sponsor a second workshop to understand whether it is possible to reconcile the telescope requirements and operational strategies for the solar system programs with the requirements for deep mapping of the universe. By summing of exposures or other operational approaches in order to reach to magnitudes as faint as 29, it would be possible to map the dark matter in a cone to \( z = 1 \) through the use of weak lensing while exploring the domain of variable objects in a completely new way.

NOAO expects to partner with Steward and Lowell in preparing a proposal for the LSST, with NOAO taking the lead in developing the plans for instrumentation and
data handling, both of which present very substantial challenges. The construction of
the telescope itself involves limited technical risk.

The National Virtual Observatory (NVO)
The primary technical challenge presented by the LSST is that of developing
methods for acquiring, reducing, distributing, and querying a petabyte database.
The AASC recognized the importance of large databases, such as the one that will
be produced by the LSST, by recommending the establishment of the National
Virtual Observatory (NVO).

The NVO is a community-based initiative that has the goal of nationwide electronic
access to astronomical data archives, survey databases, and data analysis tech-
niques through a coordinating entity that provides common standards, wide
bandwidth, and state-of-the-art analysis tools. With the advent of new observing
facilities at wavelengths from the radio to the x-ray regions, coupled with
advanced instrumentation techniques, it is clear that a vast new array of data sets
will soon be forthcoming at all wavelengths. It is essential that these very large
databases be archived and made available in a systematic and uniform manner;
only in this way will the full potential of the new observing facilities be realized.
It is the aim of the NVO to provide the framework for this nationwide access to
the various data archives by facilitating the standardization of archiving and data
mining protocols and by taking advantage of state-of-the-art advances in data
handling software that are being made in astronomy and in other fields, such as
biology and earth resource sciences.

With its experience in the development and distribution of IRAF, its undertaking
of the NOAO Deep-Wide Survey, its support of community-based surveys, its
proposed liaisons with the SIRTF and Chandra missions, and its links to one of the
two national supercomputer centers, NOAO is developing the staff and skills set
required to play a key role in the implementation of the ground-based components
of the NVO. The NVO is currently in the early stages of definition, and NOAO is
working with the community on the development of models for managing the NVO
in these early phases. As the NVO becomes more mature, NOAO can contribute
to the data archives from its own facilities—including the Gemini telescopes—and
it can also assist in the development of NVO protocols and tools. As a national
center, NOAO can act as portal to the NVO for the US ground-based optical and
IR community. In addition, NOAO can assist in establishing the needed links
between ground-based and space-based initiatives to ensure compatibility of the
data sets and analysis tools that will be made available through the NVO. A strategy
for implementing the NVO is presented in Appendix G.
NOAO has worked with the community to prepare a white paper describing the scientific goals of the NVO, a phased program for implementation, and a structure for managing a distributed effort. This white paper was presented to NSF and NASA in May 2000. Appendix G provides more detailed financial requirements for development of the NVO.

During FY 2001, NOAO will continue activities that lay the groundwork for its contribution to the ground-based component of the NVO. These initial efforts are centered around the program to support large-scale surveys on NOAO telescopes. Ten survey programs from two rounds of applications have now been approved, with data from these observations to become publicly available after a short proprietary period. One of the survey programs recommended by the TAC is the NOAO Deep-Wide Survey, a deep optical and near-IR (Bw, R, I, J, H, K) imaging survey of 18 square degrees of the sky with the primary goal of studying the evolution of large-scale structure from \( z \sim 1 \) to \( z \sim 4 \). This survey will also make it possible to investigate the formation and evolution of the red-envelope galaxy population, detect luminous distant star-forming galaxies and quasars, and address many other scientific goals. Information on the progress of the survey is available through the NOAO home page, and the first data release should take place before the end of FY 2000.

In order to support the NOAO Deep-Wide and other surveys, NOAO is in the process of developing pipelines for processing of both IR and optical data. The basic pipelines will have to be tuned to meet the particular needs of the ten ongoing surveys. This summer we will be meeting with the survey groups to define their requirements and also to evaluate their capabilities for developing software that can be incorporated into the publicly available pipelines. Ultimately, we also wish to process according to standard protocols all of the CCD Mosaic Imager data, both north and south, and make all these data available to the community, probably through the STScI archive, after a proprietary period of not more than 18 months. After working with the survey groups, we plan to submit a proposal to the NSF to support this activity.

Early involvement with targeted surveys like the ones currently ongoing at NOAO will lay the groundwork for the much more challenging problem of handling data from a facility like the LSST. We are currently exploring possible partnerships to conduct a survey over a larger area of the sky than is covered by the NOAO Deep-Wide Survey. We are especially interested in identifying a program that would search for variable objects, since this program could be used to explore many of the issues that will have to be resolved for the petabyte databases that will be produced by the LSST.

In the longer term, there are two possible levels of NOAO involvement in the NVO. First, NOAO could act as a node of the NVO, focusing exclusively on the work...
required to incorporate data taken at NOAO into the NVO with suitable interfaces. The second option is for NOAO to serve as the coordinating entity for NVO for all US ground-based OIR astronomy, including such shared observatories as SOAR and WIYN, and potentially for the independent observatories as well. In this role, NOAO would work actively with NVO to address issues of standards and protocols and act as an advocate for the US OIR community within the NVO. NOAO expects to respond to announcements of opportunity or calls for proposals that would support either of these two levels of activity.

Software Development and Maintenance
Many of the new initiatives and directions on which NOAO is embarking depend on large, complex software systems. While NOAO pioneered such systems with the development of IRAF—which has grown to include applications from data acquisition to archive pipelines—it is clear that a broader set of goals requires a different structure. As a result, the software resources of NOAO are being reorganized to address diverse activities such as participation in the NVO (preparing the O/IR ground-based community by establishing archives and the associated tools), the data processing and distribution aspects of the LSST, and the development and support of new data reduction packages for the instruments on the Gemini telescopes. The main components of this reorganization of NOAO software resources are:

The separation of operations/maintenance and development activities. Currently operations/maintenance tasks required to support the many extant IRAF sites and packages use a majority of each programmer’s time. The goal is to limit this activity to a small number of support experts and free up the majority of the group to develop new applications.

The creation of small development groups to plan, design, and carry out the development of new software applications. These groups will be fluid, and, in order to ensure the appropriate expertise is available, some programmers will split their time among several groups.

A more formal software prioritization mechanism. As software and software development become a critical aspect of NOAO’s highest priority projects, it is essential that decisions about priority and precedence are linked to the goals of the organization. A scientific advisory committee will review progress and make recommendations on potential future projects.

It is expected that this new structure will allow a broader focus for the IRAF group activities, and will provide more effective resource allocation and a more apparent connection to organization-wide priorities.
Southern Astrophysical Research (SOAR) Telescope

The SOAR project has as its goal the construction of a 4-m class telescope with superb image quality. The telescope is being designed to complement the Blanco 4-m telescope, which offers a wide field of view and has been retrofitted to provide very good image quality (median FWHM ~ 0.9 arcsec), but the ultimate performance of which is limited by the technology with which it was built. The partners in the SOAR project are CNPq - Brazil (the Brazilian federal science funding agency), the University of North Carolina, Michigan State University, and NOAO. The financial contributions of the partners to construction, commissioning, instrumentation, and operations are such that NOAO and Brazil will each receive 30 percent of the observing time. UNC and MSU will receive approximately 15 percent each, and the remaining 10 percent will be allocated to Chilean astronomers in accordance with the agreement under which AURA operates in Chile. The SOAR facility will be located on Cerro Pachón about 300 meters distant from Gemini South. The project team has been established at NOAO headquarters in Tucson and is headed by Tom Sebring, who was previously project manager for the Hobby-Eberly Telescope.

The primary technical challenge of this project is the very tight specification on image quality (0.18 arcsec FWHM system performance). The telescope mirror is a 4-inch thick meniscus that is 4.3 meters in diameter. There will be active thermal and support systems for the primary and a tip/tilt tertiary. The telescope will have one Nasmyth port that can accommodate Gemini instrumentation and a second Nasmyth that can support at least two optical instruments simultaneously. The initial instrument complement will include optical and infrared imagers, and two optical spectrographs, one with an integral field unit.

A potential concern for this project had been the ability of the partners, particularly Brazil, to meet the payment schedule to complete the project in a timely manner. However, the financial situation in Brazil has now stabilized: Brazil expects to make future payments at a rate that will allow the project to maintain its original schedule. UNC and NOAO have provided their funds up front, and MSU has nearly completed its payments.

At this writing, all the major contracts have been let, the primary mirror blank has been fabricated by Corning and shipped to Raytheon for polishing, and construction of the building enclosure is proceeding on Cerro Pachón. First light is scheduled for mid-2002.
NOAO is responsible for management oversight of all Gemini instruments built in the US. In addition, we are developing university partnerships to build a wide-field IR imager and wide-field optical spectrograph for the NOAO 4-m telescopes; completing a state-of-the-art suite of instruments for SOAR; and providing 4K x 4K IR focal plane arrays.

Gemini Instruments

During FY 2001 we will continue with the construction of the Gemini Near Infrared Spectrograph (GNIRS). In addition to GNIRS, we will be completing CCD controllers for Gemini and adapting Phoenix for use on Gemini South. In FY 2001, approximately half of the manpower in the Tucson instrumentation program will be devoted to Gemini work. Since Gemini pays only after milestones are achieved, NOAO must provide the working capital to achieve each milestone, being reimbursed afterwards. We will then use these funds to make capital purchases for NOAO instruments or to purchase services from universities interested in partnering on NOAO instruments. We will also have to cover approximately $1.5M of the remaining costs of the GNIRS with NOAO funds in FY 2001 and 2002.

Because we must cover most of the manpower costs of completing GNIRS with NOAO funds, we are forced to slow down instrumentation programs for the NOAO nighttime telescopes. However, this slowdown would be inevitable even if we were subsequently reimbursed. Based on the earlier experience with GNIRS, we are now pursuing the project with the best people NOAO has rather than with new hires—and therefore these NOAO staff are unavailable for NOAO instrument projects. Since we have no commitments to work on Gemini instruments beyond the completion of GNIRS, we are unable to increase the size of the staff permanently to accommodate the extra workload associated with Gemini.

In addition to the work ongoing at NOAO, a number of Gemini instrument projects are in progress elsewhere in the US. The University of Hawaii has completed NIRI, the Near-Infrared Imager. The mid-IR imager and spectrograph, T-ReCS, is being built at the University of Florida. NOAO provides management oversight for these contracts and will be responsible for both scientific and management oversight of the contract to provide the Near-Infrared Coronagraphic Imager (NICI) for Gemini; NICI will be built by Mauna Kea Infrared with funding from NASA. We are currently exploring options for providing Flamingos II for shared use at Gemini South and SOAR.
Tucson-Based IR and OUV Instrumentation Program

For its own 4-m class telescopes, NOAO is building instruments that take advantage of wide fields of view. Like most of the other US large telescopes, Gemini offers only a small field of view, and the NOAO 4-m telescopes will play an essential role in defining samples and selecting objects to be observed with the 8- and 10-m telescopes. Two candidate instruments are under development: 1) a wide-field (4Kx4K) IR imager and 2) a wide-field high throughput spectrograph that would be able to obtain spectra of several hundred objects over a 40 arcmin field of view. Both instruments are likely to cost on the order of $4M—the cost of detectors and controllers alone will exceed $1.5M for each.

NOAO recently held a workshop to identify partners for the construction of the wide-field IR imager. Two interesting options for collaborations emerged and are being explored in more detail so that we can prepare proposals to the NSF. The two vendors of IR arrays in the US (Rockwell and Raytheon) are both interested in using existing 1Kx1K and 2Kx2K devices to build mosaics of 4Kx4K arrays, taking advantage of technology being developed for NGST. Mosaics built up from existing devices are thought to offer lower development risks than attempting to fabricate larger monolithic arrays. NOAO will commission planning studies by both vendors for proposals to develop 4Kx4K arrays and will then lead a consortium proposal to the NSF to pay for the development costs. Because of the NGST investment, these costs will represent only the incremental effort required to adapt the readouts to the high background, high readout rates required for ground-based astronomy. Even so, the development will be quite expensive; a 4Kx4K array is likely to cost substantially more than $1M.

The second partnership option relates to the imaging camera itself. Both NOAO and Smithsonian would like to build a 4Kx4K camera and both would like access to this capability in each hemisphere. We are currently working on plans to have one camera in each hemisphere, with time trades providing access to the capability in the opposite hemisphere. The NOAO camera would move between the Blanco and the Mayall, out of phase with shipments of the Smithsonian camera between the MMT and Magellan South. NOAO is also in the process of identifying a university partner to participate in construction of the NOAO camera.

The participants in the IR imager workshop are also exchanging information about controller designs with the goal of standardizing on a single design.

In order to explore the technologies that will be used in the Next Generation Optical Spectrograph (NGOS) at low cost and low risk, we plan to upgrade Cryocam at KPNO. The dewar of this workhorse instrument failed recently, and as part of the
repair program, we will improve its red efficiency by >50 percent. This will greatly improve the spectroscopic capabilities offered at the Mayall and will make it possible to explore the redshift range $1 < z < 2$ with high efficiency, while reserving GMOS and Gemini for fainter objects at still higher redshift.

Specifically, we propose to install two new low resolution VPH grisms, optimized for the red; obtain on loan a new high-resistivity LBNL CCD; implement charge shuffling; and coat the Schmidt camera reflective mirror with a Livermore protected Ag coating. The entire project is likely to take no more than six man months of effort.

The largest NOAO project currently in progress in Tucson is construction of a tip/tilt system for imaging at WIYN (WTTM), which should be ready for shared risk observing near the end of FY 2001.

Work on detector R&D has been scaled back because we expect to have only a small number of arrays in house for testing and characterization. We are exploring the possibility of taking single InSb devices to 2Kx2K, but we will undertake this work only if outside support becomes available.

CTIO and KPNO Instrumentation Improvements

The Blanco 4-m Infrared Side Port Imager (ISPI) will cover a 10 x 10 arcmin field at the Blanco F/8 focus, using a Rockwell 2K HgCdTe array. Construction is expected to be completed and entering test phase by the end of FY 2001. ISPI will use the IR version of the Leach array controller, operating under LabView/Linux, development of which is proceeding along with the CCD version of the controller for SOAR instruments. This will be the first use of this popular software environment with the Leach controllers, and other users of the Leach controllers have evinced much interest in using this combination when development is completed.

The SOAR 4-m Optical Imager is a high-resolution (0.08 arcsec pixels) CCD imager with a 4Kx4K format consisting of a pair of high-QE, low-noise Lincoln Labs CCDs. The instrument mounts at one of the folded Cassegrain ports, and incorporates an atmospheric dispersion corrector, focal reducer, and tip-tilt sensor. System throughput is very high down to the atmospheric cutoff due to careful selection of glasses and anti-reflection coatings. The Imager is scheduled to be finished at the end of FY 2001, and is the first-light instrument for SOAR.

Construction of an Integral Field Unit (IFU) for the 4-m Blanco telescope began late in FY 1999. It will feed the Hydra Bench Spectrograph and can be configured in
several modes to cover a wide range of spectral resolutions. Tests of some of these modes will commence early in FY 2001, with the goal of identifying scientifically interesting configurations that will allow us to retire one or both of the Echelle and RC spectrographs. Since the IFU can be permanently installed on the telescope, retirement of the spectrographs will allow the 4-m to be operated with few or no instrument changes, thus reducing the support burden.

During FY 2001, CTIO will begin a project to upgrade the venerable Infrared Spectrograph (IRS) for use as an interim spectrometer on SOAR. The upgrade will involve installing a 1K HgCdTe array and changing some optics and associated assemblies. Eventually, SOAR hopes to procure an IRS with multi-object capabilities, either via a collaboration among some of the SOAR partners or by a sharing partnership with Gemini. If the early procurement of such an instrument becomes a reality, we would cancel the upgrade of the CTIO IRS.

The next CTIO instrument start is an adaptive optics system for SOAR and, since a scientist has been hired to lead the program, we will begin this project in FY 2001 with the goal of installing a laser-guided AO system in FY 2005. Low cost natural guide star systems are available commercially, and we will upgrade to lasers when they become available. NOAO IPG resources are also scheduled to be used for this project. Since for a given degree of correction a 4-m telescope is able to correct the atmosphere down to half the wavelength achieved with an 8-m, the high optical quality of the SOAR telescope will give it an AO capability into the optical that will complement the Gemini multi-conjugate AO system. Together, Gemini and SOAR will be the only southern-hemisphere facilities with AO available to US astronomers.

In FY 2001, KPNO expects to begin testing of FLAMINGOS I. This project is being led by Richard Elston (University of Florida) and will produce a wide-field near-IR imager with multi-object spectroscopic capability. The detector will be a 2048 x 2048 HgCdTe array with 0.3"/pixel at f/8 on the 4-m telescope. A smaller dewar compartment at the front of the instrument will allow for quick pump down and cooling, enabling daytime changes of custom focal plane masks. Grisms will yield a spectral dispersion of ~ 2000 through a 0.6" slit. The instrument will be present at KPNO for use at the 2.1-m and 4-m telescopes for a portion of each semester.

A detailed plan for FY 2001 Instrumentation is presented in Appendix C. The five-year runout of the instrumentation program can be found as Appendix D in the recently submitted NOAO Long Range Plan FY 2001 - 2005.
Direct User Support and Telescope Improvements

NOAO provides an array of services to the user community. These include access to a variety of telescopes both at NOAO and elsewhere that together constitute an observing “system” that enables a comprehensive attack on a broad range of fundamental scientific questions.

The Gemini Telescopes
The Gemini North telescope began science operations in June 2000. The US Gemini Program (USGP) has assigned 12 scientific staff members and four technical or administrative staff to support US community access (see: www.noao.edu/usgp/noao support.html) to these state-of-the-art 8-m telescopes. Both engineering run and demonstration science programs have evolved and will continue to engage USGP scientific staff. In FY 2001, the USGP will supply approximately two scientific staff-months of assistance in Hilo for Gemini North QuickStart (Semester 2000-B) programs, which are being queue observed.

For this QuickStart set of shared-risk and early science use on Gemini North, 78 proposals were submitted by the US community; these were processed via the standard NOAO TAC system. This process worked smoothly, given the still preliminary understanding of the (visitor) instrument performance on Gemini North. Both visitor instruments are supplied by US institutions (U. Hawaii supplies Hokupa’a + QUIRC, a 1-2.5 micron AO imager; U. Florida supplies OSCIR, a mid-IR imager and spectrometer). Proposal preparation was aided by information provided on the NOAO and Gemini Web pages, and by interactions between investigators and USGP support scientists.

<table>
<thead>
<tr>
<th>Gemini Telescope Instrument Combinations FY 2001</th>
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<tbody>
<tr>
<td><strong>Gemini North:</strong></td>
</tr>
<tr>
<td>• OSCIR: 8 - 25 micron mid-IR imager and spectrograph</td>
</tr>
<tr>
<td>• Hokupa’a + QUIRC: 1 - 2.5 micron adaptive optics imager</td>
</tr>
<tr>
<td>• NIRI: 1 - 5 micron imager and grism spectrometer (est. Semester A, CY 2001)</td>
</tr>
<tr>
<td>• CIRPASS: 1 - 1.5 micron IFU spectrograph (est. Semester A, CY 2001)</td>
</tr>
<tr>
<td>• GMOS: 0.36 - 1 micron MOS spectrograph and imager (est. 8/01)</td>
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<tr>
<td><strong>Gemini South:</strong></td>
</tr>
<tr>
<td>(All est. Semester B, CY 2001):</td>
</tr>
<tr>
<td>• FLAMINGOS I: 1 - 2.5 micron MOS spectrograph</td>
</tr>
<tr>
<td>• Phoenix: 1 - 5 micron high resolution spectrograph</td>
</tr>
<tr>
<td>• T-ReCS: 8 - 25 micron imager and spectrometer</td>
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</tbody>
</table>
For the 2001B semester, it is expected that Gemini South will begin science operations; a call for proposals will go out to the community in March 2001. USGP support scientists and staff are in place to support our community for this new facility, with both visitor instruments (Phoenix and FLAMINGOS I) and facility instruments (T-ReCS).

In FY 2001, software data reduction resources will be needed to address Gemini-specific processing tasks, and to develop routines for the community for AO and IFU/MOS spectroscopy reductions.

Representing the views of the US community, USGP staff participated in Gemini instrument reviews of NICI, FLAMINGOS II, the Multi-Conjugate AO (MCAO) system, and project meetings of the Instrument Forum and Operations Forum.

The NOAO Telescope System

One of the strengths of the NOAO program is that we take a systems approach to observing. The components of this system include: (1) extensive documentation of the available equipment so that observers can take full advantage of the capabilities; (2) reliable operation; (3) thorough calibration of instrument performance; and (4) software with robust algorithms for data reduction. Information is provided to the user community in a variety of formats, including Web pages and the NOAO Newsletter.

The goal is to maintain a level playing field for proposers; observing time is awarded on the basis of the quality of the scientific case and the soundness of the experimental design, not on the basis of institutional affiliation or privileged knowledge.

The suite of facilities offered by NOAO changes with time. As new facilities come on line with greater capability, older telescopes are closed and, in most cases, transferred to a university or consortium for operation. The figure below shows the historical and prospective changes in facilities at KPNO and CTIO from the year 1984 to about 2004.

Four telescopes have been closed at KPNO since 1984, and two more are currently being offered to the community as we phase out their operations. One of the 0.4-m telescopes was transferred to Georgia State University, where it is used for photometry and public outreach; the second is in the Kitt Peak Visitor Center. The 0.9-m was transferred to SARA (the Southeastern Association for Research in Astronomy); it remains on Kitt Peak and is used mainly for photometry. The Burrell-Schmidt was returned to Case Western Reserve University, which continues to operate the telescope for wide-field CCD imaging in partnership with several other universities. After the 1.3-m was closed, it was made available to 2MASS for testing their cameras and observing protocols, and we are currently negotiating with Western Kentucky, which is leading a consortium that won the right to continue operations by virtue of their response to a call for proposals. CTIO no longer operates the 0.6-m and 1.0-m telescopes. The 1.0-m was
returned to Yale, which is operating it primarily in service mode through a consortium with Ohio State University and Portugal. The NOAO community has access to 10 percent of the observing time on this telescope. CTIO has announced that the Curtis-Schmidt will no longer be available to the NOAO community after semester 2001A. In addition, it is likely that the 0.9-m will no longer be available after 2001B or alternatively operation of this telescope may be consolidated with the 1.0-m, and only one will remain in service, depending on the eventual partnership arrangements that are worked out. Starting in 2002A, the instrument complement on the 1.5-m will be reduced, possibly only to ANDICAM, a dual IR-CCD imager now used on the 1.0-m YALO telescope.

KPNO has already completed reductions in its budget and services to the minimum level consistent with continued operation of the 4-m and WIYN, with the 2.1-m being used for IR imaging and IR instrument commissioning while receiving minimum maintenance support. Astronomers using the 2.1-m now operate the telescope without all-night assistance from observatory staff. In semester 2000A, we began phasing in observer-present operations at WIYN, and we will eliminate staff observers for the queue program in semester 2000B. We will explore alternative methods for supporting interrupt-driven observing programs (e.g., supernovae, gamma-ray bursters) through remote observing. Successful remote observing will require the high bandwidth link for which we have received funding from NSF. Observing schedules are being constructed with fewer instrument changes and longer observing runs to compensate for a reduction in staffing of about 10 percent, which was implemented during the spring of 1999. Electronics maintenance support is not typically available after 8:00 PM.
The scientific emphasis at KPNO is on providing the support needed to use the Gemini telescopes effectively. Effective use, in our judgment, requires access to the two 4-m class telescopes for precursor and supporting observations. The wide fields of view enable surveys to select objects for detailed study, as well as to obtain photometric and astrometric calibrations that are required in planning and analyzing Gemini data.

In summary, we are committed to operating three telescopes at each of NOAO’s sites through at least the next five years. All of the 4-m class telescopes will continue to operate until their wide fields are replaced with larger aperture survey capabilities, such as the LSST. We will work out a timeline for those facilities and for the GSMT after construction funding is identified for the new telescopes.

In addition to operating NOAO facilities, KPNO and CTIO act as hosts for eighteen telescopes operated by various consortia and universities. (KPNO hosts ten such “tenant” facilities on Kitt Peak, CTIO eight.) A list of these facilities is included in Appendix J.

Access to the Hobby-Eberly Telescope and the MMT
We have begun awarding observing time on the HET and the MMT. We expect to have access to 26 nights each on the HET and the MMT for a period of six years. This observing time is the result of NSF funding of facility class instruments for these two telescopes. Access to the HET is being handled in such a way as to make NOAO look to the HET like a single user. That is, proposals for open access on the HET are received by NOAO on our standard proposal form and reviewed by an NOAO TAC. The successful proposers are then asked to fill out a second form, which is required by the HET queue program, describing their planned observations in detail. NOAO then forwards those forms to the HET and receives the data for distribution to the community. NOAO has also established a mirror site so that access to HET documentation is obtained directly from NOAO. This approach has the advantage that the HET does not have to provide any support beyond that available to their own users. It does mean, however, that NOAO must find the resources necessary to provide whatever assistance is required by the community. We do not yet have enough information to estimate how much effort will be required.

Observers at the MMT will go to the telescope and make observations themselves; they will be supported at the telescope by MMT and University of Arizona staff. In order to minimize the support burden on MMT staff, only observers with substantial large telescope experience will be allowed to apply.

Unfortunately, both the MMT and the HET have been slow to achieve scientific operations; we expect that community users will not receive any scientific data until FY 2001.
In FY 1999 we modified the TAC and proposal processing systems to accommodate the much larger number of proposals that we expected to receive when Gemini North, the MMT, and the HET all became available for scheduling. This system worked well in the spring of 2000, when we received proposals for all three telescopes for the first time.

Telescope Upgrades at CTIO

In FY 2001 the Gemini 8-m telescope on Cerro Pachón will begin routine operations. CTIO scientific staff will provide support for the US community for several of the Gemini instruments, while ETS and TelOps will help maintain NOAO visitor instruments such as Phoenix, and provide technical backup to the Gemini staff if necessary.

<table>
<thead>
<tr>
<th>CTIO Telescope and Instrument Combinations FY 2001</th>
</tr>
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<tbody>
<tr>
<td>See also: <a href="http://www.ctio.noao.edu/telescopes/TheFuture/crystal_ball.html">www.ctio.noao.edu/telescopes/TheFuture/crystal_ball.html</a></td>
</tr>
</tbody>
</table>

### Blanco 4-m
- Hydra Multi-Object Spectrograph + Hydra Camera + SITe 2K CCD
- R-C Spectrograph + Blue Air Schmidt (BAS) Camera + Loral 3K CCD
- Echelle Spectrograph + Blue Air Schmidt (BAS) Camera + Loral 3K CCD
- Echelle Spectrograph + Long Cameras + SITe 2K CCD
- Prime Focus Camera + Mosaic Imager +8K SITe CCDs
- OSIRIS, OSU/IR Imaging Spectrometer + 1K HgCdTe
- CTIO IR Spectrometer + 256 InSb

### 1.5-m
- Cass Direct + Tek 1K and SITe 2K CCDs
- Cass Spectrograph + Loral 1200 x 800 CCD
- OSIRIS, OSU/IR Imaging Spectrometer + 1K HgCdTe
- ASCAP Photoelectric Photometer

### 1-m
- Re-opened in mid 1998 as a consortium of Yale U., Ohio State U., U. of Lisbon, and NOAO.
- Dual channel O/IR imager ANDYCAM

### 0.9-m
- Cass Direct + SITe 2K CCD

### Curtis Schmidt
- SITe 2K CCD (Direct or Prism)

The SOAR telescope building will be completed by mid FY 2001 and telescope installation and integration will begin. CTIO ETS, Telops, and scientific staff will be heavily involved in this phase of the SOAR project. In anticipation of this activity, only minor upgrades to present facilities are scheduled for this period.
Direct User Support and Telescope Improvements

4-m Thermal Control Improvements: The new thermal control and monitoring system installed in FY 2000, together with improvements to the mirror cooling system, have proven very successful in maintaining the temperature of the 4-m primary close to the nighttime ambient. We will continue to tune and optimize the system, and plan to include meteorological forecasting data to improve our ability to compensate for the large temperature swings that occur mostly during the winter months.

A new primary mirror cover will replace the present cover, which when open greatly restricts air flow in the vicinity of the mirror. The new cover will reduce the probability that pockets of warm air are trapped above the mirror, and thus degrade the image quality.

Telescope Upgrades at KPNO

The KPNO engineering group will work on three projects in FY 2001: completion of upgrades to the Mayall 4-meter, an upgrade to the main instrument interface on the WIYN telescope, and redesign of the Cassegrain and possibly prime focus cages to accommodate the next generation of wide-field instruments, NGOS and NEWFIRM.

