NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

FY 1999 PROVISIONAL PROGRAM PLAN

July 6, 1998
# FY 1999 Provisional Program Plan

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I. EXECUTIVE SUMMARY

NOAO MISSION STATEMENT

The mission of NOAO is to provide leadership in the establishment and operation of premier ground-based astronomical research facilities, to promote public understanding and support of science, and to advance all aspects of US groundbased astronomical research.

In order to accomplish this mission, NOAO shall provide peer-reviewed access to state of the art observing facilities; develop and promote new astronomical initiatives in cooperation with other institutions, both domestic and foreign; maintain an active scientific staff that is engaged in both carrying out vigorous research programs and providing essential program leadership; develop and construct leading edge astronomical telescopes, instrumentation, and software; encourage public information and science education through an active outreach program; serve when appropriate as a coordinating agency for the dissemination of new technologies, data bases, and information about other astronomy related issues; and act as an advocate for US groundbased astronomy.

New Technology Telescopes: AURA has recently submitted a five year plan for NOAO that spans the time interval 1999-2003 and defines the program that will fulfill the obligations outlined in the mission statement. The next five years are a critical phase in the evolution of NOAO. The nighttime program will complete the transition from an earlier generation of telescopes and instruments to an almost completely new suite of facilities, and we will begin planning for the next generation of groundbased facilities. During this same time interval, the solar program will be redefined, and what is at stake is nothing less than the scope and future of groundbased solar physics in this country.

- WIYN
- SOAR
- Gemini
And Beyond

Advanced Solar Telescope During the next five years, the central effort in the solar program will be to define the scientific requirements for a large-aperture telescope, establish the technical feasibility of building a telescope that will meet those requirements, identify the best possible site, and prepare and submit a proposal for such a telescope to the NSF.

The remainder of the NSO program is well defined and includes: the continuation of GONG for at least one 11-year solar cycle; the upgrade of the spatial resolution of the GONG cameras by a factor of 4; the construction of SOLIS, which is a suite of instruments designed to support Synoptic Optical Long-term Investigations of the Sun; operation of the PSPT (Precision Solar Photometric Telescopes) to study irradiance variations; demonstration and use of a low-order adaptive optics system at the NSO/SP Vacuum Tower Telescope; and the continuation of the infrared program at the McMath-Pierce Telescope with upgraded cameras based on the 1K × 1K InSb arrays.

Automated Delivery of Solar Activity Data The construction of SOLIS is now in progress, with three years required to complete the project. The three instruments that will be built are: (1) a vector spectromagnetograph for high-sensitivity full-disk measurements of the Sun’s magnetic field; (2) a full-disk imager for high-fidelity spectral images of solar disk activity; and (3) a solar spectrometer for accurate measurements of spectral line profiles of the Sun as a star. Reduced results will be made available.
immediately over the Internet.

The major instrumental initiatives at NSO are the demonstration of solar adaptive optics and replacement of the existing 256x256 IR array camera at the McMath-Pierce Telescope with Aladdin arrays. Work will continue on improving the image quality of the solar telescopes and on replacing the control systems.

Gemini Science Operations

The first of the two Gemini telescopes is currently scheduled to achieve first light during FY 1999 and to begin at least limited scientific operations in FY 2000. During FY 1999 NOAO will complete the development of the procedures for receiving and reviewing Gemini proposals and will test the procedures by applying them to the KPNO telescopes. In terms of facilities operations, NOAO will focus its efforts on providing telescopes with capabilities that either are not offered by the Gemini telescopes or are complementary to Gemini. Such capabilities include imaging to very deep limiting magnitudes to identify and characterize objects for Gemini observations and multi-object spectroscopy with fibers, both over very wide fields. New telescopes, with apertures of approximately 2.4 meters and superb image quality, will replace the existing smaller telescopes in order to enable imaging to the limiting magnitudes in both the optical and the infrared that can be reached spectroscopically with the Gemini telescopes. We also plan to provide software to remove the instrumental signature from observations made with the Gemini telescopes; assist users with optimizing their observing strategies; complete the instruments contracted to us by Gemini; and explore innovative scheduling and observing modes to support new types of scientific programs. (This program plan will be the last to be presented in the format that has been used for more than a decade and in which the costs of Gemini support are scattered throughout the program. Over the next year we will aggregate the costs of Gemini-related activities to illustrate more clearly the impact of Gemini on NOAO and NOAO’s own commitment to Gemini.)

Telescope Construction

In terms of new telescopes, concept design work has been completed on the 4-m SOAR telescope, a partnership involving Brazil, the University of North Carolina, and Michigan State University, with groundbreaking having occurred on 17 April 1998. Contracts for the primary mirror, active optical support system, and telescope mount will be placed during FY 1999. A proposal has been submitted to the NSF to build a 2.4-m wide-field O/IR imaging telescope on Kitt Peak with the Universities of Minnesota and Colorado as partners, and we have identified partners and are beginning to seek funding for a southern hemisphere counterpart.

During the next year, we expect to complete several major instruments, including 8K x 8K mosaic CCD imagers for both CTIO and KPNO; a multi-fiber spectrograph for the Blanco telescope, which will match the capability of the Hydra spectrograph already at WIYN; and Phoenix, which will be sent to CTIO as soon as its performance is verified at KPNO. Work on medium resolution IR spectrometers for both Gemini North and SOAR/Gemini South will continue. We also expect to begin work on a tip/tilt system at WIYN.
NOAO is the only observatory that can offer observing time in both hemispheres, on telescopes with a range of apertures, and with a broad complement of infrared and optical instrumentation. In order to take advantage of this uniqueness, we must learn how to use this suite of telescopes in an optimum fashion. How do we match complex observing programs to telescopes in order to maximize the scientific output? How do we inform the community most effectively about options for their programs? How do we best support programs that require the use of more than one facility? What kinds of supporting infrastructure are required in order to use the time on Gemini and the large telescopes at the independent observatories most effectively? During the coming year, NOAO will continue to work with the community to develop answers to these questions and to provide user support that is unified across all of the facilities accessed through NOAO.

The use of new observing modes, such as queue scheduling, can potentially increase efficiencies and can enable studies—which until now have been impossible—of variable objects and targets of opportunity. During the next year, we will continue to operate the queue observing program at WIYN and fine tune the procedures used for scheduling observations; design the 2.4-m telescope control system to support remote observing; and begin to define what types of service observing will be required to support Gemini observations.

The nighttime community must begin planning now for the project that will follow after the 8- to 10-m telescopes, although construction is not likely to start for another 10 years. What is the scientific case for building a major facility of 30- to 50-m equivalent aperture that would significantly extend the angular resolution or sensitivity offered by the facilities now under construction? In order to begin to address this question, NOAO will participate in the working group being established by AURA through ACCORD, its council of directors of major US observatories, to evaluate the major scientific opportunities in groundbased astronomy and to define the scientific case and the corresponding technical requirements for a facility that would represent a major advance in capabilities. The report of this working group should be completed during FY 1999. The realization of an extremely large telescope will require the combined efforts of NOAO and the independent observatories and will have to be preceded by the continued development of key technologies, including adaptive optics. After we achieve a reasonable degree of community consensus on the long term goal, NOAO expects to play a leadership role in coordinating community activities and making sure the necessary technology development and design studies are completed. NOAO will also continue to work on the development of interferometric techniques through our participation in CHARA, which is building an interferometer on Mt. Wilson.
II. THE DEVELOPMENT PROGRAM: MILESTONES PAST AND FUTURE

The primary component of the NOAO program is the continued operation of observing facilities for the user community at all four sites, where support of Gemini North and South is now a major component of our activities. In addition to operations, NOAO conducts an ongoing development program for both telescopes and instruments in order to ensure that what we offer to the community is competitive with the best facilities available worldwide. Expenditures on Gemini instrumentation now nearly match the expenditures on CTIO/KPNO instrumentation combined. In this section, we list new milestones for FY 1999 and summarize our progress toward milestones included in the plan for FY 1998.

Milestones for FY 1999

**Advanced Solar Telescope (AST):**
- Complete phase A study document on Advanced Solar Telescope.
- Prepare proposal for AST technology studies.
- Construct Solar Dual Image Motion Monitor (S-DIMM) for optical site testing.
- Explore national and international partnership(s) for AST.
- Present AST to NAS/NRC decade astronomy study.

**SOLIS:**
- Complete design work.
- Start construction.
- Continue acquisition of long lead time items.
- Continue development of software.

**GONG:**
- Operate and maintain the network and coordinate activities with the host sites.
- Develop additional software for analysis of instrument functions.
- Reduce network data and deliver it to the community.
- Acquire production quantities of high-resolution cameras, high speed memory, and high density tape drives.
- Develop data acquisition software for high-resolution camera.
- Develop analysis pipeline for high-resolution data.

**RISE/PSPT:**
- Operate RISE/PSPT network.

**Solar Adaptive Optics:**
- Complete construction of 20 Zernike AO system.
- Integrate 20 Zernike AO system in Sac Peak VTT.
- Start 20 Zernike system tests.

**Infrared Array and Controller:**
- Identify suitable Aladdin array.
- Initiate controller project.

**CCD Mosaic Imager II:**
- Commission the imager with eight scientific grade CCDs for use by visiting astronomers at CTIO.

**Hydra/CTIO**
- Commission the multi-fiber positioner and spectrograph, along with the new corrector and atmospheric dispersion compensating prisms at the R-C focus of the Blanco 4-meter.

**GNIRS:**
- Advance to assembly phase.
SQIID: Commission and deploy the near-IR imager with at least three ALADDIN arrays and a customized NOAO/Gemini Controller.

WIYN Tip/Tilt Imager: Pass design reviews and begin fabrication for rapid atmospheric compensation system for imaging at the WIYN port.

Phoenix: Resolve problems with Phoenix grating, commission Phoenix at KPNO, and deploy instrument at CTIO

HET & MMT: Complete MOU with MMT; receive observing proposals for both telescopes.

SOAR: Let contracts for primary mirror, active optics, and telescope mount.

USGP Gemini Work Packages:

- Integrate Gemini CCDs and controller into Gemini GMOS camera.
- Complete design phase of Gemini Mid-IR Imager.

Proposal Process

- Complete modification of telescope time request form to accommodate Gemini, HET, MMT requirements.
- Extend proposal process to include HET, MMT, and (perhaps by end of FY 1999) Gemini North.

Archiving

- Initiate work to establish science archive for NOAO Mosaic Imager data.

CTIO Blanco Telescope:

- Complete modification of prime focus pedestal to accommodate the CCD Mosaic Imager.
- Upgrade the f/14 guide cameras.
- Install new servo system.
- Cover dome with stick-on aluminum foil to provide better thermal performance.

KPNO 2.4-m Telescope (if funded)

- Design primary mirror cell and supports.
- Design secondary mirror cell and possible tip/tilt capability.
- Design tertiary mirror cell and rotator.
- Design observatory control software and user interface.
- Develop facility requirements.

KPNO 4-m Telescope (if 2.4-m not funded)

- Characterize Mayall primary support system and develop look-up tables for mirror support corrections as function of telescope position.
- Design and install f/8 wavefront camera at the Mayall.
- Develop thermal control model for 4-m Mayall primary and evaluate feasibility of surface heating.
Status of 1998 Milestones

A similar list of milestones was included in the program plan for FY 1998 and are repeated in boldface type below. The status of each milestone as we approach the end of the fiscal year is as follows:

SOAR: Hire project team; select site; initiate design; complete agreement among partners.

The core project team has been hired and established in Tucson. Two hires (software and electronics engineers) were deferred until completion of the conceptual design review, and consultants were used to prepare for the review. The conceptual design and detailed costing have both been completed and reviewed very positively by an external committee. The SOAR Board has completed negotiations on all of the agreements required to establish the SOAR Corporation, and all of the financial issues have been resolved. The agreements will be submitted for institutional review and signature before the end of FY 1998.

SOLIS: Complete definition and detailed engineering of the SOLIS instrumentation. Procure the long lead time items.

SOLIS was funded in January 1998. Two full time staff have been hired, and the design phase has been jump started by assigning personnel part time from elsewhere within NOAO. The Scientific Advisory Group has been established, and conceptual design of the instruments is in progress. Preliminary cost estimates for some expensive items are encouraging. A conceptual design review will be held in early FY 1999.

Gemini Work Packages: Conclude the competition to design and build Gemini Mid-IR Imager; develop work scope for CCD controllers and initiate work; complete IR array procurement.

The competition to design and build the Gemini mid-IR imager was completed and the contract awarded to the University of Florida. The workscope for the CCD controllers has been signed, and the work, which involves the UK for software, Dr. R. Leach (SDSU) for controllers, and NOAO for management and integration, is in progress and on schedule. Work on the Gemini IR array controllers is nearing completion, although the project will be at least nine months late as a result of staff turnover and the difficulties in meeting the Gemini requirements. Delivery is now scheduled before the end of FY 1998. The Gemini IR array procurement is proceeding well, with two science grade 1K x 1K arrays having been delivered.

GONG: Continue operation of the network and the pipeline processing and distribution of data; continue development of data reduction and management software; complete proof-of-concept high-resolution breadboard instrument; submit proposal for upgrade to high resolution cameras.

The GONG stations continue to operate reliably, with the scientific duty cycle frequently exceeding 90 percent and the equipment down time being less than 2 percent. Twenty-seven months of data have been processed and made available to the community. The prototype high resolution camera has been successfully tested in Tucson.

Flagship Solar Telescope: Complete the feasibility study of CLEAR. Carry out a program of community outreach leading to AURA sponsored workshop concerning the science requirements for the telescope. Prioritize the science drivers and set the technical requirements. Continue the seeing tests and expand the site survey to include cloud-cover, coronal sky, and IR characterization.

The feasibility study was completed and an interim report submitted to the Parker committee, along with a document describing the scientific case for what is now being called the Advanced Solar Telescope.
The staff of NSO agreed internally on what the science requirements should be and took some steps toward prioritizing them. Site surveys of scintillation have been initiated at additional lake sites. Further work on site characterization has been deferred until after Beckers' return to the scientific staff, when he will have more time to pursue this effort. The AURA community workshop will take place after a new director is selected.

RISE: Complete deployments of the Mauna Loa and NSO/SP Precision Photometric Telescopes; establish routine operation of the network by the end of FY 1998.

One RISE telescope has been deployed at the Osservatorio Astronomico di Roma and now generates solar precision photometric data on a daily basis. A second PSPT has recently begun operation from Mauna Loa. Operations, maintenance, data reduction, and distribution issues are under discussion with partners in this project and must be resolved for FY 1999.

CCD Mosaic Imager (for KPNO): Upgrade the eight detectors to thinned science-grade SITe CCDs, and re-commission the upgraded instrument for scientific use by visiting astronomers.

The engineering grade CCDs were replaced with science grade CCDs in June 1998, with telescope commissioning scheduled for July. The first observing runs will occur in the fall of 1998.

CCD Mosaic Imager (for CTIO):

The fabrication of mechanical parts has been completed as scheduled. The instrument will be shipped as planned to CTIO in FY 1999.

Hydra/CTIO: Complete fabrication of this multi-fiber positioner for the Blanco 4-m and its associated corrector and atmospheric dispersion compensator. Complete the testing in Tucson of its positioning performance and prepare for shipment to CTIO.

This instrument is on track for its scheduled completion and delivery to CTIO in October 1998. The untimely death of the responsible software engineer may lengthen the commissioning phase of the project.

CTIO Blanco Telescope: Complete commissioning and implementation of the f/14 tip/tilt system for use with the COB IR imager and the newly-converted IR spectrometer. Improve tracking and guiding system, including the addition of acceleration feedback in the servo loop and upgrade guide camera to permit faster readout of subrasters; complete substantial fraction of work required to modify the telescope to allow installation of the Mosaic CCD Imager.

The f/14 tip/tilt system has been commissioned. A fast (100 Hz) guide camera and GUI interface have been installed. The prime focus upgrade will be completed in FY 1999. The efforts to improve and tune the existing servo system were only partially successful, and after a system analysis the decision has been made to provide a Delta-Tau system, analogous to that on the Gemini telescopes.

KPNO Mayall Telescope: Install dome ventilation system; increase cooling capacity of mirror cooling; optimize use of Mayall thermal control system both for scientific performance and for improved energy efficiency; ventilate volume above the primary mirror; complete analysis of gains from active primary mirror support and secondary collimation systems.

The installation of the dome ventilation system is complete. We are currently evaluating operating strategies for both ventilation and mirror cooling. An active primary support system has been designed and will be installed during summer shutdown in 1998. Work on the secondary collimation system has been deferred for lack of resources.
GNIRS: Carry out the Critical Design Review for the Gemini Near-IR spectrograph. Maintain the fabrication schedule required to meet the planned delivery date.

The critical design review was held in November 1997, with a follow up review of a few specific items in April 1998. Fabrication is continuing, but there have been modest schedule slips because of the late delivery of specifications for certain Gemini-supplied components and from turnover in mechanical designers.

SQIID: Upgrade this near-IR imager with the installation of at least three ALADDIN arrays and a customized NOAO/Gemini Controller.

This project follows behind the development of the Gemini IR array controller. The latter has proven more difficult than anticipated, and upgrade of SQIID to ALADDIN arrays is not yet under way. Current schedule calls for completion near the end of FY 1999. To support imaging at KPNO, we have made arrangements to exchange observing time for access to an IR imager built at Ohio State.

Phoenix: Transfer this high-resolution IR spectrometer to CTIO and commission it at the Blanco 4-m telescope.

Operation of this high-resolution near-IR spectrograph on the telescope uncovered a number of mechanical difficulties, including the loss of the echelle grating surface from thermal cycling. The primary problem has to do with a mismatch between the CTE of the epoxy used and the CTE of the grating substrate. In addition to delamination, the grating itself is physically distorted as a result of this mismatch, causing astigmatism. We have as yet not identified an epoxy and substrate that can be used to resolve the problem. Major rework of mechanical components is planned for summer 1998, with deployment to CTIO deferred until 1999.

Next Major IR Instrument: Develop a scientific definition and conceptual design for the next planned IR instrument: the Wide-Field-of-View IR Imager.

Scientific definition and an optical layout were developed for a wide-field-of-view near-IR imager. However, because of prior commitments, especially to Gemini, it is clear that NOAO cannot initiate work on this imager in-house in a timely way. As a consequence, we plan to partner with the University of Florida to deploy a wide field imager/multi-object spectrograph on KPNO telescopes.

Telescope Proposal Process: Unify proposal process for KPNO and CTIO. Merge HET, MMT, and Gemini into proposal submission/review system as these telescopes come on-line.

KPNO and CTIO have adopted a common proposal form and a common mechanism for proposal submission. The KPNO TACs are now being managed by USGP/SCOPE, and the methods being used for review are extensible to Gemini and other telescopes.

HET and MMT: Complete Memoranda of Understanding for how program of public access to the Hobby-Eberly Telescope and the MMT will be managed.

The Memorandum with the HET has been signed. Negotiations with the MMT are nearly complete but have been deferred pending progress on the conversion to the 6.5-m primary. It is unlikely that time will be available on these telescopes before FY 2000, although we may solicit proposals at the time of the normal fall submissions in September 1999.
NIM 2: Complete commissioning of filter-based Near-Infrared Magnetograph.

Construction of the instrument is complete, and telescope tests are in progress.


The Shack-Hartmann WFS for solar adaptive optics has been successfully demonstrated, as has active optics using commercial components. The remaining component of the program is to speed up the system to a 20 Zernike adaptive optics system using a commercial reconstructor. The rate of progress will depend on funding, including the level of contributions from the US Air Force Research Laboratory.

Kitt Peak Solar Vacuum Telescope: Complete TCS upgrade.

This project was terminated when it became clear that SOLIS was going to be funded. Some of the concepts developed are applicable to SOLIS.

McMath-Pierce Facility: Install ALADDIN 1024 x 1024 InSb array and controller.

This project is not yet started for two reasons. First, we have not yet received delivery of any suitable arrays and are likely to require an additional foundry run to obtain an array. Second, the Gemini IR controller may require some modifications to meet solar requirements, and personnel will not be available until the Gemini system is complete.
III. NIGHTTIME PROGRAM

A. SOAR

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 whose ultimate performance is limited by the technology with which it was built. The partners in the SOAR project are Brazil, the University of North Carolina, Michigan State University, and NOAO. The financial contributions of the partners to construction, commissioning, instrumentation, and operations will be 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 accord with the agreement under which AURA operates in Chile.

The SOAR project team has been established at NOAO headquarters in Tucson and is headed by Tom Sebring, who was project manager for the Hobby-Eberly Telescope. The Conceptual Design Review was conducted during the first week of June, 1998, and based on the assessment of an external review committee headed by Jim Oschmann, project manager of the Gemini telescopes project, and Massimo Terenghi from the VLT project, the SOAR Board approved the next phase of the project. That same week, the SOAR Board also concluded the negotiation of the SOAR Agreement, the Memorandum (which details the financial obligations and payment schedules of the partners), the By-Laws, and the incorporation papers. We are now proceeding to obtain the required signatures from the appropriate officials of the sponsoring institutions.

The SOAR facility will be located on Cerro Pachon about 300 meters distant from Gemini South. The SOAR site has been leveled and prepared for construction, and the official laying of the first stone occurred on April 17, 1998.

The next step is to prepare interface documents and bid specifications for the major components of the project, including the active optics system, mount, and enclosure. We expect to let the contract for the primary mirror blank in the next three months, and the contracts for the active optics system and mount should be placed during the early part of FY 1999.

The primary technical challenge in the project is the very tight specification on image quality (0.18 arcsec FWHM system performance). The telescope itself will be 4 m in diameter and will have a 3-4 inch thick meniscus mirror. 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, an optical spectrograph with an integral field unit, and a clone of the near-infrared spectrometer being built for Gemini North.

B. Access to the Hobby-Eberly Telescope, the MMT, and the Independent Observatories

The NSF has funded instruments for the Hobby-Eberly Telescope and for the upgraded (6.5-m) MMT. In return, approximately 7 percent of the time on each will be available to the community for six years. An MOU for how this time will be provided has been signed with the Hobby-Eberly Telescope consortium. Access to this facility will be 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 will be received by NOAO on our standard proposal form and reviewed by an NOAO TAC. The successful proposers will be asked to fill out a second form, which is required by the HET queue program, describing their planned observations in detail. NOAO will then
forward those forms to the HET and receive the data for distribution to the community. NOAO will also establish a mirror site so that access to HET documentation is obtained directly from NOAO. This approach has the advantage that the HET will not have to provide any support beyond that available to their own users. It does mean that NOAO will have to 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.

We are waiting to provide access to the HET until commissioning is sufficiently far advanced that the probability of obtaining good data efficiently is high. Unfortunately, commissioning is going rather slowly, and we do not yet know when the access programs will be initiated. It is unlikely to be before the fall of 1999.

We have partially negotiated an agreement with the MMT, but certain details remain to be worked out. In this case, the observers will go to the telescope and make observations themselves and will be supported at the telescope by MMT and University of Arizona staff. In order to minimize the support burden on MMT staff, it is likely that only observers with substantial large telescope experience will be allowed to apply.

It appears unlikely at this time that other independent observatories will be willing to make time available to the national community in return for NSF support of instrumentation. In order to achieve the dual goals of the McCray committee report—enhanced support of instrumentation and improved access for the national community—ACCORD has recommended to the NSF that the facilities instrument program be revised so that both NOAO and the independent observatories would be permitted to apply; that matching funds of 50 percent be required (NOAO would be allowed to use its existing operating budget to make the match); but that there be no requirement for national access.

The advantage of this new approach from the standpoint of the NOAO user community is that we will be able to provide access to better instrumentation than we could with our existing budget, provided that we succeed in writing competitive instrumentation proposals, and that the users will not have to familiarize themselves with a wide variety of operating instruments and environments but will be able to work with common NOAO/Gemini standard user interfaces.

If the ACCORD proposal for the revision of the facilities instrument program is supported by the NSF there are two implications for NOAO. First, the bulk of public access must continue to be provided on NOAO-operated facilities: the independent observatories are not going to supplant NOAO to any significant degree as the providers of open, competitive access, although we may still arrange for time swaps to gain access to specialized instrumentation. Second, NOAO has to be prepared to spend more of our resources preparing outstanding proposals for instrument initiatives. Since large proposals require AURA approval, it is likely that we are going to have to streamline the review process with the dual goals of providing a critical evaluation by AURA but on a time scale short enough that we can meet NSF deadlines for submission.

C. Joint Nighttime Instrumentation Program

1. Overview

The scientific staffs of the two observatory divisions have defined a five-year plan that will result in balanced instrumental capabilities at the two sites. This plan takes into account the strengths of the Gemini telescopes, and provides complementary and supporting instrumentation for optical and near-infrared imaging and spectroscopy. The new capabilities are based on the gains to be realized through the large-format detector arrays for optical and infrared developed under NOAO leadership. This program plan for FY 1999 defines the means of getting 20% of the way to completing the five-year plan.
The scientific oversight of the priorities and progress of the Instrument Projects Group (IPG) resides in IPAC, the Instrumentation Program Advisory Committee. The committee consists of Taft Armandroff, who heads the optical program, Dave De Young from USGP/SCOPE, Alistair Walker and Ron Probst from CTIO, Todd Boroson from USGP/SCOPE, Jay Elias the Gemini Near-IR Spectrograph project scientist, and Richard Green, NOAO Deputy Director, KPNO Director, and Chair. IPAC meets approximately monthly, and sets the scientific priorities of the projects for the allocation of resources by the engineering managers. FY 1999 will see the delivery of the Hydra multi-fiber positioner and CCD Mosaic camera to CTIO, followed by shipment of a working Phoenix high-resolution spectrograph. These three instruments are the first to be delivered to CTIO through the IPAC process.

The operational plan for IPG/IPAC includes a relatively strict model for the approval and allocation of resources for new instrument projects. Each project is led by a project scientist and a project engineer. Design engineers with the requisite skills, including software, form a project team to develop the instrument concept. This matrix group stays together at least through the Preliminary Design Review, which provides the gate for approval of allocation of resources for detailed design. The critical design review then clears a project for fabrication, assembly, and commissioning. IPAC benefits from community expertise in convening non-advocate external review panels for these occasions.

2. Description of Individual Major Projects

- **Phoenix**
  This high-resolution near-infrared spectrograph provides a resolution \( R = 100,000 \) for a \( 0.4'' \times 30'' \) slit on the 4-m telescopes. The detector is a 1024 x 512 ALADDIN array. Because of its compatible approach to design and cooling, with a cold dichroic for optical guiding, the Gemini Project has chosen Phoenix as a desirable loaner instrument. The instrument saw first light at the telescope in June 1996. Project costs in FY 1999 are for preparation for shipment and initial commissioning at CTIO. Phoenix will be shared among KPNO, CTIO, and the Gemini telescopes.

- **CCD Mosaic Imagers**
  This is a large format CCD imaging system, with a single dewar containing a mosaic of eight 4K x 2K CCDs producing an 8192 pixel square format, covering more than half a degree at the prime focus of the 4-m telescopes. The system consists of the dewar and associated ARCON controller electronics, a filter transport for 14 six-inch filters, and data system. The first system saw first light at the KPNO 0.9-m telescope in May 1996, with engineering grade CCDs. That system is being retrofitted with science-grade CCDs purchased in a mass buy with the Observatories of the Carnegie Institution of Washington (OCEW), and will be tested at the telescope in July 1998. A clone of the first system has been produced, and will be shipped to CTIO in October with the engineering-grade chips. Science-grade CCDs will be installed later for operation beginning early in CY 1999.

- **SQIID Upgrade**
  SQIID is a four-color near-IR imager, which records the J-L bands simultaneously through splitting the beam with cold dichroics. The first NOAO application of the project to produce upgraded array controllers for use on Gemini IR instrumentation will be to adapt the prototype to operating SQIID. SQIID will be upgraded with (up to) 4 ALADDIN type InSb arrays with one working 512 square quadrant each. Deployment is expected in late 1999. The delays in this project compared to previous projections are attributed to the considerable extra effort required to develop the working Gemini controller system and to the slower than anticipated delivery of arrays from the ALADDIN foundry process.
• **FLAMINGOS**
This project is a collaboration with Richard Elston (University of Florida) to produce two wide-field near-IR imagers with multi-object spectroscopic capability. The planned detector is a 2048 square HgCdTe 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 plan is to build one copy of the instrument to support Elston’s science at various observatories, and one copy to be resident at KPNO, shared between the 2.1-m and 4-m telescopes.

• **Gemini IRS**
This is a Gemini facility instrument produced with support from the International Gemini Project. The current design calls for a long-slit spectrograph with a reflecting collimator, a choice of dispersions, and two camera image scales, one with 0.05"/pixel and one with 0.15"/pixel projected onto an ALADDIN 1024 square array. The schedule for FY 1999 calls for completion of the fabrication and significant progress on the integration and test. Delivery to Gemini North is planned for FY 2000. NOAO plans to produce a near clone of this instrument to be shared between Gemini South and SOAR, with support from Gemini. Fabrication of parts for the second instrument will proceed in FY 1999 while the first instrument is in assembly and test.

• **Hydra for CTIO**
The CTIO Users cited this as the highest priority new instrument for CTIO. The multi-fiber robot positioner is similar to the version used at the R-C focus of the KPNO Mayall 4-m before it was converted to use at the WIYN telescope. Modifications include fibers of different diameter to optimize for extended objects (galaxies) and stellar objects in good seeing, and new motor controllers that will increase the speed and replace obsolete hardware in the older version. Optimum image quality at the 4-m requires a new wide-field corrector with atmospheric dispersion compensation for the R-C implementation. The system will be commissioned at CTIO at the start of the fiscal year, on the schedule set out in previous years’ program plans.

• **ALADDIN Arrays, Controllers**
NOAO, USNO Flagstaff, and Hughes Santa Barbara Research Corporation formed a partnership to develop 1024 x 1024 InSb arrays for astronomical research. NOAO is also managing the production of arrays for the Gemini Project. As of April 1998, three out of five Gemini foundry attempts produced working four-quadrant devices, with two of full scientific grade. Critical to the successful operation of the arrays are capable controllers with adequate bandwidth, multiplexing, and image format reconstruction. In FY 1998, NOAO will deliver controllers to Gemini for NIRI and for laboratory use. A further controller will be purchased by them for GNIRS for delivery in FY 1999. Upgrades will be made in this plan year to COB for use as the commissioning imager for Gemini South. As discussed above, the first NOAO application of the new generation controller will be in the upgrade to the SQIID imager. Further adaptations will include use in solar instrumentation and potentially in Wide Field of View IR Imagers and additional spectrograph applications.

• **GoldCam II**
This project was strongly requested by the KPNO Users Subcommittee to enhance the quality of spectroscopy at the 2.1-m telescope. This achromatic, wide-angle camera is being fabricated to address the wide format of the 3K x 1K CCD detector. The project has endured substantial delays because of loss of priority against work for Gemini and the 4-m telescopes, as well as the resignation of our only senior optician, but we expect to see commissioning in mid-1999.
• **Prototype Micro-Mirror MOS**

At this writing, this project is a potential collaboration among KPNO, STScI, and the NGST project at Goddard Space Flight Center. The goal is to produce a spectrograph with cold, programmable multi-slit masking utilizing digital micro-mirror arrays. NOAO’s role in the partnership is to provide an ALADDIN array controller and the closed-cycle helium refrigerators for the instrument, as well as access to telescope time for the team in exchange for full-time availability to KPNO users of the 4-m and 2.1-m telescopes. The design goal is to produce a spectral resolution of ~ 5000 through a reasonable slit (~ 0.75") on the 4-m, as a replacement for the capabilities of CRSP. Reviews and more definite planning will take place near the beginning of FY 1999. The capital is likely to come from KPNO instrument-improvement funds.

• **WIYN Tip/Tilt Module**

The optical quality and thermal management of the WIYN telescope allow it to deliver a median image quality of 0.8", only slightly degraded from the site-delivered seeing, which tests show to be < 0.7". Rapid tip/tilt correction can remove residual seeing contributions from wind buffeting and some atmospheric effects. The module is designed to be upgradable to include a deformable mirror for focus and higher-order correction in the future. The manpower will come from KPNO’s share of EPG resources.

• **WIYN Mini-Mosaic Imager**

The current STIS-supplied SITe CCD has a 2048 square format of 21 micron pixels. The WIYN consortium scientists desire both a larger field of view and better sampling of the PSF under the best seeing conditions. Two of the SITe 4K x 2K CCDs will comprise a mini-mosaic imager to replace the current STIS device. Some reprogramming of the hybrid Arcon system will be required for the upgrade. Although the intention is to complete that small project in FY 1998, work on Gemini CCDs and controller make take priority, and a placeholder was inserted as contingency in the FY 1999 plan.

• **4-m Wavefront Sensor**

This device is required to close the loop on the active optics control of the Mayall 4-m primary installed during summer shutdown 1998.

• **High-Throughput Spectrograph**

Studies are currently underway to define a new-generation moderate-resolution spectrograph for the 4-m telescopes. Scientific performance tradeoffs are being investigated to identify the most effective combination of field of view, spectral dispersion, and wavelength coverage. A key goal is to use the new generation of large-format CCDs with smaller slits and adequate pixel sampling in order to exploit the expected improvement in delivered image quality. In addition, the use of holographic volume phase gratings, coupled with the highest performance anti-reflection coatings on all optical surfaces, should allow a significant increase in throughput. Conceptual optical designs that meet the scientific performance goals will be undertaken in FY 1999.

A summary of the overall instrumentation program, including manpower and costs, is presented in Table III-1. Detailed project plans are available on request. Neither expenditures nor reimbursements for the Gemini IRS are shown since this work is effectively done on a cost-recovery basis for direct costs.
### TABLE III - 1
NOAO INSTRUMENTATION PROJECTS - FY 1999

<table>
<thead>
<tr>
<th>PROJECT NO.</th>
<th>PROJECT</th>
<th>CAPITAL ($K)</th>
<th>MANPOWER (MM)</th>
<th>PAYROLL ($K)</th>
<th>TOTAL</th>
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<tr>
<td>N-NX510-000</td>
<td>Instrument Operations</td>
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<td>$37</td>
<td>$72</td>
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<td>N-NX510-001</td>
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<td>N-NX510-007</td>
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<td>N-NX510-400</td>
<td>General Projects/Adv Development</td>
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<td>15</td>
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<td>N-NX510-409</td>
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<td></td>
<td><strong>Subtotal: O&amp;M Total</strong></td>
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<td><strong>$199</strong></td>
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<td>N-NX529-446</td>
<td>FLAMINGOS</td>
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<td></td>
<td><strong>Subtotal: IR Total</strong></td>
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<td><strong>$390</strong></td>
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<td><strong>Subtotal: OUV Total</strong></td>
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<td>N-NX539-201</td>
<td>Gold Cam II</td>
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<td>N-NX539-202</td>
<td>WTTM/WIYN Tilt-Tip Imager</td>
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<td>WIYN Mini-Mosaic</td>
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<td>N-NX539-</td>
<td>4M Wavefront Sensor</td>
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<td><strong>Subtotal: KP Projects</strong></td>
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<td>N-NX519-ALL</td>
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<td>7</td>
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<td>N-NX518-195</td>
<td>O/UV CCD Development</td>
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<td></td>
<td><strong>Subtotal: R&amp;D</strong></td>
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<td><strong>$273</strong></td>
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<td></td>
<td><strong>REQUIRED NOAO CAPITAL &amp; LABOR</strong></td>
<td><strong>$916</strong></td>
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<td><strong>$1,400</strong></td>
<td><strong>$2,316</strong></td>
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<td>Z-ZUP44-100</td>
<td>Gemini IRS</td>
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<td>140</td>
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<td>$948</td>
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<td>Z-ZUP44-300</td>
<td>Gemini CCD Controller/GMOS</td>
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<td>GNIRS Support Project</td>
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<td>Gemini MOS Study</td>
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<td>150</td>
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<td></td>
<td>SOLIS Support</td>
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<td>65</td>
<td>65</td>
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<tr>
<td></td>
<td>2.4-M Telescope ( KPNO)</td>
<td>0</td>
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<td>37</td>
<td>37</td>
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<tr>
<td></td>
<td><strong>KPNO, GEMINI &amp; SOLAR CAPITAL &amp; LABOR</strong></td>
<td><strong>$375</strong></td>
<td><strong>201</strong></td>
<td><strong>$1,188</strong></td>
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<td><strong>TOTAL REQUIRED CAPITAL &amp; LABOR</strong></td>
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<td><strong>$4,020</strong></td>
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<td><strong>TOTAL RESOURCES AVAILABLE</strong></td>
<td><strong>$4,210</strong></td>
<td><strong>491</strong></td>
<td><strong>$4,350</strong></td>
<td></td>
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</table>

### RESOURCES AVAILABLE

**Gemini Payment Recovery**
- GNIRS: $188
- Gemini IR Controller: 223
- Gemini CCD Controller/GMOS: 150
- COB Upgrade: 265
- CTIO MRS: 300
- Gemini MOS Study: 150
- SOLIS Support (labor recovery): 65
- KPNO Capital & Labor Recovery: 250
- 2.4-M Telescope (Kitt Peak) (labor recovery): 37

**TOTAL SALARY RECOVERY OFFSET**
- $1,628

**IPG CAPITAL & FTE mm BUDGET**
- $2,582

**TOTAL RESOURCES AVAILABLE**
- $4,210
1. The NOAO Instrumentation Program contains six major components: 1) general operations; 2) infrared instrumentation for both KPNO and CTIO; 3) optical/ultraviolet instrumentation for both KPNO and CTIO; 4) instrumentation improvement projects for KPNO; 5) research and development activities, currently focused on detector and fiber technology; and 6) outside projects, mainly for Gemini. CTIO instrumentation improvement projects are budgeted directly in the CTIO budget and carried out in Chile. NSO instrumentation projects are budgeted within NSO. **Note that 44 percent of the total program activity is for programs other than CTIO and KPNO instrumentation, including mainly Gemini.**

2. The total expenditure on line 34 for the KPNO/CTIO programs of $2.316M falls short of the available budget of $2.582M by $266,000. While there are planned nighttime projects that would benefit from this expenditure, we do not have the available manpower because of commitments to outside projects, including especially Gemini, and the funds are needed to cover some of the costs associated with Gemini work not covered by the international project. The highest priority in the overall program is completion of projects for Gemini.

3. In general, capital recovery from each outside project over the project lifetime will match the total expenditure of funds, apart from cost overruns. However, detailed balance is not achieved in any given calendar year because payments are normally made according to milestones and may exceed or fall short of actual expenditures in any given fiscal year. For example, in FY 1999 we expect to receive $188K in milestone payments for the Gemini near-infrared spectrograph, and we expect to expend $948K. Some of this has been covered by payments in FY 1998; we also expect to overrun the project by about $700K, at least $100K of which is attributable to delays in the delivery of specifications for the wavefront sensor by Hawaii. This overrun will be covered by delaying NOAO projects. As another example, we expect to spend $112K on the Gemini CCD controller project, while we expect to receive $150K in milestone payments. We do not currently expect an overrun on this project.

4. Line 39 (GNIRS Support Project) provides for the purchase of equipment, including compressors and test equipment, needed to support the construction of Gemini-scale instrumentation. Since we are not allowed to charge Gemini overhead, this equipment must be provided out of the NOAO budget.

5. Line 40 is an estimate of the effort involved in developing technology required for infrared multi-object spectroscopy. We will be submitting a proposal to Gemini for this project; the proposal will be reviewed competitively along with whatever other proposals Gemini receives and may or may not be funded.

6. Line 41 indicates that we expect staff from this program to work on the SOLIS project and to be reimbursed by it.

7. Line 42 is an estimate of the staff time from the instrumentation program that will be required to start the 2.4-m telescope project if it is funded. This effort will be reimbursed from the Kitt Peak operations budget (see line 56).

8. Line 44 is an estimate of the cost, over and above standard NOAO labor rates, required to hire 9.3 FTE contract personnel in order to carry out these projects. Man-months in Table III-1 were
converted to costs by using standard NOAO labor rates. Contract help costs more, mainly because of the need to pay overhead and profit to the contracting company. However, the use of contract personnel gives us the flexibility to change the skills mix as required.

9. Line 49 shows the expected milestone payment for the IR controller project for Gemini. We expect all work on the controller project to be completed in FY 1998, and that is why this project does not appear as an active project requiring expenditures in FY 1999.

10. Line 51 is the advance payment for the upgrades to COB, which is the commissioning instrument for Gemini South. We expect to do only a small amount of work on this project in FY 1999 and will complete the bulk of the work in FY 2000. Since COB will revert to NOAO when commissioning is completed, COB is listed under the NOAO instrumentation program (see line 12).

11. Line 52 shows the advance payment of $300K that we expect to receive for the GNIRS clone work in FY 1999. The clone costs and observing time will be shared equally between Gemini South and SOAR.

12. Line 55 shows the recovery from KPNO for expenditures by the instrumentation group beyond the 6.0 FTE allocated to KPNO.
D. US Gemini Project (USGP) and Science Operations (SCOPE)

During FY 1999, the procurement of the second generation of Gemini instruments is expected to begin. Early elements of this program will include laser guide star adaptive optics, a near-IR coronagraph/imager, and studies for near-IR multi-object spectrographs. The USGP will assist community efforts to participate in this program by working with groups to develop competitive proposals and advocating US interests in the Gemini instrument forum.

In addition to these new instrument efforts, the USGP will continue to manage the existing Gemini instrumentation work packages, including the Near-IR Spectrograph, the Mid-IR Imager, and the CCDs and CCD controllers. For most of these instruments, this year marks the transition from design work to fabrication and integration, with delivery and commissioning to follow a short time later. As Gemini North nears first light in early FY 1999, NOAO personnel will have to take on the responsibility for providing telescope- and instrument-specific support for US proposers and observers. The Gemini management plan states that the national Gemini offices will be the first point of contact for astronomers to obtain information about the facilities other than the periods that they are actually at the observatory. In order to provide this support, NOAO astronomers will be involved in early observations at the Gemini telescopes including the science verification period that follows commissioning. It is hoped that NOAO astronomers in Tucson and La Serena can provide the same level of support for the community for the Gemini telescopes as they currently provide for the KPNO and CTIO telescopes.

SCience OPErations (SCOPE)

In FY 1999, the Science Operations Division (SCOPE) will begin providing support for US access to Gemini as well as the time that will be available to the US community on the Hobby-Eberly Telescope and the MMT.

The operations-phase activities that are in support of US access to the large telescopes will be integrated with the analogous tasks to provide "before and after" assistance to users of the NOAO facilities at KPNO and CTIO. The goal is to unify these processes, so that users in the community can work with a single interface and a single set of rules for getting information about the facilities, applying for telescope time, preparing for observing runs, and reducing and analyzing their data.

The following specific activities will be undertaken by SCOPE in FY 1999:

- The proposal form and the process for telescope time allocation will be expanded to include HET and MMT (expected in March 1999) and Gemini North (expected in September 1999)

- A mechanism will be developed to consider proposals for survey projects that would support future programs on very large telescopes. This is a direct result of the workshop held in September 1997 to identify the required supporting capabilities for 6.5 - 10 meter telescopes.

- An archive for data from the NOAO nighttime telescopes will be initiated. While we now save all data from the telescopes, the new effort will be aimed at providing an effective scientific resource. It will start with data from the CCD Mosaic Imager.
E. Telescope Operations and User Support

1. CTIO: Overview and Accomplishments

CTIO's program for the coming years focuses on upgrading and instrumenting NOAO's southern telescopes so that they remain scientifically productive in an era of modern 4-m and 8-m apertures. The Gemini 8-m telescope construction is well advanced on Cerro Pachon, and the SOAR project, which provides a modern 4-m companion, is underway. CTIO ETS and scientific resources will be used extensively throughout the SOAR project, and we anticipate that our resources will also be called upon for commissioning Gemini. The combination of SOAR and the Blanco 4-m and their instruments will be configured as far as possible—through sharing arrangements between the 4-m telescopes—as a complementary observing system in support of work with Gemini.

In FY 1998, CTIO accomplished the following:

- Completed commissioning the f/14 tip-tilt system on the Blanco, for use with COB and the IR spectrograph (IRS), including a fast (100 Hz) guide camera and GUI interface.
- Completed the Hydra bench spectrograph, atmospheric dispersion correcting wide-field optical corrector, camera, and dewar in preparation for the arrival of the Hydra multi-object spectrograph at the beginning of FY 1999.
- Completed construction of the 16-port Arcon CCD controller, to be used with the NOAO Mosaic Imager II, expected to be commissioned in FY 1999.
- Completed installation of the Delta-Tau servo controllers at the 4-m, ready for final tests and commissioning during FY 1999.
- Completed work on the thermal environment of the 1.5-m telescope by improving insulation on the main floor, replacing the inefficient power transformers with more efficient units, and installing air conditioning units in the building.

We will continue to improve the performance and general maintainability of the 4-m telescope. The addition of active optics, an image analyzer, and thermal controls over the past several years has proven highly successful, and delivered image performance has improved significantly. In FY 1998 we have specified a new servo control system for the Blanco 4-m drives, and have planned upgrades to the thermal control for the R-C and PF cages.

2. Telescope Upgrades at CTIO in FY 1999

- **4-m Prime Focus Pedestal Upgrade/Mosaic Installation**
  The existing Prime Focus Pedestal is not strong enough to support the NOAO Mosaic Imager, and during FY 1999 we will modify and strengthen this assembly. The pedestal for the 4-m Mayall telescope was modified in FY 1996 for the same reason, but due to differences in corrector design it is not possible to copy the KPNO system. We will also take the opportunity to install new focus motors and to provide lateral and tilt adjustment for the PF corrector. This latter facility will greatly simplify procedures for collimating the telescope. The PF cage will be prepared to accept this instrument through modification of the entrance doors and removal of internal structures.
• **4-m Control System Improvements**
  In FY 1996, the antiquated 4-m telescope control logic was replaced with a modern programmable logic controller based system, following the upgrades made to the KPNO 4-m several years ago. With the improvement of the optical quality of the telescope, tracking and guiding performance have become limiting factors on delivered image quality.

  During FY 1997 and early FY 1998 efforts were made to tune and improve the existing servo system. These were only partially successful, and after a system analysis it was decided to replace the servo system in order to provide a modern and maintainable level of performance. The chosen model is a Delta-Tau system, analogous to that on the Gemini telescopes.

• **4-m F/14 Guide Camera Upgrades**
  During FY 1999 we will replace the present CCD in the tip-tilt camera with a new, thinned, 80x80 EEV CCD. This will more than double the system QE, and because the new CCD has extended response into the blue, will allow use of the tip-tilt system in the optical, with suitable dichroic beam-splitters. However, along with improvement to both camera hardware and servo-loop software, the major benefits will be to allow the use of fainter guide stars and to increase the bandwidth for all but the faintest stars. We will also implement the f/14 conversion optics to allow the Image Analyzer (IMAN) to be used at this focus, thus permitting active control of the primary mirror. The tip-tilt system has already demonstrated that it is capable of producing images with better than 0.25 arcsec FWHM in the K band; the aim of this project is to permit this performance to be realized under a wider range of conditions.

• **4-m Thermal Control**
  The 4-m dome will be covered with stick-on aluminium foil. This provides better nighttime performance than the present TiO paint (which overcools) and aluminium paint (which has poor daytime performance.) Monitoring of the thermal performance of the building will continue with the aid of many temperature probes. A LabView based control system, which apart from reading temperatures will also drive the primary mirror cooler, will replace the present simple controller. It appears that there is still some heating of the dome air by the building interior, of particular importance in low wind conditions when little natural flushing occurs. The NOAO 10-micron camera system will be used to help diagnose which building surfaces are responsible for the heating, followed by installation of insulation or air conditioning where necessary.

  The present 4-m primary mirror cover, when open, forms a 2-m deep cylindrical enclosure above the mirror which can trap air and thus degrade the seeing. We plan to replace the mirror cover with a two-component folding cover, which will provide a completely clear path in the N-S direction to the level of the primary and thus ensure that flushing is rapid and efficient.

3. **New Instrumentation at CTIO**

  During FY 1999, in a collaboration with Tucson IPG, we will commission three major new instruments at the Blanco 4-m: 1) the NOAO 8K Mosaic Imager II; 2) the Phoenix high resolution IR spectrometer; and 3) the Hydra/CTIO multi-fiber spectrograph. Much of the CTIO ETS effort in the past year has been devoted to preparation for these arrivals.

  We are also actively pursuing collaborations with US universities in order to offer additional state-of-the-art instrumentation that complements our own. At present we have such arrangements with Rutgers (Fabry-Perot Interferometer, from 1988), Lucent Technologies (BTC Mosaic Imager, from 1996), and the
University of Florida (Mid IR imager-spectrometer, from 1997). New activities in this category are as follows.

- We have negotiated a loan of the Osiris IR imager/spectrometer with Ohio State University, starting mid-FY 1999 for three years. This versatile workhorse instrument will be used at the 4-m telescope, and will be fitted with a Rockwell 1K array detector supplied by CTIO. It will replace COB (to be loaned to Gemini S for commissioning) and the IR spectrometer.

- We will continue our collaboration with Rutgers by participating in the design of Fabry-Perot II during FY 1999. This instrument will with suitable dichroics work at the f/14 tip-tilt focus of the Blanco 4-m, at the f/13.5 1.5-m, and in the future on SOAR and Gemini.

- The IR Fabry-Perot module (Univ. of North Carolina–Rice Univ.) is expected to be tested with the wide-field IR imager CIRIM during late FY 1998, with a view to being available to users in FY 1999. CTIO has constructed a filter wheel for use with this instrument.

By the end of FY 1999 we should have a well-instrumented 4-m telescope with superb image quality over a small field at f/14, dedicated to near-IR imaging and spectroscopy. In the optical, the wide-field aspects are being emphasized with the Mosaic imager and Hydra spectrograph; the telescope will be able to deliver excellent image quality at both f/3 and f/8 foci on a routine basis over a 45-arcminute field.

4. Collaborative and Guest Facilities at CTIO

The following is a brief summary of facilities likely to be under construction or in operation at CTIO during FY 1999. These facilities involve a variety of new collaborative, shared, and/or contractual arrangements with other institutions or organizations. Where NOAO has agreed to provide supporting services to programs in which it is not a direct partner, such services will be made available on a strict, at-cost, aperture-priority basis; for example, smaller facilities that encounter problems during a weekend may not get help until the following Monday.

- **Gemini South 8-m Telescope**
  Work on construction of the Gemini South telescope on Cerro Pachon is described at [http://www.gemini.edu/](http://www.gemini.edu/). CTIO staff are likely to continue to serve on a variety of Gemini committees, both for the international and US parts of this effort. Importation of Gemini hardware into Chile will continue to be supported by AURA's CTIO offices in Santiago and La Serena. During FY 1998, CTIO supported two scidar runs by Gemini staff at the 1.5-m telescope, in order to characterize the vertical turbulence profile of the atmosphere. Knowledge of the turbulence profile is a prerequisite for the design of the Gemini South adaptive optics system. FY 1999 will be a period of major activity on Cerro Pachon, with most plant and equipment being installed in preparation for first light in 2000. The IR imager COB will be borrowed from CTIO for use as the Gemini S telescope commissioning instrument, while during scheduled operations (starting 2001) other instruments (Phoenix, Gemini IR spectrometer) will be shared either with the SOAR or Blanco 4-m.