Completion of Current 4-Meter Upgrades

The re-investment in delivered image quality performance over the last five years has started to bear fruit, with the median full-width half-maximum now below 1 arcsecond. The goal for the work during shutdown in summer 2000 is to rebuild the actuators for the f/8 secondary support. The purpose is to allow for tilting the secondary as a function of telescope position, in order to compensate for residual coma currently induced by the telescope truss. Some continuing engineering effort, particularly software, will be required in FY 2001 to implement open-loop control of the secondary tilt, with the ultimate goal of full integration with the active primary support system for control of tilt and focus as a function of telescope position.

In addition, the deferred project of installation of a wavefront camera will definitely proceed in the coming fiscal year. This camera will allow wavefront sampling and, ultimately, slow, closed-loop correction for the 4-meter primary support system and the secondary tilt and focus motion.

WIYN Upgrades

The major WIYN upgrade for the coming year is modifying the WIYN instrument adaptor to accommodate the WIYN Tip/Tilt Module (WTTM). The new configuration will have both the WTTM detector and the CCD Mini-Mosaic mounted simultaneously and addressable by a remotely controlled flip mirror. The installation of the WTTM optics modules, second filter wheel, and calibration optics is a substantial effort that will require the removal of the adaptor from the telescope for some three months. The
WIYN Board approved the construction of an instrument adaptor for the Cassegrain port. The work will be carried out mainly at the University of Wisconsin. KPNO resources will be needed to provide for the software interface to the telescope control system. The goal is to have the Cassegrain adaptor available by the time the main

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**KPNO Telescopes and Instrument Combinations – FY 2001**

<table>
<thead>
<tr>
<th>SPECTROSCOPY</th>
<th>Instrument</th>
<th>Detector</th>
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<tbody>
<tr>
<td>Mayall 4-m</td>
<td>R-C CCD Spectrograph</td>
<td>T2KB CCD</td>
</tr>
<tr>
<td></td>
<td>CCD Echelle Spectrograph</td>
<td>T2KB CCD</td>
</tr>
<tr>
<td></td>
<td>IR Cryogenic Spectrograph</td>
<td>InSb (256 x 256, 0.9 - 5.5 μm)</td>
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<tr>
<td></td>
<td>CryoCam Spectrometer</td>
<td>LBL CCD (800 x 1200)</td>
</tr>
<tr>
<td></td>
<td>FLAMINGOS Multi-Object Spectrograph</td>
<td>HgCdTe (2048 x 2048, 0.9-2.5 μm)</td>
</tr>
<tr>
<td></td>
<td>IR Cryogenic Spectrometer</td>
<td>InSb (256 x 256, 0.9 - 5.5 μm)</td>
</tr>
<tr>
<td>WIYN 3.5-m</td>
<td>Hydra + Bench Spectrograph</td>
<td>T2KC CCD</td>
</tr>
<tr>
<td></td>
<td>DensePak</td>
<td>T2KC CCD</td>
</tr>
<tr>
<td>2.1-m</td>
<td>GoldCam CCD Spectrograph</td>
<td>F3KA CCD</td>
</tr>
<tr>
<td></td>
<td>FLAMINGOS Multi-Object Spectrograph</td>
<td>HgCdTe (2048 x 2048, 0.9-2.5 μm)</td>
</tr>
<tr>
<td>Coude Feed</td>
<td>Coude CCD Spectrograph</td>
<td>F3KB CCD</td>
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**IMAGING**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Detector</th>
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<tr>
<td>Mayall 4-m</td>
<td>CCD Mosaic</td>
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<tr>
<td></td>
<td>Prime Focus CCD Camera</td>
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<tr>
<td></td>
<td>Simultaneous Quad Infrared Imaging Device (SQIID)</td>
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<td></td>
<td>FLAMINGOS-Imaging Mode</td>
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<tr>
<td>WIYN 3.5-m</td>
<td>CCD Imager</td>
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<tr>
<td>2.1-m</td>
<td>CCD Imager</td>
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<td></td>
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<td></td>
<td>SQIID</td>
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<td></td>
<td>FLAMINGOS-Imaging Mode</td>
</tr>
<tr>
<td>0.9-m</td>
<td>CCD Mosaic</td>
</tr>
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</table>

1Anticipated for re-commissioning in Spring 2001.
3Integrated Field Unit: 30" x 45" field, 3" fibers, 4" fiber spacing.
Rect User Support and Telescope Improvements

instrument adaptor must be removed, to retain some of WIYN's capability for flexible scheduling of multiple instruments.

Accommodation of New Wide-Field Instruments
Over the next four years, the Mayall 4-meter will be re-instrumented to assure that it fulfills its unique role of wide-field survey instrument in support of the national system of large-aperture telescopes. The Next Generation Optical Spectrograph (NGOS) will exploit the new technology of volume-phase holographic gratings to cover a large field of view for beam-fed multi-object spectroscopy. The dual-beam design and beam angle requirements for the transmission gratings result in an instrument that will not fit in the current Cassegrain cage. The KPNO telescope engineering group will devote design effort in the coming year to realizing a new concept for support of this unique instrument, while accommodating the previous generation of Cassegrain instruments. At this writing, the final optical configuration of the wide-field near-IR imager has not yet been chosen. An attractive, high-throughput option stations the instrument at the prime focus. To accommodate the length of the dewar required for optics covering a 40-arcminute-diameter field of view, a revised infrastructure will be required for the prime focus cage, including the possibility of exchange for the f/8 secondary mirror module. These two design and construction efforts would occupy the ~3 FTE available for engineering projects for the next three years.

In addition, KPNO will receive two new instruments developed in partnership with other institutions. The first is FLAMINGOS, the FLoridA Multi-object Imaging Near-Infrared Grism Observational Spectrometer. The instrument is designed for a Rockwell 2048 X 2048 HgCdTe array, and provides direct imaging as well as multi-object spectroscopy with cooled, multi-slit masks. First science is scheduled on the 2.1-meter for December, 2000; interfacing to the 4-meter will be tested immediately following that observing run. The other instrument is being developed in partnership with Space Telescope Science Institute and NASA Goddard Space Flight Center. It will be a higher-dispersion multi-object near-IR spectrograph, built as a prototype for the Next Generation Space Telescope to demonstrate the utility of micro-mirror arrays as cold, programmable multi-slit masks. KPNO engineering is strongly engaged with the Goddard design team to assure telescope interfaces and control operations will be reliable and supportable. Delivery is expected in FY 2002. Since FLAMINGOS will be shared with Gemini South, the NASA/STScI instrument will insure year-round multi-object capability in the near-IR for Kitt Peak.
US ground-based astronomy is conducted in a diverse assembly of research institutions funded by federal, state, and private sources. Each institution has developed its plans and programs in a way that is largely independent of what is being done at other facilities around the country. In its May 2000 report on priorities for US astronomy, however, the Astronomy and Astrophysics Survey Committee recommended that in the future there should be greater coordination among US institutions.

According to the AASC report, there are several circumstances that will make greater coordination both desirable and necessary:

- **The increased size and complexity of the facilities** designated as high priority for construction during the next decade—as well as the large scope of the scientific programs that will be carried out with those facilities (e.g., all sky surveys repeated every week)—in many cases exceed the capability of any single institution;

- **The growing cost and complexity of instrumentation** makes it impossible for any single facility to support the full range of essential scientific capabilities; and

- **Well-funded and strategically targeted programs in other countries** are challenging US leadership in ground-based astronomy.

As a response to these changing circumstances, the AASC proposed that the following principle should guide future US investments in astronomy:

> U.S. ground-based optical/IR facilities...should...be viewed by the NSF and the astronomical community as a single integrated system drawing on both federal and non-federal funding sources.

A new paradigm of cooperation will be required in order for the community to implement a systems approach to the construction, operation, and equipping of observing facilities. This new paradigm must support the coordination needed to:

- **Invest limited NSF funds effectively.** Funds should be focused on providing important missing capabilities that will enable new science rather than supporting unnecessary duplication;

- **Maintain the diversity of the US community.** Creativity and innovation must be encouraged and supported;

- **Bring new resources to US OIR astronomy** by making a compelling case for investments in new capabilities;
INTEGRATING THE OBSERVING SYSTEM

• **Increase the impact of existing facilities** through broader access for the very best science programs;

• **Plan and carry out the largest projects.** The systems approach must encourage joint efforts that combine public and private resources. For projects that are international in scope, there must be a way to develop a strong, unified, US perspective;

• **Articulate an evolving community-based strategic plan.**

In FY 2001, NOAO will work with the AURA Coordinating Council of Observatory Directors (ACCORD), others in the community, and with the NSF to engage the community broadly in an effort to realize the principle enunciated by the AASC. The first step will be to hold a community workshop jointly chaired by Alan Dressler, chair of the OIR panel of the AASC, and Todd Boroson, member of the AASC Executive Committee, to identify the key science requirements for the elements of the observing system. We will then begin exploring—again, in partnership with the community—the ways in which the various parts of the system can be assembled.

The road map that was recently completed by the AO community under the leadership of Steve Strom, Jerry Nelson, Claire Max, and Steve Ridgway is an example of an approach to coordinating activities that is extensible to a wide variety of issues—e.g., the instrumentation program for very large telescopes; the development of adaptive optics, large format detectors, and other expensive technologies; the National Virtual Observatory; access to flexible observing modes, such as synoptic or rapid follow-up observations; or any other activity that would benefit from the close collaboration of multiple institutions. The AO road map outlines the developments required for adaptive optics over the next several years both for existing telescopes and for a 30-m telescope. Endorsed by representatives of the leading AO groups and by ACCORD, this document has been favorably received by the NSF. A similar road map has been prepared for the NVO, again with key leadership by NOAO staff. We suggest that these road maps are an important first step toward achieving the kind of community consensus that is essential to realizing the AASC goal of an integrated observing system.
Educational Outreach

In order to promote public understanding and support of science and astronomical research, NOAO fosters public awareness and science education through its active outreach program. The outreach efforts that we choose to support with limited resources are selected because they take advantage of the unique capabilities of a national observatory. Our programs particularly emphasize our capacity to obtain new astronomical data in support of educational efforts at all levels, K-12 and beyond. Our programs also take advantage of the educational opportunities offered by the NOAO observing sites, which are attractive visitor destinations. The NOAO outreach program has grown in recent years, and FY 2001 will be a year of evaluation and gradual evolution.

Specific goals for FY 2001 include:

• Developing new initiatives in pre-college education that are highly leveraged through the support of partner organizations.

• Consolidating and restructuring outreach programs to make more effective use of the Web.

• Refining and streamlining the process for issuing press releases.

• Generating a new business plan for Visitor Center activities on Kitt Peak.

• Enlarging the scope and depth of the image library, which is available via the Web.

Pre-College Education Programs

The Use of Astronomy in Research Based Science Education (RBSE)

The NSF-funded Teacher Enhancement Program at NOAO, The Use of Astronomy in Research-Based Science Education (RBSE), has developed a paradigm and tools for implementing authentic research opportunities in middle and high school classrooms. With RBSE in its fourth year (of four), we are developing a revised program format, based on lessons learned from the previous workshops, and seeking funds to continue the modified program for another four years. We anticipate the four-week workshop being reduced to two weeks, with additional program hours taking place in an online distance learning course and follow-up at national teacher meetings. Participants will choose between solar astronomy and nighttime astronomy, rather than having to learn about all three RBSE research areas as they do now. If all goes well, the refined RBSE program will premiere in the summer of 2001.
**Project ASTRO-Tucson**

Project ASTRO-Tucson has received funding from the National Science Foundation Astronomy Division to support NOAO's leadership role of Project ASTRO for the next three years. NOAO-Tucson was selected as the first Chair of the National Project ASTRO Network, an organization of all eleven ASTRO sites around the country. The Space Telescope Science Institute IDEAS Program has awarded the NOAO EO group nearly $20K to work with authors Joni Chancer and Gina Rester-Zodrow, incorporating ideas from their book *Moon Journals: Inquiry, Writing, and Art through Focused Nature Study* into our Project ASTRO workshop. These ideas were explored at last year's workshop, but continued funding allows us to better integrate astronomy, inquiry, writing, and art. The October 2000 ASTRO workshop will feature the *Moon Journals* authors, observing time on Kitt Peak with the Visitor Center 16” telescope, and Tohono O'Odham storyteller Danny Lopez, all within the context of observing and understanding the Moon.

**Research Experiences for Teachers (RET)**

For the second year, supplements were available from the NSF to support teacher participation in the Research Experiences for Undergraduates (REU) program. NOAO-Tucson will have three teachers, graduates of last year's RBSE Teacher Enhancement Program, returning to Tucson to work with staff astronomers.

**Undergraduate Education**

All NOAO sites expect to continue hosting undergraduate summer students with support provided by the NSF Research Experiences for Undergraduates (REU) program. There are currently eight students in the KPNO program and four in the CTIO program. In addition, approximately four University of Arizona undergraduate students each year are mentored by NOAO staff members as part of the UA/NASA Space Grant Consortium program.

**Graduate Education**

NOAO will continue its program of supporting a large fraction of the US Ph.D. theses in optical astronomy. In a typical semester, about 25 thesis programs are assigned time through the competitive review process, and approximately 120 graduate students participate in observing runs. NOAO provides travel support for students conducting thesis research.
Educational and Public Outreach

Instructional Materials

Other materials, including brochures describing NOAO and its programs, astronomy career information, and resource lists of astronomy information, are currently under development to expedite the process of answering inquiries from the public. We have developed and prioritized a list of materials necessary to answer the most frequently asked questions. When the materials are completed, packets of standard information will be readily available for a variety of audiences including press, educators, and VIPs. Packets can also be customized from the suite of NOAO materials and those accumulated from other sources, including Harvard-Smithsonian Center for Astrophysics, the Astronomical Society of the Pacific, Lockheed-Martin, Space Telescope Science Institute, NASA Centers, and Science Technologies, Inc.

Media Relations

NOAO has hired a science writer/press officer, who will be responsible for media relations and for translating the science that is done at NOAO facilities into materials that are useful for a variety of programs serving interested laypersons. We plan to continue efforts to cooperate with other research facilities on joint releases, streamline our procedures for producing press releases and video materials requested by the media, and identify stories with high science value and report them accurately.

Image Collection

The NOAO Image Collection contains more than one thousand images accumulated since the mid-1950s that document the construction, facilities, and science of NOAO. The collection is used by scientists, writers, and the non-technical public. Efforts are underway to streamline the Image Collection, to increase its accessibility, and to decrease the staff time required to maintain the collection and service requests for its contents. We are currently working on selecting images, writing captions, and defining policy for commercial and non-commercial use. The NOAO Image Collection is fully accessible on line, and the major effort in FY 2001 will be to expand the breadth and depth of the collection. An outstanding virtual tour of Kitt Peak has been developed by one of the RBSE teachers, and is available on the Web.

Kitt Peak Visitor Center

Kitt Peak attracts an estimated 50,000 visitors each year. (The exact number is impossible to determine, as thousands come to Kitt Peak to visit the site without taking a guided tour or entering the Visitor Center.). The fee-based public programs and revenue centers created in recent years continue to be successful in partly subsidizing NOAO public outreach activities; in particular, these programs provide a
stable source of revenue for upgrades and improvements to the Visitor Center facility and its programs.

The Visitor Center serves as the hub for all visitor activities, providing information and services to tourists on all aspects of the mountain and its facilities. The Visitor Center is gradually being remodeled to provide a new and modern look; the interior has been refurbished with new carpet and tile. A new generation of exhibits highlighting the activities of the US astronomy community is currently under development; one of these exhibits will describe the role of NOAO as the "gateway" for US astronomers to Gemini, KPNO, and CTIO facilities. The gift shop continues to thrive through sales of tourist-oriented books, clothes, Tohono O’Odham crafts, and astronomical items, as well as the line of products directly related to KPNO and Kitt Peak. An established docent program continues to provide much-needed support to Visitor Center staff and to the visitors themselves.

The fee-based Nightly Observing and Advanced Observing Programs for individuals and small groups, which are held at the 16-inch Visitor Center telescope, continue to be highly successful. A new state-of-the-art CCD camera has been added to enhance the imaging capabilities of the facility for the Advanced Observing Program participants. An innovative pilot program of nighttime observing sessions to be held monthly for secondary school children of the Tohono O’Odham nation is currently being developed.

NOAO continues to be an active participant in the Southwestern Consortium of Observatories for Public Education (SCOPE). Thanks to this partnership, science from the member sites can be shared with over half a million public visitors. During FY 2001, SCOPE will continue to increase this exposure through cooperative advertising of the public outreach opportunities at each participating observatory.
The first section below summarizes key milestones that NOAO expects to complete in FY 2001. The subsequent section reports on the status of milestones set for FY 2000.

FY 2001 Milestones

> Giant Segmented Mirror Telescope (GSMT)

- Hold community workshops aimed at developing a Science Reference Mission for a 30-m class telescope. A key product of the exercise will be a flowdown from science to top-level requirements for the GSMT.

- Support 2-3 community-based studies of instrument concepts for the GSMT. These studies will produce a list of technology issues and challenges as well as requirements on telescope performance.

- Support community and private-sector studies of optical and structural design concepts. These will culminate in a strawman point design for other key studies.

- Support community- and private sector-based studies of the active and adaptive controls systems for NBT. These studies will lead to an understanding of the key technical challenges in compensating for the effects of gravity, temperature, and wind buffeting, as well as wavefront distortions introduced by the atmosphere.

- Support community- and private sector-based studies of mirror fabrication and polishing concepts.

- Develop a site-testing plan for locating GSMT.

- Produce a short list of potential sites in northern Chile based on archival satellite cloud cover analyses, terrain analyses and modeling, and meteorological measurements (where available). A long-term testing plan will be finalized with US and international (Gemini, ESO) collaborators, and then implemented.

> Large Aperture Synoptic Survey Telescope (LSST)

- Hold a community workshop to determine the science requirements and observing protocols for the diverse set of science programs (discovery of near-Earth objects, discovery of supernovae, measurements of gravitational lensing) proposed for the LSST and determine a prioritized set of science requirements for the facility.

- Establish a core working group with the goal of developing a preliminary proposal, including costing, for the telescope, instrument, data handling and distribution, and operations.
MILESTONES

> **National Virtual Observatory (NVO)**
  - Work with the NVO interim steering committee to prepare the proposals necessary to implement NVO.
  - Develop one or more proposals to support funding of collaborations leading to an NOAO "node" for NVO. The proposal(s) will focus on developing the pipelines, archives, and archive access tools necessary for making NOAO Deep-Wide Survey and Mosaic images accessible to the community and to the NVO infrastructure.
  - Work with the community to develop a Science Reference Mission for the NVO, in order to provide a flowdown from science requirements to functionality and cadence.

> **Surveys and Data Management**
  - As part of a larger effort to develop expertise in handling massive databases, initiate data releases for the NOAO Deep-Wide Survey, and provide access to the data and rudimentary tools.
  - Develop a plan for the management of data from the Large Synoptic Survey Telescope (LSST), possibly including the initiation of a precursor project aimed at handling a slower data stream in real time.
  - Complete the data processing pipeline and begin routine archiving of NOAO Mosaic Imager data.

> **Southern Astrophysical Research (SOAR) Telescope**
  - Complete construction of the facility building.
  - Complete assembly and installation of the dome; install mount.
  - Deliver the TCS kernel.

> **Implementing the System of Independent and National Observatories**
  - Initiate, structure, and conduct one or more community workshops aimed at identifying the capabilities (instrumentation, software, operations modes) required by the US astronomical community over the next decade. The output of the workshop will be a road map outlining: (1) the linkage between science needs and the opportunities and capabilities required to ensure the competitiveness of the US system; and (2) a strawman implementation strategy as a guide to structuring an NSF investment strategy on instrumentation at the independent observatories in return for community access.
MILESTONES

- Work with the AO community to update the Adaptive Optics road map, and with the NSF to develop implementation strategies to encourage NSF investments in key AO components, subsystems, and systems developments.

**US Gemini Program (USGP)**

- Issue call for proposals for Semester 2001A for use of a facility instrument (NIRI), and for Semester 2001B (with GMOS) for Gemini North.

- Provide USGP help for Gemini to implement the QuickStart process, including two staff-months spent in Hilo.

- Continue work on NOAO proposal process and proposal form to accommodate the special needs of Gemini observations, eventually adopting the Gemini Phase I Tool for investigators to use for applying for observing time on all facilities available through NOAO.

- Allocate software resources to work on Gemini data reductions, particularly for AO, and for multi-object and IFU spectroscopy.

- Work with the US instrument teams to deliver T-ReCS (Univ. Florida) and visitor instruments FLAMINGOS (U. Florida), Phoenix, (NOAO), and Abu (NOAO).

- Provide a wide-field IRMOS (Flamingos 2) for Gemini, perhaps through partnership with SOAR.

- Assist in the development of a management plan for starting the Coronograph/Imager (NICI) contract.

- Start science operations at Gemini South and issue call for Semester 2001B proposals.

- Provide NOAO/USGP support for visitor instruments on Gemini South and assist in the commissioning.

- Participate in the planning and implementation of the workshop to explore the science and instrumentation for MCAO.

- Continue to engage the US community in Gemini, both with talks and workshops, and by producing instruments and dedicated support teams.

- Complete prototype testing and begin fabrication of GNIRS.
Milestones

CTIO Instrumentation

- Complete construction of the SOAR Optical Imager; begin full system tests.
- Complete construction of the Blanco IR Sideport Imager, and begin in-situ array characterization.
- Install and test the Blanco Integral Field Unit, which feeds the Hydra bench spectrograph.
- Upgrade the Tololo Arcon CCD controllers with revised boards, and complete the 16-channel read-out upgrade for the Mosaic I (Mayall) and Mosaic II (Blanco) CCD imagers.
- Begin building the Nasmyth Instrument Support Boxes, comparison system, and tip/tilt support stages for the SOAR Project, under contract.
- Begin adapting the CTIO Infrared Spectrograph for use on SOAR, or alternatively partner with an external group to build a multi-object IR spectrograph.
- Start ramping up on a major new project. This is nominally a laser guide-star adaptive optics system to be installed on SOAR.

KPNO Instrumentation

- Complete assembly and integration of the WIYN Tip/Tilt Imager.
- Upgrade the Cryogenic Camera with a new red-sensitive CCD, Volume-Phase Holographic grisms, re-coated optics, and repaired dewar.
- Complete commissioning of FLAMINGOS, an IR multi-object spectrograph and wide-field imager being produced in partnership with Florida State.

CTIO Blanco 4-m Telescope

- Complete present phase of thermal performance modifications, which involves replacing the primary mirror cover with one that provides little restriction to wind-flow when open, and implement a new thermal control system.

KPNO Mayall 4-m Telescope

- Achieve routine operation of active f/8 secondary control to cancel tilt-induced coma.
- Install and commission wavefront camera for tuning up active primary performance.
- Develop concept and design for rapid guiding of f/8 secondary.
MILESTONES

KPNO 2.1-m Telescope
- Begin modification of telescope to support wide-field infrared imaging surveys and to serve as test bed for new IR instruments.
- Implement improvements to the RA drive and focus stability.

WIYN Telescope
- Upgrade Instrument Adaptor System to accommodate WIYN Tip/Tilt Module (WTTM).
- Complete integration of Modified Cassegrain focus adaptor produced by Wisconsin.
Status of FY 2000 Milestones

The Next Big Telescope (NBT)

- A recommendation for the general characteristics of the next major OIR facility, and a requirements document for that facility. A spreadsheet or analogous assessment tool to analyze the relative performance capabilities of alternate configurations.

- The proceedings of a workshop defining science program and/or opportunities. An assessment of competing conceptual approaches for the next facility (e.g., a scaled up version of the HET, a Keck-like instrument, small segments versus large mirrors, etc.).

- A document assessing the critical risk technologies. Prepare proposal for the next phase of the project.

- Construction of three DIMMs (Differential Image Motion Monitors) as the first phase of a program for evaluating potential sites.

Status of Milestones

- Eight task groups with members drawn from both the university community and the private sector identified key technical issues and challenges and defined short- and long-term design studies needed for NBT. Science cases driving a wide range of capabilities were developed at a top level. Key design and technical issues were identified for NBT instruments.

- Mapping between science and instrument requirements and various NBT implementations not yet complete.

- NOAO-led science task groups provided the science input to the AURA MAXAT II workshop. Subsequent activities have refined the science cases. Additional workshops are planned for Fall 2000.

- Assessments of design studies required for different conceptual approaches were made in the context of the task group efforts. Key investment areas have been identified. The first studies will be funded in Summer 2000.

- Critical risk technologies were identified in the course of the task group activities conducted during Fall 1999 - Spring 2000.

- A list of system and subsystem technical issues and studies has been compiled and prioritized, and an internal road map prepared. A formal proposal to the NSF was deferred at the agency’s request.

- Key elements of a site testing plan were identified (including needed hardware). Full-up site testing was deemed premature at this stage.

- The DIMMs (including a fourth for KPNO) were completed and are under test on Cerro Tololo. They will be used in a Cornell-led site testing campaign near Chajnantor in northern Chile during August 2000. A computerized drive upgrade is to be evaluated; it will allow hands-off operation.
MILESTONES

> **Southern Astrophysical Research (SOAR) Telescope:**
  - Award dome contract; install foundation of enclosure. Conduct critical design review of active optical system. Transfer finished blank to ROSI to begin optical fabrication.

**Status of Milestones**
- The dome contract has been awarded to Equatorial of Brazil, and the foundation work has been completed on Cerro Pachón by AOSS.
- The CDR for the AO system has been completed successfully.
- The blank has been delivered to ROSI.

> **CTIO Blanco 4-m Telescope:**
  - Cover dome with stick-on aluminum foil to enhance thermal performance.

**Status of Milestones**
- The materials have been ordered, and are being installed in Winter 2000 as weather permits.

> **KPNO Mayall 4-m Telescope**
  - Achieve routine operation of primary mirror active support system and mirror.

**Status of Milestones**
- Hardware and operational debugging are complete; operational protocols are being developed.

> **KPNO 2.1-m Telescope**
  - Begin modification of telescope to support wide-field infrared imaging surveys and to serve as test bed for new IR instruments. Specific milestones for FY 2000 are to complete the definition of the project and to begin design of improvements to the RA drive, thermal environment, and focus.
  - Re-work guider-rotator to accommodate a wider field and heavier load.

**Status of Milestones**
- RA drive improvements conceptual design has been completed; remainder of work has been deferred for higher priority tasks on 4-m and WIYN.


**Milestones**

**Gemini Telescopes**

- **Gemini Proposal Process:** Complete integration of Gemini tools into proposal Web site and develop software to interface to Gemini observation database. Issue call for proposals for first Gemini semester; accept and process proposals up to deadline. Perform technical review on all Gemini proposals to identify problems in technical approach or incorrect calculation of integration time. Hold meeting of national time allocation committee (TAC) to review proposals and participate in international time allocation meeting to reconcile conflicts.

**Status of Milestones**

- First round of QuickStart proposals accepted and passed to Gemini. Proposals received and processed by TAC (QuickStart proposals for Semester B): 78 proposals received. Oversubscription ratio: 6.4 to 1. Science operations began in mid-June 2000 at ~25% level, with Demo science programs, and with the community QuickStart proposals on August 1.

- The NTAC and the Gemini merging TAC have met. International merging TAC meeting scheduled for June 20, 2000.

- Technical review of all Gemini proposals successfully executed, though information on instrument and telescope system performance is currently still limited and approximate.

- **User Support:** For each Gemini instrument, designate USGP support scientists to become expert in the use of the instruments by working with the Gemini Observatory scientific staff and instrument teams. Participate in readiness reviews and staff training sessions leading up to the call for proposals and operations handover. Interact with the community through the electronic Help Desk.

- Identify data reduction software needs for the Gemini instruments, estimate the effort needed to provide them, and begin that work, emphasizing those instruments that will be available in the first semester.

**Status of Milestones**

- Twelve NOAO support specialists have been selected and are listed on USGP Web site.

- Following the November 1999 readiness review, we have participated in all such reviews. Several staff attended training sessions and one support scientist participated in an engineering run in Feb-March 2000 with the UH AO system on Gemini North.

- Interaction with the community via Helpdesk and e-mail are ongoing; some issues concerning performance and community responsiveness are being worked on.

- Data reduction software tasks have been identified and started. Current software staffing levels do not permit sufficient level of effort to keep on track for this program, and this issue clearly needs to be addressed.
Milestones

> **Gemini Instrumentation**

- Complete detailed design of GNIRS and begin fabrication.
- Begin fabrication phase of Gemini Mid-IR Imager being built at Univ. of Florida.
- Complete design study for Near-IR Coronagraph/Imager (NICI) and select group to develop a complete design and build the instrument.