- **SOAR 4-m Telescope**
  Planning for the SOAR telescope is described at [http://www.noao.edu](http://www.noao.edu), with links to partner Web pages. The SOAR 4-m telescope is currently undergoing conceptual design, and it is expected that the final construction contracts will be let by the end of 1999. One CTIO staff scientist is heavily involved at the scientific level as part of the SOAR Science Advisory Committee, and one CTIO software person presently is involved at about 70% time in the preliminary design of the telescope.
control system. There will be further involvement by CTIO engineers in the conceptual design phase; in addition, CTIO is providing support to the SOAR site engineer for the site preparation.

We expect to continue at least this level of involvement through 1999 as construction starts on the telescope building, and then see a ramp-up in 2000 and 2001 when CTIO personnel will be seconded to SOAR to participate in the outfitting of the building and the commissioning of the telescope. After 2001, SOAR will be in its preliminary period of operations, which will be a CTIO responsibility initially involving approximately 11 FTE for operations/technical personnel, plus one or more staff scientists.

In addition to the above, we expect NOAO to participate in the SOAR instrumentation effort at a level in keeping with our 1/3 partnership in the telescope. The nature of the instrumentation package is still being worked out, but we foresee a major instrument (probably a clone of the GNIRS) to be built by the IPG in Tucson, while smaller instruments and/or shared effort will be provided by the La Serena ETS division.

- **2MASS-South: 1.3-m IR Survey Telescope**
  A description of work on the construction and operation of this facility can be found at: [http://pegasus.phast.umass.edu/GradProg/2mass.html](http://pegasus.phast.umass.edu/GradProg/2mass.html). The facility was completed on schedule in FY 1998, and the southern part of this IR survey has begun. NOAO/CTIO is supplying specially contracted operators for the telescope, as well as limited maintenance under the terms of an MOU signed with the UMASS consortium.

- **Revival of the 1-m Telescope by a Yale-led International Consortium (YALO)**
  During FY 1998, the Yale 1-m telescope, closed in FY 1997 for lack of funding, was re-opened on the basis of funding received from Yale University (30%), Ohio State University (30%), the University of Lisbon (30%), and NOAO (10%). OSU will provide a simultaneous IR-optical imager, particularly useful for synoptic programs which have proven to be very difficult to schedule on the existing CTIO telescopes. Under contract, CTIO's primary contribution in FY 1998 was in the testing and upgrading of the telescope, and in subsequent years will be in the form of operations infrastructure.

- **GONG-CTIO Station**
  A description of the Global Oscillation Network Group (GONG) program in Solar Seismology appears at: [http://www.gong.noao.edu/index.html](http://www.gong.noao.edu/index.html). Further information is given in Section IV. of this Program Plan. Impact on the operations group at CTIO has been small as a result of the high quality of engineering and maintenance of the station by GONG staff, who are sent down at carefully-planned intervals from the US.

- **United States Naval Observatory’s 20-cm Astrographic Survey Telescope**
  A new astrometric survey of the Southern hemisphere was undertaken in FY 1998 using the USNO 8-inch CCD astrograph mounted in the current 16-inch dome. This program will continue in FY 1999, with CTIO providing telescope operators under contract. More details can be found at [http://aries.usno.navy.mil/ad/ucac/ucac-s.html](http://aries.usno.navy.mil/ad/ucac/ucac-s.html).

- **Swarthmore 3-cm Robotic H-alpha Survey**
  Routine science operations began in December 1997. The instrument is described briefly in the 1997 March NOAO Newsletter and also at: [http://www.noao.edu/noao/noaonews/mar97/node2.html](http://www.noao.edu/noao/noaonews/mar97/node2.html).
Operations are expected to continue throughout FY 1999. Limited maintenance will be provided under the terms of an MOU signed with the Swarthmore group.

- **The MACHO Program on the CTIO 0.9-m Telescope**
  This highly successful program, involving a 15% share of the 0.9-m telescope, is expected to continue through at least part of FY 1999; however, reorganization within the project makes longer term operation uncertain. CTIO provides telescope operator support in a cost-sharing arrangement with the MACHO consortium.

5. **Instrumentation Improvements at CTIO**

- **Hydra Corrector/ADC Mounting and Installation**
  In order to obtain high quality images over the entire 4-m R-C field, an ADC corrector has been designed as part of the Hydra/CTIO project for the Blanco 4-m. This corrector should permit fibers as small as 1 arcsec to be used efficiently. In FY 1997 we began a project to design and construct the mounting cell and rotation subsystem for the ADC/wide-field corrector, based on our experience with the prime focus ADC. Fabrication and installation will carry over into FY 1999. The corrector will be installed in the 4-m chimney and feature a motor drive to flip the elements in or out of the beam to accommodate other instruments, particularly in the IR.

- **Hydra Spectrograph**
  In order to accept the 130+ fiber spectra that Hydra will produce, CTIO began in FY 1997 a project to modify the Argus bench spectrograph. Among other things, this entails changing the focal ratio by installing a new camera. The number of fibers that can be accommodated also has to be increased and the optical path changed. Fabrication of the optics for a new camera was finished in FY 1998. During FY 1999 we will increase the size of the spectrograph by installing a second optical bench, implementing the new camera, and changing the optical path. We will then mechanically modify the system to increase its fiber capacity and implement remote controls at least for focus, filter changes, and grating tilt. With the arrival of Hydra, the new collimator will be installed. This effort also includes a calibration lamp assembly.

- **CCD Controllers**
  We intend to begin retrofitting the existing ARCONs on CTIO with the final versions of three controller electronics cards (Video, VTT, and ADC), which have been developed over the past two years. These printed circuit cards will provide increased reliability and a cleaner video path. New functionality includes remote configuration of bias and clock voltages and full telemetry.

- **Spectrograph Motor Controllers**
  The R-C (low-dispersion) spectrograph on the 4-m has a number of functions that are remotely controlled by a convoluted patchwork of Camac and 25-year-old stepping motors, only some of which still work. During FY 1998, we will continue the process of converting spectrograph control to our new generation of standard, self-contained “Smart” Motor Controllers (SMCs). This will involve changing the control of functions of the R-C spectrograph and implementing remote control of some of the movements of the Argus/Hydra and echelle spectrographs—all of which at present are operated manually. This process is part of a more general conversion of much of the old motor control at the observatory to a more modern, robust, and standard system.
• **Implementation of Two CCD Systems**
  We expect to bring up two additional CCD systems on an ARCON controller during FY 1999. These conceivably would be a STe or EEV 2048 x 4096 for 4-m spectroscopy, and a pair of CCDs in a mini-Mosaic dewar for direct imaging. Our main needs at this point would be a lower noise, faster readout CCD to replace the LORAL 3K x 1K in our 4-m R-C spectrograph, and a replacement for a STe 2K imager which failed. The capital costs include an estimate for the purchase of a single 2K x 4K (80K).

• **Telescopes and Instruments at CTIO**
  A complete list of telescope and instrument combinations available at CTIO is given in Table III-2. Estimates of the manpower required for the improvements projects described here are given in Table III-3.

### Table III-2
**CTIO Telescope Instrument Combinations Available at the Start of FY 1999**

<table>
<thead>
<tr>
<th>Telescope</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blanco 4-m</strong></td>
<td>Hydra Multi-object Spectrograph + Hydra Camera + STe 2K CCD</td>
</tr>
<tr>
<td></td>
<td>R-C Spectrograph + Blue Air Schmidt (BAS) Camera + Loral 3K CCD</td>
</tr>
<tr>
<td></td>
<td>Echelle Spectrograph + Blue Air Schmidt (BAS) Camera + Loral 3K CCD</td>
</tr>
<tr>
<td></td>
<td>Echelle Spectrograph + Long Cameras + STe 2K CCD</td>
</tr>
<tr>
<td></td>
<td>Prime Focus Camera + BTC (4K x 4K Tyson/Bernstein CCD Mosaic)</td>
</tr>
<tr>
<td></td>
<td>Cass Direct + STe 2K CCD</td>
</tr>
<tr>
<td></td>
<td>Rutgers Imaging Fabry-Perot + Tek 1K CCD</td>
</tr>
<tr>
<td></td>
<td>Cryogenic Optical Bench + 512 InSb (to be replaced by OSIRIS)</td>
</tr>
<tr>
<td></td>
<td>CTIO IR Imager + 256 HgCdTe (to be replaced by OSIRIS)</td>
</tr>
<tr>
<td></td>
<td>CTIO IR Spectrometer + 256 InSb (for high spectral resolution and long</td>
</tr>
<tr>
<td></td>
<td>wavelength)</td>
</tr>
<tr>
<td><strong>1.5-m Telescope:</strong></td>
<td>Cass Direct + Tek 1K and STe 2K CCDs</td>
</tr>
<tr>
<td></td>
<td>Cass Spectrograph + Loral 1200 x 800 CCD</td>
</tr>
<tr>
<td></td>
<td>Bench-Mounted Echelle Spectrograph + BME camera + STe 2K CCD</td>
</tr>
<tr>
<td></td>
<td>Rutgers Imaging Fabry-Perot + Tek 1K CCD</td>
</tr>
<tr>
<td></td>
<td>CTIO IR Imager + 256 HgCdTe</td>
</tr>
<tr>
<td></td>
<td>ASCAP Photometer</td>
</tr>
<tr>
<td><strong>2MASS 1.3-m:</strong></td>
<td>Continuing a dedicated 2 micron survey work, begun in April 1998</td>
</tr>
<tr>
<td><strong>1-m Telescope:</strong></td>
<td>Re-opened in mid 1998 as a consortium under Yale U., Ohio State U., U. of</td>
</tr>
<tr>
<td></td>
<td>Lisbon, and NOAO. Dual channel optical/IR imager</td>
</tr>
<tr>
<td><strong>0.9-m Telescope:</strong></td>
<td>Cass Direct + STe 2K CCD</td>
</tr>
<tr>
<td><strong>Curtis Schmidt:</strong></td>
<td>STIS 2K CCD (Direct or Prism)</td>
</tr>
</tbody>
</table>
Table III-3
CTIO FY 1999 Projects
(Labor Estimates in Manweeks)

<table>
<thead>
<tr>
<th>Project **</th>
<th>ME</th>
<th>MD</th>
<th>MF</th>
<th>OE</th>
<th>EE</th>
<th>ED</th>
<th>EF</th>
<th>CS</th>
<th>$K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydra Installation</td>
<td>4</td>
<td>8</td>
<td>6</td>
<td>--</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>PF Pedestal and Mosaic Inst.</td>
<td>20</td>
<td>35</td>
<td>75</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>30</td>
</tr>
<tr>
<td>4-m Primary Cover/Thermal</td>
<td>10</td>
<td>15</td>
<td>28</td>
<td>3</td>
<td>--</td>
<td>2</td>
<td>4</td>
<td>--</td>
<td>19</td>
</tr>
<tr>
<td>4-m Guiders</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>12</td>
<td>6</td>
<td>12</td>
<td>24</td>
<td>--</td>
<td>20</td>
</tr>
<tr>
<td>CCD Controller Retrofits</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>8</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>6</td>
</tr>
<tr>
<td>R/C Spectrograph motor control</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>--</td>
<td>4</td>
<td>5</td>
<td>8</td>
<td>--</td>
<td>20</td>
</tr>
<tr>
<td>4-m f/14 Tip-tilt upgrades</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>18</td>
<td>4</td>
<td>6</td>
<td>28</td>
<td>--</td>
</tr>
<tr>
<td>CCD Mosaic II</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>28</td>
<td>--</td>
<td>--</td>
<td>28</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>CCD Minimosaic + spectr. CCD</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>1</td>
<td>36</td>
<td>8</td>
<td>8</td>
<td>--</td>
<td>80</td>
</tr>
<tr>
<td>Hydra upgrades (IFU, IR, Echelle)</td>
<td>10</td>
<td>24</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>58</strong></td>
<td><strong>108</strong></td>
<td><strong>159</strong></td>
<td><strong>11</strong></td>
<td><strong>120</strong></td>
<td><strong>36</strong></td>
<td><strong>52</strong></td>
<td><strong>110</strong></td>
<td><strong>$194</strong></td>
</tr>
</tbody>
</table>

Resources Available for Major Projects | 52 | 96 | 125 | 11 | 158 | 36 | 55 | 118 | $230 |

**Key to Column Labels:** ME, MD, MF = Mechanical Engineering, Design, and Fabrication estimates; OE = Optical Engineer; EE, ED, and EF = Electronics Engineering, Drafting and Fabrication; CS = Computer Software; all in manweeks. Column $K$ lists non-payroll expenses in units of $1000. The $K$ available is a nominal figure.

6. KPNO: Telescope Improvements

Uncertainty as to the timing for funding of design and construction of the new proposed 2.4-m telescope mandates alternative plans for KPNO telescope improvements in FY 1999. If funding is available in FY 1999 for the telescope project to begin, essentially all of the engineering resources available to KPNO will be committed to this project and to development of the base tip/tilt system for WIYN. If funding is not available, we plan to proceed as we have in recent years with the primary emphasis for KPNO telescope improvements on the two largest telescopes, the Mayall 4-m, where improvements will address the delivered image quality, and the WIYN, where improvements to operations efficiency and telescope performance are the chief goals.

Progress on Work Proposed for FY 1998

As declining budgets have restricted resources for telescope improvements, we have concentrated available resources on projects for the Mayall 4-m and WIYN where they have the largest potential gain. At the Mayall 4-m, the two most significant projects completed in the past fiscal year—installation of the dome ventilation system and of the active primary support system—are large projects with significant potential gain in improving image quality. At WIYN, the completed modifications to this new telescope reflect the reality that improvements begin as soon as commissioning ends and continue through the lifetime of the telescope as new scientific demands are made on the telescope by its users.

- The Mayall ventilation system was installed over Summer Shutdown 1997 and work had been sufficiently completed to allow "first wind" in November 1997. The vents have been in routine nightly operation with no failures to date. Minor sealing, insulation, and painting will be completed during Summer Shutdown 1998. The vents provide some 200 flushes per hour in a 10 mi/h wind from twenty-two six ft. wide by 22 ft. high panels. Analysis of the effect of the vents is awaiting collection of sufficient nights of measurement of the delivered image quality and environmental conditions.
• The Mayall active primary support system is based on the design used by CTIO to provide substantial improvement to their delivered image quality. The design was initiated in FY 1998 and installation will be completed during Summer Shutdown 1998, with system characterization to be undertaken during the first half of FY 1999. A wavefront camera for optimal use of the active optics is to be a FY 1999 project. The system actively controls the air pressure to each of the 33 mirror support pads and includes active control of the three defining units, a significant enhancement over the CTIO design as it provides active collimation of the optical system for all three foci (prime, f/8 and f/15).

Significant progress was made in almost all of the work proposed for FY 1998, given the resources available. Other 1998 work completed included:

• Characterization of the Mayall Thermal Control System—which controls the temperature of the dome floor, mirror cooling, oil temperature, and use of the dome air mixing fans—revealed that use of the dome air mixing fan substantially improves the temperature uniformity within the dome and confirmed earlier analysis that the mirror cooling system is only sufficient to offset heat gained during the daytime and is not able to substantially change the bulk temperature of the mirror. Optimal operating procedures could not be defined due to insufficient capacity of the mirror cooling system. Design of a thermal control system for the Mayall primary, which will likely include mirror heating, is a major FY 1999 project (see below).

• Improved encoding of the Mayall Cassegrain instrument rotation, an improvement that will address a limitation to the ability of the telescope to offset accurately, will be completed during Summer Shutdown 1998. This work has been delayed for several years due to resource non-availability.

• Design work for replacement of the "leaky" guider systems at the Mayall 4-m and 2.1-m was completed in FY 1998, with implementation planned for early FY 1999. The decades-old KPNO electronic guiders are based on commercial circuit boards that cannot be repaired. A commercial frame-grabber unit identical to the second-generation WIYN guider has been selected so that spares can be shared among the three telescopes. Tests at the 2.1-m in FY 1998 demonstrated that the WIYN system could be easily integrated into the KPNO Telescope Control System and that the new design delivered guiding performance comparable to the KPNO "leaky" and DTI-21 systems. The new electronic guiders will be characterized so that guiding produces minimal degradation to the delivered image quality, as preliminary tests indicate that a single time-constant parameter adds significantly to the DIQ under circumstances of best seeing. This project may carry into FY 1999.

• Year 2000 testing of Kitt Peak computer systems. The year 2000 affects Kitt Peak computer systems in fundamental ways, particularly including telescope pointing because of the precession of the equinoxes. Tests during the past year have identified century dependencies in our control software. Further tests are planned for Summer Shutdown 1998, and software changes will be made and tested in early FY 1999, well before the millennium arrives.

• Ventilation of the volume immediately above the Mayall primary mirror and changes to the mirror cover were proposed, but not undertaken in FY 1998 because of lack of engineering resources. This project addresses a major source of potentially significant image degradation. In comparison with modern telescopes such as WIYN and Gemini where natural wind blowing across the mirror disrupts convective currents, the Mayall primary is in a relatively deep cavity with signifi-
cant potential for stagnant air. Progress here will certainly be delayed until the Mayall primary temperature control is completed.

**Major Work Planned on KPNO Telescopes for FY 1999**

- **2.4-m Telescope for KPNO**
  The optimistic plan is that funding will be secured for producing a 2.4-m telescope. In that case, much of the engineering resources available to KPNO will be devoted to detailed project definition and the placement of fabrication contracts. Some advance work during FY 1998 will involve the translation of scientific performance requirements to engineering and technical performance requirements. Enough detailed definition of the telescope mount configuration will be developed to proceed with a final optical design before the end of FY 1998. In addition, initial exploration of modifications to the current commercial telescope mount will be undertaken, so that options for proceeding will be well defined by the start of FY 1999.

The following tasks relative to the proposed 2.4-m will be performed in-house:

1. **Design of primary mirror cell and supports.**
   The design will build on the heritage of the WIYN system and the recent modification of the Mayall primary supports. The Hubble spare mirror is extremely stiff, so an articulated airbag system may be adequate to meet the imaging specifications. If not, a modest number of actuators should be sufficient. A simple thermal control system will be incorporated.

2. **Design of secondary mirror cell and possible tip/tilt capability:**
   The secondary mirror will be of large diameter to accommodate the 1-degree field of view. Some analysis will be required to realize the combination of light-weighting and stiffness for that mirror and to define a cost-effective system of articulation.

3. **Design of tertiary mirror cell and rotator:**
   The concept will be based on the WIYN system design, in which the tertiary must address either Nasmyth port or be folded out of the way. In some ways, this telescope is more challenging, because the positioning of the wide-field corrector stack in the Cassegrain hole limits some options for stowing the tertiary out of the beam.

4. **Electronics and controls:**
   The mount and rotator servos will be provided by L&F, the commercial vendor. The observatory control software and user interface must be designed and developed by us. The current developments for WIYN, Gemini, and SOAR will figure prominently in the system architecture.

5. **Development of facility requirements:**
   A new enclosure will be developed for this telescope. Services and performance requirements must be specified in detail to serve as the basis for an RFP for commercial design and fabrication.

If identification of funding and the completion of a partnership agreement for the 2.4-m telescope are delayed beyond the start of the fiscal year, we will begin efforts on improvements to the existing facilities. The following represent our list of highest priority projects at this time. Projects will be developed from this list given the mix of resources remaining from the 2.4-m project.
• **Characterization of the Mayall Active Primary Support System**
  Hardware and software for the Mayall primary mirror active support system will be installed during Summer Shutdown 1998, and characterization will be conducted during testing and engineering time in the first half of FY 1999. The intent is to construct look-up tables of mirror support correction with telescope position and to develop operating procedures that will minimize image degradation due to primary mirror figure.

• **Mayall f/8 Wavefront Camera**
  Optimal use of the active primary support system on a nightly basis requires that wavefront analysis be performed on a regular and straight-forward basis, an operating requirement for permanent installation of a wavefront camera in the Cassegrain guider. Design is to begin in early FY 1999 with installation expected during Summer Shutdown 1999 (substantial modification to the Cassegrain guider may be required to add this function and retain other critical systems).

• **Thermal Control of 4-m Primary Design and Engineering Study**
  This project will be the major new start in FY 1999; as a continued image quality improvement this project has the strong recommendation of the KPNO User Committee. Analysis of the database of nightly delivered image quality has demonstrated the critical importance for the primary mirror to be close to thermal equilibrium with the dome environment. The best DIQ is achieved when the mirror is no warmer than 1C temperature difference and no cooler than 2-3 C difference.

  The design study will consider a year of temperature data at the Mayall 4-m to define what thermal time constant and control algorithm are required to keep the primary within the specified temperature difference for the maximum percentage of observing time. Analysis will include searching for characteristic nocturnal temperature profiles and to determine the cooling capacity of the current mirror system. Given engineering resource availability, implementation of this system may not be until FY 2000.

  The prototype design for thermal control is to cool the bulk of the mirror—through a mechanism to be determined—well below the anticipated temperature of the following night and then to heat the aluminum coating of the mirror to achieve temperature equilibrium of the reflective surface of the mirror. This system, which is based on that implemented on the Gemini telescopes, has potentially larger gains in thick mirror applications, such as the Mayall 4-m, as these mirrors have a long thermal time constant (on the order of 35 hours) and inland sites have larger and less predictable temperature variations. The success of this design and its pioneering implementation on Kitt Peak will again demonstrate the leadership NOAO has taken in demonstrating that “old” telescopes can deliver excellent images that are only minimally degraded from what the site delivers.

• **Mayall f/15 Tip-Tilt**
  Significant image quality improvement, with resulting sensitivity and limiting magnitude gains, can be realized at both optical and infrared wavelengths by first-order adaptive optics, a small amplitude correction known as tip-tilt when achieved by motion of an optical element. Of all the major improvement projects that have been considered over the past two to three years, this one ranks highest due to its potential improvement to the image quality at the 4-m and its potential gain with a variety of instruments.

  System requirements will be specified in FY 1999 and design work initiated based upon the successful implementation of a similar system at the Blanco 4-m. Performance gains of the CTIO system will
be carefully studied and applied to the somewhat different low-atmosphere seeing characteristics of the Kitt Peak site.

The complete tip-tilt system consists of a moving optic (most likely a new light-weighted f/15 secondary mirror), an image sensor and analyzer, a servo system, and a science instrument. The design requirements will start with the basic question of the wavelength range of operation. The CTIO implementation of tip-tilt is applicable only to IR instruments—both imagers and spectrometers—for a dichroic splits IR light to the science instrument and transmits the optical to the wavefront sensor. Error correction is done at the f/15 IR secondary through commercial piezo-electric actuators. The image sensor-analyzer determines the image centroid and drives the secondary in motions of an arcsecond at a frequency of tens of Hertz.

- **Completion of Year 2000 Project**

Analysis and testing of the control software on Kitt Peak was initiated several years ago to determine century dependencies. Software changes based on these studies are to be implemented and tested in the early months of FY 1999. The nights of 31 December 1999 and 1 January 2000, will be designated as “testing and engineering,” with scientific staff as the scheduled observers and programmers on hand to address any manifestations of the new millennium that affect telescope and instrument operations.

Table III-5 lists the telescopes and instruments to be offered at KPNO during FY 1999.

<table>
<thead>
<tr>
<th>Table III-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KPNO Telescopes–Instrument Combinations for FY 1999</strong></td>
</tr>
<tr>
<td><strong>Mayall 4-m Telescope</strong></td>
</tr>
<tr>
<td>R-C Spectrograph + CCD (T2KB)</td>
</tr>
<tr>
<td>Cryocam Spectrometer (with 800 x 1200 Loral CCD)</td>
</tr>
<tr>
<td>Echelle + UVFast, Red Long and Blue Long cameras + CCD (T2KB)</td>
</tr>
<tr>
<td>Prime Focus Direct Camera + CCD (T2KB)</td>
</tr>
<tr>
<td>CCD Mosaic Imager (shared risk observing beginning in fall 1997)</td>
</tr>
<tr>
<td>IR Cryogenic Spectrograph (CRSP)</td>
</tr>
<tr>
<td>IR Imager (IRIM)</td>
</tr>
<tr>
<td>High-resolution Near-IR Spectrometer (Phoenix)</td>
</tr>
<tr>
<td>Ohio State - NOAO Imaging Spectrometer</td>
</tr>
<tr>
<td><strong>WIYN Telescope</strong></td>
</tr>
<tr>
<td>Hydra + Bench Spectrometer (T2KC)</td>
</tr>
<tr>
<td>CCD Imager (S2KB)</td>
</tr>
<tr>
<td><strong>2.1-m Telescope</strong></td>
</tr>
<tr>
<td>Direct Camera + CCD (T1KA)</td>
</tr>
<tr>
<td>GoldCam CCD Spectrograph (F3KA)</td>
</tr>
<tr>
<td>IR Cryogenic Spectrograph (CRSP)</td>
</tr>
<tr>
<td>IR Imager (IRIM)</td>
</tr>
<tr>
<td>High-resolution Near-IR Spectrometer (Phoenix)</td>
</tr>
<tr>
<td>Ohio State - NOAO Imaging Spectrometer</td>
</tr>
<tr>
<td><strong>Coudé Feed Telescope</strong></td>
</tr>
<tr>
<td>Coudé Spectrograph + Cameras 5 and 6 + CCD (F3KB)</td>
</tr>
<tr>
<td>NICMASS HgCdTe IR Array; no new programs accepted</td>
</tr>
<tr>
<td><strong>0.9-m Telescope</strong></td>
</tr>
<tr>
<td>Direct Camera + CCD (T2KA)</td>
</tr>
<tr>
<td>CCD Mosaic Imager (shared risk observing beginning in fall 1997)</td>
</tr>
<tr>
<td>CCD Photometer (CCDPHOT) (TSHA); no new programs accepted</td>
</tr>
</tbody>
</table>
7. Changes in User Services at KPNO

Driven by decreases in budget and the transfer of resources to the USGP and other programs, we continue to shrink operations on Kitt Peak. Specifically, KPNO has already transferred the responsibility for operation of the Burrell Schmidt telescope back to its owner, Case Western Reserve University. NOAO users are no longer scheduled on the telescope. The scientific rationale for this closure is that the mosaic CCD imager at the 0.9-m telescope offers better sampling of the point spread function and is therefore better suited to more than 90% of the science previously supported at the Schmidt.