**Status of Milestones**

- The GNIRS passed its pre-fabrication review in early May 2000 and remains on schedule for delivery in 2002.
- The Thermal Region Camera and Spectrograph (T-ReCS) passed its Critical Design Review in July 1999 and is midway through fabrications; it remains on schedule for delivery in FY 2001.
- Mauna Kea Infrared has been selected to build NICI, and contract negotiations are in progress. MKIR is a very small company and will require substantial management oversight from NOAO.

> **CTIO Instrumentation**

- Install high-quality SITe 2K x 4K CCD in a new folded-Schmidt camera for Hydra spectrograph on the Blanco. Design and begin construction of the Infrared Side Port Imager (ISPI), a true wide-field infrared (IR) imager (1-2.5 μm, 10 arcminutes) for the Blanco. Begin work on the construction of an Integral Field Unit (IFU), for use, e.g., with Hydra on the Blanco.
- Complete Preliminary Design Review for the SOAR Optical Imager. Implement Leach II controllers and instrument control in a LabView-Linux environment as part of work on the SOAR Optical Imager.

**Status of Milestones**

- The folded Schmidt camera and special dewar have been completed. However, the CCD has failed, and after many tests, it has not proved possible to revive it. A second CCD, a spare for the Mosaic Imager, is about to be tested.
- ISPI design is well advanced, but the project has suffered several months delay because CTIO lead mechanical and electronic engineers were recruited by Gemini. Construction will ramp up in June 2000. Rockwell appears to be making excellent progress on the IR 2K detector, and have delivered the multiplexor. Licensing difficulties relating to the export of IR arrays remain.
- The IFU project is in its early stages; the fiber mounting procedure is about to be tested and subsequent progress should be rapid.
- The SOAR Imager is on schedule, and a mid-project review is due July 1, 2000. Optics have been delivered, and mechanical engineering is nearing completion. Software and electronics design is well advanced. CCDs are being procured as part of a consortium effort with MIT Lincoln Labs; initial deliveries are scheduled for early 2001.
- The Linux driver for the Leach Controller PCI interface has been completed, and will be used by many others in the community who use these controllers. The high-level LabView software contract is due for delivery in August 2000, at which time integration with a test CCD system and the Leach II controller should take place.
Milestones

KPNO Instrumentation

- Complete fabrication of the WIYN Tip/Tilt Imager.
- Commission SQIID, a four-channel IR imager, and offer it to the community on a shared-risk basis.
- Commission FLAMINGOS, an instrument being provided by Florida State.

Status of Milestones

- WIYN Tip/Tilt Imager is on track for deployment in mid-2001.
- The first science run of SQIID took place in May 2000 and was highly successful.
- The first engineering run for FLAMINGOS scheduled for August; pacing item is delivery of Rockwell imaging arrays.

Surveys & Data Management

- Complete data processing pipeline and begin routine archiving of NOAO Mosaic Imager data.
- Begin the initial group of approved surveys, including support for community outreach and distribution of survey products.
- Begin work with the community to explore the issues of handling and mining massive databases, particularly in the context of the National Virtual Observatory (NVO).

Status of Milestones

- The pipeline for optical Mosaic data is nearly completed, and work on the IR pipeline has been initiated. Archiving of the Mosaic data taken by visiting astronomers has been deferred in order to accelerate completion of the NOAO Deep-Wide Survey.
- The first survey programs have all obtained data. The second round of survey programs was heavily oversubscribed.
- NOAO led the community effort to develop a white paper describing an implementation plan for the NVO. This paper was presented to NASA and the NSF in May 2000.
APPENDIX A: FY 2001 Program Budget

Table A-1 represents the NOAO program budget for FY 2001. The line items in this budget are briefly described below and in more detail in Appendices B through I.

**Directors and Support Staff ($1,920K):** These entries cover the salaries of the directors or heads of each program, the deputy director, if any, their administrative assistants, and associated operating expenses.

**Telescope Operations and Direct User Support ($7,035K):** These funds support the costs of operating the telescopes and maintaining the facilities on the mountain, including any technical staff that may be based at sea level and the portion of scientific staff time devoted to telescope operations.

**Instrumentation Program ($6,170K):** The first line in this category (Instrument Construction: $4,257K) covers the direct costs of designing and fabricating new instruments, characterizing detectors, etc. Scientific staff time is also included. The second line (Management & Facilities: $1,913K) shows the cost of maintaining the engineering facilities and shops, purchasing materials and supplies, and providing overall management of the engineering program. For the Tucson instrumentation program, these costs have been allocated against USGP and KPNO in proportion to the direct program costs. (Appendix C gives more detailed budget information about the instrumentation program.)

**New Capabilities ($500K):** This category summarizes the spending for major new initiatives, with current emphasis on GSMT, the NVO, surveys, and the acquisition, reduction, and archiving of large data sets. In addition to the funds allocated in Table A-1, which include only scientific staff time and $88K for programming support, we expect to provide approximately $400K to fund certain other expenses for the new programs—workshops, external contracts, travel—from a combination of carryover and funds recovered from positions temporarily vacated by staff turnover. This solution will be adequate for FY 2001, but as detailed in Appendices F and G, this will not be adequate in FY 2002 and beyond.

**Scientific Research ($1,255K):** Here we show the total cost of scientific research based on the assumption that the staff spends approximately 33% of their time on research. This category also includes the cost of supporting staff research—e.g., travel, page charges, and other incidental expenses. For the sake of clarity, all of the research carried out by Chile-based staff is listed under CTIO, but about $100K should be allocated to the Gemini and PDO programs. In addition, we show the costs of the library at CTIO and the library and photo lab in Tucson (more correctly called graphic arts department these days), which serves scientists throughout NOAO and NSO as well as Public Education and Outreach. Approximately $50K of the $207K listed under NOAO in this category supports public outreach.

**Computer Support ($1,114K):** The first line in this category (Hardware/Software Maintenance: $589K) includes support for computer networks and maintenance of software, primarily for the scientific and engineering staff, as well as costs for the distribution of IRAF to the community. The entry under the NOAO column ($469K) reflects costs divided roughly equally between IRAF distribution and in-house maintenance activities. The second line in this category (Data Acquisition/Reduction Software: $525K) supports new software development for the acquisition and reduction of data obtained with NOAO and Gemini telescopes.

**Education & Public Outreach ($333K):** This line funds the education program based in Tucson and the operation of the Visitor Center programs at KPNO and CTIO. We have recently expanded the program by hiring a science writer in Tucson.

**Support Services ($3,159K):** The business offices ($1,661K) provide financial management, procurement, human resources, and other services to the various units as detailed in Appendix I. "Sea Level Facilities" refers to the operation and maintenance of buildings other than those at the observing sites—mainly the sea level facilities in Tucson and La Serena. The Tucson support services also provide support to NSO and to externally funded programs, and the figures shown in the table are the net costs of the nighttime program after allowance is made for the expected income from NSO and external grants.

In order to arrive at the true costs of programs, we should also allocate the overhead functions listed under NOAO against the programs served by those functions. To a good approximation, these overhead functions can be allocated on the following basis:

- 8.4% (which is the federally approved G&A rate) of the total funds spent in Chile is the cost of services provided to CTIO by Tucson;
- The engineering facilities support in Tucson has been allocated among the components of the instrumentation program on the basis of dollar costs; and
- The remaining overhead funds (NOAO Director's office, business office, and facility operations) should be allocated in
proportion to the dollar costs of the individual programs—KPNO, USGP, PDO, instrumentation, and the portion of the USGP budget spent in Tucson, but for clarity we have not done so. It should be stressed that no one of these programs could be operated in a stand-alone manner for these allocated costs, if any one of the others were eliminated. By consolidating business and facilities functions, we have achieved substantial economies of scale.

Total Program Budget ($21,987K): The budget total listed in Table A-1 is $300K higher than was allotted to the nighttime program in FY 2000. These funds, according to the current plan, will be used to hire one programmer for Gemini and a second to work on survey pipelines; to hire a science writer to support public outreach and education activities; to accommodate increased expenses, especially travel costs, for the USGP now that Gemini is becoming operational and the Director of the USGP must travel from Chile to attend meetings; and to cover increased journal subscription costs. We have not at this point allowed for salary increases, which are normally made on April 1, or for any inflation of non-payroll costs. We will defer the hiring of the programmer for survey pipelines and the decision on strategy for salary increases until we know what the actual budget will be in FY 2001; what the President's request is for FY 2002; what Chilean inflation is for the first half of FY 2001; and what NSO plans to do about salary adjustments.

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<td>TOTAL PROGRAM</td>
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<td>$2,468</td>
<td>$7,431</td>
<td>$778</td>
<td>$3,669</td>
<td>$21,987</td>
</tr>
</tbody>
</table>
APPENDIX B: Telescope Operations and Direct User Support

The pie chart above and the tables below show FY 2001 expenditures for telescope operations at CTIO and KPNO, as well as expenditures for support of US users of the Gemini telescopes before and after their observing runs. In addition, we are obligated to provide some support to users of the HET and MMT. We expect that effort to be small and will assign support as needed from the CTIO, KPNO, and Gemini staff.

Gemini North, the MMT, and the HET will become available for scientific observations by the NOAO community for the first time in FY 2001. The number of nights available will be small: only 26 nights each on the MMT and HET annually, with Gemini ramping up slowly from 17.5 nights in its first semester. The challenge in providing user support, especially for Gemini, is that the instruments are different from those traditionally supported by NOAO. The first capabilities available at Gemini will be adaptive optics imaging, mid-IR imaging and spectroscopy, and integral field unit spectroscopy. Neither the NOAO staff nor our traditional community have any experience with these types of observations, and even more importantly, we have no software suitable for reducing the data. We have identified the resources to increase the applications software group in Tucson from two to three, with the third individual handling Gemini data reduction. We would like to add a second Gemini programmer in Chile and are attempting to identify resources to do so. The existing applications staff is focused on providing pipelines for Mosaic and IR imaging data to support the ongoing surveys at NOAO, including both community-based surveys and the NOAO Deep-Wide Survey.

In addition to the NOAO support for Gemini users, the NSF itself is providing approximately $7.5M annually to Gemini directly to support telescope operations, and the remaining partners are providing a comparable sum. While the NOAO dollar support may appear modest in the overall context of the NOAO program, we believe it should be adequate—apart from the issues of data reduction—for the modest number of nights currently available. As Gemini ramps up to full operation, NOAO will re-allocate resources as required.

In order to support US users of Gemini, we will assign either one or two mirror scientists to each Gemini instrument as it comes on line. These scientists will be responsible for understanding the operation of the instruments from end-to-end: from planning an observing program to reducing the data. We may also station scientists in Hilo for extended visits of two or more weeks to support queue observing during the first months of scientific operations and to familiarize the NOAO staff with Gemini instruments. We continue to explore the feasibility of a remote observing station in Tucson, but Gemini staff are currently too over-committed to be able to provide the support that will be required in Hawaii to make such a capability available. It will probably

<table>
<thead>
<tr>
<th>User Site/Service</th>
<th>Tel Ops/User Support</th>
<th>Sci Staff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTIO</td>
<td>2,128</td>
<td>430</td>
<td>2,558</td>
</tr>
<tr>
<td>KPNO</td>
<td>3,747</td>
<td>460</td>
<td>4,207</td>
</tr>
<tr>
<td>Gemini</td>
<td>198</td>
<td></td>
<td>198</td>
</tr>
<tr>
<td>TAC</td>
<td>72</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$5,947</strong></td>
<td><strong>$1,088</strong></td>
<td><strong>$7,035</strong></td>
</tr>
</tbody>
</table>
be more appropriate to implement this option a year from now when Gemini operations have become more routine.

For KPNO and CTIO, Tables B-1 and B-2 show the costs of direct expenditures for telescope maintenance, upgrades, operators, mountain infrastructure, etc. We show separately the costs of the scientific staff who provide user support, monitor telescope and instrument performance, etc.

The funding for KPNO includes the share of the mountain infrastructure attributable to the NSO facilities on Kitt Peak—i.e., essentially the services that support activities outside the NSO telescope buildings such as road maintenance, fire and safety services, etc. All of the direct costs of operating the NSO facilities—essentially the inside-the-enclosure costs—are contained within the NSO budget, which is now separate from that of NOAO.

We expect to be operating three telescopes at each site for the next five years: SOAR, Blanco, and the 1.5-m in Chile, and WIYN, Mayall, and the 2.1-m at Kitt Peak. CTIO is in the process of phasing out the 0.9-m, 1.0-m, and the Schmidt to make room for SOAR operations. Based on detailed accounting in last year’s program plan, we estimate that the costs of running the two 4-m class telescopes and one smaller one at each site are in the ratio of 2:1:0.67. The cost per telescope in the absence of any new instrumentation or off-mountain overhead (i.e., administrative services, office space for scientific and engineering staff, etc.) is listed below in Table B-2. It should be stressed, however, that these costs are based on the assumption that the mountain infrastructure costs are shared across three telescopes. The Mayall telescope could not, for example, be operated for $2.3M. in the absence of WIYN and the 2.1-m.

| Table B-2 |
| FY 2001 Spending By Site and Telescope    |
| (Excludes TAC and Gemini Support)          |

<table>
<thead>
<tr>
<th>Site/Telescope</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KPNO</strong></td>
<td></td>
</tr>
<tr>
<td>Mayall</td>
<td>2,293</td>
</tr>
<tr>
<td>WIYIN</td>
<td>1,146</td>
</tr>
<tr>
<td>2.1-m</td>
<td>768</td>
</tr>
<tr>
<td>Subtotal KPNO</td>
<td>4,207</td>
</tr>
<tr>
<td><strong>CTIO</strong></td>
<td></td>
</tr>
<tr>
<td>Blanco</td>
<td>1,394</td>
</tr>
<tr>
<td>SOAR Construction +</td>
<td></td>
</tr>
<tr>
<td>Small Telescopes</td>
<td>697</td>
</tr>
<tr>
<td>1.5-m</td>
<td>467</td>
</tr>
<tr>
<td>Subtotal CTIO</td>
<td>2,558</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>$6,765</td>
</tr>
</tbody>
</table>
APPENDIX C: Instrumentation Program

Construction of a major instrument for an 8-m class telescope or a wide-field instrument for a 4-m telescope costs several million dollars and takes typically four years or more. Therefore, the NOAO instrumentation plan for FY 2001 must be seen in the context of a multi-year plan.

Tables C-1 to C-4 show instrumentation costs for FY 2000-2005 as submitted in the recent NOAO Long Range Plan. (The costs listed under NSO are covered in the NSO budget; however, because NSO draws on a mix of personnel to access the necessary range of skills, rather than dedicated staff, the NOAO staffing plan incorporates NSO’s requirements.)

Table C-1 summarizes the total costs for the Tucson-based instrumentation program by broad spending categories; Table C-2 presents a detailed view of this program by individual projects, including the breakdown of associated principal investigators, man months, salary and benefits costs, and capital expenses for each. Table C-3 summarizes the projected costs of the CTIO instrumentation program separately. Figures 1 and 2 show the trends in allocated funding over time for the spending categories summarized in Table C-1, as instruments are completed and new ones started. The projects to be undertaken in FY 2001 are those listed in Table C-2 and submitted in the Long Range Plan. Note that the 5-year plan for instrumentation requires funding in addition to what is included in the NOAO base budget for operations. We will be seeking those funds through grant proposals and partnerships with universities. For this reason, the figures in the 5-year plan under FY 2001 do not correspond exactly to the program plan budget for FY 2001.

Table C-4 summarizes the expenditures planned for instrumentation from the base operations budget in FY 2001; these expenditures are categorized by the site where the work will be done and by ultimate destination of the instrument. For planning purposes, we have attributed the full cost of NGOS (the Next Generation Optical Spectrograph) to KPNO, although this instrument will probably be shared between the Blanco and Mayall telescopes. Most of the work on the Atacama site survey listed in the long range plan will be deferred until the science requirements are determined. This reduction, plus a slower ramp up in the AO program—which will be deferred until the arrival of the newly hired CTIO staff member who will be responsible for this program—will reduce the projected long range plan budget to the $849K allocated below in Table C-4. Similar small adjustments will be made in the Tucson-based programs.

Table C-4 also shows the costs of the scientific staff that are supporting instrument construction. Scientific staff play a key role in the NOAO instrumentation program, serving as project scientists and systems engineers, and working directly in the laboratory with the engineering staff to test and commission the instruments.

### Table C-1

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>O &amp; M</th>
<th>Solar</th>
<th>R&amp;D</th>
<th>Gemini</th>
<th>KPNO</th>
<th>NOAO</th>
<th>Total Cost</th>
<th>Available Funding*</th>
<th>Surplus (Shortfall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>$256</td>
<td>$186</td>
<td>$275</td>
<td>$2,109</td>
<td>$1,014</td>
<td>$367</td>
<td>$4,207</td>
<td>$4,723</td>
<td>$516</td>
</tr>
<tr>
<td>2001</td>
<td>256</td>
<td>128</td>
<td>275</td>
<td>1,321</td>
<td>769</td>
<td>934</td>
<td>3,683</td>
<td>3,463</td>
<td>(220)</td>
</tr>
<tr>
<td>2002</td>
<td>256</td>
<td>128</td>
<td>275</td>
<td>583</td>
<td>534</td>
<td>2,480</td>
<td>4,256</td>
<td>3,433</td>
<td>(823)</td>
</tr>
<tr>
<td>2003</td>
<td>256</td>
<td>128</td>
<td>275</td>
<td>0</td>
<td>540</td>
<td>3,662</td>
<td>4,861</td>
<td>3,052</td>
<td>(1,809)</td>
</tr>
<tr>
<td>2004</td>
<td>256</td>
<td>128</td>
<td>275</td>
<td>0</td>
<td>416</td>
<td>3,090</td>
<td>4,165</td>
<td>3,052</td>
<td>(1,113)</td>
</tr>
<tr>
<td>2005</td>
<td>256</td>
<td>128</td>
<td>275</td>
<td>0</td>
<td>416</td>
<td>2,008</td>
<td>3,083</td>
<td>3,052</td>
<td>(31)</td>
</tr>
<tr>
<td>Totals</td>
<td>$1,536</td>
<td>$826</td>
<td>$1,650</td>
<td>$4,013</td>
<td>$3,689</td>
<td>$12,541</td>
<td>$24,255</td>
<td>$20,775</td>
<td>($3,480)</td>
</tr>
</tbody>
</table>

*Available funding = NSF funding + funds recovered from WIYN, Gemini, and NSO projects.
The column in Table C.4 labeled "Management and Facilities" includes the associated costs of supporting the instrumentation effort: i.e., management, administrative support, maintenance of shops, purchase of computers, text equipment, materials, and supplies. In the case of Tucson, we have allocated these costs against the various programs in proportion to the direct dollar costs associated with them. (In Table A-1, the portion of the Management and Facilities budget attributable to work for CTIO has been listed under KPNO so as to show explicitly the infrastructure costs in Tucson and in La Serena.) For Gemini instrumentation, we have added the costs of management oversight of Gemini instruments being built in the US but outside NOAO.

<table>
<thead>
<tr>
<th>Table C-3</th>
<th>CTIO Instrumentation Program FY 2001 - 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FY (Dollars in Thousands)</td>
</tr>
<tr>
<td>SOAR 4.3-Meter</td>
<td>2000</td>
</tr>
<tr>
<td>SOAR Imager</td>
<td>286</td>
</tr>
<tr>
<td>SOAR Comm. (instr)</td>
<td>-</td>
</tr>
<tr>
<td>SOAR Comm. (tel.)</td>
<td>-</td>
</tr>
<tr>
<td>IRS Upgrade</td>
<td>-</td>
</tr>
<tr>
<td>Adaptive Optics</td>
<td>-</td>
</tr>
<tr>
<td>Subtotal SOAR</td>
<td>286</td>
</tr>
<tr>
<td>BLANCO 4-Meter</td>
<td></td>
</tr>
<tr>
<td>ISPI 2K Imager</td>
<td>583</td>
</tr>
<tr>
<td>IFU for Blanco</td>
<td>42</td>
</tr>
<tr>
<td>Hydra Camera</td>
<td>21</td>
</tr>
<tr>
<td>Blanco tip/tilt</td>
<td>86</td>
</tr>
<tr>
<td>Mosaic I&amp;II</td>
<td>42</td>
</tr>
<tr>
<td>Arcon retrofits</td>
<td>18</td>
</tr>
<tr>
<td>Guiders</td>
<td>39</td>
</tr>
<tr>
<td>Subtotal BLANCO</td>
<td>830</td>
</tr>
<tr>
<td>GSMT</td>
<td></td>
</tr>
<tr>
<td>Atacama site survey</td>
<td>78</td>
</tr>
<tr>
<td>Misc. Smaller Projects</td>
<td>-</td>
</tr>
<tr>
<td>Total CTIO</td>
<td>$1,194</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table C-4</th>
<th>FY 2001 Instrumentation Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By Direct, Scientific Staff, Management &amp; Facilities Costs</td>
</tr>
<tr>
<td></td>
<td>(Total $6,170K = 28% of Total Program Budget)</td>
</tr>
<tr>
<td>(Dollars in Thousands)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instrument Destination</th>
<th>Direct Costs</th>
<th>Scientific Staff</th>
<th>Mgmt &amp; Facilities</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile/CTIO</td>
<td>849</td>
<td>179</td>
<td>951</td>
<td>1,979</td>
</tr>
<tr>
<td>Tucson/KPNO</td>
<td>1,901</td>
<td>102</td>
<td>480</td>
<td>2,483</td>
</tr>
<tr>
<td>Tucson/CTIO</td>
<td>137</td>
<td>-</td>
<td>35</td>
<td>172</td>
</tr>
<tr>
<td>Tucson/Gemini</td>
<td>929</td>
<td>136</td>
<td>447</td>
<td>1,512</td>
</tr>
<tr>
<td>Chile/Gemini</td>
<td>0</td>
<td>24</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>$3,816</td>
<td>$441</td>
<td>$1,913</td>
<td>$6,170</td>
</tr>
</tbody>
</table>

Appendix C-2  NOAO Provisional Program Plan: FY 2001: Instrumentation Program
### Table C-2

**Tucson-Based Instrumentation Projects, Manpower, and Salary Costs**

**FY 2000 - 2005**

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>FY-2000 Dollars in 1,000's</th>
<th>MM</th>
<th>S/B $</th>
<th>Cap $</th>
<th>Total</th>
<th>MM</th>
<th>S/B $</th>
<th>Cap $</th>
<th>Total</th>
<th>MM</th>
<th>S/B $</th>
<th>Cap $</th>
<th>Total</th>
<th>MM</th>
<th>S/B $</th>
<th>Cap $</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ops &amp; Maint.</strong></td>
<td>PI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrared</td>
<td>Merrill</td>
<td>14</td>
<td>90</td>
<td>50</td>
<td>140</td>
<td>14</td>
<td>90</td>
<td>50</td>
<td>140</td>
<td>14</td>
<td>90</td>
<td>50</td>
<td>140</td>
<td>14</td>
<td>90</td>
<td>50</td>
<td>140</td>
</tr>
<tr>
<td>OUV</td>
<td>Armandroff</td>
<td>12</td>
<td>77</td>
<td>20</td>
<td>97</td>
<td>12</td>
<td>77</td>
<td>20</td>
<td>97</td>
<td>12</td>
<td>77</td>
<td>20</td>
<td>97</td>
<td>12</td>
<td>77</td>
<td>20</td>
<td>97</td>
</tr>
<tr>
<td>Adv. Development</td>
<td>Green</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Subt. O &amp; M</td>
<td></td>
<td>29</td>
<td>186</td>
<td>70</td>
<td>256</td>
<td>29</td>
<td>186</td>
<td>70</td>
<td>256</td>
<td>29</td>
<td>186</td>
<td>70</td>
<td>256</td>
<td>29</td>
<td>186</td>
<td>70</td>
<td>256</td>
</tr>
</tbody>
</table>

| **KPNO** | | | | | | | | | | | | | | | | | |
| KPCO Support | | 65 | 416 | 146 | 416 | 65 | 416 | 146 | 416 | 65 | 416 | 146 | 416 | 65 | 416 | 146 | 416 |
| WYN/Tl Imager | Clovis | 64 | 410 | 150 | 560 | 32 | 205 | 10 | 215 | - | - | - | - | - | - | - |
| Image Improvements | Jacoby | - | 20 | 128 | 10 | 138 | - | - | - | - | - | - | - | - | - | - |
| Proto Micro-Mirror MOS | Green | 6 | 38 | 38 | - | - | - | - | - | - | - | - | - | - | - | - |
| CCD Sys. Improve. | Armandroff | - | 9 | 58 | 60 | 118 | 10 | 64 | 60 | 124 | - | - | - | - | - | - |
| Subt. KPNO | | 135 | 864 | 150 | 1,014 | 117 | 749 | 70 | 769 | 147 | 474 | 50 | 534 | 75 | 480 | 60 | 540 |

| **Research & Dev.** | | | | | | | | | | | | | | | | | |
| IR R&D | Merrill | 15 | 96 | 49 | 145 | 15 | 96 | 49 | 145 | 15 | 96 | 49 | 145 | 15 | 96 | 49 | 145 |
| OUV CCD Development | Armandroff | 15 | 96 | 20 | 116 | 15 | 96 | 20 | 116 | 15 | 96 | 20 | 116 | 15 | 96 | 20 | 116 |
| New Technology | Barden | 2 | 13 | 1 | 14 | 2 | 13 | 1 | 14 | 2 | 13 | 1 | 14 | 2 | 13 | 1 | 14 |
| Subt. R & D | | 32 | 205 | 70 | 275 | 32 | 205 | 70 | 275 | 32 | 205 | 70 | 275 | 32 | 205 | 70 | 275 |

| **Major Instruments (non-Solar)** | | | | | | | | | | | | | | | | | |
| Aladdin Tlv Constr. Elect. | Merrill | 12 | 77 | 20 | 97 | - | - | - | - | - | - | - | - | - | - | - | - |
| SQUID Upgrade | Merrill | 8 | 51 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FLAMINGOS | Elias | 6 | 38 | 38 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NEWFIRM | Probst | 6 | 38 | 30 | 68 | 10 | 64 | 30 | 94 | 49 | 256 | 100 | 356 | 120 | 768 | 1,000 | 1,768 |
| NGDS | Armandroff | 13 | 83 | 30 | 113 | 60 | 137 | 456 | 843 | 160 | 1,024 | 1,100 | 2,124 | 140 | 896 | 750 | 1,646 |
| Adaptive Optics CTIO | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| New Instrument Study | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Subt. Non-Solar | | 45 | 288 | 80 | 368 | 70 | 451 | 484 | 937 | 200 | 1,280 | 1,200 | 2,480 | 290 | 1,856 | 1,806 | 3,662 |
| Solar Instruments (NSO) | - | 10 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 |
| GONG ** | Leibacher | 10 | 64 | - | - | 64 | 64 | 64 | 64 | - | - | - | - | - | - | - |
| SOLIS Support ** | Green | 19 | 122 | 122 | - | - | - | - | - | - | - | - | - | - | - | - |
| Subt. Solar ** | | 29 | 186 | - | 186 | 20 | 128 | - | 128 | 20 | 128 | - | 128 | 20 | 128 | - | 128 |

| **Gemini Instruments** | | | | | | | | | | | | | | | | | |
| GNRS # | Elias | 178 | 1,139 | 645 | 1,784 | 168 | 1,075 | 120 | 1,195 | 88 | 563 | 20 | 583 | - | - | - | - |
| CCD Controller | Barden | 10 | 64 | - | - | 64 | - | - | - | - | - | - | - | - | - | - |
| IF/Solar Wolfe | Merrill | 12 | 77 | 20 | 97 | - | - | - | - | - | - | - | - | - | - | - |
| Phoenix to Gemini S | Hinkley | 10 | 65 | 100 | 165 | 15 | 96 | 30 | 126 | - | - | - | - | - | - | - |
| Subt. Gemini # | | 210 | 1,345 | 765 | 2,110 | 183 | 1,171 | 150 | 1,321 | 88 | 563 | 20 | 583 | - | - | - | - |
| GRAND TOTAL | | 480 | $3,073 | $1,135 | $4,208 | 451 | $2,889 | $766 | $3,665 | 443 | $2,854 | $1,420 | $4,285 | 456 | $2,806 | $1,246 | $4,052 |
| NSF Funding | 405 | 2,592 | 396 | 2,988 | 405 | 2,592 | 396 | 2,988 | 396 | 2,988 | 396 | 2,988 | - | - | - | - |
| WTTM Recovery | - | 150 | 150 | - | 10 | 10 | - | - | - | - | - | - | - | - | - | - |
| Gemini Recovery # | - | 1,463 | 1,463 | 400 | 400 | 381 | 381 | - | - | - | - | - | - | - | - | - |
| Solar Recovery | - | 122 | 122 | 64 | 64 | 64 | 64 | - | - | - | - | - | - | - | - | - |
| Subt. TOTAL AVAILABLE | | 405 | $2,592 | $2,131 | $4,723 | 405 | $2,592 | $876 | $3,468 | 405 | $2,592 | $841 | $3,433 | 405 | $2,592 | $841 | $3,433 |
| Surplus/(Shortfall) | -75 | (481) | $996 | $515 | $46 | (295) | $74 | ($227) | -63 | ($245) | ($759) | $822 | -41 | ($252) | ($1,546) | ($1,808) | ($31) |

**++ MM: Man Months; S/B: Salaries & Benefits; Cap: Capital Costs**

APPENDIX C-3: NOAO Provisional Program Plan: Instrumentation
### Table C-2 (continued)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>SUMMARY FY 2000 - 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dollars in 1,000's</td>
<td>MM</td>
</tr>
<tr>
<td><strong>Ops &amp; Maint.</strong></td>
<td></td>
</tr>
<tr>
<td>Infrared</td>
<td>84</td>
</tr>
<tr>
<td>O/UV</td>
<td>72</td>
</tr>
<tr>
<td>Adv. Development</td>
<td>18</td>
</tr>
<tr>
<td>Subt. O &amp; M</td>
<td>174</td>
</tr>
<tr>
<td><strong>KPNO</strong></td>
<td></td>
</tr>
<tr>
<td>KPNO Support</td>
<td>390</td>
</tr>
<tr>
<td>WIYN T/T Imager</td>
<td>96</td>
</tr>
<tr>
<td>Image Improvements</td>
<td>20</td>
</tr>
<tr>
<td>Proto Micro-Mirror MOS</td>
<td>6</td>
</tr>
<tr>
<td>CCD Sys. Improve.</td>
<td>19</td>
</tr>
<tr>
<td>Subt. KPNO *</td>
<td>531</td>
</tr>
<tr>
<td><strong>Research &amp; Dev.</strong></td>
<td></td>
</tr>
<tr>
<td>IR R&amp;D</td>
<td>90</td>
</tr>
<tr>
<td>O/UV CCD Development</td>
<td>90</td>
</tr>
<tr>
<td>New Technology</td>
<td>12</td>
</tr>
<tr>
<td>Subt. R &amp; D</td>
<td>192</td>
</tr>
<tr>
<td><strong>Major Instruments (non-Solar)</strong></td>
<td></td>
</tr>
<tr>
<td>Aladdin III Contr. Electr.</td>
<td>12</td>
</tr>
<tr>
<td>SQIID Upgrade</td>
<td>8</td>
</tr>
<tr>
<td>FLAMINGOS</td>
<td>6</td>
</tr>
<tr>
<td>NEWFIRM</td>
<td>436</td>
</tr>
<tr>
<td>NGOS</td>
<td>403</td>
</tr>
<tr>
<td>Adaptive Optics CTIO</td>
<td>100</td>
</tr>
<tr>
<td>New Instrument Study</td>
<td>170</td>
</tr>
<tr>
<td>Subt. Non-Solar</td>
<td>1,135</td>
</tr>
<tr>
<td><strong>Solar Instruments (NSO)</strong></td>
<td>50</td>
</tr>
<tr>
<td>GONG **</td>
<td>60</td>
</tr>
<tr>
<td>SOLIS Support **</td>
<td>19</td>
</tr>
<tr>
<td>Subt. Solar **</td>
<td>129</td>
</tr>
<tr>
<td><strong>Gemini Instruments</strong></td>
<td></td>
</tr>
<tr>
<td>GNIRS #</td>
<td>434</td>
</tr>
<tr>
<td>CCD Controller</td>
<td>10</td>
</tr>
<tr>
<td>IF/Sec-ROI Gemini</td>
<td>12</td>
</tr>
<tr>
<td>Phoenix to Gemini S.</td>
<td>25</td>
</tr>
<tr>
<td>Subt. Gemini #</td>
<td>481</td>
</tr>
<tr>
<td><strong>GRAND TOTAL ABOVE</strong></td>
<td>2,642</td>
</tr>
<tr>
<td>NSF Funding</td>
<td>2,430</td>
</tr>
<tr>
<td>WTTM Recovery *</td>
<td>-</td>
</tr>
<tr>
<td>Gemini Recovery #</td>
<td>-</td>
</tr>
<tr>
<td>Solar Recovery **</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL AVAILABLE</strong></td>
<td>2,430</td>
</tr>
<tr>
<td>Surplus/(Shortfall)</td>
<td>-212</td>
</tr>
</tbody>
</table>
Fig. 1
NOAO Instrument Costs 2000-2005
(Dollars in Thousands)

Fig. C-2
CTIO Instrumentation
FY 2000 - 2005

SOAR
BLANCO
Atacama site survey
Misc. Smaller Projects
The pie chart below shows the budget allocated to scientific staff salaries and associated support, such as travel, page charges, libraries, etc. There are 14 scientific staff in Chile and 17 in Tucson, both exclusive of staff serving as associate or deputy directors. We estimate that about 33% of the scientific staff time is available for research, which makes the cost of the in house research program alone about $956K.

While we show the total costs of the scientific staff explicitly here, the specific portion of these costs attributable to functional work has been allocated in Tables D-1 and D-2 below (and in other appendices) against the programs that benefit from their services. NOAO owes its success to the sustained and committed efforts of its very talented scientific staff. NOAO scientists are directly involved in every aspect of the NOAO program. They develop strategic plans for the observatory; identify opportunities and prepare the scientific and technical justifications for new programs; serve as the links to external groups with whom we collaborate on joint telescope, instrument, and other projects; and provide oversight to NOAO projects and operations.

NOAO has adopted the philosophy that the size of the scientific staff should be determined by functional responsibilities. However, functional responsibilities have increased substantially in recent years, and research time now falls below the AURA policy of 50 percent for tenured and tenure track staff. In addition, salaries are now about 20 percent behind the AURA member institutions. These two factors will compromise NOAO's ability to attract and retain staff of the caliber required to carry out the new mission mandated by the AASC.

The reasons for the increase in time required by functional responsibilities are two: an increase in the scope of the program coupled with a decrease (by more than 30 percent over the last decade) in the size of the scientific staff. New programs include: 1) support of US involvement with, and US use of, the Gemini telescopes; 2) development of consortium telescope projects (WIYN and SOAR); 3) responsibility for several instrumentation projects for Gemini; 4) access to the MMT and HET. In addition, we are now expected to provide leadership for community involvement in the GSMT and LSST, to play a significant role in the NVO, to form university partnerships and to build instruments, and to work with the independent observatories to develop a coordinated approach to US observing facilities.

<table>
<thead>
<tr>
<th>Dollars in Thousands</th>
<th>Chile ($)</th>
<th>Time (%)</th>
<th>Tucson ($)</th>
<th>Time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope Operations</td>
<td>$430</td>
<td>36%</td>
<td>$460</td>
<td>27%</td>
</tr>
<tr>
<td>NOAO Instrumentation</td>
<td>179</td>
<td>15%</td>
<td>102</td>
<td>6%</td>
</tr>
<tr>
<td>Gemini User Support</td>
<td>96</td>
<td>8%</td>
<td>102</td>
<td>6%</td>
</tr>
<tr>
<td>Gemini Instrumentation</td>
<td>24</td>
<td>2%</td>
<td>136</td>
<td>8%</td>
</tr>
<tr>
<td>Planning &amp; Development</td>
<td>71</td>
<td>6%</td>
<td>340</td>
<td>20%</td>
</tr>
<tr>
<td>Research</td>
<td>394</td>
<td>33%</td>
<td>562</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Total Scientific Staff</strong></td>
<td><strong>$1,194</strong></td>
<td><strong>100%</strong></td>
<td><strong>$1,702</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Because of the shrinking size of the NOAO technical staff—coupled with the increasing difficulty of recruiting engineering and software personnel in today's tight labor market, as well as NOAO's non-competitive salaries—the scientific staff has also had to assume greater direct responsibility for implementing the NOAO program. Besides providing scientific management of all the facilities, with very limited administrative support staff, NOAO scientists are also serving as systems engineers on major instrumentation projects; calibrating and characterizing instrumentation; providing systems administration for scientists' workstations; carrying out the programs needed to improve the image quality at the telescopes; providing real-time software for instrumentation; writing users' manuals; assisting visiting astronomers with startups at the telescopes; and performing whatever other services may be required.

Despite their growing functional responsibilities, the NOAO scientific staff continues to maintain a very high standard of excellence in research. NOAO provides only very limited support for research—on average, about $10,000 per scientist per year to provide for travel, page charges, an up-to-date workstation, and materials and supplies. We do not provide support for post docs, graduate students, or other research assistants. The staff is, accordingly, reliant on support from NASA for most of their research programs, which are increasingly focused on space research.

Table D-3 shows the costs to NSF of the research of the Tucson-based scientific staff allocated to the programs that benefit from the functional tasks performed by the staff. An analogous table for CTIO would show the allocation of approximately $100K in research costs against the USGP and PDO programs.

A major concern is the growing lack of competitiveness of staff salaries, a situation that has been aggravated by the flat or decreasing funding in recent years. The following table shows the discrepancy between NOAO staff salaries and comparable academic salaries at AURA member institutions.

---

**Table D-2**

Total Allocated Scientific Staff Costs and Time %
By FY 2001 Program Area
(Total Scientific Staff Budget = $2,896K)

<table>
<thead>
<tr>
<th>Dollars in Thousands</th>
<th>Sci Staff ($)</th>
<th>Time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope Operations</td>
<td>890</td>
<td>31%</td>
</tr>
<tr>
<td>NOAO Instrumentation</td>
<td>281</td>
<td>10%</td>
</tr>
<tr>
<td>Gemini User Support</td>
<td>198</td>
<td>7%</td>
</tr>
<tr>
<td>Gemini Instrumentation</td>
<td>160</td>
<td>6%</td>
</tr>
<tr>
<td>Planning &amp; Development</td>
<td>412</td>
<td>14%</td>
</tr>
<tr>
<td>Research</td>
<td>955</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Total Scientific Staff</strong></td>
<td><strong>$2,896</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

---

**Table D-3**

Costs of Tucson-Based Scientific Staff Research Allocated to Functional Tasks of Specific FY 2001 Programs

<table>
<thead>
<tr>
<th>Program Area</th>
<th>Research ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPNO Operations/Instrumentation</td>
<td>277</td>
</tr>
<tr>
<td>Gemini Operations/Instrumentation</td>
<td>117</td>
</tr>
<tr>
<td>Planning &amp; Development</td>
<td>168</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$562</strong></td>
</tr>
</tbody>
</table>

---

**Table D-4**

NOAO Scientific Staff Salaries Vs. Comparable AURA Academic Salaries

<table>
<thead>
<tr>
<th>NOAO Title/Rank</th>
<th>NOAO Avg. Salary</th>
<th>AURA Universities Salary *</th>
<th>% Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asst. Astronomer; Asst. Scientist</td>
<td>$50,635</td>
<td>$65,800</td>
<td>-23.1%</td>
</tr>
<tr>
<td>Assoc. Astronomer; Assoc. Scientist</td>
<td>$65,540</td>
<td>$76,810</td>
<td>-14.7%</td>
</tr>
<tr>
<td>Astronomer/Scientist</td>
<td>$87,720</td>
<td>$114,500</td>
<td>-23.4%</td>
</tr>
</tbody>
</table>

* AURA salaries annualized

---

Appendix D - 2 NOAO Provisional Program Plan: FY 2001: *Scientific Staff Costs*
At the present time, the only staff assigned to PDO activities are scientific staff and an administrative assistant. As new programs such as the GSMT and NVO ramp up, additional technical staff will be required, and the following two appendices outline the cost requirements for these two specific programs. The funding currently identified from the base program budget for PDO is listed below in Table E-1. In this case, we have explicitly listed the support of the PDO head, including an administrative assistant and other support, since the leader of the PDO is responsible for implementing much of the PDO program. In addition to the funds in the base operating budget, we will reserve sufficient carryover (~200K), largely derived from unfilled positions, to provide term appointments for support staff to assist with the completion of the NOAO Deep-Wide Survey. We also expect to provide carryover funds of approximately $200K for work on the GSMT. So long as these programs are in the early stages of development and can be supported mainly with scientific staff and through outside contracts, consultants, and short term appointments, this method of funding is adequate. We also expect to submit separate proposals to fund some portions of these programs.

In Table E-1, we show $88K under PDO for technical support. These funds will be held in reserve until we know the actual level of funding in FY 2001; they would be used to hire programming support if we receive funding at the level of the President’s request.

| Table E-1 |
| Planning and Development Office (PDO) |
| FY 2001 Funding ($682K) |
| \[\text{| Dollars in Thousands | Tucson | Chile | Total |}\] |
| \[\text{Scientific Staff | $340 | $72 | $412 |}\] |
| \[\text{Technical Support | 88 | 0 | 88 |}\] |
| \[\text{Director's Office | 182 | | 182 |}\] |
| \[\text{Total PDO Funding | $610 | $72 | $682 |}\] |

The Planning and Development Office was established in order to facilitate the initial work on major new programs.

The primary responsibilities of this office are:

1. Development of the GSMT project, with initial emphasis on defining the scientific requirements for a 30-m class telescope;

2. Developing the scientific case and requirements for the NVO and working out a plan for the staged implementation;

3. Providing pre- and post-observing run support for ongoing surveys at NOAO, including the NOAO Deep-Wide Survey. In addition, the PDO has facilitated the preparation by the AO community of a road map for the development of adaptive optics capabilities and worked out agreements with Chandra and SIRTF for joint scheduling of observing programs. In 2001, the PDO will begin to support the initial development of the LSST concept.
In this appendix, we repeat the text from the NOAO Long Range Plan FY 2001-2005 that describes the initial steps toward building a 30-m telescope. This plan calls for an investment of approximately $1M in FY 2000-2001. Approximately $400K of the required support will be provided by the International Gemini Project (IGP) through staff time and funding for external contracts. A comparable amount of support will be provided by NOAO, again about equally divided between staff time and funding for workshops and external contracts. (We do not expect to hire either a project scientist or a systems engineer until we are assured of continued funding for this program.) No explicit funding is identified in this program plan other than existing NOAO staff salaries, but we expect to carry over an additional $200K from FY 2000. With these resources, we expect to be able to accomplish all of the work specified for FY 2000-2001. We will need increased resources in FY 2002 to begin prototyping various subsystems, as outlined in the section that follows, and we will prepare a separate proposal to fund an increased level of activity.

This initiative at NOAO is in response to highest priority of the AASC for ground-based astronomy in the next decade: i.e., the construction of a telescope with an aperture of 30 meters—the Giant Segmented Mirror Telescope (GSMT). Several groups, most notably Caltech and ESO, are initiating technical studies keyed to particular point designs to address issues of cost, schedule, and performance that must be resolved before such a project may be undertaken with confidence. NOAO and Gemini, working in close collaboration, have conducted a series of community-based workshops (Figure 1) to define the scientific potential of the GSMT, the resulting system requirements, and technical studies aimed at exploring a range of GSMT implementations.

Having defined the required studies, we now plan to coordinate our own efforts with those of ESO and Caltech to optimize the use of limited funds to achieve both community and institutional goals. While it would be premature to attempt to establish any kind of formal collaborations at this early stage, all three groups have agreed to exchange information obtained through the technical studies that each will commission.

We assume that a substantial additional investment will be made in adaptive optics over the next ten years to provide the building blocks (lasers, deformable mirrors, detectors for wavefront sensing, algorithms for atmospheric tomography, etc.) for implementing robust AO systems on both existing telescopes and on the GSMT. According to the community-based AO road map presented recently to the NSF, $50M is required for the AO program during the next decade.

We expect to conduct most of the GSMT work through external contracts to university and private sector groups, and staffing is therefore held to a minimum level.

The total cost of implementing this initial program is $6.2M plus the investment in AO. Through partnering with ESO and/or Caltech on studies relating to such issues as mirror fabrication, we should be able to lower the cost to NSF between now and 2004 to $5.0 M. Investment at this level will ensure that we can represent the US community’s scientific requirements in any partnership that may develop and can critically evaluate and advocate design options and technical approaches.

Tables F-1 and F-2 summarize the estimated costs of the required GSMT technical studies for the years 2000 - 2004.
### Table F-1
**Est. Costs of GSMT Technical Studies**  
**FY 2000 - 2001**

<table>
<thead>
<tr>
<th>Category</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science</strong></td>
<td></td>
</tr>
<tr>
<td>Develop design reference mission</td>
<td>$100K</td>
</tr>
<tr>
<td><strong>Optical Design and Fabrication</strong></td>
<td></td>
</tr>
<tr>
<td>Develop flowdown from science requirements to requirements for telescope system, AO, and site selection</td>
<td>50K</td>
</tr>
<tr>
<td>Develop strawman instrument designs</td>
<td>50K</td>
</tr>
<tr>
<td>Initiate study of aspheric mirror fabrication</td>
<td>100K</td>
</tr>
<tr>
<td>Develop strawman optical design</td>
<td>30K</td>
</tr>
<tr>
<td>Develop strawman structural design</td>
<td>30K</td>
</tr>
<tr>
<td>Study control properties</td>
<td>70K</td>
</tr>
<tr>
<td><strong>Sites</strong></td>
<td></td>
</tr>
<tr>
<td>Collect existing data on cloud cover, site topography, high altitude winds, other site characteristics for northern Chile and Mauna Kea</td>
<td>30K</td>
</tr>
<tr>
<td><strong>Structures and Controls</strong></td>
<td></td>
</tr>
<tr>
<td>Measure wind-loading on 8-m Gemini S. primary</td>
<td>100K</td>
</tr>
<tr>
<td>Investigate the interactions of a hierarchical set of controls for low (&lt;0.5 Hz), medium (&lt; 3 Hz) and high (&gt; 3 Hz) bandwidth</td>
<td>100K</td>
</tr>
<tr>
<td><strong>Adaptive Optics</strong></td>
<td></td>
</tr>
<tr>
<td>Quantify range in MCAO performance through detailed modeling efforts</td>
<td>30K</td>
</tr>
<tr>
<td>Develop &amp; explore several systems concepts</td>
<td>20K</td>
</tr>
<tr>
<td><strong>Staffing</strong></td>
<td></td>
</tr>
<tr>
<td>Project scientist</td>
<td>150K</td>
</tr>
<tr>
<td>Systems engineer</td>
<td>150K</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$1,010K</td>
</tr>
</tbody>
</table>

### Table F-2
**Est. Costs of GSMT Technical Studies**  
**FY 2002 - 2004**

<table>
<thead>
<tr>
<th>Category</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optical Design and Fabrication</strong></td>
<td></td>
</tr>
<tr>
<td>Initiate prototyping of aspheric segments</td>
<td>$1,000 - 2,000K</td>
</tr>
<tr>
<td>Examine options for lightweight segments</td>
<td>100K</td>
</tr>
<tr>
<td>Design &amp; develop prototype segment position actuators, segment edge sensors, segment figure actuators</td>
<td>200K</td>
</tr>
<tr>
<td><strong>Sites</strong></td>
<td></td>
</tr>
<tr>
<td>Continue characterization of Mauna Kea and northern Chile, including measurement of vertical atmospheric structure, seeing, meteorological characteristics, and geotechnical site and ownership issues; model site windflow characteristics</td>
<td>500K</td>
</tr>
<tr>
<td><strong>Structures and Controls</strong></td>
<td></td>
</tr>
<tr>
<td>Develop Structural Design Concept</td>
<td>100K</td>
</tr>
<tr>
<td>Develop concepts for enclosure</td>
<td>100K</td>
</tr>
<tr>
<td>Develop prototype to validate AO compensation of structural vibrations</td>
<td>250K</td>
</tr>
<tr>
<td><strong>Adaptive Optics</strong></td>
<td></td>
</tr>
<tr>
<td>Extend modeling of AO systems performance for low (1000) to high (10,000) systems</td>
<td>200K</td>
</tr>
<tr>
<td>Develop laser guide star systems concepts, design proof of concept demonstrations, and test concepts</td>
<td>350K</td>
</tr>
<tr>
<td>Explore deformable mirror concepts</td>
<td>200K</td>
</tr>
<tr>
<td>Develop new generation control algorithms</td>
<td>200K</td>
</tr>
<tr>
<td>Develop AO systems concepts</td>
<td>100K</td>
</tr>
<tr>
<td><strong>Staffing</strong></td>
<td></td>
</tr>
<tr>
<td>Project Scientist</td>
<td>450K</td>
</tr>
<tr>
<td>Systems Engineer</td>
<td>450K</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$5,200K</td>
</tr>
</tbody>
</table>
In this appendix, we repeat the appendix from the Long Range Plan that describes the support required for NOAO to participate in the National Virtual Observatory. In FY 2001, we expect to be able to support the NOAO Deep-Wide Survey, including both data acquisition and reduction, and we expect that STScI will archive the data and make it available to the community. We will also continue to work with the community on developing plans for implementing the NVO. Additional resources would be required to provide pipeline processing for all of the other imaging and survey data being taken at NOAO and to archive those data. We hope that the ground rules for the Information Technology Initiative at the NSF will be framed in such a way as to support discipline-based applications of software developed for the management and querying of very large data sets, and we plan to apply for additional support through this program.

The National Virtual Observatory (NVO) has as its goal the creation of an information infrastructure for astronomy. This will require the creation of a system of federated tera- and later petabyte databases containing both ground- and space-based measurements that can be accessed and queried remotely with a common user interface. In addition, the NVO will coordinate the creation of high-speed networks and innovative software tools for exploring multi-wavelength catalog and image databases. These powerful capabilities will enable qualitatively new science and will eventually enable confrontation of theoretical models and numerical simulations.

During FY 2001, NOAO will continue activities that lay the groundwork for its contribution to the ground-based component of the NVO (Table G-1). This "pre-NVO" phase will include the development of pipeline and archiving...
APPENDIX G: The National Virtual Observatory (NVO)

procedures, initially for the NOAO Deep-Wide survey, then for the other surveys that are ongoing at NOAO, and finally for all of the Mosaic data taken at NOAO. These data-intensive activities would be essential even in the absence of an NVO and are necessary precursors for NOAO participation in the NVO. NOAO is currently supporting the preparation of a community-based white paper describing how the NVO should operate, what its management structure should be, and what the time scale should be for the phased program to develop the NVO.

There are two possible levels of NOAO involvement in the NVO. First, NOAO could act as a node of the NVO (Table G-2), focusing exclusively on the work required to incorporate data taken at NOAO into the NVO with suitable interfaces. The second option is for NOAO to serve as the coordinating entity for NVO for all US ground-based OIR astronomy (Table G-3), including such shared observatories as SOAR and WIYN, and potentially for the independent observatories as well. In this role, NOAO would work actively with NVO to address issues of standards and protocols and act as an advocate for the US OIR community within the NVO.

The software tool that allows transparent access by a wide range of users to different archives, the so-called Data Access Layer, is essential for carrying out the basic functions of the NVO. NOAO is prepared to undertake the development of the Data Access Layer. In addition, NOAO is prepared to take responsibility for establishing and maintaining interfaces between space- and ground-based data, on the assumption that NRAO will provide the necessary assistance with the interfaces to the radio data. We plan to explore with NRAO the steps needed to deal with both radio and OIR data and to determine how such collaboration might best take advantage of the strengths in the two organizations while minimizing the costs to each.

The white paper currently being developed to describe the NVO and its requirements calls for an NVO core group comprising a Project Scientist, Program Manager, and Technical Manager, and a small staff to coordinate the activities at the distributed nodes of the NVO and to incorporate the work by different groups into an overall system. To assist NSF with planning, we have provided estimates of what this core group might cost (Table G-4). We expect that there will ultimately be a call for proposals to host this group, and the best location for the group will depend on a variety of factors, including the sources of funding, the relevant experience of the host organization, the expertise available in the local community, and the relationships between the space and ground-based components of the program. We also expect that the costs of this core group will be borne at least in part by NASA.

### Table G-4

<table>
<thead>
<tr>
<th>Function</th>
<th>FTE</th>
<th>Est. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming &amp; software development</td>
<td>5.0</td>
<td>$ 600K</td>
</tr>
<tr>
<td>Scientific oversight &amp; mgmt</td>
<td>4.0</td>
<td>$ 480K</td>
</tr>
<tr>
<td>Administrative support</td>
<td>2.0</td>
<td>$ 80K</td>
</tr>
<tr>
<td>Non-Payroll</td>
<td></td>
<td>$ 50K</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11.0</td>
<td><strong>$ 1,210K</strong></td>
</tr>
</tbody>
</table>

NOAO now allocates up to 20 percent of the available observing time at KPNO and CTIO to surveys. Because funding and the allocation of observing time are decoupled, proposers are subject to double jeopardy. Without a commitment of observing time, it may be difficult to obtain grant support for data reduction, development of catalogs, and archiving. Without defined funding to support data reduction and analysis, it may be difficult to obtain long term commitments of substantial amounts of observing time. It would be very beneficial if, in the case of surveys that will provide broadly useful coherent data sets to the community, the allocation of observing time and funding were coupled. The benefits to the survey teams lie in the ability to propose not only a strong science program, but also a credible
APPENDIX G: The National Virtual Observatory (NVO)

delivery schedule for survey products. The benefit to the community lies in the timely availability of a major high-fidelity database.

Based on the ongoing surveys, we estimate that it costs approximately $500K on average over a three-year period of time to process the data to the point where it can be archived. If we assume that on average there are 10 surveys being conducted at any given time on NOAO telescopes, the annual cost of supporting surveys would be (10 surveys x $500K/survey)/(3 years/survey) = $1.67M/year (see Table 5). This funding would go to the community—not to NOAO.

Table G-6 shows an estimate of projected five-year annual costs for NOAO’s potential participation in the NVO.

Table G-6
Est. 5-Year Costs for NOAO Participation in NVO Activities
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-NVO Phase Budgeted</td>
<td>335</td>
<td>335</td>
<td>270</td>
<td>270</td>
<td>270</td>
</tr>
<tr>
<td>New Funds</td>
<td>340</td>
<td>340</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OIR Node at NOAO</td>
<td>-</td>
<td>407</td>
<td>407</td>
<td>407</td>
<td>407</td>
</tr>
<tr>
<td>Coordinate OIR GB Activities for NVO</td>
<td>-</td>
<td>630</td>
<td>630</td>
<td>630</td>
<td>630</td>
</tr>
<tr>
<td>NVO Headquarters</td>
<td>-</td>
<td>605</td>
<td>1,210</td>
<td>1,210</td>
<td>1,210</td>
</tr>
<tr>
<td>Community Surveys</td>
<td>835</td>
<td>1,670</td>
<td>1,670</td>
<td>1,670</td>
<td>1,670</td>
</tr>
<tr>
<td>Total</td>
<td>$1,510K</td>
<td>$3,987K</td>
<td>$4,187K</td>
<td>$4,187K</td>
<td>$4,187K</td>
</tr>
</tbody>
</table>

1 Probably at NOAO
2 Probably at existing archive center; should be funded at least in part by NASA
3 Grant funding to groups outside NOAO
Computer support covers three types of activities: (1) maintenance of hardware and software, including both internal networks and links to the outside world; (2) distribution of IRAF software to the community; and (3) development of new software for data acquisition and reduction. The NOAO/Tucson cost for maintenance includes both maintenance of the in house computers and the costs of supporting the IRAF distribution to the community, and the $469K is divided nearly equally between these two activities. The cost of writing new software is attributed to the programs for which the work is done. The primary efforts in FY 2001 will be developing data reduction packages for Gemini instruments and completing pipelines for reducing Mosaic and infrared imaging data at NOAO.

There are approximately 400 computers in Arizona—NSO, KPNO, Engineering, IRAF, Administrative Services, etc.—all linked to the network. This inventory includes both UNIX-based machines and PCs. There are about 100 computers at CTIO. Attacks on the system by external hackers and infiltration by viruses are increasing in frequency and becoming a time-consuming problem. A staff of 6 FTE (3.5 from CCS, 2 from ETS, and 0.5 from KPNO Mountain electronics) maintains the computers in Arizona. A 1995 benchmark survey of technical organizations showed that the median number of machines per system administrator was 70. The number for NOAO—Tucson is 110 if we include only the 3.5 system administrators in Central Computer Services (CCS).

Key goals for in the coming year are the following:

**NOAO Tucson:** Convert the network infrastructure to a totally switched Ethernet with a Gigabit Ethernet backbone and Fast Ethernet links to every computer.

**KPNO Kitt Peak:** Establish a 45 Mbps data connection from the Tucson headquarters to Kitt Peak replacing the current 1.5 Mbps connection.

**CTIO:** An OC-3 (155Mbps) fiber/microwave backbone and associated network hardware (firewalls, routers, etc.) will be installed and commissioned for connections between La Serena, Cerro Tololo, and Cerro Pachón for use by CTIO, Gemini, SOAR and any future facilities based on either mountain.

**AURA Chile:** Internet services to the AURA Observatory in Chile will be upgraded from the current 256K/512K leased line to a high-speed fiber connection either through REUNA2 or directly to the US networks.