The Coude Feed is unique in offering resolutions of 200,000 for spectroscopy. However, the Feed has an aperture of only one meter, and therefore is limited to the very brightest stars. We are currently exploring the feasibility of moving the spectrograph optics to the 4-m dome and feeding them with a fiber in order to extend the limiting magnitude. In the meantime, we have restricted the number of programs supported at the Feed so that only one new setup per week is required.

If the budget permits, we will continue to operate the 2.1-m and the 0.9-m telescopes until they are replaced with the proposed 2.4-m telescope. The only work planned for the 2.1-m is the replacement of the motors on the guider. The goal is to lower the maintenance effort; the existing motors are of low torque and stall at times with consequent loss of observing efficiency. No improvements are planned for the 0.9-m telescope. This telescope, in combination with the mosaic CCD, offers a powerful new capability to the community.

Sometime in the next few months, we will ask the community for proposals to restore operation of the 1.3-m telescope.

8. WIYN

Several improvement projects on the WIYN telescope are slated for completion in FY 1998.

The primary and tertiary mirrors are being aluminized in May 1998. Software upgrades were made to the Control System (TCS) and Image Processing System (IPS). The TCS upgrades enable the replacement of the VSIO serial port and the upgrade of the main CPU in order to reduce system complexity and improve system reliability. The associated hardware changes to complete the system upgrade are taking place in May 1998. A global watchdog has been installed: this monitors the status of all interlocks and safety systems, and performs the proper shutdown of the control system when an error is detected in any telescope component. This is in addition to several other system enhancements (comprising ~ 20 individual items such as installing hardware limits and interlocks) completed in FY 1998 that were driven by safety requirements. A new telescope brake system will be installed that requires low air-pressure replacing the current high pressure system, since the high pressure system is a major maintenance problem. Data system upgrades include the installation of a fast ethernet, more disk storage, and higher speed tape drives. The WIYN archiving and data distribution system has been installed and is being tested. It is expected to be fully operational by June 1998.

Currently identified projects for FY 1999 are instrument upgrades directed towards the following:

- **Installation of a CCD mini-mosaic which will deliver finer spatial sampling over a larger field.** This project is awaiting the delivery of the CCDs and some software development; dewar and control electronics are ready. We estimate that this instrument will be completed this fiscal year, but testing and commissioning will carry into FY 1999.
• **Development of a tip-tilt camera has been identified as a major goal for the WIYN telescope.**

Optical and mechanical design work have begun, as we work towards a preliminary design review in December 1998. The MRI proposal submitted to NSF would enable near IR imaging with the tip-tilt module.

Support for both of these projects is allocated in the Instrument Projects Group budget, as discussed in that section. In addition, discussion is in progress on developing a Cassegrain Instrument Adaptor System. A design requirements document is under review. An upgrade to the fiber positioners on Hydra is also in consideration: this is required from an operational standpoint (to be compatible with new hardware and software), and it will also significantly increase fiber positioning speed, which is currently a significant overhead in observing time.
IV. NATIONAL SOLAR OBSERVATORY

A. Major Projects

1. The Advanced Solar Telescope (AST)

NSO’s most important initiative is the construction of an “Advanced Solar Telescope” (AST). Planning for a major new solar telescope has been endorsed by several external committees, and the NSO scientific staff is intensely engaged in various technical studies, all aimed at developing a proposal for construction of the AST. These studies will be presented to, and reviewed by, two major National Academy committees, the current one on groundbased solar astronomy (the Parker Committee) and the decadal study which is expected to start in FY 1999. The goal of the current effort is to sharpen the science focus for the large telescope and to broaden community participation and consensus.

One of the options for the AST is CLEAR, the Coronagraphic and Low Emissivity Astronomical Reflector (CLEAR), and technical and budgetary feasibility studies of CLEAR will be completed in FY 1998. This 4-m aperture solar telescope aims at doing very high angular resolution observations of the Sun at all visible and infrared wavelengths transmitted by the earth’s atmosphere. Its design will allow accurate polarimetry in solar spectral lines and continuum radiation. It will include adaptive optics initially designed for 1.6 microns. Care is being taken to minimize scattered light with the goal of making coronal observations possible. The cost model will consider various options, including a descoping in size/aperture, relaxed requirements on scattered light, and several different sites.

CLEAR was initially planned to go to an existing NSO site. Ongoing site survey observations, however, have confirmed earlier indications that lake sites offer superior conditions for good seeing over long durations. We intend to continue this survey, extending it to several lake sites in the southwest US and including observations of the seeing with a Solar Dual Image Motion Monitor (S-DIMM). As a result, we expect to understand better the conditions needed for best seeing, leading ultimately to a recommendation for the telescope siting. It may turn out, of course, that it will be impossible to identify a site on which all conditions for solar observations (good seeing, IR transparency, low cloud cover, and coronagraphic skies) are simultaneously satisfied. In that case the scientific goals of the large facility must drive the site selection. Depending on the outcome of such site selection procedures, several options will exist concerning the location of most of the future NSO operations. Transfer of these to the flagship site with concomitant installation of robotic operations at other sites is one possibility; on the other hand if the flagship facility is located at an extremely remote site, then the most viable option may be retention of some combination of the current facilities with largely remote operation of the flagship facility. There are obviously many options between these two extreme cases.

FY 1999 will also see extensive testing of telescope seeing and dust control measures using the 1/7 scale mock-up now mounted on the Sacramento Peak large 28 foot spar. Personnel limitations in FY 1998 prevented the completion of these tests in that year.

The CLEAR resources carried forward from FY 1998 and an additional allocation of resources for the construction of the S-DIMM should suffice to complete the feasibility study and to fund the modest seeing site survey now underway. Therefore no new FY 1999 resources are currently assigned to this feasibility study.
2. SOLIS

SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to make optical measurements of processes on the Sun, the study of which requires well calibrated, sustained observations over a long time period. The project was conceived in 1995, submitted to NSF in early 1996, and received funding in January 1998. The design and construction phases will require three years, and the 25-year operational phase will start during FY 2001. The project was descoped, primarily by reducing the capability for coronal observations, when funding fell short of the request. A Science Advisory Group provides expert advice from the user community.

Fiscal Year 1999 will see the completion of design studies and the start of two years of construction. We will also learn if a proposal by the High Altitude Observatory to NSF/ATM to construct two additional vector spectromagnetographs and mountings will be funded. The staffing level of SOLIS will reach a peak in FY 1999 of 6.5 FTE with additions from the NSO and ETS bases augmenting this roster. Major contracts for the mounting, a CCD camera system, the integrated sunlight spectrometer, the vector spectromagnetograph modulation system, and data handling systems will be placed during FY 1999.

Major software developments will be underway in FY 1999. These consist of real-time operating code, a scheduler for automatic queuing of background and foreground observing programs, and algorithms to calibrate the data. Some of these algorithms will be tested using existing NSO telescopes.

Planning for cross calibration between the new SOLIS instruments and the old synoptic equipment (to be retired) will be initiated during FY 1999. Scientific observing plans with the NASA HESSI mission (to be launched in late 2000) will be started.

A design review of the SOLIS project will be held early in 1999. Changes that result from that review will be implemented as rapidly as possible preceding a final review prior to major construction. Construction will be a combination of in-house and vendor provided elements with assembly and testing taking place in-house. Acceptance tests will be defined and carried out for all major elements. The project holds weekly meetings to ensure that communication channels are open and that progress and problems are closely monitored.

SOLIS: Objectives for FY 1999

- Complete design work
- Start construction
- Continue acquisition of long lead time items
- Continue development of software

SOLIS: Funding Requirements (1999-2000)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Budget ($ in Millions)</td>
<td>$1.55</td>
<td>$1.55</td>
</tr>
</tbody>
</table>

3. Global Oscillation Network Group

The Global Oscillation Network Group (GONG) is an international project conducting a detailed study of the internal structure and dynamics of the closest star by measuring resonating waves that propagate throughout the solar interior. To overcome the limitations imposed by the day-night cycle at a single obser-
GONG has developed and deployed a six-station network of extremely sensitive and stable solar velocity mappers located around the Earth to obtain nearly continuous observations of the “five-minute” pressure oscillations. To accomplish its objectives, GONG has also established a distributed data reduction and analysis system to facilitate the coordinated analysis of these data, which are available to all qualified researchers.

The network commenced observing in October 1995, and the performance and reliability are excellent, with an equipment downtime of less than 2%. The scientific duty cycle routinely exceeds 90% and the daily-sidelobe artifacts are virtually invisible. Routine servicing of the field stations has proceeded since the deployment according to plan, with the intention of assuring satisfactory operation over an eleven-year solar cycle. Development of engineering data-analysis software is continuing to facilitate the review and analysis of the functioning of the remote instruments, including fault diagnosis and long-term trend analysis.

Twenty-seven months of data have been processed by the project’s data management group and have been made available to the research community for scientific analysis. A number of improvements have been made in the data reduction processes, and a reprocessing of earlier data is nearing completion.

Results to date demonstrate that an eleven-year data run, combined with a higher-resolution camera, can produce significant increases in our knowledge of the Sun, at a relatively small cost. Accordingly, it is the advice of the GONG Scientific Advisory Committee that the project should continue the observing run for an eleven-year solar cycle and pursue the installation of higher-resolution detectors in the network instruments to catch the rising phase of the next solar maximum.

The GONG instrument group has integrated a Silicon Mountain Designs IM 60-20, 1024 x 1024 square-pixel camera and prototype high-speed electronics into the Doppler imager optical system at the Tucson shelter. This new detector has excellent characteristics and provides spatial resolution comparable to the optical system resolution, eliminating the spatial aliasing in the current system and overcoming the inherent problems with the current rectangular pixels. A seeing-effects study indicates that the current optics and the image sampling rate are satisfactory for the larger format system. Increasing the detector scale will provide significantly improved helioseismic resolution in the near-surface regions, home of the intense magnetic fields that seem to cause many of the more dramatic aspects of solar activity, extend all aspects of “local helioseismology,” and enable many non-helioseismic, diachronic solar measurements, e.g. continuous magnetograms.

If funding were available, the new camera systems could be integrated during FY 1999; the technical feasibility has been successfully demonstrated.

The cost of continued operation of the GONG network is included within the current NOAO budget. Support for the new cameras will be requested from the NSF through a special proposal. The cost of these two activities is shown separately in the following table.

<table>
<thead>
<tr>
<th>Plan Year</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Budget</td>
<td>1.85</td>
<td>1.96</td>
<td>2.22</td>
<td>2.29</td>
<td>2.36</td>
</tr>
<tr>
<td>New Cameras</td>
<td>1.01</td>
<td>.62</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Annual Total</td>
<td>$2.86</td>
<td>$2.52</td>
<td>$2.22</td>
<td>$2.29</td>
<td>$2.36</td>
</tr>
</tbody>
</table>
The increase in operating costs after the new camera is completed reflects the factor of 16 increase in the data flow. We believe that with continuing improvements in the price/performance of modern computing systems, we can keep the increase in annual operating costs to $300K. The increase is largely in the area of data storage media and in processing, with some additional operating costs for sparing and maintenance of the increased on-site image storage electronics.

4. RISE/PSPT Program

The Italian PSPT telescope was deployed at the Osservatorio Astronomico di Roma and now generates solar precision photometric data on a daily basis. A second PSPT has recently begun operation from Mauna Loa and is jointly operated by the National Solar Observatory and the High Altitude Observatory. These instruments will allow, for the first time, full-disk photometric measurements of the differential surface brightness of the Sun with an accuracy comparable to the precision of absolute bolometric measurements from space.

The PSPT operations were descoped from the original 1992 plan, and budget constraints have made it necessary for us to depend heavily on commercial vendors and partnerships with other institutions. Nevertheless, with the proposed configuration, we will achieve daily measurements of solar photometric variability. Occasional higher cadence observations will be possible (for example to support space experiments or to monitor brief periods of exceptional solar activity) depending on the availability of support from our partner institutions. In this configuration we expect to be able to satisfy the data needs of up to 10 research groups, but much of the higher level data processing beyond the lowest level instrument calibration will be the responsibility of our scientific collaborators.

To date, we have established partnerships with two other institutions—the Osservatorio Astronomico di Roma, which operates the Rome facility, and the NCAR High Altitude Observatory (HAO)—which have agreed on a collaboration to provide a RISE data distribution center (primarily from HAO).

NSO scientist H. Lin has overall responsibility for the scientific performance of the PSPT network. Operations and maintenance support issues for the full network are still being negotiated and have not yet been determined for FY 1999.

B. Instrumentation Program

The following tables summarize the NSO instrumentation program at Sacramento Peak and Kitt Peak.

Table IV - 2
FY 1999 Instrumentation Projects
NSO/Sacramento Peak
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Project</th>
<th>Project Scientist</th>
<th>Priority</th>
<th>Payroll (MM)</th>
<th>Non-Payroll NSF $</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLIS</td>
<td>Harvey</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Adaptive Optics</td>
<td>Rimele/Radick (AFRL/VSBS)</td>
<td>2</td>
<td>22</td>
<td>$ 96</td>
</tr>
<tr>
<td>IR Vectormagnetograph</td>
<td>(USAF)</td>
<td>3</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><strong>Total NSO/Sac Peak</strong></td>
<td></td>
<td></td>
<td><strong>46</strong></td>
<td><strong>$ 96</strong></td>
</tr>
</tbody>
</table>
Table IV - 3
FY 1999 Instrumentation Projects
NSO/Kitt Peak
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Project</th>
<th>Project Scientist</th>
<th>Priority</th>
<th>Payroll (MM)</th>
<th>Non-Payroll NSF $</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLIS</td>
<td>Harvey</td>
<td>1</td>
<td>40</td>
<td>—</td>
</tr>
<tr>
<td>IR Array and Controller</td>
<td>Rabin</td>
<td>2</td>
<td>23</td>
<td>$ 80</td>
</tr>
<tr>
<td>Solar DIMM Breadboard</td>
<td>Beckers</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total NSO/ Kitt Peak</strong></td>
<td></td>
<td></td>
<td><strong>65</strong></td>
<td><strong>$ 85</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL NSO(SP+KP)</strong></td>
<td></td>
<td></td>
<td><strong>111</strong></td>
<td><strong>$ 181</strong></td>
</tr>
</tbody>
</table>

1. **NSO/Sacramento Peak**

- **SOLIS**
  NSO/Sacramento Peak will participate in SOLIS by designing and fabricating the full-disk patrol instrument. The 15 man-months of payroll represents the level of support required from NSO’s operating budget.

- **Adaptive Optics**
  Two years ago the Sacramento Peak image quality improvement program was restructured in a major way. In the new program, a step-by-step approach is being followed, which will lead in three years to a full-up adaptive optics system in which atmospheric wavefront distortions at the Sac Peak Vacuum Tower Telescopes will be corrected up to 20 Zernike terms. This new program was designed to produce increasingly better imaging as it progresses, and this improved image quality will be used for new science programs during the course of the three-year program. The development effort will also allow staff to learn gradually about the technology involved.

**Milestones and Status of Adaptive Optics Program**

- Improve Telescope Optics (Window T-Control, Mirror) DONE
- MARK II Correlation Tracker (CT using commercial components) DONE
- Full-Up Tip-Tilt System (with German KIS collaboration) DONE
- Image Selection Observations Using CT and Tip-Tilt DONE
- Explore Wave-Front Sensor (WFS) Options (LCD, S-H) DONE
- Demonstrate Solar Shack-Hartmann WFS Sensor DONE
- Build and Demonstrate Active Optics Using Commercial Components Solar WFS DONE
- Combine Active Optics and Image Selection (longer exposure time, larger isoplanatic patch, more often) DONE
- Speed Up System Using Parallel Processing and USAF/SOR or Commercial Reconstructor Aiming at 20 Zernike Adaptive Optics System FY 1999

As intermediate results of this systematic approach to solar adaptive optics, we have achieved: (1) a rapid solar tip-tilt system (or 2 Zernike adaptive optics system); (2) the best (diffraction-limited) images of the Sun ever obtained (1/8 arcsec resolution) using image selection techniques; and (3) full correction of the residual aberrations of the VTT by means of active optics. The next step, image
selection using the aberration-free telescope, is expected to lead to even better quality imaging (more frequently, larger isoplanatic patch, and longer exposure times).

The budget listed above is by itself inadequate to accomplish the goal of the 20 Zernike system. This project benefits very much from the synergism created by the partnership with US Air Force Research Laboratory (AFRL/VSBS) solar group at Sac Peak. In addition to contributing payroll and non-payroll resources (the Xynetics 97-element adaptive mirror procurement was only possible by their contribution), this collaboration provides an important link to the Air Force Research Lab Starfire Optical Range expertise in adaptive optics. In addition to benefiting from US AFRL/VSBS collaborations, this project has the highest priority for the assignment of FY 1998 year-end resources.

Benefits of the development of this solar adaptive optics system extend well beyond the Sac Peak VTT. It provides the know-how essential for the implementation of the Advanced Solar Telescope (AST). The prime requirement for the AST is diffraction-limited resolution. The availability of a functioning solar adaptive optics system and the experience gained from its operation are crucial for the successful pursuit of the funding for such a telescope.

• IR Vectormagnetograph
The USAF wants to develop a stand-alone IR-VMG prototype. This instrument, while being tested for suitability for inclusion into the ISOON system, will also be available as an active region development monitoring system during the upcoming solar maximum. The stand-alone system will be installed on either the Hilltop spar or the Evans spar.

2. NSO/Kitt Peak

• SOLIS
Both NSO sites will contribute from the operations budget a total of three FTE of technical labor per year towards the completion of the SOLIS project. NSO/KP resources will be applied mainly to the development of the vector spectromagnetograph and the integrated sunlight spectrometer instruments.

• Large-Format Infrared Array and Controller
The McMath-Pierce facility is the world's only large solar telescope without an entrance window, thus giving it unique access to the solar infrared spectrum beyond 2.5 micron. NSO, like NOAO, has focussed its in-house instrumentation program on the 1-5 micron region. The McMath-Pierce also carries out observations in the important 12-micron region through a collaboration with NASA Goddard Space Flight Center.

NSO's plan for 1-5 micron observations is to take full advantage of NOAO's investment in the ALADDIN array development project. With 16 times as many pixels, higher quantum efficiency, lower readout noise, and better immunity from electronic interference, a 1K × 1K ALADDIN-based camera will be superior to the current 256 × 256 camera in every respect and will enable new types of scientific observations, such as vector magnetograms of weak field concentrations.

No single instrumental improvement at NSO/KP in recent years will have a greater impact on its capabilities than this one. The large-format camera will be used for exploratory imaging and spectroscopy as well as with the Near Infrared Magnetographs.
FY 1997 and FY 1998 funds have been committed to have NOAO/ETS construct a controller for an ALADDIN-based camera by mid-1999, and NSO has formally requested a science-grade 1K × 1K array from the ALADDIN arrays available to NOAO.

- **Solar Dual Image Motion Monitor (S-DIMM)**
  It is important that the daytime seeing measurements using the Seykora solar scintillometry technique be confirmed by optical measurements. We plan to construct a breadboard version of the solar equivalent of the now common Dual Image Motion Monitor (DIMM) used for nighttime site testing and mount it on an existing 30-cm portable telescope. It will be used at both Sac Peak and Big Bear Solar Observatory.

In addition, we will initiate a collaboration with the Yunnan Observatory in China. The Yunnan Observatory is currently evaluating a new site for a solar observatory at Fuxian Lake, 100 km south of Kunming, using a S-DIMM. Plans call for installing one of our solar scintillometers there and sharing experiences with the scintillometer-S-DIMM comparisons.
V. THE SCIENTIFIC STAFF

The scientific staff of NOAO continues to maintain a very high standard of excellence in terms of both research and service to the community. Appendix 3 provides a summary of their recent research, functional responsibilities, and plans for FY 1999. The observatory owes its success to the sustained and committed efforts of this very talented group of individuals.

The roles, responsibilities, and terms and conditions of employment of the scientific staff were described in the renewal proposal. We have adopted the philosophy that the size of the scientific staff should be determined by functional responsibilities. Over the past several years, however, the functional responsibilities of the staff have increased while its size has declined (by about 30 percent over the past decade). The increased responsibilities have come about because of new program requirements: 1) support of US involvement with, and US use of, the Gemini telescopes; 2) the development of consortium telescope projects (WIYN and SOAR); 3) leadership of the GONG project; 4) responsibility for several major instrumentation projects for Gemini; 5) the construction of SOLIS and SOAR; and soon 6) access to the MMT and HET; and (we hope) (7) construction of 2.4-m telescopes.

NOAO believes that direct involvement of scientific staff in defining requirements for, and evaluating the implementation of, major new projects is crucial to the success of those projects, and for this reason each initiative has a project scientist assigned to it. Because none of the initiatives listed above has brought with it support for the scientific staff, staff responsibilities have grown to the point that there is very little time for research. According to AURA policy, tenured and tenure track staff should have 50 percent of their time available for research, and scientists should be able to devote about 25 percent of their time to research. It is uniform throughout the organization that the staff estimates that they are spending less than half this amount of time on research. Attempts to date to ameliorate this situation, including reducing the workload by reducing services offered to users and by re-organizing the way work is carried out, have led to greater efficiencies in some parts of the program, but these efficiencies have been insufficient to compensate for the workload increases associated with the new programs that are being undertaken.

Over the past few years, the staff responded to this situation by taking sabbaticals, thereby increasing the burdens on those who were not on sabbatical. Fortunately, this coming year will see the completion of most of this round of sabbaticals. The problem of understaffing, which is a consequence of the budgetary stringency under which we operate, was further aggravated by our failure to fill some of the vacant positions that did exist. Again, however, this situation has now been corrected by the hiring of Steve Strom, Arjun Dey, and Joan Najita by NOAO/Tucson and Chris Smith at CTIO. CTIO does, however, still have one remaining vacancy, and recruitment is continuing. Scientific productivity has recently been enhanced by the availability of NASA support for space-related, including especially HST-based, research. Many of the staff now have post docs working with them on their research programs through the availability of NASA funds.

As we have also noted in each year’s program plan for the past several years, scientific staff salaries seriously lag (by about 15 percent) salaries computed on an 11-month basis at comparable institutions. A very high priority for any budgetary increase is to improve scientific staff salaries.
VI.  PUBLIC AND EDUCATIONAL OUTREACH

To promote public understanding and support of science and astronomical research, NOAO encourages public awareness and science education through an active outreach program that has grown substantially in the last two years. FY 1999 will be a year of stabilization and evaluation. We will examine individual programs, evaluate their effectiveness and impact, and use this information to further develop the NOAO Outreach Program.

A. Graduate Education

NOAO will continue its established record of supporting a large fraction of the observational theses in the US. The current annual level of graduate education support involving NOAO is significant. 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. Approximately 1/3 of Hubble fellows, 1/3 of Pierce Prize winners, and 1/4 of Trumpler Prize winners used NOAO for a major portion of their research. NOAO has also added a program that supports graduate student residents on Kitt Peak, which is expected to continue through FY 1999.

B. Undergraduate Education

NOAO will continue to host undergraduate summer students, funded by the NSF Research Experiences for Undergraduates (REU) program. KPNO, NSO/Tucson and NSO/Sac Peak, and CTIO will host as many students as funding permits, currently eight students at KPNO, seven at NSO, and four at CTIO. In addition, approximately four University of Arizona undergraduate students are mentored by NOAO staff members as part of the UA/NASA Space Grant Consortium program. This level of activity will remain constant or increase.

C. Pre-College Education Programs

The initiative begun two years ago in the NOAO pre-college education program has grown to a substantial and stable level, including direct classroom involvement as a Project ASTRO expansion site, the development of instructional materials as resources allow, and a major national teacher enhancement program promoting research based science education.

1. Direct Classroom Involvement

As lead institution for the expansion of Project ASTRO to Tucson, NOAO annually matches 25 astronomers with teachers, with the goal of forming ongoing partnerships to enhance science education in the classroom. By the end of FY 1999 we will have trained more than 150 participants in hands-on activities for teaching astronomy. Our funding from the Astronomical Society of the Pacific (from the NSF Informal Science Program) runs out at the end of FY 1999, and we will be faced with the challenge of continuing the program without outside funding. The main expense is the salary of a half-time program coordinator without whom the responsibilities of recruiting, matching, and supporting partnerships, as well as planning and running the training workshop, are impossible.

During FY 1999, NOAO will evaluate the role of Project ASTRO in the overall NOAO Educational Outreach program and determine if the program will continue without additional outside funding. At the same time, we are interested in promoting the expansion of ASTRO within NOAO. We have discussed running a Project ASTRO workshop in Chile for CTIO and other Chilean astronomers and teachers. We also advocate
a Project ASTRO training workshop in conjunction with the international Gemini Project, with participants from all member countries.

2. Instructional Materials

Instructional materials based on science undertaken at NOAO have been produced over the last two years with funding from NASA IDeAS grants. We anticipate applying for another IDeAS grant this year to support follow-up workshops for teachers participating in the Teacher Enhancement program described below.

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 for information 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 CfA, the Astronomical Society of the Pacific, Lockheed-Martin, and Science Technologies Inc. We expect this effort to be completed in mid-FY 1999.

3. Teacher Enhancement

The NOAO Teacher Enhancement program, “The Use of Astronomy in Research Based Science Education (RBSE)”, funded for four years through the NSF Educational and Human Resources Directorate, will enter its third year of operation during FY 1999. Our first year was a local, Tucson-based pilot program; in the second year we expanded nationally. This third year we anticipate refining the program content further with another national group of participant teachers. An important component of the program, matching astronomers as mentors with RBSE teachers in their local areas, will be a priority during FY 1999, as the summer 1998 teachers return to their home schools to implement the program during their 1998/1999 academic year.

Midway through FY 1998, a new position of Outreach Astronomer, 1/3 funded through the RBSE grant, was filled. In FY 1999 the Outreach Astronomer will be able to spend time on projects in addition to RBSE, which should expedite completion of informational materials developed through Educational Outreach and the on-line NOAO Image Collection described below.