<table>
<thead>
<tr>
<th>Table H-1</th>
<th>FY 2001 Computer Support Budget</th>
<th>(Total $1,114K = 5% of FY 2001 Program Budget)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dollars in Thousands</strong></td>
<td><strong>CTIO</strong></td>
<td><strong>USGP</strong></td>
</tr>
<tr>
<td>Hardware, Software, &amp; Network Maintenance</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Data Acquisition &amp; Reduction</td>
<td>104</td>
<td>126</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$224</strong></td>
<td><strong>$126</strong></td>
</tr>
</tbody>
</table>
The implementation of the programs described in this program plan requires a supporting infrastructure, which consists of scientific management, administrative services, and maintenance of offices, laboratories, computer networks, and other facilities at sea level.

The pie chart above and Table H-1 below shows the costs of these programs by activity. The facilities and administrative services listed under NOAO represent the net cost of supporting the nighttime program after subtracting the costs attributable to NSO and to externally funded programs. The nighttime support should be distributed across the programs that are supported—CTIO, for which many administrative services are provided in Tucson; KPNO; USGP, and PDO. To a rough approximation, the fraction of services attributable to CTIO is the federally approved G&A rate, which is 8.4 percent of total spending in Chile, or approximately $592K. The cost of infrastructure to support activities in Chile and in Tucson are essentially identical at about $2.35M each, if allowance is made for the fact that USGP Director’s Office staff are to be found in both locations.

Scientific Management/Directors’ Offices ($1,920K)

With the increasing emphasis on partnerships with the community for new telescopes, instrumentation, developing “road maps” for activities like the NVO and Adaptive Optics, and the advent of the operational phase of the Gemini telescopes, NOAO has been forced to expand its senior scientific management team. The effective participation of NOAO in these activities, and the leadership of at least some of them, requires that at least one experienced and respected NOAO staff member with the authority to make decisions be directly engaged in each of these separate activities.

Accordingly, we have established five major units within the nighttime program, each led by a staff member with considerable authority. The units are: CTIO, with Malcolm Smith playing the dual role of Director of CTIO and Head of AURA Observatory Support Services in Chile, and Alistair Walker serving as Assistant Director of CTIO; KPNO, with Richard Green as Director; USGP, with Robert Schommer in Chile serving as Director, Caty Pilachowski in Tucson serving as Deputy Director, and Taft Armandroff serving as Instrumentation Scientist overseeing Gemini work in the US; the Planning and Development Office (PDO), which under Steve Strom, is

<table>
<thead>
<tr>
<th>Table I-1</th>
<th>FY 2001 Management, Support Services, and Facilities Maintenance Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Total $5,079K = 23% of FY 2001 Program Budget)</td>
<td></td>
</tr>
<tr>
<td><strong>Dollars in Thousands</strong></td>
<td><strong>CTIO</strong></td>
</tr>
<tr>
<td>Directors' Offices</td>
<td>426</td>
</tr>
<tr>
<td>Administration</td>
<td>665</td>
</tr>
<tr>
<td>Sea Level Facilities</td>
<td>515</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,606</strong></td>
</tr>
</tbody>
</table>

Appendix I -1  NOAO Provisional Program Plan: FY 2001:  Management and Support Services
APPENDIX I: Management and Support Services

in charge of the new programs such as the GSMT, LSST, NVO, and survey activities; and NOAO, headed by Sidney Wolff with Todd Boroson as Deputy. Each of these offices has associated with it administrative assistants to provide clerical support, and in addition, the NOAO Director’s office provides the receptionist for the NOAO’s Tucson headquarters and copying services for all Tucson-based activities.

**Administrative Services ($1,661K)**

Based in Tucson, Central Administrative Services (CAS) serves all NOAO activities as well as providing many administrative services to NSO. Specifically CAS provides human resources services for all US hires at all sites—in Tucson, at Sac Peak, and in Chile. In addition, CAS manages payroll, procurement, contracting, accounts payable and receivable, property management, and general accounting for all actions in the US. CAS handles shipping and receiving for Tucson and expedites shipments to Chile. CTIO provides human resources services for Chilean hires, procurement and contracting, accounts payable and receivable, and property management for Chile-based activities. The CTIO system interfaces to the NOAO-Tucson accounting system, which is the accounting system of record, and information is transferred daily. NSO/SP has a limited administrative staff to manage local activities and purchases but relies on Tucson for most services.

**Facilities Maintenance ($1,488K)**

The Facilities Maintenance line in the budget represents the costs of the sea level facilities in Tucson and La Serena. Included are both the costs of operations—utilities, telephones and postage, office materials and supplies, etc.—as well as major repairs and maintenance.
APPENDIX J. Tenant Facilities

KPNO Tenants and Facilities

1. Warner & Swasey Observatory (Case Western Reserve Univ.): Burrell-Schmidt 0.6/0.9-m Telescope

2. Edgar O. Smith Observatory: 1.2-m Calypso Telescope

3. MDM Observatory (Michigan-Dartmouth-Columbia-Ohio State Univ.): 2.4-m Hiltner; 1.3-m McGraw-Hill

4. NASA/MIT Observatory: Optical Transient Experiment


7. Steward Observatory (Univ. of Arizona), 2.3-m Bok Telescope; 0.9-m Telescope – Spacewatch survey for near-earth asteroids; 1.8-m Telescope – Spacewatch survey instrument in commissioning.

8. Univ. of Wisconsin, H-alpha Mapper (WHAM)

CTIO Tenant Facilities

1. Gemini South 8-m

2. SOAR

3. MACHO Program on CTIO 0.9-m

4. NOAO-UNC-Univ. of Michigan-Brazil: SOAR 4-m

5. Swarthmore: 3-cm Robotic H-alpha Survey

6. Univ. of Chile-Max Planck Institute 1-m Millimeter-Wave Antenna

7. Univ. of Massachusetts 2MASS South: 1.3-m IR Survey telescope

8. USNO 20-cm Astrographic Survey telescope

9. YALO 1-m

Appendix J-1: NOAO FY 2000 Provisional Program Plan: Tenant Facilities
<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidney Wolff</td>
<td>Director, NOAO</td>
</tr>
<tr>
<td>Todd Boroson</td>
<td>Deputy Director, NOAO; Head of Surveys &amp; Data Management (SDM) Group</td>
</tr>
<tr>
<td>Richard Green</td>
<td>Director, KPNO – Associate Director, NOAO</td>
</tr>
<tr>
<td>Malcolm Smith</td>
<td>Director, CTIO – Associate Director, NOAO</td>
</tr>
<tr>
<td>Robert Schommer</td>
<td>NOAO Associate Director for USGP</td>
</tr>
<tr>
<td>Steve Strom</td>
<td>Head of Planning and Development Office (PDO)</td>
</tr>
<tr>
<td>Alistair Walker</td>
<td>Assistant Director, CTIO</td>
</tr>
<tr>
<td>Caty Pilachowski</td>
<td>Deputy Director, USGP</td>
</tr>
<tr>
<td>Taft Armandroff</td>
<td>Instrumentation Project Manager, USGP</td>
</tr>
<tr>
<td>Larry Daggert</td>
<td>Manager, Engineering and Technical Services (ETS)</td>
</tr>
<tr>
<td>Steve Grandi</td>
<td>Manager, Central Computer Services (CCS)</td>
</tr>
<tr>
<td>Larry Klose</td>
<td>Manager, Central Administrative Services (CAS)</td>
</tr>
<tr>
<td>Sandra Abbey</td>
<td>Human Resources Manager</td>
</tr>
<tr>
<td>James Tracy</td>
<td>Controller</td>
</tr>
<tr>
<td>Glen Blevins</td>
<td>Financial Manager</td>
</tr>
<tr>
<td>John Dunlop</td>
<td>Facilities Manager</td>
</tr>
<tr>
<td>Suzanne Jacoby</td>
<td>Manager, Education Outreach</td>
</tr>
<tr>
<td>Jane Price</td>
<td>Manager, Public Outreach</td>
</tr>
</tbody>
</table>
La Serena-Based Scientific Staff

Robert Blum, Assistant Astronomer

Areas of Interest

Recent Research Results
Blum's current work centers on near-infrared studies of massive stars. Blum is particularly interested in the youngest massive stars and young stellar objects (YSOs) associated with Galactic giant HII regions. This project is being carried out primarily with the Ohio State InfraRed Imager and Spectrometer (OSIRIS) at CTIO, in collaboration with P. Conti (U. Colorado) and A. Damineli (U. Sao Paulo).

Recent results include new spectroscopic classifications for OB stars in the obscured HII regions W42 and W43 (Blum, et al. 1999, AJ, 117, 1392; 2000, AJ, 119, 1860). This work includes characterization of the stellar initial mass function and investigation of high-mass YSOs.

Blum is also collaborating with K. Sellgren and S. Ramirez (both Ohio State U.) on measuring the first stellar abundances in M giant and supergiant stars in the central parsec of the Milky Way. This research comprises the Ph.D. thesis of Ramirez, whose findings have been recently accepted for publication in the Astrophysical Journal. The main result is that the sample of stars studied to date in the central parsec of the Galaxy has (perhaps surprisingly) solar iron abundance.

Future Research Plans
Blum’s project on the stellar content of giant HII regions continues to occupy most of his research time. To date, the group has high angular resolution images (~ 0.4–0.8 arcsec FWHM) in about ten of twelve target HII regions. The group continues to obtain 4-m spectra of the brightest objects, with an eye toward Gemini observations for fainter targets. Infrared spectroscopy will provide the first detailed look at the upper end of the mass function in the youngest/largest galactic star-forming regions.

Blum, Conti, and Damineli will continue their survey of the inner Galaxy for massive emission line stars (e.g., Wolf-Rayet stars) using OSIRIS and the CTIO 1.5-m telescope. N. Homeier (U. Wisconsin) has joined the project, which will become her Ph.D. thesis project. Homeier is a student of J. Gallagher and will spend time working with Blum on IR observing, data reduction, and analysis in Chile in May-June 2000.

Service
Blum’s primary duties at the observatory involve all aspects of supporting the infrared spectrometers and imagers at CTIO for visiting astronomers. Blum has primary responsibility at CTIO for the new OSIRIS infrared imager/spectrometer, which is a collaborative effort between CTIO and the Astronomy Department of Ohio State U. to bring a versatile infrared imager/spectrometer to CTIO. This is an upgrade to an existing Ohio State instrument. OSIRIS employs a new generation array (1024x1024 format HgCdTe from Rockwell, purchased/owned by NOAO) and provides for multiple pixel scales in real time to take advantage of the best delivered image quality from the new tip/tilt system and provide a larger field of view.

Like most of the scientific staff at CTIO, Blum has been participating in the development of new instrumentation initiatives for the SOAR telescope and expects to join in the commissioning aspects of the telescope over the next few years. Blum is also participating as a mirror scientist for the Gemini NIRI instrument. The mirror scientists are charged with interfacing with the US community for Gemini facilities under the guidance of the US Gemini Project office. Blum sits on the CTIO instrumentation advisory group (ACTR) and the joint NOAO instrumentation advisory group IPAC.

Patrice J. E. Bouchet, Associate Scientist

Areas of Interest
Infrared Instrumentation, Adaptive Optics, Dust in Supernovae, SN1987A, Vega-like Disks around Nearby Main-Sequence Stars.

Recent Research Results
Near-IR observations of SN1987A and its inner ring: new “hot spots” discovered in the HeI (1.08 microns) line with the Blanco 4-m and tip/tilt system at CTIO, as described in NOAO Newsletter 61 (March 2000); results from broadband and narrow band filters submitted (with light curves).

Ten-micron observations of SN1987A: data reduced, publication in preparation. IR observations of cold disk of dust around solar type stars, from ISO and OSCIR at 10 and 20 microns: results being analyzed.

Appendix L - 1 NOAO FY 2001 Provisional Program Plan: NSF-Funded Scientific Staff
“Incidence and survival of remnant disks around main-sequence stars” (H. Habing et al.): to appear in A&A.

**Future Research Plans**

Use the La Serena turbulator for improving and characterizing the tip/tilt system in use at the Blanco telescope at CTIO. Continue the monitoring in the infrared of supernova SN1987A, and model the dust observed around it. Data reduction of the high spatial resolution near-infrared images obtained at the Blanco, through a wavelet deconvolution method with a multi-scale maximum entropy algorithm.

Use the OSCIR instrument at Gemini North to look for more dust disks around nearby main-sequence stars. Compute models for the observed dust.

**Service**

Contact person for the 2MASS project at CTIO. Member of the CTIO infrared team, which implies setting up the instruments and providing assistance to observers. Project manager for the tip/tilt system at the Blanco telescope. USGP support scientist for OSCIR and TRecs.

**Brooke Gregory, Support Scientist**

**Areas of Interest**

Gregory is an instrument physicist who works primarily in the area of development of IR instrumentation and telescope optics.

**Recent Research Results**

Gregory has recently returned from a sabbatical leave at Adaptive Optics Associates in Cambridge, MA, where he worked on various aspects of wavefront sensors and other areas of applied optics.

**Future Research Plans**

Gregory is involved in the design process for the Gemini IR spectrometer being built at NOAO-Tucson. Gregory will also be overseeing the continuing effort to improve the optical performance of the Blanco 4-m telescope. On a somewhat longer time scale, Gregory will be helping to plan for the installation of adaptive optics on the SOAR 4.2-m telescope. He will also be designing an upgrade of the CTIO IR spectrometer to be used on the SOAR telescope.

**Service**

Gregory is a manager of the Engineering and Technical Resources Group at CTIO (on leave during his work with the Gemini IR spectrometer project). He also serves as liaison to Gemini in development of a plan for sharing technical resources between Gemini and CTIO, and supports users of IR instrumentation generally.

**Donald Hoard, Research Associate**

**Areas of Interest**

Cataclysmic Variables and Other Interacting Binary Stars, Accretion Disks, Mass Inflows and Outflows, Planetary Nebulae, Pre-Main Sequence Binary Stars, Globular Cluster Systems.

**Recent Research Results**

Hoard is continuing his investigation of the SW Sextantis “class” of CVs with ongoing studies of V442 Ophiuchi and DW Ursae Majoris. In collaboration with P. Szkody (U. Washington) and J. Thorstensen (Dartmouth College), Hoard broke the long-standing 1-day orbital period alias for the non-eclipsing system V442 Oph. Its orbital period is now established at 0.1243 d. Hoard also demonstrated that V442 Oph is one of the long-sought low inclination examples of an SW Sex star, bringing the total number of known low inclination members of this class to three.

In collaboration with C. Knigge (Columbia U.), K. Long (STScI), P. Szkody (U. Washington), and V. Dhillon (U. Sheffield), Hoard has performed a preliminary analysis of HST/STIS UV spectroscopy of DW UMa obtained in January 1999—the first time-resolved UV spectroscopy of an SW Sex star throughout its orbital cycle. These data suggest the presence of a self-occulting accretion disk in the SW Sex stars.

Hoard continues to work with D. Geisler (U. Concepción, Chile) on a project to measure the V-H color distributions of globular cluster systems (GCS) of nearby elliptical galaxies from Hubble Space Telescope WFCPC2 and NICMOS images. These data will be used to determine the metallicity distribution of the globular clusters. An explanation for the bimodal metallicity distribution often seen in GCS of elliptical galaxies would have important implications for the understanding of galaxy formation.

**Future Research Plans**

Hoard is continuing his research on cataclysmic variables in collaboration with P. Szkody, S. Wachter (CTIO), A. Linnell (U. Washington), B. Gaensicke (Universitaets-Sternwarte Goettingen, Germany), J. Thorstensen, C.
APPENDIX L: NSF-Funded Scientific Staff

Knigge, and others. Hoard’s upcoming research on CVs will include an ongoing study of the double-lined system Phe 1; an investigation of the possible presence and origin of collimated mass outflows (“jets”) in CVs; and analysis of observations of SW Sextantis-type CVs, including time-resolved, ground-based, and HST/STIS spectra of DW Ursae Majoris, WX Arietis, and V1776 Cygni.

In addition, he will undertake searches for low accretion rate “hibernating” CVs in the NOAO Deep Wide-Field Survey data (with B. Gaensicke), and will begin analyzing observational data obtained in 2000 to search for pre-main-sequence binary stars located in the Vela Molecular Ridge star-forming region (with S. Wachter and M. Sterzik [ESO]) and to search for binary and variable stars in the Galactic open cluster NGC 3532 (with S. Wachter and A. Landolt [U. Louisiana]).

Service
Hoard is site director of the CTIO Research Experiences for Undergraduates (REU) Program, which is funded by the National Science Foundation, and the analogous Practicas de Investigación en Astronomía (PIA) program for Chilean students. Each year, four astronomy undergraduate students from the US are selected to spend the Chilean summer (January-March) at CTIO to participate in the REU program alongside two Chilean students in the PIA program. The students work on individual research projects with an adviser from the CTIO scientific staff, as well as participate in their adviser’s observing runs. This year, results from all six REU and PIA projects will be presented at the June 2000 or January 2001 meetings of the AAS.

Hoard is also the CTIO staff contact for photoelectric photometry; support scientist for the 0.9-m telescope (with S. Wachter); and the Synoptic, Service, and Target-of-Opportunity (SSTO) Program Scientist (with S. Wachter).

Tom Ingerson, Support Scientist

Areas of Interest

Recent Research Results
Ingerson’s work consists of developing and improving instruments and facilities at CTIO. He is the project manager of the CTIO portion of the “CTIO Hydra” project, which is nearly finished. During the past year he designed an IFU for use with the Hydra bench spectrograph and an instrument selector/guider assembly for the SOAR telescope.

Future Research Plans
During FY 2001, he plans to conclude the commissioning of the CTIO Hydra and finish the IFU unit, which it is hoped will be able to replace most of the functions of the R/C and Echelle spectrographs. He will also be heavily involved in the installation of a 155Mb/s OC-3 link between La Serena, Cerro Tololo, and Cerro Pachón, recently funded by NSF, and the subsequent connection of the Gemini and CTIO networks to Internet2 via high-speed links which are now under negotiation. Assuming that SOAR approves construction of the instrument selector box, he will spend a large fraction of his time during the next year managing this project.

Service
Ingerson is head of the Computer Applications group. During half of the past year he was also Acting Head of CTIO ETS. He is the scientist in charge of the Hydra ETs, maintains the CTIO WWW site, and works as a consultant on optical instrumentation for the SOAR project.

Knut Olsen, Assistant Astronomer

Areas of Interest
Stellar Populations, Magellanic Clouds, Nearby Galaxies, Interaction of Stars with the ISM.

Recent Research Results
Olsen’s most recent research has focused on the very youngest and the very oldest stellar populations in nearby galaxies. In collaboration with S. Kim (U. Illinois) and REU student J. Buss (U. Wisconsin-Oshkosh), Olsen has looked at all of the components that make up the LMC OB association LH 72 and its surroundings. LH 72 lies in the interior of the kpc-sized supershell LMC-4. From spectra and UBV photometry obtained with the CTIO 1.5-m telescope, they have studied the properties of LH 72’s ionizing stars. From narrowband H-α and H-β imaging, they have examined the ionized gas and identified Be stars. With 21-cm spectra obtained by Kim from ATCA, they have observed the distribution and kinematics of the HI gas. The main results are that the spread in age within the 100 pc-sized association LH 72 and its surroundings. LH 72 lies in the interior of the kpc-sized supershell LMC-4. From spectra and UBV photometry obtained with the CTIO 1.5-m telescope, they have studied the properties of LH 72’s ionizing stars. From narrowband H-α and H-β imaging, they have examined the ionized gas and identified Be stars. With 21-cm spectra obtained by Kim from ATCA, they have observed the distribution and kinematics of the HI gas. The main results are that the spread in age within the 100 pc-sized association is as large as in the entire surrounding supershell; that LH 72 lies on the rim of a filament expanding with a velocity of ~20 km/s at the edge of the supershell wall; and that there is no evidence for the age gradient in LH 72 suggested earlier by

Appendix L - 3 NOAO FY 2001 Provisional Program Plan: NSF-Funded Scientific Staff
Olsen et al. The results suggest that LMC-4 may have been produced by star formation activity distributed over a wide area, rather than by a single large event.

Olsen, in collaboration with J. Bright (Mesa State College, CTIO REU student), R. Schommer (CTIO), N. Suntzeff (CTIO), and B. Miller (Gemini), is studying the globular cluster systems of the late-type spiral and dwarf galaxies of the Sculptor Group. Because the number of clusters is usually small compared to the number of contaminating background galaxies and foreground stars, globular cluster systems in late-type galaxies have not been studied as thoroughly as in elliptical galaxies. The galaxies of the Sculptor Group are near enough that globular clusters can be identified from morphology as well as photometry, yet far enough away that the cluster systems can be observed with single telescope pointings. Olsen et al. have observed six of the galaxies with Mosaic II on the CTIO 4-m, and also have data from the LCO 2.2-m telescope. Analysis of the Mosaic II images has generated 100–150 candidate clusters per galaxy. By comparing the properties of the candidates to known globular clusters in NGC 253, Olsen et al. estimate that 50% of the candidates are true globular clusters. Judging from their C-M and C-R colors, the candidates appear to include both old metal-poor clusters and bright young clusters.

**Future Research Plans**
Spectroscopy of the candidate Sculptor Group globular clusters will reveal their true nature and produce kinematics of the cluster systems. Hydra-CTIO is the natural instrument to use for this purpose.

Together with J. Holtzman (NMSU), Olsen is seeking to improve constraints on the field star formation history of the LMC. With the CTIO 1.5-m and 0.9-m telescopes, they have obtained VRIC photometry of an LMC field previously observed with the HST. In combination, these bands provide a sensitive metallicity indicator with which it is possible to break the age–metallicity degeneracy inherent in color–magnitude diagrams. Uncertain metallicities are a primary source of ambiguity in interpreting HST color–magnitude diagrams of the LMC field. The data await analysis.

In collaboration with D. Zaritsky (U. Arizona), Olsen will try to use red clump stars from the study of Zaritsky et al. — Magellanic Clouds Photometric Survey of the Small Magellanic Cloud—to map the three-dimensional structure of the SMC.

**Service**
Olsen was the CTIO representative on the Scientific and Local Organizing Committees for the CTIO/ESO/LCO Workshop “Stars, Gas, and Dust in Galaxies: Exploring the Links” held in La Serena in March 2000. He is also co-editor of the Proceedings. Olsen is a member of the LOC for the proposed IAU Symposium “Extragalactic Star Clusters” to be held in Pucón, Chile in March 2001. Olsen helps to support the Hydra spectrograph, Mosaic II camera, and optical slit spectrographs at CTIO. He supports software in his role as the IDL expert. Olsen is the CTIO section editor for the NOAO Newsletter. He also organizes CTIO’s scientific colloquia.

Robert A. Schommer, Associate Director of NOAO for the US Gemini Program

**Areas of Interest**
Stellar Populations, Magellanic Clouds, Galaxy Dynamics, Large-Scale Structure, Cosmology.

**Recent Research Results**
Schommer is a member of the high-z supernova team, which has discovered more than 40 SNe Ia over the past five years. Current results continue to favor a cosmology with $\Omega_{\text{matter}} = 0.2-0.3$ and a significant cosmological constant. Several SNe Ia beyond $z=1$ have been found by our group. Schommer is continuing work with Suntzeff and Phillips (LCO) on the Hubble diagram of SNe Ia, focusing on calibration issues and the removal of reddening effects, and has finished a study with REU/PIA student A. Bonacic on the peculiar motion of the LG with respect to the nearby SNe sample. Current determination of the Hubble constant remains in the mid-60s, and the LG motion is within one sigma of the CMR vector. The convergence depth of the motion appears to be ~9000 km/sec. A study of the motions of LMC C stars with D. Graff indicates a possible kinematically distinct population, perhaps a tidal residue, which could provide significant signal for the microlensing studies.

**Future Research Plans**
Future work on the old populations of Local Group galaxies includes continuing studies of field populations in the outer regions of the LMC and M33, using photometry, abundances, and velocities, with both ground-based and HST data. A study of NGC121, an old cluster in the Small Magellanic Cloud, is also in progress. Schommer is currently analyzing velocities for a sample of C stars in the LMC, with Suntzeff, Hardy, and Alves, in an attempt to understand the velocity dispersion profiles and thus the
thickness of the LMC for self-lensing. Schommer continues his role in the high-z SNe searches, and plans for additional searches out to $z = 1$ (and beyond) are underway. Schommer is working with C. Smith, Suntzeff, and Phillips on searches for nearby supernovae, in order to understand the range of astrophysical parameters of the explosions and to characterize more completely the scatter in the magnitude-light curve width relation. He is a member of the NOAO Deep-Wide Survey Team, and continues to be involved with J.A. Tyson in observations of weak lensing, and searching for transients in that database.

Service
Schommer’s service activities currently include support of the BTC imager on the Blanco 4-m and the soon to be ready Mosaic II camera. As of 1 February 2000, Schommer became the US Gemini Project scientist and an Associate Director of NOAO. As such, he is responsible for coordinating the US Gemini program, including visitor support, proposal preparation, and reduction of the scientific data from the Gemini Observatory. He also presents to the Gemini Project the US position with respect to the operation and instrumentation of the Gemini telescopes.

Malcolm Smith, Director, CTIO; Associate Director, NOAO

Areas of Interest
Quasars, Active Galactic Nuclei, Faint Red Objects at High Galactic Latitude.

Recent Research Results and Future Research Plans
Smith is following up on a number of complementary, collaborative surveys aimed at discovery of quasars at $z > 5$ and characterization of the quasar luminosity function at such redshifts. This research has the primary goal of clarifying the controversial question of the evolution of the luminosity function of quasars at early epochs in the universe. Leading models differ by an order of magnitude in their prediction of the surface density of quasars expected to result from such surveys. An estimate of the elapsed time between the Big Bang and the period when quasars switched on should prove relevant to an understanding of the early formation of galaxies. The search for such objects should also give clues as to their nature and early environments, as well as provide a list of individual, distant objects to be used in subsequent work such as absorption-line, emission-line ratio, and gravitational lensing studies. Normal galaxies as well as quasars are now being found at $z > 5$, which is a necessary first step towards understanding the relationship between quasars and more normal galaxies close to their epochs of formation.

This is a long-term project involving quite large and distributed teams doing extensive calibration work, surveys, and data reduction. The surveys at the prime focus of the Blanco 4-m telescope have been based on selecting such high-redshift quasars by means of their very red $V$-I colors and blue $I$-$Z$ colors.

As an example of some of this work (the NOAO Deep-Wide Survey is described elsewhere), Smith, Kennefick (Oxford), Hall (Toronto), Osmer (OSU), Green (NOAO), Monier (OSU), and Conti (OSU) have imaged 40 sq. deg. through $B$, $V$, $I$ and $Z$ filters with the aim of detecting faint quasars at $z > 5$ and $i < 22$ (as well as gravitational lenses, and $z > 0.6$ clusters of galaxies). This imaging provides an unprecedented data set in terms of magnitude and area coverage for the rare objects they are seeking.

Spectroscopic follow-up of the brightest candidates for quasars from the 40 sq. deg. survey has already resulted in the discovery of quasars with redshifts of 4.6 and 4.8 and magnitudes near the limit of the Sloan survey. With an appropriate spectrometer on the Gemini telescopes, it will be straightforward to reach fainter magnitudes and complement the Sloan hemispheric-scale survey work on brighter quasars (and thus provide key information on the luminosity function at these high redshifts).

Service
Smith has multiple service duties as director of CTIO, in addition to serving as the Head of AURA’s Observatory in Chile (AURA-O), of which CTIO is one of the major units (along with the Gemini South and SOAR telescopes, which are currently being constructed on Cerro Pachón). During the past year, the USGPO and SOAR directors have been selected—both are from the CTIO staff and will be based in La Serena in the steady state. Smith has initiated and participated in an extensive program to combat light pollution in Chile. He has recently taken on a wider role, following his appointment as chairman of the IAU Working Group on “Controlling Light Pollution,” and is now also a member of the Board of Directors of the International Dark Sky Association. The Chilean National Office of Light Pollution Control has started work in La Serena, following the recent promulgation of a set of national regulations concerning outdoor lighting in the northern regions of Chile (where many of the world’s premier observatories are...
located). The director of that office is employed by AURA. Smith is also working closely with local schools, an amateur observatory, and two universities in the La Serena region on an extensive, carefully conceived outreach program, which it is hoped will interface with similar programs in the US once fast, wide-band links are completed for the Gemini program.

R. Chris Smith, Assistant Astronomer

Areas of Interest
Supernovae, Supernova Remnants, Interstellar Medium, and the Magellanic Clouds.