D. Visitor Center Programs

The Kitt Peak Visitor Center attracts approximately 50,000 visitors per year. An aggressive business plan has been implemented to introduce new public programs and create new revenue centers to subsidize NOAO public outreach activities. This program has developed extremely rapidly, and so the focus during FY 1999 will be to consolidate the program, stabilize the staffing, and make sure the projected revenue stream can be achieved and sustained.

A fee-based Nightly Observing Program for the public has been created to introduce participants to astronomy and basic telescope usage using the 16-inch Visitor Center Telescope. A second fee-based program, the Advanced Observing Program, intended for amateur astronomers interested in observing with the 16-inch telescope and its CCD imaging equipment, has also been introduced and well received. Both programs run at nearly full capacity during the winter tourist season, a level we expect to maintain during FY 1999.
The Kitt Peak Docent Program recruits and trains volunteer tour guides and Visitor Center hosts. Within the past year the number of docents has doubled, and their training has been improved. We anticipate increasing still further the number of docents during FY 1999.

NOAO continues to be an active participant in the Southwestern Consortium of Observatories for Public Education (SCOPE), a consortium of several observatories located in the southwest which was organized in 1997.

In FY 1999 we expect to inaugurate a fee-based automated tour program for visitors to Kitt Peak featuring recorded information via individual headphones.

E. Media Relations

NOAO has renewed efforts to distribute press releases and promote the science done at Observatory facilities. Efforts over the past six months have been successful, and we plan to continue the same strategy: cooperating with other research facilities on joint releases, streamlining our procedures for producing press releases and video materials requested by the media, and selecting stories with a high science value and reporting them accurately.

F. Image Collection

The NOAO Image Collection contains more than one thousand images accumulated since the mid-1950s documenting the construction, facilities, and science of NOAO. Efforts are underway to streamline the Image Collection, to increase its accessibility by scientists, writers, and non-technical public as well as decrease the staff time required to maintain the collection and service requests for its contents.

Our eventual goal is to develop a Web-based pictorial index of the collection containing thumbnail sketches and brief captions of every available image. Downloadable digital versions of selected images at different resolutions will also be provided, with all requests for hard copies of images (paper or slides) handled outside NOAO. We are currently working on a prototype database, selecting images, writing captions, developing software for web access, and defining policy for commercial and non-commercial use. With current staffing and priorities, the NOAO Image Collection will be fully accessible on-line at the close of FY 1999.
VII. COMPUTER SERVICES

A. NOAO – Tucson

The computer facilities in the Tucson office complex serve several general needs for NOAO-Tucson: data reduction and analysis for the scientific staff and visitors, general computing for all staff members, infrastructure for dedicated computers and for PCs and workstations on staff members' desks, administrative computing, and IRAF development and support. Our distributed computing strategy for Tucson implements a combination of central, shared facilities (provided and maintained by Central Computer Services—CCS) and a variety of desktop facilities including workstations, PCs, and X-terminals (provided and maintained by the individual observatories or departments). Computing systems are networked and linked to the computers on Kitt Peak and to the worldwide Internet.

The central facilities maintained by CCS must provide an environment for data reduction and analysis of data taken at Kitt Peak by visitors and staff members. As the scientific workstation revolution of the past decade has proceeded and powerful computers have appeared on almost every scientist's desk, it is no surprise that fewer visitors and staff members utilize the CCS facilities. Nevertheless, a significant number still use these facilities to reduce and analyze their data in Tucson, especially for the largest and most challenging datasets. Moreover, with the arrival of new instruments such as the 8K x 8K mosaic and the 1K x 1K IR arrays on Kitt Peak, again outstripping individual workstation capabilities, CCS needs to keep up by upgrading the central facilities devoted to data reduction and analysis. Thus, during FY 1999, we will add disk space and high capacity tape drives to the "visitor" machines Ursa and Gemini. These upgrades should cost $20K.

An academic and scientific institution such as NOAO-Tucson must provide a set of computing services to its staff such as e-mail, document processing, scientific plotting packages, etc. These needs are met by providing sufficient servers and the necessary infrastructure to connect these servers to several hundred terminals, X-terminals, PCs, and workstations on staff members' desktops. Upgrading the infrastructure is ongoing as more computers are attached to the network, as these computers are upgraded to faster systems, as more and more scientists and engineers need access to the computer facilities from their home computers, and as servers need to be updated and upgraded to handle the load of more and faster systems utilizing their services. During FY 1999, we plan to upgrade the network connections to most of our servers and to upgrade the tape drives on these machines at a cost of $20K. We will continue to upgrade the network infrastructure in the building with the goal of providing a 100 Mbps Fast Ethernet connection to every scientist's desk by the end of FY 1999. The FY 1999 portion of the cost will be $10K.

NOAO is firmly committed to distribute information and interact with our users through the World Wide Web over the Internet. Internal uses of the Web to increase efficiency and share information also abound. During FY 1999, a project to accept telescope proposals from scientists through the Web will continue as we gear up for observing with Gemini.

A staff of 5 FTE (3.5 from CCS, 1 from ETS, and 0.5 from KPNO Mountain Electronics) maintains approximately 150 Suns and other workstations, approximately 35 X-Terminals, and approximately 100 PC and Macintosh systems in downtown Tucson and on Kitt Peak.

B. KPNO – Kitt Peak

Computers on Kitt Peak serve three broad (but overlapping) functions: real-time control of the telescopes and instrumentation, data taking (including data reduction and initial analysis), and support for observing
and operations of the Observatory. Continuing replacement and upgrading of these computers is required for three reasons: obsolescence, which implies high maintenance costs and lack of functionality (for example, the telescope control system at the 0.9-m telescope is over 15 years old); new technology and improved techniques (for example, the 8K x 8K mosaic imager now in use results in nightly datasets of the order of 30 GB); and changes in standards and approaches (for example, planning for SOAR, SOLIS, and the new 2.4-m telescope should lead to adoption of common user level software owing much to that developed by Gemini). Furthermore, we strive to provide scientific computing facilities in our domes for visiting astronomers that are comparable in speed and sophistication to those at their home institutions.

The various locations on Kitt Peak (including tenant facilities) are networked together by two fiber-optic rings which are equipped with electronics to emulate 10 Mbps Ethernets. Tenant facilities on the West Ridge are connected to the mountain network via copper connections. The mountain network is connected to the network in the NOAO-Tucson building (and hence to the Internet) via a T-1 line running at 1.5 Mbps. We plan to double the bandwidth of the Tucson-Kitt Peak connection during FY1999.

At the 4-m telescope, new instrumentation (new controllers for both IR arrays and CCDs) and new standards (the Gemini OCS, in particular) are slowly converging to mandate a future major revamping of the computer systems. In the short term, during FY 1999, incremental improvements are planned. These include: combining the IR data taking functions into the same Sun computer used for CCD data taking; replacing the IR data taking Sun with a much faster Sun dedicated to data reduction; providing a facility to write data on CD-ROM; continuing the project to eliminate CAMAC from the dome; replacing the leaky guider with a VME board embedded in the TCS computer system; tying the new active control functions of the primary mirror into TCS; and improving the GUI display programs used to control the TCS.

At the other telescopes, projects will continue to address the Y2000 problem and to replace the leaky guider at the 2.1-m. New projects include software to support the mini-mosaic on the WIYN.

The administrative facilities on Kitt Peak (supporting both KPNO and NSO) include computer systems for staff and visitors not scheduled at a telescope dome, the mountain-wide data archiving system ("Save the Bits"), and communications facilities that link the mountain network with NOAO-Tucson. During FY 1999, we plan to upgrade the Sun used for data archiving.

C. CTIO – La Serena

The computer facilities in the La Serena offices serve the needs of diverse groups: visiting astronomers, the resident scientific staff, the engineers of the CTIO ETS, and the secretarial and administrative staff.

A group of four "public" computers located in the La Serena computer room are used by visiting astronomers for data reduction. They also act as central servers providing software, a substantial body of disk storage, and peripherals such as tape drives and printers. During FY 1999, a new, more powerful public workstation will be purchased, at an approximate cost of $10K, in order to handle the large volumes of data generated by the BTC and NOAO Mosaic imagers. In addition, the two main server machines, which are no longer equal to their task, will receive a CPU upgrade at a cost of $5K.

A total of 16 workstations located on the desk tops of individual members of the scientific staff are used for data reduction and general computing. At the end of FY 1998 and continuing into FY 1999, two new workstations will be purchased to provide for the net increase in the size of the CTIO scientific staff, and a number of older low-end workstations will be replaced or upgraded for a total cost of $24K.
There are five laboratory machines in La Serena: two used for Arcon development, one for support and maintenance of optical CCDs, one for support and maintenance of the IR detectors and instruments, and one for general electronics use. These machines will be upgraded by installation of a new CPU module in order to maintain compatibility with the mountain data acquisition machines (see below) at a total cost of $6K.

The machines used by the engineering and administrative staff have all been substantially upgraded during the period FY 1997-8 and hence will not need to be upgraded during the current plan period.

During FY 1998, the La Serena network was completely restructured by installing a central Ethernet switch and new Ethernet cables permitting the interconnection of all machines at up to 100 Mbps. About a quarter of the machines are now connected at 100 Mbps; the remaining machines will be switched to 100 Mbps during FY 1999 as need dictates and funding permits.

D. CTIO - Cerro Tololo

Data acquisition at CTIO's telescopes is supported by a network of Sun computers located in the various domes. The primary data acquisition machine at each telescope (a SPARCstation 10-41) is directly connected to the optical CCD (ARCON) and IR (Wildfire) controllers and is used for the collection, reduction, and initial analysis of the data delivered by these devices. These machines typically have 10-11 GB of disk storage and are equipped with both Exabyte and DAT tape drives. Both Arcon and Wildfire use S-Bus based host interfaces. Sun is now moving away from the S-Bus, and their next generation of machines will be PCI-bus based. Rather than port our existing detector controllers to this new bus architecture, we plan to maintain the S-Bus host computers for the remainder of the useful lifetime of the detector systems (about five more years). To make this possible, we will upgrade the CPUs and key peripherals of these host machines at the end of FY 1998 and into FY 1999 for a total cost of $15K. At the same time, we will gradually shift the data analysis and reduction load to ancillary machines in each dome (which can be freely replaced by more modern computers). The ancillary machine at the 4-m telescope is already a powerful UltraSPARC workstation installed in FY 1998 in order to cope with the large volumes of data delivered by the CCD mosaic imagers (BTC, in service now, and the NOAO mosaic scheduled for deployment in mid-1998). New ancillary machines will be purchased during FY 1999 for the 1.5-m and 0.9-m telescopes at a total cost of $18K. The old VME bus machines currently fulfilling this role will then be retired.

In addition to the machines distributed in the domes, two low-end SPARCstations and a number of PCs are located around the mountaintop and in the Tololo library in order to provide network access and limited data reduction capabilities for visitors without telescopes.

Two mid-level workstations and a number of PCs are used by the Cerro Tololo Support staff for data reduction and general computing. An additional SPARCstation 10-41 fully equipped for data acquisition with ARCON is located in the Cerro Tololo electronics laboratory. This machine is used for test and maintenance work on the optical CCD systems and is also available as a hot spare for the data acquisition computers. The cost of an upgrade for this machine is included in the costs estimates above.

Cerro Tololo is host to an increasing number of tenants. The MACHO collaboration, the Swarthmore robotic telescope, GONG, 2MASS, the US Naval Observatory, and the YALEO consortium all have machines connected to the mountaintop network.

The mountaintop machines are connected to one another via a conventional Ethernet, to the USA by a satellite link, and to La Serena by a microwave link (see the communications discussion below). During
FY 1998 and continuing into FY 1999, this network is being restructured to provide 100 Mbps subnets (those for the 4-m and 1.5-m telescopes are already complete) which will then be connected at 100 Mbps to a central Ethernet Switch. The portion of this work that remains to be done during FY 1999 has an estimated cost of $20K.

There are two rather different telescope control systems in use on Cerro Tololo. The 4-m and 1.5-m telescopes are controlled by VME bus-based processors running software based on the VxWorks operating system. The 0.9-m telescope is operated by an aging and obsolete commercial TCS, which is a serious maintenance headache. The replacement of this system with a modern commercial system similar to that recently installed at the 1.0-m YALO telescope would cost about $50K. However, at present funding levels, it is not clear whether CTIO will be able to purchase such a system for the 0.9-m during FY 1999.

E. CTIO Communications

The networks in La Serena and on Cerro Tololo are joined via a commercial 8 Mbps microwave link, divided into four 2 Mbps E1 channels. Backup and maintenance are provided by the contractor. At present one of the E1 Channels is used for network connections while another provides 30 telephone telines. During FY 1999, we plan to install ATM routers in La Serena and on Cerro Tololo so that ATM can be used on the link between the two sites. The computer networks in both locations will be connected to the ATM switches as will the E1 lines in the existing telephone plants. This will immediately increase the burst bandwidth of data transfer between La Serena and Cerro Tololo from the current 2 Mbps to 8 Mbps at no additional recurring cost. The total cost of this upgrade will be approximately $70K.

Network connectivity to the outside world is currently provided by an obsolescent 56Kbps satellite link to the US, supplied by NASA. The low speed and low reliability of this link are seriously hampering CTIO operations. A more reliable and much higher speed connection is a prerequisite for remote/queue scheduled observing and will be essential before the turn of the century. The agreement to provide the current line expires in June 1998. CTIO is negotiating with NASA for an interim extension and upgrade of this line, which is proposed to increase its speed to at least 256 Kbps for up to three years. If approved, the new line should markedly improve communications quality and speed. This upgrade will suffice for the present, but we must ultimately make a transition to terrestrial fiber links, which in the long run are intrinsically less expensive, have higher bandwidth, are more reliable, and have significantly less latency time than satellite links.

Fortunately, communications to the USA via terrestrial fibers are beginning to become available in Chile. Fiber connections already exist between Santiago and La Serena and to the USA via Argentina and Brazil. Direct fiber connections from Chile to the US west coast are being installed. The first such lines are scheduled to become operational before the end of FY 1998. As a result, we expect that links of speeds as high as OC-1 (55 Mbps burst bandwidth) between CTIO and the US will become commercially available at affordable cost within three years. The ATM switch which will be installed in La Serena will be available to connect directly to such a terrestrial fiber optic link to provide a high bandwidth connection to the US Internet. However, it must be recognized that rental and traffic costs for the commercial connections will need to be paid from CTIO’s budget when NASA terminates its funding of the satellite link. This could happen as soon as June 1998.

At the end of FY 1996 a 64Kbps terrestrial link between La Serena and Cerro Calan Observatory in Santiago (and thence to the Chilean Internet) was implemented in partnership with Universidad de Chile. This allows for more efficient communication between CTIO and the Chilean astronomical community and the other observatories in Chile. It also serves as a backup Internet connection.
F. NSO – Sacramento Peak

The computer facilities at NSO/SP are in four areas: Main Lab (ML), Evans Solar Facility (ESF), Hill Top (HT), and the Vacuum Tower Telescope (VTT). The ESF, HT, and VTT computer systems are mainly used for telescope control and data collection with limited data analysis. The ML facility is used for data reduction, analysis, and general computing for local staff and visitors.

**Main Lab Plan for FY 1999**

- **Upgrade the NSO/SP network backbone to 100Base (100 Mbps) Ethernet with the capability to link telescope sites with an ATM or Gigabit Ethernet backbone in the future.**
  
The first phase would allow all servers and each telescope building to be connected at 100Base Ethernet. Most workstations would continue to use 10Base (10 Mbps) Ethernet but would allow workstations to move to 100Base Ethernet if necessary. This upgrade would also allow our old Galactica switch to be used in our network but would give us a quick replacement path if it should die. This project, which will cost an estimated $25K, will require the following equipment:

  (1) Two 8 port 10/100Base Ethernet switches with one high speed stacking port, to be installed at the ML. This will allow growth to 100Base for newer workstations

  (2) Two 16 port 10Base stackable switches, with one high speed stacking port, to replace the aging Galactica 10 base 24 port switch, to be installed in the ML.

  (3) Three 12 port 10Base switch, with one 100Base port to installed at each of the telescope sites.

- **Upgrade aging workstations, NFS server, and computer servers.**
  
  NSO/SP has many workstations that are over six years old, are very slow, and are becoming unproductive. These old units need to be replaced as soon as possible.

  (1) Upgrade 1 NFS server to an Ultra 1 x 200MHz CPU plus one 24GB multi pack disk unit: $17K

  (2) Upgrade 2 SS10 computer servers to one Ultra2 2 x 200MHz host: $25K

  (3) Continue to upgrade old Sun workstations.

- **Purchase software to centralize system administration of hardware and software on the NSO/SP LAN.**
  
  With the increase of local staff for new projects comes the increased need of new hardware and software on the network. To continue to administer more hardware and software on our network with the same number of people, software is needed to allow the one system administrator to manage the network from a centralized remote location. Cost: $5K

**Telescope Computers Plan for FY 1999**

The NSO/SP Telescope Computers plan for FY 1999 is as follows:

- Purchase and/or upgrade CCD camera controllers to Ultra CPU.

- Purchase HP Laser printer for the VTT to replace an aging SPARC printer: $2.5K
G. NSO – Tucson

The initial development phase of the NSO Digital Library is now complete. This project has been motivated by the continual heavy demand for data from the NSO/Tucson anonymous FTP archive. The currently available data products consist of the daily KPVT images, synoptic maps, FTS solar spectral atlases, FTS real spectra, and NSO/SP spectroheliograms. In the past year, FTP accesses by non-NOAO users exceeded 46,000 scientific file acquisitions, while WWW interrogations for the NSO/Tucson web pages exceeded 55,000 hits. The NSO Digital Library is placing data in three CD-ROM jukeboxes with a total capacity of 300 discs. Currently, 129 CDs (90 GB) of data are on-line for FTP access, including the entire KPVT data set. The user interface and search tool are now available on the web at http://www.nso.noao.edu/diglib. A second CCD digitizer is being installed at NSO/Tucson to migrate historical solar images from Mt. Wilson and the USNO from film to disk. Funding from the NSF Space Weather Program continues to support the NSO Digital Library development. In the next year we expect to enhance the user interface functionality, and increase the amount of data in the Library to include the FTS raw interferograms and the McMath-Pierce solar/stellar data.

Administrative and support staff computers used at NSO/Tucson continue to be Macintosh-based. The Macintosh platform is fully integrated into NSO operations, being used for both administrative tasks and observing support at the mountain. NIM is a fully Mac-based instrument, as is NIM2, the new Fabry-Perot based imaging magnetograph. In addition, LabView is being used for quick instrument development and in support of the seeing project at the McMath-Pierce. We continue to support the standard Microsoft software suite adopted by NOAO including the FileMaker database. We have installed MAE (Apple’s Macintosh Application Environment) on some staff Sun workstations, allowing them to run the same applications used by the administrative and support staff. We have purchased a couple of Mac-based laptops to be checked out by NOAO staff during travel, and have upgraded two of our current Mac systems to RISC PowerPC architecture to be used by the programming staff for development.

NSO is keeping pace with new developments in Sun workstations. Recent upgrades have typically been to increase the internal memory and disk space on individual machines. The transition from SunOS 4 to Solaris is now complete.

H. NSO – Kitt Peak

The Telescope Control Program (TCP) upgrade at the KPVT has been superseded by the successful proposal for SOLIS, the new suite of instruments that will replace the KPVT in 2001. The advent of SOLIS will usher in a new era of computing at the Solar complex, with remote web-based VME control of the telescope and instrumentation, high-speed data transfer to the downtown facility, and substantial data processing power at the SOLIS instruments.

The McMath-Pierce main spectrograph grating control system has now been upgraded to a VME-based system with a user-friendly handpaddle that accurately displays the grating position.

The McMath-Pierce facility remains in need of a TCP upgrade. The current TCP is still based on the PDP-11/FORTH/CAMAC model that has long been supplanted by more modern systems at most other NOAO facilities. The first phase of this upgrade is now underway with a project to install an accurate guiding system using VME architecture similar to that planned for SOLIS.
I. IRAF

IRAF, the Image Reduction and Analysis Facility developed and distributed by NOAO, is used to process and analyze data from NOAO and other astronomical observatories. IRAF is estimated to be used by over 5000 astronomers at over 1500 sites throughout the world. IRAF is heavily used within both the groundbased and NASA space astrophysics communities and is freely available via the Internet from sites in the US, England, Germany, Japan, and India.

IRAF is a portable software system for astronomical data acquisition, reduction, and analysis. It provides tools for general image processing, graphics, and visualization of small or large datasets, as well as instrument specific data reduction software for a wide range of astronomical instruments, including all NOAO instrumentation. Additionally, optional IRAF packages developed by sources outside NOAO are available to provide data reduction support for non-NOAO instruments, such as those on the Hubble Space Telescope.

NOAO receives support from NASA in the form of grants and subcontracts to help fund collaborations with NASA sites, making IRAF suitable for the needs of the wider astronomical community. This funding pays mainly for general system software improvements that benefit both the NOAO and NASA communities.

IRAF is one of NOAO's most scientifically productive and visible "facilities." with over 25% of all groundbased observational papers in the major astronomical journals relying on IRAF to some degree. It also serves as the basis for CCD data acquisition and quick-look assessment at NOAO telescopes, and serves as the image analysis package for most NOAO staff science.

Major Developments in IRAF Projects During FY 1998

1. Open IRAF:
   The main goal of this project is to support NASA projects (HST, AXAF) that are developing or releasing software based on the Open IRAF prototypes.

2. CCD Mosaic Support:
   System work has concentrated on the data capture agent for data acquisition and on the development of the underlying technology (message bus, distributed shared objects) on which the subsequent data handling system and real-time display and analysis tools will be based. Elements of the data pipeline to process, shift and align CCD mosaic data were completed. An interim display task, based on Ximtool, was added for real-time display of incoming data from the NOAO mosaic.

3. Gemini Support:
   A set of generalized image header definitions has been developed to unify NOAO and Gemini data. A new image file structure that will serve Gemini and is consistent with the FITS standard is now in use with the CCD Mosaic.

4. Updated Platform Support: All X11 IRAF products have been released for all supported IRAF platforms.

Major Efforts in IRAF During FY 1999

1. Data Handling System for the CCD Mosaic:
   (4) Data reduction agent
   (5) Automated pipeline data reductions
   (6) Real-time display for analysis of data during readout

2. Open IRAF to enhance integration of IRAF and non-IRAF software via:
   (7) Multi-language programming support (e.g., C, FORTRAN)
   (8) Host callable IRAF libraries
   (9) Distributed applications and network access to IRAF tasks
   (10) Direct access to standard data formats (FTS, PC image formats)

3. Plug-In Extensible Image Server:
   (11) Powerful stand-alone image browser
   (12) Plug-in capability for dynamically extending browser
   (13) Message bus and distributed object support
   (14) Implement prototype plug-in extensible image server

4. New Science Applications/Upgrades
   (15) Astrometry package, world coordinate system support
   (16) Data reduction support for CCD mosaics
   (17) Error vector support
   (18) Pixel mask support for image processing
   (19) Infrared data reductions

5. Data Archive Support:
   (20) Data archiving and data distribution system
   (21) Network access to archival data

6. Support for Gemini and NOAO Observers:
   (22) NOAO/Gemini unified image headers

7. Updated Platform Support: (e.g., PCs running Linux, FreeBSD, and Solaris; Macintosh systems running MkLinux; upgrade all supported IRAF platforms to Version 2.11.1).

In addition, support and other interaction with users around the world will continue to occupy about 25% of the IRAF group's effort.
VIII. FACILITIES MAINTENANCE

A. Cerro Tololo

1. Fire Prevention and Fire Fighting

In addition to the project to furnish the Blanco Telescope with a modern, efficient fire prevention system, we have planned to equip the smaller telescopes, as well as the rest of the facilities on Cerro Tololo, with a similar system for fire prevention and control. We expect this project will be installed and deployed over a period of time no greater than two years.

To accomplish this objective we will need financial resources in addition to those projected for the purchase and installation of a Chemetron 2000 fire fighting system for the Blanco Telescope.

2. Renovation of the Vehicle Fleet

CTIO has continued with its ongoing effort for the programmed periodic renovation of its vehicle fleet. This program aims to reduce the excessive down-time resulting from the natural mechanical wear of old vehicles, and also, to reduce maintenance and operation costs.

A minimum of $50K is required to continue with our renovation program, which aims to provide a modern, safe, and cost-effective fleet of vehicles.

3. Improvement of the Main Access Road

The severe storms of July, August, and September 1997, originating in the unusual conditions caused by the El Nino warm current, seriously damaged the 23-mile unpaved road to the Observatory. Water pouring from nearby gulches and ravines deeply slashed large sections of the road, producing extensive cuts which had to be repaired using special steel culverts and drains to prevent future similar incidents. The surface of the road was literally washed away almost throughout its entire length; in several sections the width of the road was also reduced to about half its size, allowing for vehicle traffic on just one lane.

A portion of the funds provided for the safety improvement had to be used for the immediate emergency repair needed to restore the road back to safe driving condition. We have continued, however, with the ongoing program for the installation of guard-rails in those sections where it is most urgently required.

4. Repainting the 4-m Blanco Telescope

The repainting work (using lomit paint) originally programmed for 1998 on the Blanco Telescope has been superseded by a plan to apply a self-adhesive, brilliant aluminum film, which would keep the dome from getting excessively cold at night. This work is programmed to take place next summer season (January 1999).

5. Cerro Tololo Power House

We will expend $25K for the replacement of outdated and obsolete switching gear for the Power House on Cerro Tololo. This equipment has been in use for more than 25 years and is beginning to show significant signs of wear.
6. Water System - Cerro Tololo Pipeline

CTIO has continued with the improvement and upgrade plan of the water supply utilities for its installations on Cerro Tololo.