Recent Research Results
The majority of Smith’s research time is invested in leading two large projects, the Magellanic Cloud Emission-Line Survey (MCELS) and the Nearby Galaxies Supernova Search (NGSS). MCELS is a complete survey of both the Large and Small Magellanic Clouds in the optical emission of Hydrogen (Hα), Sulfur ([S II]), and Oxygen ([O III]). The survey will provide a complete picture of the ionized component of the interstellar medium and its components, such as planetary nebulae, HII regions, supernova remnants (SNRs), and superbubbles, in the Magellanic Clouds. Smith is working with a group that includes J. Bregman (U. Michigan), Y.-H. Chu (U. Illinois), R. Ciardullo (Penn State), G. Jacoby (KPNO), R. Kennicutt (U. Arizona), F. Winkler (Middlebury College), and others to take advantage of the many areas of interstellar medium research touched by the survey. Specific portions of the MCELS data set have already been analyzed, leading to publications such as (most recently) “Supernova Remnants in the Magellanic Clouds. II. Supernova Remnant Breakouts from N11L and N86” (Williams et al. 1999, ApJ, 514, 798) and “The Multi-phase Medium in the Interstellar Complex N44” (Kim et al. 1998, ApJ, 503, 729).

Together with L. Strolger, a graduate student from U. Michigan, and the CTIO SN Group (including N. Suntzeff and B. Schommer), Smith is also leading the CTIO/LCO Nearby Galaxies Supernova Search (NGSS), a search for relatively nearby supernovae (z<0.1) using the KPNO 0.9-m with the NOAO Mosaic, in order to provide a systematic and statistically complete sample of SNe for detailed study at both optical and infrared wavelengths. Smith is serving as thesis advisor to Strolger, who will be basing his thesis research on the detailed study of the supernovae discovered in this new NOAO SN search. In the three NGSS campaigns to date, a total of 26 supernovae have been discovered, of which 12 have been followed with detailed optical photometry and one with additional IR photometry. Smith is also a member of the High-z Supernova Search group, together with N. Suntzeff and B. Schommer of CTIO.

Future Research Plans
As observations for the MCELS project come to a close, Smith will be focusing efforts both on undertaking analysis of the extensive data set and providing public access to the data. Smith is especially interested in identifying SNRs in the Magellanic Clouds and studying the way these remnants interact with, and shape, the interstellar medium. In addition to these studies of Magellanic Cloud SNRs, Smith will continue to pursue investigations of Galactic remnants, such as his work on RCW 86 (AJ, 1997, 114, 2664).

Together with Strolger, Smith will also be pursuing detailed studies of the SNe discovered in the NGSS project. This search has a planned lifetime of two years, over which Strolger and Smith hope to identify more than 50 SNe for statistical studies and follow some 15 in detail. Smith also will continue to play a supporting role in the High-z Supernova Search group.

Service
Smith has taken up lead support on several instruments. He is the principal contact scientist for the Blanco 4-m RC spectrograph, Echelle spectrograph, and the 1.5-m Cassegrain spectrograph. He also serves as one of the three support scientists for the Mosaic II imager, and is the scientific staff contact for the Arcon CCD controller (which runs all of the scientific CCD cameras at CTIO). Although he handed over support of the Curtis Schmidt to U. Michigan last year, he continues to serve as the local authority on its use.

Together with T. Ingerson, Smith oversees the CTIO computer support group, serving both as co-manager of the four-person group and as scientific staff contact for computer problems and suggestions. Smith also continues to provide overall supervision of the CTIO student program, working with REU Site Director D. Hoard to promote and continue not only the CTIO REU program, but also the parallel Chilean PIA program (Prácticas de Investigación en Astronomía), and other visiting student activities.
Nicholas B. Suntzeff, Astronomer

Areas of Interest

Recent Research Results
Suntzeff’s major research project continues to be the study of the geometry of the universe as measured by the distances to Type Ia supernovae. In 1999, the High-z Supernova Search Team that he co-founded with Brian Schmidt (MSSSO) announced its results: the Type Ia supernovae at \( z \approx 0.5 \) are fainter by about 0.2 mag than expected for a universe with no deceleration. The results strongly rule out a flat \( \Omega_m = 1 \) universe and are consistent with a flat universe with a matter component of \( \Omega_m = 0.25 \). This would imply a “dark energy” which has its simplest parameterization as the Cosmological Constant of Einstein. These results imply that the universe is actually approaching the free expansion state modeled by de Sitter, where the vacuum energy of repulsion has overcome the gravitational attraction of all forms of matter. In astronomical units, the results show that \( q_0 < 0 \) at the 3-sigma level. An independent group, the Supernova Cosmology Project, has also found a similar faintness in their independent Type Ia sample.

Suntzeff is also continuing to study local supernovae. In the past two years he has published papers on SN 1990N, 1991T, 1992ar, and 1998bu in collaboration with M. Phillips (LCO), R. Schommer and R.C. Smith (CTIO), J. Maza (U. Chile), M. Hamuy (Arizona), A. Clocchiatti (U. Catolica), and many others. He will also continue to collaborate on the observation of these and other local supernovae through the HST Supernova Intensive Study (SInS) collaboration of R. Kirshner (CfA), and in particular on SN 1987A. He is presently working on SN 1999ac, SN 1999em, and SN 2000cj. In particular, he is using the YALO telescope to observe near-infrared colors of supernovae to characterize the progenitors.

Suntzeff continues to collaborate with V. Smith (U. Texas-El Paso) on detailed abundances of red giant stars. They are writing up their results on the chemical abundances of stars in NGC 288/362 globular clusters and field RGB stars in the LMC and SMC. With R. Cavallo (GSFC), Suntzeff is reducing CTIO 4-m Hydra data on the Na/Al abundances of giants in Galactic globular clusters. In collaboration with E. Hardy (NRAO), R. Schommer (CTIO), and D. Graff and A. Gould (OSU), he has published a study of the rotation of the LMC as measured from radial velocities of the carbon stars.

Future Research Plans
The future research plans of Suntzeff are to continue to find and study supernovae to prove, or disprove, the conclusions of the acceleration of the universe. In 2000, he will collaborate with the High-z Supernova Team to find Type Ia supernovae at higher redshifts. The maximum effect of the dimming of distant supernovae happens at \( z=0.9 \) for a cosmological constant with \( \Omega_A = 0.75 \). At higher redshifts, the luminosity distance of the supernovae will no longer be affected by a cosmological constant. Thus, by going to higher redshifts, one will be able to see if the luminosity distance follows a single cosmological parameterization, or if other systematic effects (evolution, dust) are corrupting the interpretation. The group has time at CFHT (J. Tonry, UH) and CTIO in October/November 2000 to find SNe at \( z = 0.85 \) to 1.2 to test this hypothesis. The supernovae will be followed at CTIO, Keck, CFHT, VLT, UKIRT, and HST. The group also has HST and ground-based time to get precision colors of a few SNe at \( z=0.5 \) in rest-frame UBVRI to check for the presence of dust in the host galaxy. One explanation for the dimming of distant SNe (that Suntzeff’s group interprets as the effects of a cosmological constant) is that there may be a gray form of dust ejected from galaxies. By comparing colors of distant and nearby SNe, the presence of dust can be determined.

Suntzeff will continue to collaborate with Phillips, Hamuy, Clocchiatti, and Maza on supernovae in the nearby Hubble flow. They are studying both Type Ia and II in the optical and infrared. In particular, the plateau Type II supernovae will be used to get geometrical distances via the “Expanding Photosphere Method.”

Suntzeff is a member of the Willick-Hudson team, which has an NOAO survey proposal to use fundamental plane distances to elliptical galaxies out to redshifts of 0.03 to test for flows at the largest scales near the depth of convergence to the COBE dipole.

Suntzeff will also continue in stellar astronomy projects. With V. Smith, he will finish the study of abundances of RGB stars in the LMC and SMC. He will continue to collaborate with the GSFC GRB team to follow GRB candidates in the Southern Hemisphere. He is collaborating with B. Schmidt (MSSSO) to use the databases available to search for distant RR Lyrae stars out to 150 kpc.
**APPENDIX L: NSF-Funded Scientific Staff**

**Service**

Suntzeff will continue a multi-faceted program of service to CTIO. He is the support astronomer for the Hydra fiber spectrograph and the bench-mounted echelle spectrograph. He will continue to work with M. Boccas to improve the image quality on the smaller telescopes. Suntzeff will continue to serve on the NOAO TAC and the CTIO ACTR committees. He is in charge of the CTIO Library. He continues to be in charge of the site monitoring at CTIO—the seeing and basic environmental data collection. With Walker and Blum, he has begun a site survey of northern Chile for possible sites for a US MAXAT/ELT large telescope project. He has served on the Chilean TAC, and also the NOAO Director’s Search Committee. He participates in the NSF REU program every year, during which he directs one or two students in research projects.

**Stefanie Wachter, Research Associate**

**Areas of Interest**
X-Ray Binaries, X-Ray Transients, Compact Objects, Accretion Disks, Star Formation, Pre-MS Binaries, Multi-wavelength Observations.

**Recent Research Results**

Wachter’s recent research has focused on the study of low-mass X-ray binaries (LMXBs), i.e., interacting binary systems in which mass is transferred from a late-type star to either a neutron star (NS) or a black hole. X-ray binaries provide one of only two ways to determine the masses of NSs and therefore to constrain the equation of state of nuclear matter. In order to explore the dynamics of the emission regions in LMXBs, Wachter conducted simultaneous optical, IR, and X-ray observations of various LMXBs in collaboration with A. Smale (NASA/GSFC). Wachter is particularly interested in studying the outburst mechanism and decay characteristics of transient X-ray binary systems and, together with C. Bailyn (Yale), obtained optical light curves of X1659-298 during its 1999 outburst. Synoptic monitoring of X-ray transients in the optical coordinates with observations in X-rays is currently being carried out for SAX 1808-365 (with R. Wijnands, MIT) and X1608-52 (with C. Bailyn, P. Kaaret, S. Corbel, CfA).

Wachter also conducted simultaneous X-ray, optical photometric, and spectroscopic observations of the X-ray burster X1636-536 in collaboration with T. Strohmayer (NASA/GSFC) and D. Hoard (CTIO). The discovery of Doppler-shifted X-ray burst oscillations in this source was thought to provide a new way to determine the radial velocity curve, and therefore the mass, of the compact object. Wachter derived an updated ephemeris for the source and showed that the frequency shift in the burst oscillations is inconsistent with being caused by the orbital motion of the neutron star.

Wachter continued her program of monitoring various poorly studied LMXBs in order to determine their orbital periods. Only few LMXBs have accurately known periods, and the information on long-period systems is especially sparse. At the same time, the long-period systems are crucial for constraining population synthesis parameters. The new synoptic monitoring capability provided by the YALO telescope allows, for the first time, an efficient way to explore the long-term variability of LMXBs. The current work on two systems, X0614+091 and X0921-63, has been accomplished with the help of REU 2000 summer student Ben Johnson.

In addition to her LMXB research, Wachter has initiated several projects to study star formation. Together with D. Hoard, she conducted a search for eclipsing pre-main sequence (PMS) binary stars in the Vela molecular ridge in order to identify candidates for dynamical mass measurements via spectroscopic follow-up studies. Dynamical mass estimates for PMS stars are of particular importance because the absolute mass calibrations of theoretical evolutionary tracks are currently unconstrained by observational measurements. In collaboration with M. Sterzig (ESO) and D. Hoard, Wachter is also involved in a study of star formation scenarios through multi-wavelength observations of the nearby small isolated molecular cloud NGC1788.

**Future Research Plans**

In the future, Wachter will continue her involvement in coordinated X-ray and optical observations of LMXBs, X-ray transients and related objects. Wachter is participating in the optical survey for the Chandra Multiwavelength Project (ChaMP), which will provide the optical characteristics of X-ray sources in selected deep Chandra fields.

Together with R. Bandyopadhyay (NRL), Wachter will work on characterizing the IR properties of accretion disks in interacting binaries through near-IR photometric and spectroscopic observations of a large sample of LMXBs. She is also involved in surveying the IR properties of cataclysmic variables using the 2MASS database (with D. Hoard).
Service
Wachter (together with D. Hoard) is currently support scientist for the 0.9-m telescope and the 0.9-m SSTO (Synoptic, Service, Target-of-Opportunity) program, and NOAO contact scientist for the YALO telescope project. In the future, Wachter will also be responsible for the scheduling of the CTIO telescopes and will be involved in various aspects of support for the Gemini telescopes.

Alistair Walker, Assistant Director, CTIO

Areas of Interest
Stellar Populations, Magellanic Clouds, Distance Scale, Stellar Photometry.

Recent Research Results
Walker is PI of a Cycle 8 HST program to test stellar evolutionary theory using the very rich young LMC cluster NGC 1866, by analysis of the color-magnitude diagram and luminosity function, which for the first time will include all the luminous evolved cluster stars. The deep and accurate CMD will allow fitting of a fiducial ZAMS and thus derivation of a precise distance, which will calibrate the luminosities of the many Cepheids in the cluster. The distance to the LMC is now one of the major uncertainties in the cosmic distance scale.

In a project led by W. Gieren (U. Concepción, Chile), Walker is participating in a study of the Cepheids in the nearby galaxy NGC 300 by obtaining images with the Mosaic II CCD camera. Follow-up with IR photometry will allow a critical evaluation of the properties of the Cepheids in this favorably sited galaxy.

Together with H. Smith (Michigan State U.) and E. Brocato, F. Caputo, and V. Castellani (Italy), Walker is collaborating in a comprehensive survey of the variable star population of the Carina dwarf galaxy, using the Blanco telescope with Mosaic imager and the WFI instrument on the ESO 2.2-m telescope. Comparisons are being made with extensive sets of evolutionary and pulsation models applicable to the wide ranges of metallicity and mass expected, which will both test the models exhaustively and probe in detail the properties of the older stars in Carina.

Future Research Plans
D. Terndrup (Ohio State U.) and R. Peterson (Lick Obs.) are leading a team, of which Walker is a member, to survey for hot evolved stars in the Galactic Bulge using the Mosaic II imager, with follow-up spectroscopy. This survey will characterize the space density of hot Blue Horizontal Branch stars, which are likely to be responsible for the UV excess in elliptical galaxies.

With Y.-W. Lee, S.-C. Rey (Yonsei U. Obs.) and S. Baird (Benedictine College), Walker will study the RR Lyrae variable stars in the Galactic globular cluster M22. The team has completed studies of the cluster Omega Centauri, obtaining accurate abundances for the RR Lyraes and a CMD for the whole cluster, showing that there are multiple populations and an age spread. The similarity to a CMD for the Sagittarius Dwarf Galaxy suggests that Omega Cen is the remnant nucleus of a dwarf galaxy that was accreted by our own galaxy many Gyr ago. M22 is probably the only other globular cluster in our Galaxy with a metallicity spread, and so will be subject to an analysis similar to that for Omega Cen.

Service
Walker is Assistant Director of CTIO. He is also chair of the Advisory Committee on Technical Resources (ACTR), which oversees the observatory instrumentation program and telescope operations. Walker directs and coordinates CCD operations and upgrades, and supervises the operation of the CCD laboratory. He is the CTIO project scientist for the Mosaic II imager and the project scientist for the SOAR optical imager. He is chair of the “sites” working group as part of the NOAO-led community effort to develop plans for building the next-generation extremely large telescope, and is in charge of the CTIO site campaign in northern Chile. Walker also serves on the HST Wide Field Camera 3 Science Oversight Committee.

Tucson Based Scientific Staff

Taft Armandroff, Associate Astronomer, USGP Project Manager

Areas of Interest
Stellar Populations in the Galaxy and Nearby Galaxies; Dwarf Spheroidal Galaxies; Globular Clusters.

Recent Research Results
Armandroff has been studying the dwarf spheroidal satellite galaxies of M31, in collaboration with Da Costa (Mt. Stromlo), Caldwell (SAO), and Seitzer (Michigan). This was motivated by the opportunity to increase the number of galaxies defining the properties of dwarf spheroidals, and by the fact that the somewhat different environment of the...
M31 dwarfs compared to those of the Galaxy allows a first look at how dwarf spheroidal properties change with environment. Images were obtained with the HST WFPC2 camera of And I and II, dwarf spheroidal (dSph) galaxies located in the outer halo of M31. The resulting color-magnitude diagram reveals for the first time the morphology of the horizontal branch in these galaxies. They find that, in a fashion similar to many of the Galactic dSph companions, the horizontal branch (HB) of And I and II is predominantly red. Combined with the metal abundances of the dSphs, this red HB morphology indicates that And I and II can be classified as “second parameter” systems in the outer halo of M31. This result then supports the hypothesis that the outer halo of M31 formed in the same extended chaotic manner as is postulated for the outer halo of the Galaxy. In addition to the red HB stars, blue HB and RR Lyrae variable stars are also found in the And I and II color-magnitude diagrams. The presence of these stars indicates that And I and II contain a minority population whose age is comparable to that of the Galactic globular clusters. Thus, again like many of the Galactic dSphs, there is clear evidence for an extended epoch of star formation in And I and II. The most recent of this research is published in the *Astronomical Journal* (2000, 119, 705).

**Future Research Plans**

Pursuing the theme described above of studying the properties of dwarf spheroidal galaxies as a function of environment represents a significant portion of Armandroff’s research agenda for the coming year. WFPC2 observations of three other M31 dwarf spheroidals, And III, V, and VI, have been obtained. From these data, he hopes to learn whether these three galaxies resemble their Galactic counterparts as much as do And I and II.

**Service**

Armandroff serves as US Gemini Project Manager. In this capacity, he is responsible for the US contributions to instrumentation for the Gemini telescopes. Armandroff is a member of the Committee of Gemini Offices, participating in the Gemini Instrument Forum and Operations Forum. Armandroff also chairs NOAO’s Instrument Projects Advisory Committee (IPAC). Finally, Armandroff serves as a WIYN Consortium Board member and is the Board’s Secretary.

**Samuel C. Barden, Scientist**

**Areas of Interest**

Stellar Physics and Dynamics, Binary Stars, Spectroscopic Instrumentation.

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**Recent Research Results**

Barden has focused his research on the evaluation of a new type of diffraction grating technology through an NSF-funded research grant. The gratings (volume-phase holographic, or VPH) diffract light from modulations in the refractive index of the grating material, rather than by surface modulations as in classical gratings. These new gratings have the potential for higher diffraction efficiencies than classical gratings, along with many other benefits. Eight gratings were fabricated by Kaiser Optical Systems, Inc. (KOSI), Barden’s collaborators on the grant, and have been evaluated at NOAO by Barden and J. Williams (a student hired by the grant). A 1200 line grating shows peak efficiency of 87%, and a “complex” grating (actually two gratings in the same structure) shows a peak efficiency of 93% for one of the grating components. This study has helped spawn a new generation of spectrograph design. Many astronomical observatories (NOAO, AAO, Magellan, SOAR, ESO) are currently investigating spectrograph concepts that will utilize these novel gratings.

Barden is continuing to work with KOSI to enhance their fabrication facilities for the production of large-format gratings with sizes up to at least 200 mm. This effort is also being supported by the Department of Astronomy at U. Michigan, as they anticipate using this grating technology in an instrument for the Magellan II telescope.

**Future Research Plans**

Barden will continue to focus on evaluation of this new grating technology and on spectrograph designs that exploit its unique characteristics. Presentations on VPH technology will be or have been given at several meetings, and the first of several papers is appearing in the publications of the Astronomical Society of the Pacific in June 2000.

**Service**

Next Generation Optical Spectrograph (NGOS). Barden is leading the development of a wide-field, high-efficiency spectrograph for the KPNO 4-meter based upon volume-phase holographic gratings. This instrument will be an imaging spectrograph with slitlets covering a 10x40 arcminute field of view on the telescope. The design will serve as a technological stepping stone for similar types of instruments that will exploit wide-field spectroscopic surveys on large aperture telescopes (8 to 30 meters).

Cryocam Upgrade. Barden is assisting with an effort to fix and enhance the performance of the 4-meter Cryocam instrument. The upgrades will include new optical coatings,
volume-phase holographic gratings, and a new high-resistivity CCD. Many of the efforts will provide invaluable experience for items critical to the development of the NGOS.

Committees. Barden currently serves on the NOAO Instrumentation Project Advisory Committee (IPAC), which provides counsel to the NOAO director for instrumentation projects within NOAO. He recently served on both the Preliminary Design Review Committee (held in August 1999) and Critical Design Review Committee (held in May 2000) for the HROS (High-Resolution Optical Spectrograph) instrument destined for Gemini South. Barden also held a workshop in February 2000 to discuss instrumentation issues for a 30- to 100-meter telescope. He is also preliminarily involved in a similar activity in a collaborative effort with the Europeans.

Bruce Bohannan, Scientist

Areas of Interest
Stellar Evolution; Spectroscopic Studies of Hot, Luminous Stars; Astronomical Instrumentation and Data Reduction.

Recent Research Results
Bohannan’s research centers on observational studies of the evolution of massive stars. The evolution of these stars is insufficiently understood to account accurately for their contribution to the chemical element evolution and kinetic energy of their parent galaxies. The critical factor is that models are not connected to simple spectral morphology during the most critical stages of stellar evolution, the stages when significant mass is lost over very short time scales. Through direct measurement of basic stellar properties (temperature, gravity, mass, mass loss rate, and surface element abundances), Bohannan has sought to better define the evolutionary path of massive stars and to make connections between various stages of massive stars.

Future Research Plans
Investigations of stars in the Galactic Center and in other galaxies similar to those outlined above provide critical diagnostics of stellar evolution because they give clues to the effect of different stellar environments on stellar evolution. Such studies require infrared observations because of extreme interstellar absorption (e.g., in the Galactic Center) or severe crowding of stellar images (e.g., other galaxies), research that requires a moderate-resolution IR spectrometer combined with an image compensation system that provides high spatial resolution (e.g., tip/tilt and fast focus). IR diagnostics have been developed with Crowther and analyzed through observations obtained at CTIO and Hillier model atmospheres (Bohannan and Crowther, 1999). The next stage is to analyze a set of Of and WN stars in the Large Magellanic Cloud, to be followed by observations of stars in the Galactic Center thought to be of similar spectral morphology, and then to undertake a similar study of stars in the nearby spiral galaxy M33.

Service
Bohannan is the project scientist for the Mayall Active f/8 Secondary and the Mayall Cassegrain Wavefront Camera. The Active f/8 Secondary, the final component of a long-term series of projects to improve the delivered image quality at the KPNO 4-m telescope, will add control of the secondary alignment to the active primary mirror system. The wavefront camera is intended to enable wavefront measurements on a nightly basis and could eventually be used for closed-loop control of the telescope optical system. Bohannan also serves as the system coordinator for the IRMOS project, a collaboration between STScI, NASA Goddard, and KPNO, to construct a multi-object infrared spectrometer for Kitt Peak. Bohannan is also the Editor-in-Chief of the NOAO Newsletter.
density of emission-line objects found in this survey is almost 200 times that found by the Markarian survey. This first paper gives an overview of the survey and examines the selection criteria and potential applications for the resulting database of objects.

**Future Research Plans**
Together with R. Green, Boroson is exploring relationships between luminosity, black hole mass, and emission-line properties for a sample of quasars. Recent studies have shown a convincing correlation between the mass of the nuclear black hole, derived in a number of ways, and the mass of the spheroidal component of the galaxy in which the black hole resides. Given the black hole mass, one can compare the luminosity of the active nucleus with that expected at the Eddington limit. Preliminary study suggests that objects that are emitting at a large fraction of their Eddington luminosity have optical spectra dominated by Fe II emission lines, while those that are emitting at only a few percent of this limit have very weak Fe II, but have strong forbidden emission. The next step is to confirm this and quantify the relationships with a well-defined, complete sample.

**Service**
Boroson serves as Deputy Director of NOAO. He leads the Surveys and Data Management group. Activities of this group include the NOAO proposal and time-allocation process, the NOAO survey program (and particularly the NOAO Deep-Wide Survey), and the development of software for data reduction, archives, and data mining.

Boroson chairs the Liaison committee for the NOAO Director Search and serves as the US member of the Gemini International TAC. National: Member, Astronomy and Astrophysics Survey Committee and Vice-Chair, OIR Panel; member, Committee on Astronomy and Astrophysics; contributor to NVO white paper.

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**Charles F. Claver, Assistant Scientist**

**Areas of Interest**

**Recent Research Results**
Claver’s research has focused mainly on two observational projects addressing stellar ages in the Galaxy. Specifically he has been investigating the necessary age concordance between two different techniques—white dwarf cooling times and main sequence turn-off ages. This is part of an effort to pursue a reliable age estimate for the Galactic disk using white dwarf cooling times and the “cut-off” found in the white dwarf luminosity function.

A critical test of stellar ages can be made by estimating the age of the same object using these two different techniques. If there are no significant systematics, then both techniques will be in agreement. The preliminary H-R diagram for field stars in the Galaxy indicate there may be a discrepancy in ages when compared with the age of the disk as estimated from white dwarf cooling times. New models for white dwarf cooling and recent work on the oldest open clusters in the galactic disk support the idea that there is an “age crisis.” For example, perhaps the oldest open cluster known, Berkeley 17, is estimated to be 9-12 Gyrs old, where the latest white dwarf cooling models indicate a disk age of 6-9 Gyrs.

Claver has been investigating the nature of this discrepancy by searching old galactic clusters for their white dwarf stars. Observations by Claver, Von Hippel (WIYN), and recently Ritcher et al. of clusters up to 4 Gyr show no real difference between their turn-off ages and the oldest white dwarfs. In collaboration with D. E. Winget (Texas), M. Wood (FIT), and M. Bolte (UC Santa Cruz), Claver is analyzing data on four clusters to estimate their ages from white dwarf cooling times. These clusters are NGC-752 (2-3 Gyrs), IC4651 (2 Gyrs), NGC-3860 (2-4 Gyrs), and M67 (4-5 Gyrs). In addition, they have scheduled time with HST to observe the old open cluster NGC-188.

As part of his dissertation work at U. Texas, Claver began the Texas Deep Sky Survey (TDSS). This is a digital survey designed to cover ~ 100 square degrees of sky in seven photometric colors. The aim of the TDSS is to identify some ~ 600 cool white dwarfs and roughly 1 million galaxies. The white dwarfs identified will be used to explore the nature of white dwarf cooling at low temperatures and how this impacts the age of the Galaxy inferred from white dwarf cooling times. Claver’s collaborators at U. Texas are using the galaxies and galaxy clusters to explore large-scale structure in the universe.

As part of his work on white dwarfs in open clusters, Claver has found supporting evidence of a complex Initial-Final mass relation between white dwarfs and their progenitors. The results are based on studies by Claver in the Praesepe and Haydes open cluster, which have nearly identical ages, hence progenitor masses, and abundances, but have produced very different white dwarf masses. This implies...
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that there is an additional parameter to the Initial-Final mass relation, perhaps analogous to the globular cluster second parameter problem. Further study is needed to confirm this behavior in the I-F mass relation as described below.

Claver has also recently presented first results from Hydra spectroscopy of white dwarf candidates in the TDSS. These results show for the first time that the photometric selection of cool degenerate stars is possible. At least three objects and a possible fourth from the first field are bona fide degenerates.

Future Research Plans
Over the next several observing seasons, Claver plans to continue spectroscopic follow-up observations with WIYN Hydra of his cool white dwarf photometric survey. The cool white dwarfs identified will be used to redefine the cool part of the white dwarf luminosity function (WDLF). These data are important not only for estimating the Galaxy’s age, but also for placing an observational constraint on the importance of phase separation of a carbon-oxygen mixture in crystallization of white dwarf cores. Phase separation, if it happens, releases additional energy into the white dwarf core, further delaying the cooling process beyond the delay caused by the release of latent heat. The exact nature of white dwarf crystallization causes observable features in the WDLF and has a large effect on the inferred white dwarf cooling ages. He will also work toward increasing the area of his survey in order to increase the detection sensitivity of older-cooler white dwarfs belonging to the Galactic Halo.

Also, Claver plans to extend his work on calibrating the stellar chronology in star clusters to ages older than three billion years. Specifically, in collaboration with D. Winget (U. Texas), M. Bolte (Lick Obs.), and M. Wood (FIT), he plans to search for and identify the oldest white dwarfs in the clusters NGC-188 and Berkeley-17 in the North and IC-4651 and NGC-3680 in the South using both ground- and space-based telescopes. These clusters will extend the calibration to roughly eight billion years, which is sufficient to constrain the source of the present differences in the universe’s expansion age and its oldest stars. In addition, the southern two clusters bracket the age and turn-off masses where Claver suspects a change in the Initial-Final mass relation. Claver plans to obtain high signal-to-noise spectroscopy of the white dwarfs in these clusters in order to obtain model atmosphere fits, which will allow further assessment of the Initial-Final mass relation.