7. Control of Light Pollution

During the last three years, CTIO has been working with the Chilean environmental protection agency CONAMA to produce a light pollution control norm, which would provide the basis for municipal lighting ordinances in the neighboring communities. Progress on the norm has been slow but steady. We expect the norm to be finally enacted during FY 99. In order to provide information to the communities concerning astronomy-friendly lighting, and to aid in the enforcement of the new norm, we are taking steps to set up a light pollution information office in collaboration with the other international observatories in Chile and several of the Chilean universities. This work will require continuing funding at a level of approximately $20K per year.

The following table reflects the program for the five-year plan, what was requested in FY 1998, milestones met during FY 1998, and our plan for FY 1999.

<table>
<thead>
<tr>
<th>Project</th>
<th>LRP (Syr)</th>
<th>FY 1998 Projected</th>
<th>FY 1999 Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fire Prevention and Fire Fighting</td>
<td>$40</td>
<td>$12</td>
<td>$20</td>
</tr>
<tr>
<td>2. Renovation of Vehicle Fleet</td>
<td>50</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>3. Improvement of Main Access Road</td>
<td>300</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>4. Repainting of 4-m Blanco Telescope</td>
<td>20</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>5. Cerro Tololo Power House</td>
<td>25</td>
<td>25</td>
<td>—</td>
</tr>
<tr>
<td>6. Water System - Cerro Tololo Pipeline</td>
<td>25</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>7. Control of Light Pollution</td>
<td>22</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>8. Enclosure for TELOPS bldg. Cable Car</td>
<td>19</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9. Bulldozer for Cerro Tololo</td>
<td>200</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>$701</td>
<td>$100</td>
<td>$210</td>
</tr>
</tbody>
</table>

B. KPNO

The Kitt Peak facilities maintenance plan for FY 1999 will concentrate on a balanced approach of reducing the backlog of deferred maintenance on roadways, safety concerns, general building and grounds repairs, etc., while continuing to modernize the Observatory’s infrastructure. Both of these efforts are critical to present and future needs of the Observatory.

Energy management is a key component of our modernization effort and will be a multi-year project. The first step was the purchase of a major cost item, the Johnson Controls hardware. The savings will not be as large as what was realized in our Tucson Central Facilities Unit; however, side benefits, such as the integration of the controller with the hardware associated with our 4-m delivered image quality (DIQ) program, will be possible.
KPNO Facilities Maintenance Program
Summary of Projects for FY 1999
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Project</th>
<th>Est. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Replacement of water, sewer, power, and telephone lines</td>
<td>$30</td>
</tr>
<tr>
<td>2. Energy Management</td>
<td>20</td>
</tr>
<tr>
<td>3. Propane System</td>
<td>15</td>
</tr>
<tr>
<td>4. General Building Repairs</td>
<td>25</td>
</tr>
<tr>
<td>5. Building Ground Systems</td>
<td>20</td>
</tr>
<tr>
<td>6. Water System</td>
<td>20</td>
</tr>
<tr>
<td>7. Road Repairs</td>
<td>20</td>
</tr>
<tr>
<td>8. 4-m aluminizing tank enclosure</td>
<td>30</td>
</tr>
<tr>
<td>9. Vehicle replacement</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>$200</td>
</tr>
</tbody>
</table>

1. Replacement of Water, Sewer, Power, and Telephone Lines

Most of the underground utilities were installed in the early 1960's and are well past their expected lifetimes. Spot checks were made in 1998 to determine the extent of effort required to repair and replace these critical components. Our findings show that at a minimum this will be a three-to-four year project. The water pipes and telephone lines are considered to be in the worst condition. The main sewer lines were replaced in FY 1995. Fiber-optic inspection of the feeder lines shows significant tree root damage, but all lines remain functional. While we have not experienced any major power line failures, inspection indicates that in several cases, preventive replacement is in order.

2. Energy Management

The studies we carried out with Tucson Electric Power and Johnson Controls in FY 1998 clearly showed that it was cost effective to proceed with the plan to install energy management hardware. Accordingly, we made the purchase of the central controller in FY 1998. For at least the next four years, we will be replacing old, inefficient equipment such as light fixtures, pumps, refrigeration units, etc. Our intent is to start at the 4-m telescope, which has been identified as a major user of power. In addition to reducing the power use at the telescope, we have determined that the controller will easily integrate with our DIQ program hardware.

3. Propane System

Our propane system was found to be in worse condition than originally expected. Consequently, in FY 1998, we concentrated on repairs to the storage tanks and lines to the buildings. They are now in good repair. We must begin replacement, within the facility buildings, of old furnaces, ranges, and water heaters. Most of this equipment is original installation and does not have the automatic shutoff pilot feature found in modern day appliances.

4. General Building Repairs

Including the telescope enclosures, KPNO has in excess of 130,000 s.f. of buildings. We have in place a plan to repair, paint, and roof all facilities, including all of the telescope enclosures and domes on a five-to-seven year rotational basis.
5. Building Ground Systems

During FY 1998, we began to evaluate what would be necessary to carry out a project to improve the grounding grid for all our telescopes and support buildings. The need to do so is clear when we consider the cost of repairing lightning damage to our electronic equipment each year. Test equipment has been purchased, and we will begin to develop and implement changes to the grid over FY 1999 and possibly FY 2000 as required.

6. Water Systems

Water harvesting, distribution, and conservation are of prime importance on Kitt Peak since we are totally reliant on rainfall. In wet years such as FY 1998, water use is not a problem. However, there have been years when we fell below the recommended minimum storage level. To compensate for an increase in the number of tenant observatories and visitors in general, we have replaced some existing high water use fixtures with no, or low, water use fixtures. We will continue to do so in this fiscal year, as well as encouraging our tenants to modify their own facilities. In addition, we will study and possibly begin development of a new location on the summit of Kitt Peak as a third water collection site.

7. Road Repairs

The roadways at the summit of Kitt Peak, as opposed to the State of Arizona access road from the highway to the summit, are the responsibility of the Observatory. These roads are subject to severe weather damage and must periodically be resealed. In FY 1998, we were able to partially chip-seal the worst of them. In FY 1999, we must complete the job.

8. 4-m Aluminizing Tank Enclosure

The 4-m aluminizing facility is the only large coating chamber that is made routinely available to astronomy-related organizations. More than half the mirrors coated each year belong to organizations other than NOAO. The tank is built into the ground floor of the 4-m building within a large open space. It is very difficult to keep this area clean enough to prepare mirrors for new coatings. We contracted with M-3 Engineering in FY 1997 for a design study. We are now prepared to proceed with our own design review and get underway. This will be a two-year project and will need to be contracted out since it exceeds our available manpower resources. The first year will involve the relocation of wiring for the high-power equipment as well as extension of the railroad tracks. The second year will be devoted to construction of the enclosure.

9. Vehicle Replacement

In FY 1998, we evaluated the acquisition of an electric truck (through lease arrangement). Based on this evaluation, we intend to purchase at least one electric truck along with a new 4-wheel drive vehicle as we begin to upgrade our mountain-based motor pool. We intend to add a few new vehicles each year until all the old, high maintenance vehicles are replaced.

C. Tucson: Central Facilities Operations

The reorganization of Central Facilities Operations (CFO) and Kitt Peak Facilities Operations under a single management structure has proven to be highly successful. This unified oversight strengthened both departments and provided needed backup in critical skill areas. CFO principally maintains and services the needs of the Tucson headquarters building and staff, but also provides limited minor construction,
architectural, and civil engineering support to NSO/Sac Peak, GONG, Gemini, and SOAR projects as required.

Table VIII – 3
Tucson Central Facilities Program
Summary of Projects FY 1999
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Projects</th>
<th>Est. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correction of headquarters building (HVAC)</td>
<td>$10</td>
</tr>
<tr>
<td>2. Energy Management Control Systems</td>
<td>5</td>
</tr>
<tr>
<td>3. Fire/security alarm system</td>
<td>45</td>
</tr>
<tr>
<td>4. Shuttle Vehicle Replacement</td>
<td>45</td>
</tr>
<tr>
<td>5. Asphalt paving of maintenance yard</td>
<td>15</td>
</tr>
<tr>
<td>6. General building repairs</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>$140</td>
</tr>
</tbody>
</table>

1. **Correction of Headquarters Building (HVAC)**

One additional benefit of our energy management system is its ability to troubleshoot and pinpoint heating and air conditioning deficiencies. As expected, the headquarters building, due to its piecemeal construction, has its share of problems. We will continue with this multi-year project to sort out the deficiencies as we fine-tune the HVAC system.

2. **Energy Management Control Systems**

The Tucson facilities energy management program will continue in FY 1999, as a multi-year project. However, the rate of expenditure will be at a much lower pace, relative to prior years, since most of the short payback improvements have been completed. The emphasis on the program is shifting from Tucson to Kitt Peak. The estimated electric utility cost savings, due to this program, remain on track. We should be able to meet our most recent estimate of $195K for calendar year 1998.

3. **Fire/Security Alarm System**

To date, we have installed fire/intruder alarms in the Central Administrative Services area and GONG DMAC buildings. In FY 1999, we plan to extend this alarm coverage to include the warehouse building, optical coating lab, and carpenter shop. Within the main headquarters building, our system has become outdated, and we plan to replace it with a new, current technology system.

4. **Shuttle Vehicle Replacement**

To maintain safe highway vehicles, each year we purchase, on average, three shuttle vehicles for the transportation of staff and visitors to/from Kitt Peak. In FY 1999, we will need to purchase at least four shuttle vehicles. Since we have been unsuccessful in obtaining a waiver, three of the four vehicles will need to be of the alternate fuel type. Unfortunately, this raises the cost of each vehicle by several thousand dollars. For the present, we have deferred installation of any alternate-fuel underground storage tanks in hope that a waiver will be granted in the future.
5. Asphalt Paving of Maintenance Yard

The asphalt surface of our main parking lot deteriorated to a point that we had no choice but to remove and replace it in FY 1998. The lot had been seal coated on a routine basis, but the surface was so old it no longer responded to the sealing process. In FY 1999, we will remove and replace the asphalt surface of our maintenance yard since it is in a similar condition.

6. General Building Repairs

The NOAO headquarters facility is comprised of eight buildings for a total of approximately 136,000 s.f. Each year, we repair, paint, re-roof and modify the buildings to meet continually changing needs. The largest single expense we encounter in this category is the stucco repair and painting of the headquarters building.

D. NSO Facilities Maintenance

The current budgets for the National Solar Observatory are insufficient to provide for an optimum maintenance program of the facilities at Sac Peak and Kitt Peak. There are, however, sufficient funds to carry out essential maintenance. Year-end funds, to the extent that they become available from vacant positions or indirect charges on grants, are used to supplement this minimum maintenance program.

1. Sac Peak

The FY 1999 NSO/SP budget includes approximately $15K for items above the normal reactive maintenance program and approximately $20K from housing revenues above the normal maintenance for housing. The general funds will be used to replace roofs on the Hilltop Telescope and the Facility Maintenance shops. The housing revenue funds will be used to replace the electrical lines in the housing areas. In addition, the Long Range Plan lists as other maintenance tasks the re-roofing of the Cloudcroft facility/RCA building and a new staff vehicle which will be funded through year-end funds if they are available.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Est Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Replacement</td>
<td>$ 15</td>
</tr>
<tr>
<td>Power Line Replacement</td>
<td>20</td>
</tr>
<tr>
<td>Upgrade Underground Petroleum Storage Tanks</td>
<td>*33</td>
</tr>
<tr>
<td>Cloudcroft Facility/RCA Building Reroofing</td>
<td>*75</td>
</tr>
<tr>
<td>Staff Vehicles</td>
<td>*20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 163</strong></td>
</tr>
</tbody>
</table>

* = from FY 1999 year-end funds if available

- **Roof Replacement:**
  The roof replacement on the Hilltop Telescope building and the maintenance shops are part of an ongoing maintenance program of the Sac Peak facilities.
• **Power Line Replacement:**
  The power lines in the housing area were installed in the 1950's and are beginning to show signs of serious degradation.

• **Underground Storage Tanks:**
  NSO/SP has two remaining steel, unlined, underground storage tanks for storing gasoline and diesel in service. Federal and State regulations require that these tanks be upgraded before 31 December 1998. Upgrades include spill/overfill protection, automatic leak detection, and cathodic protection. An option to upgrading is replacing them with smaller above ground tanks. It appears that the cost is about the same and both options are being researched.

• **Cloudcroft Facility:**
  NASA recently spent over $175K in renovation of the main telescope building at the Cloudcroft Telescope Facility. Other buildings, in particular the RCA building, require roof repair to prevent water damage.

• **Staff Vehicles:**
  The vehicles used for travel by staff members are over ten years old and have over 100K miles on them. They are used to travel long distances at all hours. The need for maintenance and its associated costs have gone up dramatically.

2. **Kitt Peak**

In contrast to NSO/SP, where NSO is fully responsible for site and building maintenance, KPNO continues to be responsible for the labor and non-payroll associated with the routine maintenance of the solar telescopes of NSO/KP and the Kitt Peak site and facilities. NSO/KP is responsible, at the level of $30K/year, for non-payroll costs associated with major solar facility maintenance, such as the recent repair of the Kitt Peak Vacuum Telescope clamshell pistons.

Maintenance items that should be addressed at the McMath-Pierce facility in FY 1999 include: (1) re-roofing and sealing; (2) energy management; and (3) fall protection. In addition, the Long Range Plan lists as other maintenance tasks the electrical upgrade and painting of the McMath-Pierce facility.

<table>
<thead>
<tr>
<th>Project</th>
<th>Est. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-roofing and Sealing McMath-Pierce</td>
<td>$ 5</td>
</tr>
<tr>
<td>Energy Management McMath-Pierce</td>
<td>5</td>
</tr>
<tr>
<td>Fall Protection McMath-Pierce</td>
<td>10</td>
</tr>
<tr>
<td>Electrical Upgrade McMath-Pierce</td>
<td>30</td>
</tr>
<tr>
<td>Painting McMath-Pierce</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$65</strong></td>
</tr>
</tbody>
</table>

• **McMath-Pierce Facility:**
  Several water leaks in the McMath-Pierce facility, especially those in the main observing room and in the FTS stairwell, require attention.
Improvement of energy management within the McMath-Pierce complex will result in significant cost savings. We plan to upgrade the cooling system to a “closed-loop” operation with the addition of a smart controller and sensors, as well as change the general building lighting.

Access to the east and west auxiliary heliostat drives is difficult and can, under certain circumstances, present a safety hazard. A redesign will allow us to remove the current restriction on access. Sections of the wiring and electrical components within the main observing room and telescope structure will be replaced to ensure that the facility remains operational.

The exterior of the McMath-Pierce was painted in 1991. Maintenance of the interior surfaces is, however, long overdue. The section of the windscreen just below the top of the pier requires extensive work.
IX. CENTRAL SERVICES

NOAO has consolidated in Tucson the types of administrative support that companies normally provide through a “home office.” Included are all financial management, the NOAO Director’s office, and the space occupied by the above. The cost of this administrative support, as shown in the proposal to renew the cooperative agreement, is low relative to the costs of comparable activities in universities, industry, and federal research centers.

A. NOAO Director’s Office

Staffing includes the Director; three administrative assistants; a half-time manuscript specialist, who prepares the NOAO Newsletter and assists with proposals and other long documents; the receptionist in the lobby; and the head of the copy center, who is responsible for all major copying tasks and in-house maintenance of copying machines. The Deputy Director, who heads the joint CTIO/KPNO instrumentation program and is also the Director of KPNO, is funded in the KPNO budget. We have examined the alternative of contracting outside for copying and also for handling outgoing mail; the contract costs were approximately twice what we spend doing the tasks in-house.

B. Central Administrative Services (CAS)

This office provides business management support to all sites, including human resources services for all US hires at all sites, payroll, procurement, contracting, accounts payable and receivable, property management, and general accounting for all actions in the US. In addition, this department handles shipping and receiving for Tucson and expedites shipments to Chile. The Gemini international project has relied on CAS for these same services while the construction team was based in Tucson. However, in FY 1999 Gemini is expected to provide all of its own administrative support.

C. Tucson Facilities

The Tucson facilities staff is responsible for maintaining 136,123 square feet of space and for operating the shuttle fleet, which provides transportation and cargo service to and from Kitt Peak. As noted in the proposal to renew the cooperative agreement, we have benchmarked the staffing and costs of this activity against NCAR and against the Best-in-Class in the Benchmark II Report from the International Facilities Manager Association (Cooperative Agreement, Appendix 3-R). In every area, NOAO compares very favorably to these benchmarks, which is especially impressive given that our facilities are more than 30 years old and that the floor area is smaller than that at NCAR. The benchmarks show that certain economies of scale reduce the cost per square foot as the total area maintained increases. Both Tucson and Kitt Peak facilities are now under common management.

In addition, the Tucson Facilities group provides support for all of the activities based in Tucson, including KPNO, NSO, SOAR, SOLIS, and the small portion of the Gemini staff remaining in Tucson during FY 1999.
X. THE BUDGET

A. Budget History

The starting point for preparing the budget for FY 1999 is: a) the budget requested for NOAO in the President's submission to Congress and b) the funding levels for the components of the program in FY 1998. We have not conducted a new zero-based budget exercise because that was done as part of the proposal that NOAO submitted about three years ago to the NSF to renew the cooperative agreement under which we operate. We believe the assessment at that time of the minimum staffing levels for various components of the program remains valid. However, it is unlikely that a program of the scope defined at that time is sustainable given the failure of the budget to keep pace with rising costs, and as noted elsewhere in this section of the program plan, we plan a new assessment over the coming year and a further descoping.

The zero-based staffing models developed for the renewal proposal were based primarily on benchmarking with respect to other observatories, and the costs per telescope at both CTIO and KPNO were shown in that proposal to be low relative to other international observatories (CFHT, AAO, UKIRT), very low relative to ESO, and comparable to that of the one university observatory (Texas) that was willing to make comparison data available. Good benchmarks do not exist for solar observatories, but NSO is operating at levels below what is required to maintain operations and facilities at their current level of quality, competitiveness, and repair over a long period of time. Given the plans to replace the solar facilities and develop an entirely new site, it is probably acceptable to continue to operate NSO in a non-steady-state mode for the next few years.

In the FY 1998 plan, which was prepared to the budget level of $28.2M requested by the President, we showed that KPNO was then operating five telescopes—the Mayall, WIYN, 2.1-m, 0.9-m, and Coude Feed—with staffing that was only 85 percent of what was estimated to be the minimum required for a three-telescope operation. The problems experienced as a result of understaffing relative to the benchmarks at all three locations were outlined last year: very slow progress on telescope and instrument improvements; lack of documentation; inadequacy of preventive maintenance; bottlenecks in development, especially in the software areas; and inability to hire and begin training of key technical staff to replace senior staff who are planning retirement.

The overall problems were compounded when we learned halfway through the fiscal year that the core NOAO budget for FY 1998 would be $27.7M, even though the NSF received more than the President's requested budget overall. We were given an additional $0.5M to cover costs associated with providing support for Gemini, including building Gemini instruments, which made it possible to balance the budget in FY 1998.

B. Budget Assumptions

In order to estimate the budget for FY 1999, we have started with the budget for FY 1998 and made the following changes:

1. A 2.5 percent pay increase was granted in February 1998—the first pay increase in 16 months. We have carried that pay increase forward into FY 1999.

2. We have assumed that Chilean salaries will increase at the rate of Chilean inflation as mandated by our union agreement, that the inflation rate will be 6 percent, and that this rate of inflation will not be compensated for by a change in the exchange rate. These assumptions are consistent with our
experience in previous years. An agreement with the union provided an additional 3 percent increase in total compensation in January 1998, and this amount has been carried forward into FY 1999.

3. We have assumed that Air Force funding in FY 1999 will be at the level of $535K. If this is not the case, then any shortfall or program re-adjustment will be made within the NSO budget. Funds will not be transferred from elsewhere in NOAO in order to compensate for any reduction in Air Force funding. Funding for the new NSO Director will also be provided from within the current NSO budget, an option made viable by the resignation of other senior NSO staff.

4. We have assumed that the $500K earmarked for support of Gemini, including Gemini instrumentation, is a one-time payment and will not be carried forward into FY 1999.

5. We have assumed that most of the Gemini staff now based in Tucson will have transferred either to Hawaii or Chile; that Gemini will assume responsibility for all its administrative services; that most of the administrative services now performed by NOAO for AURA will be transferred to the corporate office; and that the ApJ operations will be transferred away from NOAO. All of these factors lead to a reduction in indirect cost income from $957K in FY 1998 to $350K in FY 1999. Unfortunately, we do not anticipate a corresponding savings in required administrative support. We did not increase the administrative staff significantly in order to accommodate these outside programs because the effort involved in managing payroll, accounting, tax returns, and other reports to the federal government scale only slowly with the size of the program given computer automation. Correspondingly, the workload does not decrease significantly with the departure of these outside programs. We will also be making the transition this coming year to new management as Glen Blevins moves to part time, and there will transition and training costs.

6. We have assumed that the budget for SOLIS will be $1.4M.

7. We expect to commit fully the NOAO contribution to SOAR by the end of FY 1999. Some but not all of the funds shown in FY 1998 ($1.85M) will carry over into FY 1999.

8. We have made no adjustments for inflation in the non-payroll funds either in the US or in Chile.

9. The difference between the budget as modified according to assumptions 1-8 above and $29.720M has been allocated to a pay increase for non-Chilean hires. The amount of increase that is allowed is 1.2 percent—and this is feasible only if the President’s request is received in full.

For reference, the funds required to maintain the current staff at its current salary with no adjustment in FY 1999 and to index Chilean salaries as described above is $28.1M. The annual cost of a one percent salary increase for northern hemisphere staff, excluding GONG and SOLIS staff, who are funded with project funds and must comply with project funding caps, is $173,000.

C. Budget Priorities

Inasmuch as the President’s request for NOAO is almost never realized in practice, it is appropriate to outline our budget priorities for FY 1999:

• Operations funding at a level of $28.1M so that we can avoid layoffs and abrupt program changes.
• An increment to operations funding of $350,000 for a total budget of $28.45M so that we can provide a 2 percent pay increase. A higher increase is likely to be required in order to provide competitive salaries in the technical areas. We will undertake to descope the program in order to provide for increases above 2 percent. Options include eliminating the post-doctoral program; reducing the technical staff and obtaining more instrumentation from outside the observatory; reducing administrative support after this transitional year; providing options for phased retirement and/or work weeks of less than 40 hours; phasing down maintenance of facilities that will be closed within the next five years; increasing room and board costs for users; eliminating the queue observing program at WIYN; etc. These and other possibilities will be explored with the directors and senior management and presented to AURA over the next several months.

• Funding for SOLIS at $1.4M. Timely funding for this project is necessary if it is to be completed for $6M.

A budget summary is shown in Appendix 5. The figures shown for FY 1997 are actual expenditures; for FY 1998 are the budget including carryover, and for FY 1999 are for new funds requested in the President's budget.
APPENDIX 1

NATIONAL OPTICAL ASTRONOMY OBSERVATORIES (NOAO) ORGANIZATIONAL CHART

June 1998
APPENDIX 2

NOAO Management

Sidney Wolff  Director, NOAO
Richard Green  Deputy Director, NOAO/Director KPNO
Jacques Beckers  Associate Director, NOAO/Director NSO
Todd Boroson  Associate Director, NOAO/Director USGP/SCOPE
Malcolm Smith  Associate Director, NOAO/Director CTIO
John Leibacher  Project Director, GONG
Robert Barnes  Assistant to the Director, KPNO
Glen Blevins  Manager, Central Administrative Services
Larry Klose  Associate Manager, Central Administrative Services
James Tracy  Controller, Central Administrative Services
Larry Daggert  Manager, Engineering and Technical Services
John Dunlop  Manager, Central Facilities Operations & Kitt Peak Facilities Operations
Rex Hunter  Administrative Manager, NSO/Sacramento Peak
Pat Eliason  Manager, GONG Project
Yvette Estok  Manager, Public Outreach
Steve Grandi  Manager, Central Computer Services
Suzanne Jacoby  Education Officer, Scientific/Educational Outreach

Effective July, 1998
APPENDIX 3
FY 1999 Provisional Program Plan

CTIO Scientific Staff: Research Interests and Service Roles

Jack Baldwin, Astronomer

Areas of Interest
QSOs and active galaxies, HII regions.

Recent Research Results
During 1997 Baldwin worked together with G. Ferland (U. of Kentucky) and K. Korista (Western Michigan U.) on improved models of the broad emission lined regions in QSOs. These models were used to study the source of the correlation between luminosity and emission line strengths in QSOs. The best explanation of the detailed luminosity dependence of QSO spectra is that the primary driver is a change in the shape of the ionizing continuum, but that an important secondary effect is a dependence of the gas-phase metal abundance on luminosity (in the sense that higher metallicity goes with higher luminosity). The goal of this research is to try to decrease the scatter in the line strength-luminosity diagram to the point that QSOs can be used as standard candles for cosmological tests. Baldwin, Ferland, Korista, and others are organizing a workshop on the topic “Quasars as Standard Candles for Cosmology,” to be held in La Serena in May 1998.

Baldwin also continued his work with R. Rubin (NASA Ames), Ferland, P. Martin (CITA) and others on studies of the Orion nebula using both HST and the echelle spectrograph on the Blanco telescope. This work showed that the spectrum of the photodissociation region is consistent with a warm, low-density gas, contradicting some previous results, and that the gas-phase iron abundance is consistent with heavy depletion of iron onto grains. Finally, in work still in progress, Baldwin, A. Cooke (Edinburgh), A. Wilson (U. of Maryland) and others studied the Seyfert 2 galaxy NGC 3393 using an extensive set of HST and groundbased data.

Future Research Plans
Baldwin is continuing investigations of the LOC models and of QSO luminosity indicators in collaboration with Korista, et al. He is also continuing a study of the Orion nebula in collaboration with Rubin, Ferland, et al. and will be obtaining further groundbased echelle spectra to complement HST observations. An immediate effort is to finish up the work on NGC 3393, which is a very detailed study of a case where the NLR consists primarily of bow shocks swept up ahead of a double-lobed radio source.