Service
Within the Kitt Peak scientific staff Claver holds the title of Imaging Scientist. As part of his service activities he has begun and continues a coherent comprehensive look at the imaging quality produced by Kitt Peak telescopes with the aim of having all Kitt Peak telescopes deliver the excellent seeing of which the site is capable. To this end, Claver has taken on the responsibility of overseeing and maintaining optical alignment of Kitt Peak telescopes, as well as debugging problems when they occur.

As a member of the 4-m imaging improvement group, Claver is investigating the performance of the 4-m primary support system to determine if and where significant improvements can be made in the delivered image quality of this valuable telescope. Claver’s efforts, as project scientist, have resulted in a major improvement project to install an active back support system for the 4-m primary mirror.

Claver has also conducted a study of high frequency image motion at WIYN. This study has shown that high-speed tip/tilt compensation will result in 0.1-0.2 arcsecond improvements in delivered FWHM over moderate fields with the WIYN telescope. The WIYN consortium has approved a project to design, build, and commission a tip/tilt compensating imager with Claver as the NOAO project scientist. The WIYN Tip/Tilt Module (WTTM) recently passed its preliminary design review and received the “go” to proceed with project as planned. The WTTM expects first light with an optical imager in the Spring of 2001.

Claver has also served as the NOAO representative for the Adaptive Optics Technology Center proposal being submitted by J. Nelson (Lick Observatory).

Arjun Dey, Assistant Astronomer
Areas of Interest
Galaxy Formation and Evolution, Distant Galaxies, Large-Scale Structure, Active Galactic Nuclei.

Recent Research Results
Dey, J. Graham, and M. Liu (UC-Berkeley), along with various collaborators in the US and UK, are investigating the optical and infrared properties of sub-mm sources discovered by SCUBA on JCMT sources. A significant fraction of the sub-mm sources discovered using the SCUBA at the JCMT are found to be associated with extremely red galaxies whose properties and redshifts are
APPENDIX L: NSF-Funded Scientific Staff

only just being understood. It is believed that some of these galaxies are dusty starburst galaxies at intermediate redshifts (i.e., Arp 220 analogs at z=1-2), whereas a small fraction may lie at much higher redshift.

In addition, Dey is collaborating with H. Spinrad (UC-Berkeley) and D. Stern (JPL) on various searches for distant galaxies. This team has successfully detected several galaxies with redshifts z>5. In addition, they are characterizing the properties of samples of galaxies selected at z~4 using the Lyman drop technique.

With A. Zirm (a student at JHU) and M. Dickinson (STScI), Dey is working on understanding the properties of the host galaxies of z=1-2 powerful radio galaxies. This group has analyzed HST NICMOS data of a small sample of these sources and found that the hosts are typically dynamically relaxed elliptical galaxies with a central surface brightness - effective radius relation that parallels the fundamental plane of local elliptical galaxies, thus adding support to the hypothesis that high redshift radio sources are the progenitors of the most massive local ellipticals.

**Future Research Plans**

Starting in 1997, Dey and B. Jannuzi have been carrying out a deep survey (the NOAO Deep Wide-Field Survey, hereafter NDWFS) of two 9-square-degree regions of sky with the primary goal of studying the evolution (with redshift) in the large-scale clustering properties of galaxies. The optical and near-infrared imaging observations for the NDWFS will be completed by mid-2001, when it will be possible to use the full data set to study the galaxy clustering out to large redshift and on large angular scales. The NDWFS data will enable a number of investigations of galaxy evolution in the context of large-scale structure evolution. Dey is also a Co-I on a SIRTF GTO project to map the NDWFS Boötes field using MIPS and spectroscopically follow up sources using IRS.

**Service**

Dey serves in the PDO and Survey divisions. Dey has worked with J. Najita and S. Strom on a science case for the GSMT, a 30-m diameter telescope recommended by the Decadal Report. This team organized preliminary workshops and a core scientific team to lead this study effort. In addition, Dey, Najita, Barden, Jacoby, Claver, and Harmer drafted a white paper on the need for a wide-field spectroscopic capability (SWIFT) for large telescopes accessible to the US astronomical community.

Dey worked on the implementation of a nod-and-shuffle mode on the RC spectrograph at the Mayall 4-m telescope. This mode results in excellent sky subtraction and enables spectroscopy at the shot noise limit. This spectroscopic mode is critical for efficient faint-object spectroscopy in the red and for multi-object spectroscopy in crowded regions.

Tiede and Dey have determined the non-linearity correction coefficients for the InSb arrays in the ONIS IR camera, and are currently working on the calibrations for SQUIF. With R. Lynds, S. Barden, and R. Reed, Dey is involved in an upgrade to the Cryocam spectrograph that would greatly improve the spectroscopic capabilities offered at the KPNO 4-m telescope.

**David S. De Young, Astronomer; Outreach Coordinator**

**Areas of Interest**

Active Galaxies, Galaxy Clusters, Galaxy Evolution, Radio Sources, Hydrodynamics.

**Recent Research Results**

Much of De Young’s research in recent years has revolved around the common theme of astrophysical outflows and their interaction with the environment. This is a basic problem in nonlinear physics, many aspects of which are poorly understood or not understood at all. This is especially true for highly supersonic and relativistic outflows for which there is little or no experimental data. For these flows, the only accessible laboratory often lies in distant galaxies, where the interpretation of the data is often ambiguous. Nonetheless, such outflows can reveal characteristics of a large variety of astronomical objects, from protostellar jets and HH to starbursts in galaxies and the creation of megaparsec scale radio sources—the largest single coherent objects in the universe.

For example, De Young has investigated the fate of graphite grains in the environment of the high-speed outflows associated with extragalactic jets. Such grains are thought to give rise to the polarized optical emission observed to lie along the axis of the radio emission (the “alignment effect”) by scattering the UV continuum arising in the nuclear region of the AGN. An analysis of the evolution of grain populations in this environment shows that the grains will almost always be destroyed by the shock and hot gas associated with the passage of the hypersonic jet; hence, an initial grain population cannot readily act as a scattering medium to give rise to the polarized emission. A possible
alternative is in situ grain production after the shock passage; this could arise from supernovae explosions in a population of young stars whose birth was triggered by the compressive action of the shock associated with the jet.

In a related research area, De Young has completed a collaboration with B. Durney (NSO) that examines the stability of the narrow boundary between the radiative and convective zones in the Sun. Three-dimensional numerical hydrodynamics of this region reveal complex and often periodic shearing flows, and these may be closely linked to the turbulent generation of magnetic fields in the Sun. A subsequent effort is now underway to explicitly include the development of magnetic fields in this layer.

**Future Research Plans**

**Galaxy Evolution**

In collaboration with C. Norman (STScI), De Young is investigating the fate of hot, metal-rich gas that is injected into galactic halos by OB associations and supernova remnants. It has been widely conjectured, but never demonstrated, that this debris causes the halo gas to cool and condense into clouds which then settle back into the galactic disk. Testing this model requires accurate modeling of the thermal instability in three dimensions in its non-linear phase. The basic computational tools are now in place, and detailed calculations are commencing. In a related project with T. Heckman (Johns Hopkins U.) and C. Martin (STScI), an extended study of mass loss from dwarf galaxies due to starburst activity is being initiated. The issue is that of possible recollapse of an inflated ISM in the galaxy versus complete dispersal of the ISM due to energy injection from the starburst event, and the object is to reproduce the observed low metallicities in these objects together with their observed stellar populations.

More recent collaborations have been initiated with M. Corbin (U. Arizona) in modeling the wind-torus interface in BAL QSO’s to see if mass entrainment from the torus into the wind can reproduce the emission line signatures, and with J. Bally (U. Colorado) in modeling the time variations of collimated outflows from young stellar objects. The latter study involves the modulation of outflows with radiative cooling, coupled with observations of HH objects in order to constrain the basic mechanisms that regulate the outflow itself. De Young is also working on a book, entitled *The Physics of Extragalactic Radio Sources*, to be published by the University of Chicago Press.

**Service**

De Young’s service activities to NOAO include acting as Coordinating Chairman of the telescope time allocation process for all telescopes that can allocate time to NOAO programs. This includes facilities at CTIO, KPNO, Gemini, MMT, and the HET. In addition, De Young serves as Chair of three of the seven allocation committees and is a member of the Merging TAC. De Young has also become the coordinator for NOAO participation in the National Virtual Observatory (NVO) initiative and is a member of the NVO interim Steering Committee; he authored a major portion of the NVO White Paper that was presented to NASA and NSF in May 2000. De Young is also Director of the NOAO Outreach Program that includes the areas of Educational Outreach, Press and Media Relations, Public Outreach, and the KPNO Visitor Center.

Other service activities include membership on the NOAO IPAC Committee, membership on the NOAO Management Committee, supervisor of the NOAO Tucson library, member or chairman of ad hoc KPNO Personnel and Post Doctoral Selection Committees, Chairman of the AURA Strategic Planning Committee, and membership on various ad hoc NOAO committees. De Young is carrying out numerical modeling of air flows associated with possible sites for the Advanced Solar Telescope of the National Solar Observatory, and he is initiating preliminary studies for similar modeling of possible sites in northern Chile. De Young also serves on the Board of Trustees of the Aspen Center for Physics and is the coordinator of the NOAO membership in the National Partnership for Advanced Computational Infrastructure (NPACI). At the request of the NPACI Director, De Young is also acting as the NPACI Liaison to the NVO initiative.

**Jonathan Elias, Astronomer**

**Areas of Interest**

Star Formation and Evolution, Magellanic Clouds, Infrared Instrumentation.

**Recent Research Results**

Elias’s most recent research project has been an investigation of stellar mass loss in the Magellanic Clouds. In the later stages of their evolution, stars become red giants and lose mass. As material flows out from the star, it cools and forms dust. The dust is detectable at infrared wavelengths (if there is enough of it); it will also hide the star itself from view. The abundance of dust in the circumstellar material...
and the rate and velocity of mass loss may all depend on the abundance of heavy elements in the star losing mass, but it is not known in which ways. In order to see what actually happens, it is necessary to compare observations of stars with different heavy element abundances. As stars in the Magellanic Clouds have lower abundances than similar stars in the Galaxy, and since these galaxies are close enough for individual stars to be readily observable, they provide a useful basis for comparison.

**Future Research Plans**

Elias's work to date shows that the data are consistent with the hypothesis that only the amount of dust depends on the heavy element abundance and that the two are directly proportional, while the overall mass loss rate is insensitive to abundance variations. Other workers suggest, though, that mass loss rates should be lower in stars with lower heavy element abundances. Few Magellanic Cloud mass-losing stars have been identified, especially in the Small Magellanic Cloud, so the evidence does not strongly favor one hypothesis over the other. Elias has obtained 1-15 micron data from the Infrared Space Observatory (ISO) and from CTIO on selected regions of the Large and Small Magellanic Clouds. The new data will provide much larger samples of mass-losing stars than have been available up to now and should settle the issue. The ISO data will be correlated with visible-wavelength and near-infrared data in order to obtain a fuller picture of the stars' properties.

A second project is being conducted jointly with D. Geisler and several other collaborators. This is a project to investigate the metal abundance distribution in the rich globular cluster systems surrounding giant elliptical galaxies. The metal abundance distributions in these systems are, in principle, diagnostic of the history of the host galaxies and should, therefore, help us understand their evolution. However, most such systems are too distant to permit direct spectroscopic measurements, so the metallicities must be inferred from a surrogate index. The V-H color is sensitive to metallicity and relatively insensitive to other parameters, such as age. This particular color is well suited to measurements with the HST. The collaborators have assigned HST time to observe the globular cluster systems around five distant giant ellipticals. In addition, M31 globular clusters have been observed from the ground in order to improve the calibration of the V-H color.

**Service**

Elias's service over the last year has been primarily as project scientist for the Gemini Near-InfraRed Spectrometer (GNIRS).

Richard F. Green, Director, KPNO; Associate Director, NOAO

**Areas of Interest**

Active Galactic Nuclei, Chemical Abundance Evolution, Galaxy Nuclear Dynamics.

**Recent Research Results**

Green is collaborating with Y. Izotov of Kiev to investigate elemental enrichment patterns in the most metal-poor galaxies. Izotov et al. published an analysis in 1999 of the He abundances in the two most metal-poor galaxies, and found He/H ratios consistent with hot Big Bang predictions. In addition, Hopp et al. published a new list of metal-poor emission-line galaxies confirmed at Kitt Peak from the Hamburg Survey. Green and Izotov received a NATO collaborative grant to continue their investigations.

**Future Research Plans**

Green has Instrument Team guaranteed time for the Space Telescope Imaging Spectrograph. He leads an Internal Key Project to perform a census of supermassive black holes in the nuclei of early-type galaxies. He is also a member of the "Nuker" proposal team that won a number of orbits in Cycles 7 and 9 to perform a complementary survey. The two teams have confirmed a tight correlation between measured black hole mass and global velocity dispersion, implying coeval formation of the black hole and bulge during dissipative collapse. Green is analyzing NGC 4486B, the dwarf companion to M87, with a double nucleus and complex internal velocity structure.

Green is a member of the science team for the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite, which was launched on 24 June 1999. A major goal of the mission is to trace the evolution of D/H as a function of metallicity, with the aim of determining the primordial value and its cosmological consequences. In addition, he will work with a subgroup of the team in analyzing a large number of AGN spectra for their intrinsic properties; the objects are observed as D/H probes. In addition, personal orbits will be devoted to observing the brightest high-z BAL quasar, which has shown very high ionization species in spectra with IUE and HST.

**Service**

Director, KPNO; Board of Directors, WIYN Consortium; Chair, WIYN Director Search Committee. National: Chair, Astronomy Section, AAAS; Sloan Digital Sky Survey Operational Readiness Review.
Kenneth H. Hinkle, Associate Support Scientist

Areas of Interest

Recent Research Results
Over the past year, Hinkle has worked extensively with the high-resolution infrared spectrograph Phoenix. His instrumental work has been reported in a paper to the SPIE. Data from Phoenix have been used in several publications. With co-investigators T. Geballe (Gemini), B. McCall (U. Chicago), and T. Oka (U. Chicago), Hinkle has collaborated to measure the abundance of the H^3+ ion in the diffuse interstellar medium. H^3+ is one of the key molecules to understanding the chemistry of the interstellar medium. H^3+ is formed by cosmic ray ionization of molecular hydrogen and reacts via a proton hop route to produce the wide variety of complex molecules known in the interstellar medium. Results have been recently published in the Astrophysical Journal. With N. Ryde, B. Gustafsson, and collaborators at Uppsala Astronomical Observatory (Uppsala, Sweden), Hinkle used Phoenix to measure circumstellar emission in the infrared CO fundamental lines. Maps of resonant scattered CO emission were made for a number of circumstellar shells. Results have appeared in Astronomy and Astrophysics, With F. Fekel (Tenn. State) and R. Joyce (KPNO), 1.6-micron spectra obtained with Phoenix have been used to determine the orbits of symbiotic stars. Symbiotic stars are not only intrinsically interesting mass-transfer systems, but they make up most of the binary systems containing an AGB star in which the mass of the AGB star can be determined. Results have recently appeared in the Astronomical Journal. Hinkle has also continued his work on variable stars, publishing with T. Lebzelter (U. Vienna) and L. Kiss (U. Szeged, Hungary) a paper on the velocity and light variations of semi-regular stars. His work on stellar and solar spectral atlases in collaboration with L. Wallace (KPNO) has also continued. In the last year an atlas of sunspot umbral spectra in the visible was produced in collaboration with Wallace and W. Livingston (NSO), and an atlas of J band stellar classification spectra was published with Wallace, M. Meyer (U. Ariz.), and S. Edwards (Smith).

Future Research Plans
Hinkle has a diverse research program, involving infrared spectroscopy with Phoenix and other instruments, visual and ultraviolet spectroscopy, as well as planning for new instrumentation. Hinkle and collaborators B. Hrivnak (Valparaiso) and S. Kwok (Calgary) have obtained Phoenix spectra of molecules in the circumstellar shells of stars in transition between the AGB and proto-planetary nebulae. This data should provide insight into the fast wind phase of planetary nebulae. Hinkle, R. Joyce (NOAO), and D. Lambert and V. Smith (U. Texas) are continuing observations of Sakurai's star and FG Sge. In addition to photometry, reported in IAU Circulars, a program of spectroscopic monitoring is underway. Both Sakurai's star and FG Sge are believed to be undergoing a final post-AGB helium shell flash. Significant changes in the infrared spectra of both stars have occurred over the past few years. With L. Wallace (NOAO) and J. Valenti (STScI), Hinkle will continue investigating rotation, magnetic field, and atmospheric structure of M dwarfs using high-resolution K band spectra. Hinkle, F. Fekel (Tenn. State), R. Joyce (NOAO), and M. Skrutskie (U. Mass.) plan to continue their program of orbital determinations of late-type binary stars. Periodic observations of the infrared spectra of a group of late-type binary stars, including symbiotic systems, are planned using the Phoenix spectrograph as well as a HgCdTe array on coude spectrographs. Orbits can be readily measured from this data since only the infrared spectrum of the cool star is observed with no contribution from the hot components (star and accretion disk) in these systems. The preparation of a series of papers is underway. Hinkle in a collaboration with L. Wallace, J. Valenti, and D. Harmer (NOAO) have produced a high-resolution, high signal-to-noise atlas of the Arcturus spectrum in the visual. This high resolution visual atlas of Arcturus will be published as a monograph by ASP in 2000. Hinkle, Wallace and Valenti have been granted HST time to continue this work into the UV. By using ground- and space-based observations, a third atlas in the Arcturus atlas series is planned that covers the 1200-3700 Â region.

Service
Hinkle's service activities include being project scientist for the Phoenix spectrograph. In the past year, Phoenix has become a facility instrument at Kitt Peak; Hinkle has also been providing visitor support at KPNO, including instrument setups and observer checkouts, and is a point of contact for issues related to Phoenix. Work on the documentation for the instrument is continuing, along with changes in the operational software and data reduction procedures. In the last year, plans have started to go forward to install Phoenix at Gemini South as a first-light instrument. Hinkle has been involved with preparations for this move. Hinkle is also the US mirror scientist for two Gemini instruments, Michelle and NIRSPEC. Hinkle maintains FTS spectra dating back to 1976 in an archive; spectra are avail-
George Jacoby, Astronomer

Areas of Interest
Galaxy Distances, Dynamics, and Chemical Compositions; Planetary Nebulae; Local Group Galaxies; Instrumentation. Recently appointed WIYN Director.

Recent Research Results
Nearby Galaxies
Dwarf Galaxies. With T. Armandroff, Jacoby and J. Davies (Johns Hopkins student) have found two new dwarf galaxies in the Local Group: And V, And VI around M31. Previously, there were only three such dwarfs near M31. The first of these, And V, is nearly as faint as any known dwarf galaxy. Both new galaxies were found using the Digital Sky Survey and an innovative digital image processing technique. They recently surveyed ~200 additional candidates drawn from a sample defined using the Sky Survey technique. None, though, were found to be Local Group dwarfs.

Planetary Nebulae in M31. In 1999, Jacoby and R. Ciardullo (Penn State) presented the chemical compositions of 15 planetary nebulae in M31. From these measurements, it is clear that the stars in M31 are derived from a complex history of chemical enrichment because they span a very wide range of compositions, from 20 times lower than the Sun to just slightly higher than the Sun. During this past year, they have expanded their study to include an additional 20-30 PN in order to define the chemical history of M31 much more clearly.

Planetary Nebulae in the Galactic Center. Jacoby and G. V. de Steeene identified 95 candidate planetary nebulae at the center of our Galaxy, and have obtained follow-up spectra for ~65 of these to confirm all but a couple as bona fide nebulae. They recently obtained new measurements to define the brightness of these PNe, both at radio wavelengths using the Australian array, and in the optical using the KPNO CCD Mosaic imager on the 0.9-m telescope. The latter observations revealed another 26 Galactic Center PNe. The chemical compositions are currently being analyzed; preliminary results show them to be similar to the PNe found in M31.

Distant Galaxy Systems
Stars Between the Galaxies. With R. Ciardullo and J. Feldmeier, Jacoby has been exploring the population of stars between galaxies in the Fornax and Virgo clusters of galaxies. Remarkably, a significant fraction of the stars and light in a cluster come from the regions between galaxies; perhaps as much as 25% of the entire cluster light is not in galaxies. Among the stars, the group has found a substantial number of very young star-forming galaxies.

Future Research Plans
Stellar Dynamics
Virgo Intracluster PN. R. Ciardullo, J. Feldmeier, and Jacoby have been using the WIYN observatory and the ESO VLT to obtain velocities of the PN between the galaxies in Virgo. The observation and analysis of planetary nebula motions in galaxies is of growing interest because there is no better way to measure the stellar velocities, especially for these very faint stars in Virgo. The velocities will map out the distribution and quantity of dark matter in the Virgo cluster far better than the galaxies because there are hundreds of thousands of PN and only a few hundred galaxies. Assuming that the PNe derive from stars torn out of galaxies, it may be possible to trace the orbits of those galaxies back several billion years as they traveled across the cluster.

Chemical Compositions
The Galactic Center. Thus far, only ~12 of the new ~130 PN in the Galactic center have been analyzed to derive their chemical compositions. In most of the remaining cases, it will not be possible to make the measurements because the nebulae are extremely faint, being extinguished by an enormous amount of dust between the Galactic center and the Earth. Thus, each nebula that can be studied is an important one. R. Ciardullo, J. Feldmeier, and Jacoby are continuing their analysis of the existing spectra.

The Small Magellanic Cloud. With O. De Marco (U. College London), Jacoby found 32 new PN in the SMC—all fainter than the discoveries by anyone else; and most are slightly extended, indicating extreme age. The stars in the SMC have very low chemical compositions, nearly one-tenth that of the Sun. Thus, those stars provide an excellent test area for processes that may depend on the metallicities of stars. For example, we will measure the strengths of the
winds coming off the PN central stars to see if they are, in fact, weaker than those in our Galaxy. We have applied for 4-m telescope time at CTIO to: 1) verify that the candidates are truly PNe, 2) measure their chemical compositions, and (3) extend the survey to the outer regions of the SMC to investigate age and composition gradients in the galaxy.

Dwarf Galaxies. Simulations predict that there should be ~1000 dwarf galaxies in our Local Group. We know of about 20. Have the surveys been so poorly executed that most of those galaxies have not been recovered? With T. Armandroff and J. Chen (summer student), Jacoby surveyed nearly 7% of the sky to look for the missing dwarfs. Since none were found, a discrepancy is beginning to emerge that needs to be understood.

Service

Image Reduction and Analysis Facility (IRAF). Until February 2000, Jacoby served as the project scientist for the IRAF, setting priorities and giving scientific direction to the project; and interfacing between the programmers and the users, NOAO management, and outside organizations interested in the project (STScI, AXAF, EUVE). Jacoby is the PI for the Open IRAF initiative being funded by NASA.

CCD Mosaic. Jacoby is the scientist responsible for the CCD Mosaic Camera. In addition, he was the scientist responsible for the new optical correctors recently built for the 4-m and 0.9-m that are required to provide the very wide fields of views (50' and 80', respectively) needed by the Mosaic.

ADASS Conferences. Jacoby serves as a member of the scientific organizing committees for the annual Astronomical Data Analysis and Software Systems conferences.

IAU Symposia on Planetary Nebulae. Jacoby is a member of IAU Commission 34 (Interstellar Matter) and the Planetary Nebula Working Group. He has been a member of the scientific organizing committees for the Symposia for the past several meetings, as well as the upcoming meeting in November 2001.

Buell T. Jannuzi, Associate Astronomer

Areas of Interest

Observational Cosmology, Quasar Absorption Line Systems, Active Galaxies, Instrumentation for Surveys.

Recent Research Results and Future Research Plans

Jannuzi's current research activities are mainly in two areas: 1) studies of the properties of the inter-galactic medium and the gaseous content of the universe as probes of the formation and evolution of structure in the universe; and 2) studies of galaxies and large-scale structure at redshifts between one and three as traced by the distribution of individual, groups, and clusters of galaxies. He also continues to be involved in studies of various classes of active galaxies and other projects.

Lyman-\(\alpha\) absorbers are observable from redshifts of zero to over four, spanning most of the age of the universe. Understanding how they relate to large-scale structures at low redshift will facilitate using studies of absorbers to understand the formation and evolution of structure in the universe. Jannuzi is currently the coordinator of the Quasar Absorption Line Key Project Team, a group of researchers that used the Faint Object Spectrograph of the Hubble Space Telescope to obtain ultraviolet spectra of quasars during the first four cycles of HST operations. The large and homogeneous catalogue of low redshift absorbers that resulted from this work is being used for a wide variety of studies. Recent results include evidence for clustering of some low redshift Ly-\(\alpha\) absorbers near metal line systems (Jannuzi 1998, in Proceedings of the 13th IAP Astrophysics Colloquium, Structure and Evolution of the Intergalactic Medium From QSO Absorption Line Systems, ed. P. Petitjean and S. Charlot [Paris: Editions Frontieres], 93) and for a change in the nature of the evolution of the number of these systems as a function of redshift from near the beginning of the universe \((z = 4.5)\) to the present \((z = 0)\). This observational result is being further analyzed in the light of recent cosmological simulations, and is yielding insights into the formation and evolution of large-scale structure. Jannuzi also leads a team that is mapping the distribution of galaxies in the fields of the same quasars observed as part of the Key Project. The comparison of absorbers and galaxies can be extended to higher redshifts with the new generation of large ground-based telescopes, including the Gemini 8-m telescopes.

Jannuzi, together with A. Dey, is Co-PI of the NOAO Deep Wide-Field Survey, a deep optical (Bw,R,I) and near-infrared (J,H,K) imaging survey that will sample the sky in two 9-square-degree patches. The survey is designed to: 1) investigate the existence and evolution of large-scale structures at redshifts \(z > 1\) as sampled by a diverse set of objects; and 2) provide the astronomical community a sensitive multicolor database of objects from which samples may be selected for the study of other interesting problems.
and for follow-up with the Gemini telescopes. Further details and survey status updates can be found on the NOAO Deep Wide-Field Survey Web page. The optical imaging portion of the survey should be completed during the first half of 2001. The survey fields will also be the target of SIRTF, Chandra, and VLA surveys. These data will be used to study a very diverse set of astronomical topics in the years to come, and will be available to the entire astronomical community.

Jannuzi also has approved programs with HST, AXAF, and NOAO telescopes to continue studies of the nature of AGNs.

Service

Jannuzi was recently assigned to NOAO’s Surveys and Data Management group, which is led by T. Boroson. Jannuzi continues to serve as site director for the NSF-funded Research Experiences for Undergraduates (REU) program held each summer at KPNO. Jannuzi serves on numerous national and international committees, including the US Gemini Scientific Advisory Committee, the Gemini Science Committee, and the SIRTF Users Panel. Jannuzi is involved with other members of the NOAO staff in the preliminary development of a new high-throughput spectrograph and a wide-field IR imager. He is a member of NOAO’s Instrument Projects Advisory Committee (IPAC), which meets monthly to provide advice to the NOAO director regarding the priorities for NOAO’s engineering and instrumentation activities.

Richard R. Joyce, Support Scientist

Areas of Interest

Late-Type Stars, Mass Loss, Infrared Detector and Instrument Development.

Recent Research Results

In collaboration with P. Green (Harvard) and B. Ali (IPAC), Joyce has obtained K band (2.0-2.45 micron) spectra of selected hot white dwarfs that have been identified as binary candidates on the basis of infrared excesses, which suggest a main-sequence companion. The CO and atomic lines will yield the mass and spectral type of the cool companion and lead to better estimates of the fraction of WD stars with main-sequence companions and binary mass ratio distribution. These interesting systems are the progenitors of novae, CVs, symbiotics, and dwarf carbon stars. Last year, he utilized CRSP on the KPNO 2.1-m telescope to obtain spatial/spectral datacubes of Mars during its opposition. These data cover the spectral range 2.2-4.8 microns at spectral resolutions ~ 700-1500. Joyce and others at NASA Goddard were part of a multi-observatory campaign to observe Mars in support of Orbiter observations. The results were presented at the 1999 DPS meeting. A long-term collaborative program with K. Hinkle (NOAO) and F. Fekel (Tennessee State U.) to determine orbits of symbiotic stars from their infrared spectra (using the Coude Feed telescope) was completed in 1999. Orbital determinations from optical spectra have been problematic; the infrared spectrum, on the other hand, is almost completely that of the cool giant, and an unambiguous velocity determination of one of the stellar components is possible. The results would not only confirm that symbiotics are mass-transfer binaries, but, given the constraints on the mass of a white dwarf secondary, could yield accurate masses for cool giants over a range of evolutionary stages. This program is expected to yield five publications; one has already appeared in the literature and another has been submitted. Joyce and Hinkle are also following the evolution of the exotic star V4334 Sgr (Sakurai’s Object), a very rare example of a star in the beginning of its white dwarf cooling track which suddenly and dramatically undergoes a final He flash and temporarily returns to its asymptotic giant branch luminosity. Such “born again” giant stars undergo changes in luminosity and metallicity on extremely short timescales.