Service
Baldwin is serving as the NOAO representative on the Science Working Group for the SOAR 4-m telescope project, and is working on improving the optical performance of the 4-m Blanco Telescope.

Olin Eggen, Astronomer

Areas of Interest
Stellar and Galactic Structure and Kinematics

Recent Research Results
The available Hipparcos astrometry has confirmed the existence of the two superclusters in Stream I and the Sirius supercluster in Stream II as well as the extensive supercluster of young stars (< 50 million years) in Stream O.
Future Research
The investigation of moving groups and superclusters, and their application to astrophysical problems will be the main thrust of Eggen’s future research.

Service
Olin Eggen serves on the Time Assignment Committee and supervises the Library.

Brooke Gregory, Support Scientist

Area of interest
As a Support Scientist, Gregory is an instrument physicist working primarily in the area of development of IR instrumentation.

Recent Research Results
On sabbatical this year at Adaptive Optics Associates in Cambridge, Massachusetts, Gregory is using this opportunity to gain experience in the design and realization of adaptive optics (AO) systems by working with a group that has extensive experience in the area. In addition to study of the literature, he has already gained experience lab-testing a new type of low cost deformable mirror.

Future Research Plans
Gregory expects to be involved in the planning and execution of the next major IR instrumentation effort undertaken at CTIO. He is particularly interested in the prospect of building a simple wide-field imager for the f/14 foci on 4-m and 1.5-m telescopes, to take advantage of the larger format devices (with HgCdTe or Aladdin InSb) that are now available. He is particularly interested in ways in which AO could be effectively deployed at CTIO, notably on the SOAR telescope. He is currently thinking about ways to utilize the above-mentioned deformable mirror in a prototype AO system for CTIO.

Service
On his return from sabbatical, Gregory will continue to serve as the Manager of Engineering and Technical Resources Group at CTIO, as well as continuing general support of IR instrumentation users. He expects to help set up mechanisms for efficiently sharing technical resources among the increasing number of customers on the AURA property in Chile: CTIO, Gemini, SOAR, and others.

Steve Heathcote, Associate Astronomer

Areas of Interest
Star formation, Herbig-Haro objects, Supernovae and Novae

Recent Research Results
Heathcote’s recent research efforts have concentrated on the study of Herbig-Haro jets using high spatial resolution images obtained with the Hubble Space Telescope. It is now known that stars in the process of formation blow extremely powerful, often highly collimated winds. The collision of these highly supersonic outflows with gas surrounding the nascent star excites luminous shock waves, which we observe as a Herbig-Haro jet. These jets provide key information about the mechanisms at play in forming a star. In particular, it is possible to measure how much mass the star is losing now and how the rate of mass loss has varied over the last few thousand years. Such jets are also valuable astrophysical laboratories for the study of shock physics and chemistry.

In two recently completed papers, Heathcote and collaborators, B. Reipurth (ESO), R. Schwartz (U. of Missouri), J. Bally (U. of Colorado), J. Morse (U. of Colorado), P. Hartigan (Rice U.), and J. Stone (U. of
Maryland) present HST images of two of the finest examples of such jets, HH 46/47 (AJ 112, 1141) and HH 111 (AJ 114, 757). These images provide the first clear evidence that shocks within these jets are excited by fluctuations in the velocity and direction of the outflow from the source. At the very high spatial resolution obtained with HST, it is possible to study for the first time the structure of the zone behind these shocks. The data also provide new insights into the way in which jets sweep up material in their surroundings, helping to clear away the debris left behind after formation of the star.

In a separate project, carried out in collaboration with B. Reipurth (ESO) and A. Raga (UNAM), Heathcote has combined HST images with groundbased high resolution spectroscopy and proper motion measurements to study the structure and kinematics of the HH 80/81 complex (AJ in press). Whereas most HH flows (including HH 46/47 and HH 111) are driven by low luminosity stars with masses similar to that of the Sun, the source of the HH 80/81 outflow is a much more luminous, B0 type star. As might be expected, this much more powerful source drives a more energetic outflow, and contains stronger shocks than in any other Herbig-Haro flow.

**Future Research Plans**

Heathcote is now reobserving four HH jets already imaged with HST. The velocities of such jets are so high that motion is detectable over periods of only one or two years. Thus these second epoch images will supply crucial information on how the various shock waves move. Repeat images so far obtained for one system, HH 1/2, not only show the expected motion but also reveal changes in structure and brightness which are remarkable in view of the short period of time which has passed. Second epoch data on a further three systems will be obtained over the next year. Heathcote, in collaboration with B. Reipurth (ESO), M. McCaughrean (MPIfR), and H. Zinnecker (Potsdam), will also obtain IR images of two HH jets using both the NICMOS imager on HST and the COB imager plus tip-tilt secondary on the Blanco 4-m telescope. While the optical emission from an HH jet traces the strongest shocks, molecular hydrogen emission in the IR probes the weaker shocks at the periphery of the jet. At IR wavelengths it is also possible to study the sections of the jet closer to the driving source, which is hidden from view in the optical by overlying extinction.

**Service**

Heathcote is responsible for scientific oversight of CTIO’s computer system and network, and of the CTIO computer programming group. He also supervises the data reduction assistants on Cerro Tololo. During the past three years, Heathcote has been heavily involved in the software side of CTIO’s Arcon CCD controllers. He is consequently closely involved with the development of the NOAO CCD mosaic imagers based on these controllers, the first of which was commissioned during 1997; the second will come into service in early 1999. Heathcote is also project scientist and manager for a multi-year project—which is now nearing completion—to upgrade the drives and control system for the Blanco 4-m telescope. During Alistair Walker’s sabbatical, Heathcote also took over supervisory responsibility for CTIO’s optical CCDs. Heathcote is a member of the Advisory Committee on Technical Resources at CTIO.

**Tom Ingerson, Support Scientist**

**Areas of Interest**

Astronomical Instrumentation, Optics, Spectroscopy, Fiber Optics, Electronics, Computer Networking

**Recent Research Results**

Ingerson is a Support Scientist whose work consists of developing and improving the instruments CTIO needs to maintain itself as a world-class facility with state-of-the-art equipment. He is the Project Manager for the CTIO portion of the Hydra project, to be commissioned early in FY99, currently the highest priority project at CTIO. This includes supervision of the design and installation of a new R-C corrector with Atmospheric Dispersion Correction for the Blanco Telescope, building a new spectrograph and comparison lamp system and overseeing the software integration and instrument commissioning. As part of this project, he has been
conducting a study of how to produce absolute astrometric-quality models of field correctors with ADC and is submitting a paper giving some of his conclusions.

**Future Research Plans**
After the CTIO Hydra is commissioned, Ingerson plans to continue to work on improved instrumentation for optical spectroscopy at CTIO, including work on tip-tilt, Integral Field Unit and echelle upgrades for Hydra, as well as acting as a consultant for the design of the SOAR spectrographs. He also will be spending much of his time working towards improving the telecommunications and networking infrastructure of the observatory complex and its communications with the outside world.

**Service**
In addition to participating in the development of new instruments and being responsible for some visitor support, Ingerson is currently the head of the Engineering and Technical Services Division of CTIO, the CTIO Computer Applications Group, and the Webmaster of the CTIO WWW site.

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**Robert A. Schommer, Associate Astronomer**

**Areas of Interest**
Stellar Populations, Magellanic Clouds, Distance Scale, Cosmology

**Recent Research Results**
Current results from the High-Z Supernova search yield puzzling results, indicating an accelerating universe (negative $q_0$), based on distances to 15 SNe at median redshift of approximately 0.5. Considerable attention is being given to possible systematic effects which could mimic an expansion dominated by the cosmological constant. The old star clusters in the Large Magellanic Cloud and in M33 are being studied with Hubble Space Telescope (HST) data. Deep photometry for central clusters is being used to measure the age and search for the oldest population in the LMC. Current results indicate that the oldest LMC clusters appear identical to the oldest Milky Way clusters. In the local group spiral M33, photometry and horizontal branch morphologies for 10 old clusters are being obtained to evaluate the difference between the halo of this local group spiral and that of our own Galaxy; in particular, the “second parameter” is being examined to see if these very different halos might have similar formation processes. Preliminary reductions indicate several intermediate aged clusters residing in the halo of M33.

**Future Research Plans**
Future work on the old populations of Local Group galaxies will include studies of field populations in the outer regions of the LMC, using photometry, abundances, and velocities, with both groundbased and HST data. A study of NGC121, an old cluster in the Small Magellanic Cloud, is also being planned. As a member of the high-z supernova team, Schommer is searching for SNe at redshifts of ~ 0.5. Over the past 2+ years, more than 40 SNe Ia at redshifts 0.3 have been found and confirmed by the group. HST cycle 6 and 7 time is being collected to provide accurate photometric followup for a portion of this sample. The project’s goals include a measurement of the deceleration parameter, $q_0$, from these data, and thus a determination of the geometry and age of the Universe.

**Service**
Schommer was on sabbatical April-September 1998. Through March 1998, Schommer’s service activities included chair of the CTIO Advisory Committee on Technical Resources (ACTR); he was thus an ex-officio member of NOAO’s IPAC (central instrument planning group). Schommer is working on plans to coordinate the CTIO technical and support staff with that expected for the Gemini project effort in Chile. He is working on operations plans for CTIO with the expected additions of Gemini South and SOAR to the telescope mix. He remains in charge of small telescope improvements, currently focusing on the 0.9-m and 1.5-m. He is the staff
contact and coordinator for the MACHO project, which uses time on the CTIO 0.9-m, and for the Yale 1-m collaboration. He has served as CTIO member of several Gemini committees, including the optical instrument working group, and served on the conceptual design review committee for the Gemini multiple object spectrograph (GMOS). He is responsible for staff support of the Rutgers Imaging Fabry-Perot.

Malcolm Smith, Director, CTIO

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

Recent Research Results and Future Research Plans
Smith has continued observational work on three complementary, collaborative surveys aimed primarily at: 1) Discovery of quasars at redshifts $z = 5$, and 2) Characterization of the quasar luminosity function in the redshift range $3 < z < 5$.

This research has the goal of clarifying the controversial question of the evolution of the luminosity function of quasars at early epochs in the Universe; an estimate of the time elapsed between the big bang and the time when quasars switched on should prove relevant to an understanding of the early formation of galaxies. This is a long-term project involving extensive calibration work, surveys, and data reduction.

Smith is carrying out these surveys as a member of three quite large groups, each able to handle the substantial amount of data involved. All of these groups are now using the Bernstein-Tyson BTC camera (four-shooter CCD optical imager) to survey large areas of sky to different depths with the 4-m Blanco telescope.

The first of these 4-m surveys, by Falco, et al., has covered ~ 50 square degrees in I, V, and B in an effort to search for $z = 5$ quasars, gravitational lenses, and $z = 0.6$ clusters of galaxies. The “BTC50” photometric catalogs are now in hand. Extrapolation of the quasar luminosity function (QLF) for $5 < z < 6$ predicts 0.02 (Warren, et al. 1994) to 0.5 (Schmidt, et al. 1995) quasars per sq. deg. to $I = 22$ mag. The BTC50 survey should thus find between 1-25 quasars with $z = 5$ to $I = 22$. The full 50 sq. deg. are needed to distinguish at the 5-sigma level between QLFs that agree well at $z = 4$. It has been found (from spectroscopic follow-up of a deeper, more limited survey by Kennefick et al.) that additional Z-band information will be required to distinguish between the many faint, high-latitude M-stars and the much rarer high-redshift quasar candidates.

The detection or non-detection of the most distant objects in the Universe and the characterization of their QLF with this survey is expected to yield important constraints on models of massive galaxy formation and on the ionizing UV background at high redshifts.

The second of the 4-m surveys, by Hall, et al., has as its aim the determination of the shape of the QLF between $3.3 < z < 5.0$ and should prove complementary to the work of Falco, et al. at higher redshifts.

Smith is also a member of the team conducting the NOAO Deep Wide-Field IR and Optical Survey, led by Buell Jannuzi and Arjun Dey. This survey is discussed elsewhere in the Program Plan.

Service
Director, CTIO; Associate Director, NOAO; Interim Head of AURA’s Observatories in Chile. Smith has multiple service duties as Director of CTIO and interim Head of AURA’s units in Chile. He has been initiating the renewal of CTIO, an international observatory centered around support of the 8-m Gemini South telescope and two complementary 4-m telescopes, the Blanco and SOAR telescopes. In addition, he has initiated and participated in an extensive program to combat light pollution in Chile. He is also introducing a greater degree of privatization in the operation of the smaller telescopes at CTIO. He has worked closely with NOAO Tucson to
Encourage collaboration in the production of large instruments for Gemini and the NOAO telescopes. Most recently he has been involved in intense activity for AURA as its representative in Chile.

Nicholas B. Suntzeff, Associate Astronomer

Areas of Interest
Stellar Populations, Globular Clusters, Stellar Chemical Abundances, Galactic Structure, Magellanic Clouds, Supernovae, Large-Scale Structure, Cosmology, Astronomical Site Characteristics

Recent Research Results
The major research project that Suntzeff has been involved in is the Supernova High-Z Search. This project seeks to measure the local curvature of the Universe by finding Type Ia supernovae out to $z = 1$. Since 1995, Suntzeff and collaborators have used the CTIO 4-m telescope with the PFCCD and the BTC to find Type Ia SNe to $z = 0.55$ or equivalently $R = 23.5$. To date, they have found roughly 50 SNe and have collected data for over 30 Type Ia events, including the most distant Type Ia found to date at $z = 0.97$. With the semester 98-2, they will terminate the search. The search results have begun to appear in the refereed press (they have four papers published or submitted as of this note) and have been widely reported in the popular press. Based on ~15 SNe, the Search Team has announced that the distant SNe are apparently too faint for a matter-dominated Universe, and the simplest extension to the equation-of-state used in the basic GR equations requires a positive cosmological constant. Formally, the results require a positive constant at greater than the 99% level. For this cosmological model and the local calibration of the Type Ia absolute magnitudes based on the Cepheid work of Sandage and Saha, they find the age of the Universe is $14 +/- 2$ Gyr, which is not in contradiction to stellar age estimates. They are about half-way through their data, and similar exciting results can be expected in the next year. The search for the supernovae is concentrated at CTIO, with followup spectra and photometry at Keck, HST, ARC, MSSSO, and WIYN. The Supernova High-Z Search Team is an international collaboration of astronomers at CfA, University of Washington, the MSSSO in Australia, and in Chile. The PI is Brian Schmidt at MSSSO. A by-product of this survey will be a list of variable stars, which Suntzeff will use to continue his Galactic structure studies with Kinman, Cook (LLNL), and Schmidt (MSSSO), with the goal of measuring Galactic structure based on field stars out to 100 kpc. Suntzeff will continue to observe all bright southern supernovae in a longterm standing collaboration with M. Phillips (OCIW), P. Bouchet, C. Smith, A. Clocchiatti (U. Catolica), and the SInS HST team of R. Kirshner (CfA).

In stellar astronomy, Suntzeff is working with T.D. Kinman (KPNO) to measure the spatial and kinematical structure of the Galactic halo. This study will provide clues as to the origin of the halo, and ultimately, the origin of the Milky Way Galaxy. Suntzeff, in collaboration with Schommer, Walker, Olsen, and Hodge (U. of Washington), Olszewski (Steward) and Mateo (U. of Michigan), is also pursuing a similar project in the Large and Small Magellanic Clouds. They seek to find the original population of the stars in the Clouds to study the age and kinematics of the oldest stars, in order to compare the galaxian formation of these close satellite galaxies with the formation of our Galaxy. In their latest paper, they have found that the central bar globular clusters in the LMC are coeval with the oldest globular clusters in the Galaxy, which points toward a common epoch of initial star formation for the Galaxy-Magellanic Cloud system.

Future Research Plans
Future research for Suntzeff will concentrate on using new samples of supernovae to measure physical properties of supernovae explosions and to measure the local geometry of the Universe. In collaboration with R. Schommer, C. Smith, Phillips (OCIW), B. Schmidt (MSSSO), and others, he will start a new search for supernovae, concentrating on galaxy clusters out to $z = 0.1$. This search will attempt to find up to 100 SNe to estab- lish the natural population of supernova explosions. These data will be a key to understanding the explosion mechanism for Type Ia events (which is still unknown) and estimating the intrinsic luminosity spread in the range of Type Ia explosions. This latter property is extremely important to tie down, since many modern studies
of the local rate of expansion and the geometry of the Universe rely on a detailed knowledge of the range of SNe luminosities. Suntzeff is collaborating with V. Smith (UTEP) and R. Kraft (Lick) on a number of stellar abundance projects. They are presently analyzing spectra of LMC and SMC giants to determine if the history of chemical evolution in the LMC is similar to that of the old disk in our Galaxy. Suntzeff is collaborating with C. Stubbs (U. of Washington), K. Cock (LLNL), and others on a project associated with the LONEOS survey at the Lowell Observatory. This project seeks to use the LONEOS data to find all supernovae, variable stars, and other time-variable phenomena in the northern sky, down to m = 18. The LONEOS camera is in operation in 1998 and the first data are being taken.

Service
Suntzeff will continue in a multi-faceted program of service to CTIO. He is actively participating in the upgrade of the Argus fiber system to a Hydra system similar to that at the WIYN telescope, which will increase the number of objects that can be observed by a factor of six. He will work with M. Boccas to try to bring significant improvements in image quality to the smaller telescopes, using the knowledge gained during the 4-m telescope image improvement campaign. Suntzeff will continue to be in charge of the basic site monitoring at CTIO, including the seeing telescope that is now routinely measuring the CTIO site seeing. He will also work with Gemini to begin a permanent monitoring for the Pachon site, in order to build up environmental and seeing data prior to the inauguration of the Gemini South Telescope. Suntzeff will continue to serve on the CTIO TAC and ACTR committees. Suntzeff and R. Blum will continue their work on the project to bring a 2.5-m wide field telescope to CTIO via a collaboration with C. Stubbs (U. of Washington).

Suntzeff is one of the co-organizers for the IAU Symposium 190 “New Views of the Magellanic Clouds.”

Alistair Walker, Associate Astronomer

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

Current Research
Walker is PI of a Cycle 6 HST program which will study the oldest Small Magellanic Cloud cluster and two distant field regions, one in each Cloud. Approximately half the observational data is in hand. Extensive complementary photometry with the Blanco 4-m telescope has been reduced; an 0.25 sq. degree region of the Large Magellanic Cloud shows that there are almost no stars younger than 5 Gyr and the older stars may come from multiple populations. Further groundbased photometry and spectroscopy is planned.

Walker is a member of a team awarded HST WFPC2 time in Cycle 5 (N. Suntzeff, P.I.), to determine ages and abundances for several old or probably old clusters in the inner regions of the Large Magellanic Cloud. The analysis has been completed: all the clusters are found to be as old as galactic globular clusters, implying that the LMC formed at the same time as our own galaxy. This work, together with the complementary photometry of Magellanic Cloud field stars mentioned above, will allow the early star formation history of the Magellanic Clouds to be deciphered. The results will bear directly on our ideas on the early formation and subsequent evolution of galaxies in general.

Walker, with Y-W Lee, S-C Rey (Korea) and S. Baird (Benedictine College) are measuring [Fe/H] abundances for all the RR Lyrae variables in the galactic globular cluster Omega Centauri. Data reduction is complete and at present calibration issues are being addressed. This work will allow comparison with evolutionary and pulsation models, and further constrain the relative contributions of primordial enrichment and evolutionary mixing to the present-day metallicity distribution of the cluster.

Future Research Plans
Together with H. Smith (Michigan State U.), E. Brocato, F. Caputo, and V. Castellani (Italy), Walker plans a comprehensive survey of the variable star population of the Carina dwarf galaxy, using the Blanco telescope with BTC Mosaic Imager. Comparisons will be 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.

With G. Kovacs (Hungary), Walker is collaborating on a detailed theoretical pulsation analysis of double-mode RR Lyrae stars, aimed at defining the masses and luminosities of RR Lyraes. Most of the observations utilized in the study were collected as part of an extensive campaign of study of southern galactic globular clusters, mostly using the CTIO 0.9-m telescope between 1987-1995.

Service
Walker is 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, supervises the operation of the CCD laboratory, and is responsible for optical imaging programs on all telescopes. He is responsible for the Schmidt telescope and has managed the projects that have automated the wide-field imager at that telescope. He is the CTO scientist who liaises with NOAO Tucson on the production of the NOAO 8K x 8K imager and is leading the effort to upgrade the Blanco 4-m telescope so that it is ready for a clone of that instrument, due at CTIO in early 1999. He is project scientist for most projects involving production and implementation of the Arcon CCD controllers. He has organized the highly successful long-term visit to CTIO of the Tyson and Bernstein mosaic imager BTC (Big Throughput Camera) and is the CTO scientist responsible for the instrument.

Walker has served as a member of the US Gemini Science Advisory Committee since 1994, and on occasion has represented the US on the Gemini Science Committee. He is a member of the American Astronomical Society, the Astronomical Society of the Pacific, the International Astronomical Union, and the Society of Photo-Optical Instrumentation Engineers.
KPNO Scientific Staff: Research Interests and Service Roles

Helmut A. Abt, Astronomer Emeritus

Areas of Interest
Double Stars, Stellar Rotation, Stellar Characteristics, Publication Practices in Astronomy

Recent Research Results
Abt and his collaborators have recently studied how double stars are formed. Others have found that the classical mechanism (subdivision of a star that is spinning too rapidly) does not form double stars, but rather stars with disks. Abt’s work shows that three-body interactions within star clusters give double stars with the characteristics seen in young and old clusters and seems to be the primary mechanism.

Future Research Plans
Abt continues to collect statistics on publication practices. In the latest study, he wondered if the long half-life of 29 years for astronomy papers applies to other sciences. He found that for chemistry, physics, general science (Science magazine), and geophysics before 1970 the half-lives of papers are six to fourteen years. However if one corrects for the growth in those sciences, the half-lives in all those sciences are seven ± two years.

Service
Abt spends his spare time doing research but works full-time being Editor-in-Chief of the Astrophysical Journal. That journal is published every ten days and publishes 25,000 pages per year. He has been in that position for 27 years, but the AAS is now looking for a replacement.

Abt arranged to have the Van Biesbroeck Prize for outstanding service to astronomy transferred to the AAS. He received the prize in 1998 for his editing of the ApJ. In 1997 he was made Guest Professor at the Peking University and Nanjing Normal University for his support of Chinese astronomy.

Michael J. S. Belton, Astronomer

Areas of Interest
Planetary Science, Comets, Asteroids, Jupiter System

Recent Research Activities
Belton has been working with the Galileo Imaging Team, of which he is the leader, on new high-resolution (up to 6 meters/pixel) images of Europa, in a search for a global water ocean beneath the ice shell surface. Proof of the presence of liquid water together with pervasive heat generation due to internal, orbital, tides is an important step in understanding if Europa is a possible abode of extraterrestrial life. The images show evidence of a very young surface distorted by the effects of thermal convection on scales of ~10 km and other localized disruptions. This points to a thin ice crust and indirectly the presence of water a few kilometers down. This work is now being extended into a search for active cryo-volcanism on the surface.

Belton is continuing his work with Samarasinha and Mueller into the physical nature of active areas on cometary nuclei. The current focus is to take the spin model that we have developed for comet Halley and use the recently available analysis of OH production by Schleicher, et al (1998) to constrain some of these properties for the Halley case. in work with Samarasinha and Julian, a similar study has for the first time yielded an observational value for the thermal conductivity of cometary ice. Other cometary work that is in progress is a study of the spin state of the Rosetta target comet, P/Wirtanen, with B. Mueller and based on observations from
CTIO. In another study, based on HST observations, and conducted with K. Meech (U. of Hawaii), Belton is investigating the stability of the inner coma of Chiron.

Service
Belton’s service activities are primarily in the planetary astronomy community where he is a member of the NASA Keck/IRTF Management and Operational Working Group. In addition he is a member of the NASA Planetary Astronomy Committee, and the NASA Small Bodies Science Working Group. Within NOAO he provides appraisals and advice to the Director on planetary astronomy observing proposals. He has also sponsored two successful IDEA educational outreach programs at NOAO.

Bruce Bohannan, Scientist

Areas of Interest
Stellar Spectroscopy, Structure and Evolution of Massive Stars, Astrophysical Instrumentation and Data Reduction

Recent Research Results
Bohannan’s research centers on observational studies of the evolution of massive stars. Massive stars, through their radiation, mass loss, and supernovae explosions, dominate the chemical element evolution and kinetic energy of their parent galaxies. Because of their high luminosity, such stars are readily observed to great distance in the Milky Way and in other galaxies. The evolution of these stars is poorly understood because models are not readily connected to the simple spectral morphology which underlies stellar astrophysics. Bohannan and his colleagues have used the measurement of basic stellar properties (temperature, gravity, mass, mass loss rate, and surface element abundances) to define the evolutionary path of massive stars and to make connections between various stages of massive star evolution, stages most readily observed as morphological differences. For example, P.A. Crowther (U. College, London) and Bohannan recently concluded (1997 A&A 317,532) that a direct evolutionary connection may exist between certain hot, massive stars (those classified as O-type peculiar emission-line supergiants) and a later stage of stellar evolution (low excitation WN stars) without an intermediate stage of rapid and unstable evolution (commonly known as Luminous Blue Variables), a conclusion that is contrary to current evolutionary theory and suggestive of an additional process (e.g., mixing) to bring core processed material to the surface.

Future Research Plans
Similar investigations of stars in the Galactic Center and in other galaxies provide critical diagnostics of stellar evolution because they can examine 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). IR diagnostics are being developed with Crowther and tested through a set of spectral line profiles recently obtained at CTIO and analyzed with Hillier model atmospheres (Bohannan and Crowther 1998, submitted to ApJ). The next stage will be 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. The final step would be to undertake a similar study of stars in the nearby spiral galaxy, M 33, research which requires a moderate resolution IR spectrometer combined with an image compensation system to provide high spatial resolution (e.g., tip-tilt and fast focus).