Future Research Plans

Future research plans include the continuation of the highly successful symbiotic star radial velocity program from the southern hemisphere. Almost no orbital information exists for southern symbiotics. We are investigating a collaboration with P. Wood at MSSSO, which would involve the use of the same IR detector NICMASS (M. Skrutskie, U. Mass) used for the Coude Feed observations. The recent commissioning of SQIID for the NOAO Deep-Wide Survey will yield JHK images and allow color selection of distant carbon stars at high galactic latitudes and an extension of the past research that Joyce has carried out on these objects.

Service

A significant fraction of Joyce’s time is spent providing support to visiting observers using the facility instruments CRSP (a low-resolution IR spectrograph), IRIM (IR imager), PHOENIX (the recently completed high-resolution IR spectrograph), and the IR imaging spectrograph ONIS, which is shared with the MDM Observatory under a cooperative agreement. This includes direct support such as checking out the instruments after installation, providing instruction to observers, training the Kitt Peak mountain staff in technical issues associated with these instruments.
APPENDIX L: NSF-Funded Scientific Staff

off-line support in providing advice to prospective observers, and assistance with data reduction.

Approximately half of his time is devoted to the Gemini Near Infrared Spectrograph (GNIRS) project, on which he is a Project Support Scientist. His extensive involvement in this project has consisted of systems engineering efforts during the concept and design state and the testing of prototypes; he will be heavily involved in the assembly and testing of the instrument prior to its scheduled delivery to Gemini in 2002.

He has also been involved in the concept definition for a next-generation, very wide-field IR imager for NOAO (NEWFIRM), which is being pursued as a collaborative endeavor with the astronomical community. He also assists in the scheduling of the Kitt Peak telescopes through the new ALPS++ database. Other service areas include serving on the KPNO Advisory and KPNO Safety Committees.

Tod R. Lauer, Associate Astronomer

Areas of Interest

Recent Research Results
With M. Postman (STScI), Lauer has measured the I-band galaxy-galaxy correlation function from a large (16 square degree) survey. This work significantly improves knowledge of the correlation function down to faint limiting magnitudes and helps to constrain how structure within the universe evolved since $z = 1$. They also produced a catalog of galaxies from the same survey, which will allow them to observe how the cluster-cluster correlation function evolves.

Future Research Plans
The major work that Lauer is undertaking now is completion of the Lauer, Postman, and Strauss survey of nearby brightest cluster galaxies to look for an end to the large bulk flow inferred from the earlier survey. They are also starting to obtain cluster redshifts from a deep I-band survey to measure the cluster-cluster correlation function.

Roger Lynds, Astronomer

Areas of Interest
Galaxy Evolution and Cosmology.

Recent Research Results
Lynds has been studying the interacting galaxy NGC 6745, a galaxy in which the interaction has evidently triggered abundant new star formation. HST images delineate the regions of star formation particularly well and provide a first guess as to the geometrical and dynamical nature of the interaction. Some of the new star formation has undoubtedly been induced by shock wave propagation but some, in the most luminous regions, has certainly been triggered by ram pressure in volumes where the interstellar media in the two galaxies have suffered direct collision. Surface and object four-color photometry have been performed and compared with theoretical models of evolved galactic subsystems. The agreement is very good. Lynds and E. O’Neil have observed the galaxy at 21 cm with the VLA C-array and have obtained an HI velocity map that confirms the preliminary model for the interaction. In addition, L-band continuum observations with the VLA B-array have yielded a map of the synchrotron emission, which beautifully traces the distribution of active star-forming regions. In May 2000, Lynds expects to map the region in the C-band with the C-array (at the same resolution as the L-band observations) so as to obtain spectral index variations and possibly some information on polarization.

Future Research Plans
A long-term investigation concerns photometric population separation for galaxies in the Hubble Deep Fields (north and south) and other HST survey fields. One of the purposes of the study is to document the relative cosmological evolution of star-forming subsystems and evolved populations.

Service
Lynds has been an active member of the NOAO Planning and Development Office (PDO), the NBT Site subcommittee, and the NGOS instrument project. He also is a member of a team seeking the reincarnation of CryoCam as a front-line KPNO instrument and of a team that has implemented charge-shuf-
flying for the 4-meter spectrograph. Lynds has been an active member of the Observatory Safety Committee.

K. Michael Merrill, Associate Support Scientist

Areas of Interest
Star Formation, Young Stellar Objects, Interstellar Medium, Circumstellar Envelopes, Infrared Instrumentation, Array Technology, Data Acquisition and Reduction.

Recent Research Results
Observations of NGC6334 using SPIREX/ABU from the South Pole during the past two seasons reached unprecedented levels of sensitivity within the 3-4 micron region. In conjunction with J. Jackson and colleagues (Boston U.) and I. Gatley (RIT), Merrill will be reporting on observations of diffuse 3.28-micron particulate emission and Brackett $\alpha$ emission from ionized gas, which together track the UV flux within the region, and L band observations of the stellar content of the cloud. In combination with prior observations at JHK and long wavelengths, this study promises to shed new light on the star formation process and the early evolution of stars and their attendant circumstellar disks.

Using observations from SPIREX/ABU at the South Pole, Merrill will explore the spatial distribution of the 3.28-micron emission within the Galactic Center region to establish the excitation mechanism for the molecular hydrogen emission from the neutral material within the 80-arcsec-diameter circum-nuclear ring surrounding the central engine of our Galaxy. Within diverse environments, UV excited fluorescent molecular hydrogen emission has been found to be intimately associated with 3.28-micron emission. Off-band observations at L would provide a sensitive search for the IR counterpart of the central engine itself, Sgr A*.

Future Research Plans
The cosmic interface between “stellar systems engineering” and “practical astrophysics,” which conspire to produce a continual supply of new stars, has been the object of continued fascination to astronomers for many decades with each new discovery somehow whetting the appetite for more. Following the SQIID upgrade, Merrill will resume the pioneering study of regions of active star formation which has awaited extension to a significantly wider field of view (4x area) and higher sensitivity (20x) with high relative stability. The unprecedented ability to survey large regions with absolutely registered JHK(L) imaging will give renewed impetus to systematic studies of the more global aspects of the star formation process, which had heretofore been stalled by the complexity of the observations and the attendant data reduction required to adequately sample the full luminosity range over a FOV measured in tens of arcminutes in the presence of heavy, patchy extinction. Statistically significant star counts, with derived mass and luminosity functions, and the detailed distribution of the attendant gas and dust will all be amenable to careful study for regions of star formation covering a wide range in distance, total mass, and age.

Service
As Infrared Imaging Scientist at KPNO, Merrill oversees the IR imagers and attendant visitor support at KPNO, including instrument setups and observer checkouts, and is a point of contact on performance issues for both proposers and the TAC during the proposal cycle. On assignment to ETS, he oversees NOAO (non-Gemini) IR instrumentation efforts and the IR R&D lab. He is project scientist for the KPNO SQIID upgrade to ALADDIN 512x512 InSb, which went into active service in the 2000A semester. As package scientist for the Gemini/NOAO Array Controller project and responsible scientist for the ALADDIN InSb 1024 x 1024 IR array R&D effort, Merrill plays a significant role in developing and deploying state-of-the-art IR detection capability to the wider community. As mirror scientist for the Gemini near-IR imager (NIRI), he will be assisting the community with operations issues during the proposal cycle and assisting Gemini with the overall development of NIRI as a facility instrument. As the scientist responsible for user support of IR data reductions, he advises observers, programs and supports data reduction scripts, and interacts with the IRAF programming group to improve and extend IR-specific capabilities within IRAF. In support of the opportunity for community observations at 3-5 microns from SPIREX/ABU at the South Pole, Merrill has been actively involved in data quality assessment, has established the data pipeline in conjunction with colleagues at RIT, has served on the TAC, and has overseen the execution of observations on behalf of the wider community. He has been an active participant in outreach activities within the local schools (including teaching classes and coaching Science Olympiad teams), at scientific meetings, and by providing images on request for assorted publications and for advocacy of community-wide efforts such as SIRTF and SOFIA.
Joan Najita, Assistant Astronomer

**Areas of Interest**
Star and Planet Formation, the Low-Mass Initial Mass Function of Stars, IR Spectroscopy, Galaxy Formation and Evolution.

**Recent Research Results**

*The Low-Mass End of the IMF.* A direct measurement of the low-mass end of the IMF is fundamental to our understanding of the relationship between star, brown dwarf, and planet formation. J. Najita, G. Tiede, and J. Carr have used a new technique based on HST/NICMOS filter photometry to measure spectral types for late-type stars in the young cluster IC348. Due to the efficiency of the spectral classification technique, they have derived the first IMF complete to the deuterium burning limit, a fiducial boundary between brown dwarf and planetary mass objects. The derived IMF is significantly more abundant in brown dwarfs than the mass function for companions to nearby Sun-like stars. This provides compelling observational evidence for different formation and evolutionary histories for substellar objects formed in isolation vs. as companions.

*Dynamics of Planet Formation Environments.* The formation of stellar and planetary companions in disks is expected to alter disk structure, creating a “gap” at the orbital distance of the companion. J. Carr, R. Mathieu, and J. Najita have obtained robust, kinematic evidence for this process from the discovery and high-resolution spectroscopic study of 4.7-micron CO fundamental emission from AU binaries, where the line emission arises from residual gas in the gap, which appears bright in contrast against the dark (absent) continuum background. A similar study of systems without known stellar companions is in progress. This is one of the few techniques currently capable of diagnosing ongoing planet formation and observationally determining the formation distances of planets.

**Future Research Plans**

*X-Ray Induced Molecular Chemistry.* In collaboration with A. Glassgold (NYU), Najita is investigating the chemical structure of disk atmospheres. The expectation is that surface X-ray irradiation is significant in determining the column densities and molecular content in HI and H$_2$ layers. In collaboration with T. Bergin (CFA), Najita is also exploring the utility of stellar X-rays as a molecular desorption mechanism in protoplanetary disks.

*Infrared Spectroscopy of Planet Formation Environments.* Najita will continue ongoing work on probing the dynamics and physical/chemical structure of planet formation environments through high-resolution infrared spectroscopy. This relatively new approach is the only currently viable technique with which to study the physical conditions under which planets are formed.

*Galactic Structure with the NOAO Deep Wide-Field Survey.* Najita will work with a summer REU student on several Galactic structure issues that can be studied with the NOAO Deep Wide-Field survey data.

**Service**
Najita is working on the science cases for NGOS and an NOAO initiative to build a large aperture (~30-m), wide-field, spectroscopic telescope. She will also work with the NOAO Deep Wide-Field Survey team on exploring some implications of the survey for Galactic structure and in obtaining the space-based data in order to create a multi-wavelength archival database of the survey results. During the past year, Najita also refereed papers for the *ApJ* and *Science*, wrote a review article on star formation for the IOP’s *Encyclopedia of Astronomy and Astrophysics*, and helped the SIRTF IRAC and IRS GTO teams in defining their star and planet formation science goals.

Catherine A. Pilachowski, Astronomer, Deputy Director for USGP

**Areas of Interest**
Stellar Compositions, Stellar Evolution and Nucleosynthesis, the Origin of the Elements in the Milky Way, Stellar Seismology.

**Recent Research Results**
Pilachowski, in collaboration with C. Sneden, R. P. Kraft, and others, is continuing to investigate abundance variations in globular clusters. Their previous work in M13 established the role of in situ proton-capture nucleosynthesis in the abundances of neon, sodium, magnesium, and aluminum in stars on the giant branch. More recent work includes a survey for lithium in 261 cluster giants, and a study of barium and sodium abundances in the metal-poor clusters M15 and M92. With the Hydra multi-fiber spectrographs on WIYN and the Blanco 4-m telescopes, they are accumulating spectra of a thousand giants in more than a dozen globular clusters to survey lithium, H-$\alpha$ emission, and several critical abundances (e.g., barium, europium, aluminum).
APPENDIX L: NSF-Funded Scientific Staff

Pilachowski, in collaboration with D. Burris, T. Armandroff, J. Cowan, C. Sneden, and H. Roe, has investigated the origin of heavy, n-capture elements in the early Milky Way. Their results suggest that significant production of r-process elements began at a metallicity of [Fe/H]=-2.9 in the early Galaxy, although some production occurred at earlier time. The onset of the bulk of r-process production was followed by the production of s-process elements at a metallicity near [Fe/H]=-2.4, but with some spread in the metallicity at which s-process elements first appeared. The abundances of the lighter n-capture elements (Sr, Y, Zr) in very metal-poor stars cannot be explained by a combination of r- and (main) s-process, but require an additional neutron-capture process.

Future Research Plans

Pilachowski, in collaboration with A. Quillen, is investigating the role of falling evaporative bodies in the dynamical evolution of solar systems, using observations from the WIYN telescope of the Ca II K line in young A-type stars in clusters.

Valenti and Pilachowski, in collaboration with B. Chaboyer and solar astronomers from NSO, are attempting to detect acoustic oscillations in solar-type stars using HST.

Saha and Pilachowski are conducting Baade-Wesselink analyses of an ensemble of RR Lyrae variables in the globular cluster M3, using data from the WIYN and the 0.9-m telescopes.

Service

Pilachowski serves as Deputy Director for the US Gemini Program, with particular responsibility for telescope proposals, user support, and community outreach. She also supports the Public Access program providing observing time to the community on the new 6.5-m telescope at the MMT Observatory and on the Hobby-Eberly Telescope, as well as collaborative programs with the SIRTF and Chandra observatories.

Pilachowski is involved with numerous educational outreach projects and serves on the local ASP/Project Astro Coalition. She assists students interested in gaining research experience in astronomy and participates with the University of Arizona’s Women in Science and Engineering Program. She serves as a Shapley Lecturer for the American Astronomical Society.

Pilachowski serves on the Council of the American Astronomical Society, and on the Nominating Committees of the Astronomical Society of the Pacific and the Astronomy Section of the American Association for the Advancement of Science. She is also a member of the US National Committee for the International Astronomical Union.

Ron Probst, Associate Support Scientist

Areas of Interest


Recent Research Results

Together with M. Rubio (U. de Chile) and collaborators in the US, France, and Argentina, Probst has been investigating star formation regions in the Large and Small Magellanic Clouds. This group has combined high sensitivity CO observations, high spatial resolution imaging in the 2.12-μm H₂ line, and continuum observations in the near- and mid-IR with ground-based facilities and ISO to study the morphological and physical relationships between molecular gas, photodissociation interfaces, and very young stars. Recent results for N66 in the SMC (A&A, in press) suggest three stellar generations have taken place in less than 3 million years. Previous CO and IR imaging data for 30 Dor are also suggestive of a new generation of very young, high-mass stars formed on the periphery of the R136 starburst.

Future Research Plans

Probst and his collaborators are following up their IR imaging results for 30 Dor with infrared spectroscopy to establish the nature of embedded young objects often associated with spectroscopically confirmed O stars. Careful slit placement also allows investigation of the nature of associated molecular gas revealed in H₂ images. Fluorescently excited surfaces of molecular clouds may be tracing the actual spatial extent of cold gas. Alternatively, the H₂ emission may be shock excitation, with a distinctive spectral signature. Shock excitation coupled with the observed filamentary H₂ morphology may be linked to a suggested second-generation star formation mechanism, compression of molecular material by stellar winds.

Service

The bulk of Probst’s activities are devoted to observatory service. After several years on staff at CTIO, he returned to NOAO-Tucson in January 2000. While on staff at CTIO, Probst led the commissioning and upgrading of the Blanco 4-m IR tip/tilt image stabilization system. He also initiated a new wide-field IR imager for the Blanco, which will be a permanently mounted facility instrument. He participated extensively in telescope and instrument definition for the...
SOAR project and served on NOAO and CTIO advisory panels on instrumentation (IPAC and ACTR). Probst instituted the 10-micron camera OSCIR loan arrangement with U. Florida, which provided users with a powerful new capability prior to OSCIR’s move to Gemini North. Together with R. Blum and P. Bouchet, he was responsible for instrument maintenance and observer support for IR instruments at CTIO. He was CTIO liaison with SCOPE during the transition from site-based to centralized proposal handling and database management. Probst did all CTIO telescope scheduling and handled related ongoing matters, such as discretionary time requests. He also edited the CTIO portion of the NOAO Newsletter.

Since his return to Tucson, Probst has focused on the NOAO IR instrument program and interactions with other AURA facilities. He is Project Scientist on a NASA-funded, USGPO proposal to build a coronagraphic imager for Gemini South. This project just successfully passed Conceptual Design Review. He continues to advise on instrument development for SOAR. He remains Project Scientist for the Blanco IR sideport imager, which is well into design phase. His close professional relationship with the CTIO project team, combined with his present geographical separation, is driving a more site-integrated approach to IR instrumentation. Tucson engineering staff provide a readily accessed information resource, while project definition and control clearly reside in La Serena. Probst has taken on the Project Scientist position for a new extremely wide field IR imager, which may be shared by KPNO and CTIO. In this role, he recently organized and led a very productive workshop on IR imaging capabilities which brought together several groups with similar interests. Several technology development activities were identified that may be pursued in common to create an optimal community system for IR imaging funded in a most effective way.

**Future Research Plans**
Rector is currently involved in the following research programs: 1) WIYN observations of the host galaxy and clustering environments of high-redshift BL Lacs (z>5); 2) a spectroscopic search for “radio-intermediate” quasars; 3) high-resolution VLA mapping of gravitational-lensing candidates; 4) multi-epoch VLBA monitoring for superluminal motion in XBLs; 5) an X-ray search for low-luminosity AGN in nearby “passive” ellipticals; 6) a spectroscopic study of the ROSAT-Green Bank sample of BL Lac objects; 7) a search for novae in Local Group galaxies; 8) a search for optical transients associated with gamma-ray bursts; and 9) spectroscopic monitoring of active M-stars.

**Service**
Rector is a member of NOAO’s educational outreach program and serves as NOAO’s “outreach astronomer.” He is the primary research astronomer for the Research-Based Science Education (RBSE) program. He is also a member of NOAO’s team to search for optical transients of GRBs, which is underway at Kitt Peak National Observatory.

**Stephen T. Ridgway, Astronomer**

**Areas of Interest**
Stellar Astronomy, Advanced Instrumentation.

**Recent Research Results**
In collaboration with colleagues from the U. Paris Meudon Observatory and the Harvard-Smithsonian Center for Astrophysics, Ridgway continues to employ the optical fiber detection system FLUOR at the Infrared Optical Telescope Array on Mt. Hopkins. During 1999, the group achieved the first direct interferometric operation in the thermal infrared and discovered that long-period variables have a diameter that increases strongly with wavelength in the mid-infrared. They also directly detected stellar pulsations in an evolved giant.

NOAO continues under contract to support the Georgia State University's research program.
U. Center for High Angular Resolution Astronomy (CHARA) interferometric array project. First light was achieved in 1999. In collaboration with I. Yamamura and K. Kawaguchi, Ridgway reported the first detection of the SH molecule in a stellar spectrum, confirming a solar atomic and isotopic abundance in the mira star R And.

**Future Research Plans**

Research with FLUOR is moving to exploitation of precision, multi-wavelength visibility measurements to diagnose and improve model stellar atmospheres for cool, luminous stars. At CHARA, emphasis is shifting to bringing all six telescopes into operation. During 2000, the goal will be to achieve pair-wise interferometry on increasing numbers of baselines, and the first scientific operation. Ridgway is lead scientist on a Terrestrial Planet Finder study team, under contract to SVS in Albuquerque. The team will study several alternatives to the TPF reference mission.

**Service**

Ridgway provides technical advice to the NOAO/Gemini community on adaptive optics, works with the NOAO Program Development Office, and participates with the Adaptive Optics Roadmap team. He is a member of various NASA advisory groups on Keck and space interferometry. He serves on the NOAO Telescope Allocation Committee, and in 2001, he will be the KPNO 4-m telescope scientist.

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**Abhijit Saha, Associate Astronomer**

**Areas of Interest**

Distance Scale, Cartography of Nearby Galaxies, Stellar Populations, Galactic Structure, Variable Stars, Photometric Techniques.

**Recent Research Results**

Saha has been actively involved in the HST-based distance scale programs, particularly in collaboration with Sandage et al., in establishing the absolute peak brightness of type Ia supernovae, and with the HST key project team. The former group has established Cepheid distances to the host galaxies of seven type Ia supernovae. Work is ongoing on two additional galaxies. This calibration establishes a Hubble constant of $\sim 60$ km/s/Mpc with internal uncertainty of 4 km/s/Mpc, modulo recalibration of the Cepheid distance scale, and any metallicity effects therein. The latter group has obtained Cepheid distances to about 20 galaxies to calibrate additional secondary distance indicators such as the Tully-Fisher and Fundamental-Plane relations. In a parallel ground-based effort, Saha and Hoessel have obtained Cepheid distances to seven nearby galaxies (Local group and out to 7 Mpc), and work is underway on several more. The grand aim of this project is both to map the local universe and define galaxy groups more precisely, as well as to use such galaxies as 'test particles' to probe the local dynamics and deduce the mass of the Local Group and the gravitational effect of neighboring groups such as the M81 group, CVn group, M101 group, and the IC342/Maffei group on the Local Group. Another important function of this study is to enable analysis of the stellar populations in these galaxies from color-magnitude diagrams (obtained from the ground as well as from HST), since such methods rely heavily on independent estimates of the distance. Saha is also involved in such stellar population studies and has contributed photometric techniques and Bayesian analysis methods in collaborations with Skillman, Gallagher, Hoessel, and Tolstoy. Saha is also involved in HST-based projects to investigate the star formation histories in nearby galaxies from the fossil record of their stars, as manifest in the Hess diagrams (color-magnitude diagram plus relative frequency of stars as a third dimension). Of particular interest is the question: Do all galaxies have an old population of stars corresponding to the ages of the globular clusters in our Galaxy?

**Future Research Plans**

The HST-based studies to establish the value of the Hubble constant are expected to conclude within the next year. The current continuation of the SNe1a calibration project involves HST observations of NGC4527 and NGC3982 in Cycles 7 (ongoing) and 8, respectively. The distance mapping project for nearby galaxies is expected to continue as a longer term effort. Saha and Hoessel will also seek to extend the effort to reach southern galaxies, particularly the Sculptor group, and also to monitor long period variables among the supergiants in some of these nearby galaxies.

Saha plans to return to the problem of understanding the halos of large galaxies, with a two-pronged approach: 1) in collaboration with Olszewski and Monet, to search for RR Lyrae stars in several halo fields from plate material obtained in the past on Schmidt telescopes (this will expand the sample of RR Lyraes that have been used to probe the halo of the Galaxy for density distribution and kinematics/dynamics); and 2) to mine the HST image archive for observations in the M31 halo, which provide the only chance of studying a complete in situ sample of stars in the halo of a large galaxy, where photometric methods should reveal much of the age and metallicity structures.
**Service**

Saha is serving as the telescope scientist for WIYN. He is also the NOAO representative on the WIYN Science Advisory Committee (SAC), and a member of the WIYN board. In the role of telescope scientist, he is participating in the tip/tilt imaging project on WIYN, and has worked on the testing and commissioning of the mini-mosaic CCD camera, which covers a wider imaging field at the high spatial resolution that the excellent seeing at WIYN demands. He has actively pursued several areas of general improvement in telescope performance, including damping the oscillations of the secondary mirror support structure, implementation of the auto-correction of focus drifts using real-time Shack-Hartmann measurements, and investigating the optimal parameters for the guider software. The combination of the net improvement in imaging with WIYN, and the photometric performance of the Mini-Mosaic camera was the subject of a poster paper at the SPIE meeting in March 2000. He is also in charge of the imaging camera on the 2.1-m telescope.

Saha has actively participated in the queue observing experiment with the WIYN telescope. This effort has been geared to optimizing the scientific return from a telescope that has a special-purpose instrument (Hydra), and one that gets exceptionally good seeing often enough that it can be counted upon to happen some of the time. Queued observing also enables many synoptic programs, which would be very awkward or even impossible to carry out with classical scheduling methods. The experience and lessons from this exercise were collated and presented by Saha as an oral paper at the March 2000 SPIE meeting.

Saha is also on the (NASA) Science Oversight Committee for the HST Wide Field Camera 3, which is scheduled to replace WFPC2 in 2003.

**Stephen Strom, Astronomer**

**Areas of Interest**


**Recent Research Results**

A photometric and spectroscopic survey of the young cluster NGC 2264 provides insight into the duration of the disk accretion phase and the early angular momentum evolution of solar-type stars. Our analysis suggests that accretion disks survive around stars at least as old as 10 Myr, and that stars surrounded by accretion disks appear to rotate more slowly than their counterparts which are no longer surrounded by such disks. Co-investigators are Russell Makidon (STSCI), A. Birmingham (Amherst College), L. Hillenbrand (Cal Tech), and M. Adams (UT-Austin).

**Future Research Plans**

Strom plans to continue investigations along two paths: 1) quantifying the lifetime of the disk accretion phase based on deep optical and infrared surveys of star-forming regions, and 2) understanding the relationship between initial molecular cloud conditions and the emerging distribution of stellar masses from studies of nearby star-forming regions.

**Service**

Strom is Chair of the SIRTF Users Panel, Benefits Panel, and Astronomy and Astrophysics Survey Committee. He is also a Member of the AASC “cross-panel” for National Observatories and AASC “cross-panel” for Surveys, and Senior Advisor for the Large Millimeter Telescope project. Strom is head of the recently formed Planning and Development Office (PDO) at NOAO.
AURA ORGANIZATIONAL CHART

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R. Green

AD NOAO, Director, USGP
R. Schommer

AD: Associate Director
CTIO: Cerro Tololo Inter-American Observatory, La Serena, Chile
KPNO: Kitt Peak National Observatory, Tucson, AZ
NOAO: National Optical Astronomy Observatory, Tucson, AZ

Appendix M-2  NOAO Provisional Program Plan FY 2001: NOAO Organizational Chart
CERRO TOLOLO INTER-AMERICAN OBSERVATORY
SUPPORT SERVICES UNIT

[Rev: July 2000]

Appendix M-5  NOAO Provisional Program Plan FY 2001:  NOAO Organizational Chart
Appendix M-7  NOAO Provisional Program Plan FY 2001: NOAO Organizational Chart
US Gemini Program*
[F]

Press Officer
Suzanne Jacoby
[I]

Director
R. Schommer

Deputy Director
C. Pilachowski

US Gemini Instrumentation

Manager
T. Armandroff

Project Engineer
M. Trueblood

Administrative Support
Kathy English
[B]

* Additional Scientific Staff provided by Tucson and CTIO.
1 Software FTE will be hired in 2001

NOAO Director's Office Funded [B]
Public Outreach Funded [H]
Surveys, Data Management and Scientific Staff Support

Director
T. Boroson

Library
M. Guerreri
M. Dunkley (.25)

Computer Support Manager
S. Grandi

Proposal Coordinator
M. Hartman

Photo Imaging
M. Hanna
P. Marenfield

Administrative/System Support
S. Hayes

Data Reduction/Analysis Support
Open
D. Bell

System/Software Support
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M. Peralta
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IRAF
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R. Seaman
F. valdes
N. Zarate

Appendix M-10  NOAO Provisional Program Plan FY 2001: NOAO Organizational Chart
Appendix M-11 NOAO Provisional Program Plan FY 2001: NOAO Organizational Chart
ADMINISTRATIVE SERVICES

Manager
L. Klose

Administrative Assistant
P. Stephens

Human Resources Manager
S. Abbey

Human Resources Assistants
C. Bauer (.6)
C. Burnett
L. Manriquez (.4)

Controller
J. Tracy

Procurement
C. Enterline

Buyers
G. Castillo
K. McBride
Vacant (.5)

CTIO Liaison
J. Faltin (.5)
Clerk Typist
L. Wonders

Contracts
A. Commissaris
C. O'Mahony (.5)

Disbursements
E. Fimbres
J. Kerekes
(Open)

Travel & Receivables
A. Daniel

Accounting Manager
C. Richardson

Business Manager
P. Phelan

Payroll
M. Cummins (.75)
L. Rodriguez

Ship/Receiving
F. Delahanty
Property
J. Smith
FACILITIES OPERATIONS

Manager
J. Dunlop*

Safety Security**
B. Everett

Administrative Staff
B. Jensen

Telephone Systems**

Mailroom/Supplies
J. Rees

Maintenance & Support

Electrician
O. Gary

HVAC
J. Fabins

Facilities Engineering Staff
J. Barr
(Open) (.5)

Custodial**
Groundskeeping**

Vehicle/General Support
T. Plog

Carpenter Shop
B. Porter

Painter/Carpentry
E. Shackelford

* Facilities Manager FO [K] and KPNO [E]
** Contracted Services

** ETS Funded [H]

Appendix M-14   NOAO Provisional Program Plan FY 2001: NOAO Organizational Chart

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Rev: July 2000