The mass of a star is one of the most important stellar parameters to know and one of the most difficult to measure. For massive stars there is not a direct one-to-one link between luminosity and mass. The theory of radiatively driven winds provides simple analytical expressions which link the mass, luminosity, and effective temperature of a star to the observed mass loss rate and terminal velocity. The analytical expressions use parameters which are related to the number of lines responsible for driving the wind, the opacity of the lines, and the ionization structure of the wind. These parameters are now sufficiently well established that one can
use the analytical expressions in an inverse fashion to measure stellar masses from spectroscopic analysis using
detailed models which determine the effective temperature, mass loss rate, and terminal velocity for stars of
known luminosity (i.e. of known distance). Bohannan and Crowther have begun to apply this technique to a
group of peculiar stars in the Large Magellanic Cloud that have the characteristics of both hydrogen-burning Of
stars and helium-burning WN stars and have massive circumstellar shells from either a LBV or red supergiant
phase. The determination of a stellar mass for these stars is critical in defining the evolutionary path of the stars
and defining the origin of the circumstellar shell. The method they are developing is the only way to measure
stellar masses as none of these stars are in binary star systems and few are in clusters and associations. Tracks
of stellar evolution do not provide reliable masses because of the unknown effect of stellar rotation on
luminosity and effective temperature.

Service

Service is Bohannan’s primary role within NOAO. He has recently been assigned as Chief Project Scientist for
KPNO, a position which provides top-level management and scientific oversight of KPNO projects, including
KPNO Telescope Improvement Projects and projects involving personnel from NOAO ETS/IPG allocated to
KPNO. He is to play a key leadership role in long-term technical planning to meet critical goals of the observ-
atory and assumes other assignments from the KPNO Director and from the NOAO Director as appropriate.

His principal responsibility is to provide overall coordination of the KPNO Improvement Projects where he
works with the KPNO scientific and engineering staff in developing project requirements consistent with the
scientific objectives of the project. As necessary, he assists specific project scientists and engineers with studies
necessary to define scientific requirements. He works with project managers in development of project
schedules—in particular, coordination between different projects and resource teams—and ensures that
projects are completed in a timely fashion consistent with priorities defined by the KPNO Director. Specific
goals for the coming year include formalization of the process for KPNO Improvement Projects and for how
ETS/IPG resources assigned to KPNO are allocated and managed.

In addition, Bohannan is involved in increasing the effectiveness of reporting of scientific discoveries using
NOAO facilities, an effort strongly urged by the NSF, AURA, and various external review committees. He is
developing a process to identify scientific research with “front-page” potential and will bring these discoveries
to influential audiences by directly working with reporters for critical media. Assistance will be provided to
investigators to write-up their discoveries in a way that effectively communicates their science to a non-science
audience, including effective visuals. He is to provide assistance to NOAO staff assigned to media relations by
serving as a science resource.

Charles F. Claver, Assistant Scientist

Areas of Interest

Recent Research
Claver’s research focuses on obtaining an independent estimate of the Universe’s age in order to resolve the
apparent discrepancy between the expansion age and the main-sequence age of the oldest stars we see—the
globular clusters. The age dating technique Claver uses exploits the relatively simple physics found in the
cooling remnants of stellar evolution—white dwarf stars. The age of a white dwarf is directly related to its
luminosity, and any reasonable estimates for the age of the Universe still allow for the oldest white dwarfs to be
visible. Therefore, a census of white dwarfs according to their brightness—called a luminosity function—in
any stellar population will show an abrupt cut-off at low luminosities that is dependent on the population’s age.
Claver has used this fact and observations of white dwarfs in the open clusters Praesepe and NGC752 to show
the white dwarf and main-sequence ages are in good agreement up to 3 billion years old. If the agreement
persists at older ages, then we can be confident in the ages of the globular cluster, and the current estimate of Hubble's constant does not allow for a simple inflationary cosmology and a more complex one is demanded. Otherwise, if the agreement breaks down beyond ages of 3 billion years, then we must be suspicious of the estimates of stellar ages and reevaluate the state of stellar evolution calculations.

To date all estimates of the white dwarf luminosity function for the Galaxy's disk suffer from poor statistics at their faint ends, and prevent us from fully utilizing the excellent clocks offered to us by white dwarf stars. Thus, age estimates for the Galactic disk from these luminosity functions range from 8-13 billion years, which is not precise enough to help resolve the age dilemma. As part of his thesis work, Claver has developed a method for identifying cool white dwarf candidates from photometry alone. With his technique Claver has initiated a deep photometric survey to search for cool white dwarfs in the field. To date Claver's survey has covered enough area to improve the number statistics in the cool part of the disk white dwarf luminosity function by a factor of 3-5 over previous estimates.

From his work on open clusters Claver has recently found evidence that there is a "second parameter" to the Initial-Final mass relation for white dwarfs. Claver has found that the two well known open clusters, Hyades and Praesepe, though essentially identical in age and metallicity, have very different mean white dwarf masses. Other evidence from Jacoby's work on planetary nebulae nuclei appears to support a fundamental change in physics, hence the Initial-Final mass relation, near a final mass of 0.65 M☉.

Future Research
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.

In addition, Claver plans to extend his work on calibrating the stellar chronology in star clusters to ages older than 3 billion years. Specifically, in collaboration with Don Winget (U. of Texas), Mike Bolte (Lick Obs.) and Matt Wood (FITT), he plans to search for and identify the oldest white dwarfs in the clusters M67 and NGC188 in the North and IC4651 and NGC3680 in the south using both ground and space based telescopes. These clusters will extend the calibration to roughly 8 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 the site is capable of. 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. Also, 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...
Richard F. Green, Director, KPNO

Areas of Interest
Active Galactic Nuclei, Quasar Absorption-Line Systems, Galaxy Nuclear Dynamics

Research Plans
Richard Green is a member of the Instrument Definition Team 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 Cycle 7 to perform a complementary survey. The two teams have coordinated their observing approach and will analyze the stellar absorption profiles at the calcium triplet to deduce the presence and mass of any central black hole. An initial success was M84, an elliptical in the Virgo Cluster. Gary Bower, a team associate based at KPNO, suggested this object because of its 3C radio source and morphology of emission-line gas near the nucleus. Its central gas disk showed nearly Keplerian motions, suggesting a dark mass of $1.5 \times 10^9 M_\odot$.

Green is a member of the science team for the Far Ultraviolet Spectroscopic Explorer satellite, scheduled for launch during FY 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.

Green also collaborates with B. Jannuzi in determining the association of low-redshift Lyman alpha absorption clouds with the large-scale structure of galaxies. They are conducting an imaging and redshift survey to concentrate on the range $0.1 < z < 0.4$.

Richard R. Joyce, Support Scientist

Areas of Interest
Late-type Stars; Mass Loss; Infrared Detector and Instrumentation Development

Recent Research Results
Joyce has completed an infrared spectroscopic survey of a sample of faint carbon stars near both Galactic poles. Carbon giants are excellent probes of the kinematics of the outer halo, but are difficult to distinguish from nearby carbon dwarf stars at the low spectral resolution typically used for optical classification. The infrared spectroscopy shows that those stars known to be carbon dwarfs (from their high proper motion) show weak or barely detectable (depending on metallicity) absorption in the first overtone of CO at 2.3 microns, whereas virtually all the other stars in the survey displayed the much stronger CO bands characteristic of giants. These results (AJ, May 1998) lend support to models which suggest that infrared molecular features are
suppressed in high surface gravity, low metallicity environments. As part of a multi-wavelength collaboration, Joyce has also obtained infrared spectra (0.9-3.8 microns) of the binary object that may be associated with the Soft Gamma-ray Repeater 1900+14. The two heavily-reddened objects, separated by 3 arcsec, have virtually identical energy distributions, suggesting that the extinction must be interstellar and that the two objects are M5 supergiants at a distance of 12-15 kpc, on the other side of the Galaxy. While this is highly unusual, it does not by itself connote an association (other than positional coincidence) with the gamma ray emission, which is conventionally believed to result from mass accretion onto a highly-condensed object such as a neutron star or black hole. The infrared spectra of the two stars are virtually indistinguishable, except for a significant difference in the depth of the CO first-overtone absorption bands at 2.3 microns, possibly the result of hot circumstellar dust filling in the absorption lines in one of the stars. Preliminary observations with the high-resolution IR spectrograph PHOENIX indicate that the two stars have similar radial velocities, and continued monitoring is planned to search for any velocity changes which might result from a massive component in proximity to one of the two stars. C. Pilachowski, K. Hinkle, R. Joyce, and C. Sneden (U. of Texas) have used PHOENIX to obtain high signal-to-noise spectra of the first-overtone infrared bands of CO in metal-poor giant stars. These spectra allow the determination of the ratio of $^{13}$C to $^{12}$C, which is diagnostic of the degree to which material in the outer convective portion of these stars has been mixed with the $^{13}$C-rich shell within which CN cycle hydrogen burning is taking place. Use of the infrared CO bands, rather than the blue visible CH bands, for isotope ratio determination significantly increases the available sample of stars for study because late-type giants are much brighter at 2 microns and the CO bands themselves are intrinsically strong.

**Future Research Plans**

Future research plans include the use of high-resolution infrared spectroscopy, largely with PHOENIX for a variety of stellar studies. Three primary conditions can dictate the use of infrared spectroscopy as a diagnostic tool: 1) high extinction in the visual may preclude spectroscopy; 2) dynamic events such as mass transfer in binaries may produce visual emission, which confuses the optical spectra; 3) the physical process produces spectral effects only in the infrared. Examples of these follow. The Soft Gamma Repeater 1900+14, which suffers 19 mag of visual extinction, is much more amenable to radial velocity studies in the infrared, and the manifestation of a thin hot dust shell may be apparent only in the CO absorption lines at 2.3 microns. An example of the second category is a collaborative project involving Joyce, K. Hinkle (NOAO), and F. Fekel (Tennessee State U.) to determine orbits of symbiotic stars from high-resolution spectra obtained with the infrared camera NICMASS at the Coude Feed Spectrograph. 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. The third category is exemplified by a recently-initiated project involving Joyce, Hinkle, and C. Sneden (U. of Texas) to observe the He I line at 1.083 microns in metal-poor giant stars. These stars may be considered analogs to the red giants in globular clusters. One such star has been reported in the literature to show a 1.083 micron feature indicative of a high-speed (90 km/s) wind. Since this velocity exceeds the escape velocity from globular clusters, the presence of such high-speed winds from metal-poor field stars would suggest a mass loss mechanism for globular cluster giants which could expel matter from the cluster itself and plausibly explain the observed low density of the interstellar medium in globular clusters. Results for a number of stars are being prepared for publication.

**Service**

As a Support Scientist, a significant fraction of Joyce's time is spent in providing observing 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, off-line support in providing advice to prospective observers, and assistance with data reduction. Joyce is the capability scientist for infrared spectroscopy with CRSP, as well as co-instrument scientist on PHOENIX, and has defined the specifications for a next-generation wide-field IR imager for NOAO, which has been approved for design. He is responsible for the scheduling of the Kitt Peak telescopes and is overseeing the development of the scheduling portion of the new ALPS++ database. Other service areas include serving on the Infrared Group, KPNO Advisory, ALPS++ Definition, and KPNO Safety Committees, and being the editor for the KPNO section of the NOAO Newsletter. He is also involved with the US Gemini Program in developing similar “user support” mechanisms and IRAF reduction packages for community users of IR instrumentation on Gemini.

**T. D. Kinman, Astronomer Emeritus**

**Areas of Interest**
Galactic Structure, Galactic Halo, Horizontal Branch Stars, Rr Lyrae Stars

**Recent Research Results**
The oldest stars in the Galaxy are found in the Galactic Halo; it is by studying these stars that we are most likely to discover how the Galaxy was formed. The Horizontal Branch Stars are a relatively uncommon type of Halo star that make excellent tracers of the Halo because they are less easily confused with the more numerous Disk stars than are other Halo stars. Kinman has spent the last few years searching several hundred square degrees of sky to find the brighter horizontal branch stars within a few kiloparsecs of the Sun. These stars were originally identified in various objective-prism surveys with Schmidt telescopes. Kinman has observed these stars in 5 wavebands (using a CCD on the 0.9-m telescope) so as to pick out the stars whose colors make them highly likely to be horizontal branch stars. Then, with N. Suntzeff (CTIO), Kinman has been taking spectra of these stars at the 4-m telescope in order to get their radial velocities, their metallicity, and a final confirmation of their classification. This sample is being used to study the kinematics and space distribution of the Galactic Halo within a few kiloparsecs of the Sun. Past work has shown that a “streaming motion” is present among some of the Halo stars near the North Galactic Pole, and it is hoped to discover how widespread this phenomenon is in the Galaxy. In 1997, a few proper motions for these stars became available from the new GSC2 catalog as a result of collaboration with an Italian consortium (P.I. C. Cacciari, STScI). These data allow one to compute the galactic rotation of the halo relative to the extragalactic background and it is found to be more like 300 km/s rather than the 220 km/s found in the solar neighborhood. Currently Kinman is acquiring a larger sample of halo stars that are within 10 degrees of the North Galactic Pole in order to confirm this effect.

**Future Research Plans**
Photometric and spectroscopic observing was continued during 1997 and 1998 towards getting a relatively complete data set of halo stars. The emphasis is on stars on the Galactic meridional plane (which give information on Galactic Rotation from their Proper Motions). As more GSC2 data for the North Galactic Cap will become available, it will be possible for our kinematic analysis to be extended. The advent of the Hipparcos and Tycho data (which should greatly improve our knowledge of the absolute magnitudes of these objects) will be particularly timely. It should be noted that Kinman’s photometry is being fed back into the GSC2 system, so that the GSC2 magnitudes should be significantly improved in this area of the sky; many GSC2-related programs should benefit from this. Kinman also has related programs with C. Allen (UNAM, Mexico City) and C. Cacciari (STScI) to study the horizontal branch stars of the solar neighborhood. During 1997, this collaboration was extended to include F. Castellani (Trieste) so that spectra of the nearby horizontal branch stars could be analyzed. It is becoming apparent from this work that the [alpha]/[Fe] ratio can be readily determined for these stars and that this ratio affords a straightforward way of distinguishing halo from thick disk stars.

**Service**
Kinman provides informal support to the Library and elsewhere in the Observatory on request.
Roger Lynds, Astronomer

Areas of Interest
Galaxy Evolution and Cosmology

Recent Research Results
Lynds has now completed the paper on the star-formation history of VII-Zw-403; it is tentatively scheduled for the July issue of the *Astronomical Journal*. Images obtained with the Hubble Space Telescope resolve the galaxy into individual stars and reveal especially the fact that the young, luminous blue stars responsible for the irregular classification occupy the central region of a dwarf elliptical galaxy. The color-magnitude diagram (CMD) derived from the stellar photometry displays a blue plume consisting of young main-sequence and supergiant stars, mostly confined to clusters and HII regions near the center of the galaxy, as well as a red plume of supergiants that are somewhat more dispersed than the blue stars. In addition, the red giant branch (RGB) is abundantly populated by stars that comprise the much larger underlying elliptical galaxy of older stars. But the most noteworthy feature of the CMD is a well developed asymptotic giant branch (AGB) consisting of stars that must have a metallicity at least of the order of 1/20 the solar value and an intermediate age of the order of 1 Gyr. It happens that the location of the RGB is exactly where one would expect to find not only the red giants associated with such an AGB population, but also red giants from a much older, metal-poor (1/100 solar) population. Is the elevated metallicity of the AGB population due to a precursor low-metallicity population or to some unknown “cosmological” contaminating event? The relationship between the distribution of stars in the CMD and in space seems to give at least a partial answer: the totality of RGB stars are more widely dispersed spatially than are the AGB stars; there was a star-formation event prior to what must have been a spectacular starburst responsible for the AGB population! Even though VII-Zw-403 is not entirely young, or even of intermediate age, it is tempting to suppose that the galaxy during its “AGB” starburst must have looked much like the blue dwarf galaxies at comparable look-back times that are being revealed by deep imaging with HST.

Collaborators in this investigation have been D.Hunter (Lowell Obs.), E.O’Neill (NOAO), and E. Tolstoy (Space Telescope - European Coordinating Facility).

Future Research Plans
Lynds’ future research will include VLA 21-cm mapping of VII-Zw-403 and another galaxy as an exemplar of a dynamically induced starburst. In addition, he will continue work on the integrated properties of galaxies in the various HST deep imaging fields.

Service
Lynds has been an active member of the Observatory Safety Committee and is one of the instrument scientists for the 4-meter Prime Focus CCD Camera.

Philip Massey, Astronomer

Areas of Interest
Massive Star Evolution, Star Formation, Resolvable Galaxies

Recent Research Results
Massey’s research is primarily aimed at understanding the formation and evolution of massive (> 10 M☉) stars. Using the best groundbased and spacebased instruments, he has been investigating the stellar content of star-forming regions in the Magellanic Clouds, the Milky Way, and the more distant members of the Local Group. His recent work has established that the masses of the highest mass stars and the slopes of the initial mass
functions (IMFs) are the same in OB associations of the Magellanic Clouds and Milky Way, despite the factor of 20 difference in metallicities between these systems. (This demonstrates that radiation pressure on grains must not limit the mass of the highest mass star that can form.) He has also found that an appreciable fraction (approximately 50%) of massive stars form in the field, born of smaller, more modest star-forming events than those that produce large clusters and associations. However, the slope of the initial mass function is considerably steeper for these stars, meaning that proportionately fewer of the very massive stars are being born in these small star-forming events. Since massive stars are responsible for much of the chemical enrichment of the Galaxy (the carbon in our bodies was all produced within the cores of massive stars), understanding massive star formation and evolution has significance for understanding the chemical enrichment of galaxies, including our own. This year, Massey, in collaboration with D. Hunter (Lowell Observatory), used HST to investigate the massive star content of R136, the central cluster in the 30 Doradus Nebula in the Large Magellanic Cloud. Once thought to be a single, supermassive object, ground-based speckle and WFPC images established that R136 is actually even more interesting: a “super star cluster,” possibly what all globular clusters looked like when they were only a few million years old. Spectra have now been obtained of the brightest, bluest 65 stars in this cluster, with the surprising result that most of the stars are of type O3—the hottest, most luminous stars known! The most massive of these stars are in excess of 150 M$_\odot$, making them the highest mass stars ever discovered. Despite the preponderance of high mass stars, though, their study finds that the IMF of R136 is completely normal, with a Salpeter (Gamma = -1.3) slope. The number of extremely high mass stars is just what would be predicted by extrapolating the IMF of the intermediate-mass stars. The fact that the IMF slope in R136 is indistinguishable from those of Galactic and Magellanic Cloud OB associations suggests that star formation produces the same distribution of masses over a range of nearly 1000 in stellar density, from that of sparse OB associations to that which is typical of globular clusters. The large number of O3 stars is then simply a consequence of its youth (< 1-2 Myr) and its richness, suggesting that the upper mass “cutoff” to the IMF seen in OB associations is simply statistical and not physical.

Future Research Plans
Massey is currently analyzing data on the evolved massive stars in nearby galaxies (Magellanic Clouds, NGC 6822, M31, and M33) in order to understand how metallicity affects the evolution of high mass stars.

Service
Massey's service responsibilities include: 4-m Telescope Scientist. As such, Massey is responsible for seeing that the Kitt Peak 4-m is used to maximum scientific advantage. His responsibilities include the identification of maintenance problems and software issues, overseeing the monthly testing and evaluation time, and working toward improving the delivered image quality. User documentation. Massey has written and continues to update the visitor manuals for the CCD data-taking software ICE, the direct imaging (CCD) manual, the low-to-moderate resolution spectroscopy manual, and the operation manuals for the 0.9-m and Burrell Schmidt telescopes, as well as data reduction guides for crowded field photometry, CCD reductions, and spectroscopic reductions. WIYN/Hydra assignment code. Massey wrote and maintains the software for computing the optimal assignment of fibers to objects with this instrument, and interacts with visitors as needed.

James Rhoads, Research Associate

Areas of Interest
Gamma ray bursts, Galactic structure, stellar populations, gravitational lenses, dust.

Recent Research Results
Recently, a radio counterpart to Gamma Ray Burst 980508 was observed at about the flux level and time delay predicted by Paczynski and Rhoads (1993). Rhoads has now done further work on exploiting GRB afterglows to learn about the physics of the bursts. In particular, he has published one paper and submitted a second
addressing ways to determine whether GRBs are beamed or isotropic emitters. This question is now the dominant remaining uncertainty in the energy requirements of the bursts.

Rhoads's recent research includes a study of the 2.3 micron CO index in nearby galaxies; results indicate that young stellar populations can locally dominate the emission from star forming regions in a galaxy even at near-infrared wavelengths, although their contribution to the total near-infrared light of the galaxy is modest.

Rhoads and S. Malhotra (Infrared Processing and Analysis Center) have published a paper demonstrating the potential utility of gravitational microlensing of our Galaxy's globular cluster system to probe the large scale structure of the Galaxy. Such a survey would be particularly useful for studying disk flaring and the halo core radius, neither of which is easily studied by other methods.

Malhotra, Rhoads, and E.L. Turner (Princeton U.) have shown that radio-selected gravitational lens systems are redder than optically-selected systems, which is possible evidence for dust in lensing galaxies. This suggests that a large fraction (about half) of gravitational lens systems are hidden from optical surveys by dust. Previously published limits on the cosmological constant Lambda based on the statistics of gravitational lenses, may have to be relaxed.

Finally, Rhoads and REU student C. Deloye (U. of North Carolina/U. of California) spent summer 1997 working on methods for probing the structure of our own Galaxy using the near infrared colors and fluxes of stars.

Future Research Plans
Rhoads is working on theoretical aspects of the reddening to extinction ratio for dust in clusters of galaxies, and hopes to obtain, in collaboration with I. Dell'Antonio and G. Kochanski (Lucent Technologies), a direct measurement of this reddening law. This work may help address discrepant published estimates of the dust abundance in clusters of galaxies. Rhoads also hopes to do further work on Gamma Ray bursts, exploiting the recent observational breakthrough (detection of counterparts at low energies) made possible by the BeppoSAX satellite to learn about the physics of gamma ray bursts and the nature of their environments. Rhoads, J. Kepner (Princeton), and X. Fan (Princeton) are working on a multicolor survey for galaxy clusters using data from the NOAO Mosaic CCD camera. Finally, Rhoads plans to continue working on Galactic structure studies using both near infrared photometric data and optical fiber spectra to look for photometric and kinematic signatures of spiral arms and other large-scale features in the Galaxy.

Service
Rhoads helps new visiting observers acquaint themselves with the telescopes, and assists them in using the facility instruments effectively and efficiently. He has also been an active first shared-risk observer with the CCD Mosaic camera, and is providing feedback on observing and data reduction to the Mosaic team.

Stephen T. Ridgway, Astronomer
Areas of Interest
Stellar astronomy; advanced instrumentation

Recent Research Results
In collaboration with colleagues from the University of Paris Meudon Observatory and the Harvard-Smithsonian Center for Astrophysics, Ridgway has deployed the prototype optical fiber detection system FLUOR at the Infrared Optical Telescope Array on Mt. Hopkins. The FLUOR device was developed at KPNO during an earlier phase of this collaboration. With FLUOR, the team has achieved photon-limited accuracy in the measurement of interferometric visibilities, a significant advance in the field of optical interferometry. This capability has been employed to extend the calibration of very cool giant stars to the latest spectral classes. It has been
found that the M8 class giants have an effective surface temperature of only 2780 degrees Kelvin. While cool, this is nearly 500 degrees hotter than estimated earlier by less precise techniques. A careful calibration of stellar temperatures is critical in the comparison of computer models with actual stars. The study of individual cool stars is important for advancing our understanding of the physics of the cool atmospheres, which will eventually culminate in useful models of the coolest stars, brown dwarfs, and protoplanets. Though models of individual stars this cool are not yet reliable, the calibration is already very useful in the analysis of galactic evolution. Computer models of galactic evolution predict the mix of stars in a galaxy, and color calibrations must be employed to convert the model to characteristic observable properties.

Future Research Plans
NOAO will continue under contract to support the Georgia State University Center for High Angular Resolution Astronomy (CHARA) interferometric array project. Ridgway will continue his role as technical consultant, with emphasis next year on first operation of the telescopes, installation of the vacuum system, and design and specification of the segmented optical delay system. The CHARA Array offers a unique combination of collecting area and angular resolution. When it becomes operational, toward the year 2000, it will supply a rich return of fundamental stellar data, including temperatures, diameters, and masses, and it will be a valuable test-bed for the development of interferometric technology.

Service
Ridgway provides technical advice to the NOAO/Gemini community on adaptive optics and interferometry. He is a frequent lecturer at NATO summer schools on these topics, and participates in NASA advisory groups on Keck and space interferometry. He is NOAO representative on the KPNO Galactic Telescope Allocation Committee, serves on several NASA committees, and is currently a member of the Keck Observatory Science Steering Committee.

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 is 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 6 type Ia supernovae, and a seventh is close to completion. This calibration establishes a Hubble constant of ~ 58 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 now obtained Cepheid distances to ~ 20 additional galaxies, and an analysis of the implications on other distance indicators like the Tully-Fisher relation is underway. In a parallel groundbased 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 to map the local Universe and to 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.
Future Research Plans

The HST based studies to establish the value of the Hubble constant are expected to be concluded within the next two years. The nearby galaxy mapping project 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.

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, he is searching 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 participating in the efforts to put tip-tilt imaging on the telescope, and also in the efforts to put a mini-mosaic CCD camera which will cover a wider imaging field at the high spatial resolution that the excellent seeing at WIYN demands. He is actively pursuing several areas of general improvement in telescope performance. He is also in charge of the imaging camera on the 2.1-m telescope.

Saha is actively participating in the queue observing experiment with the WIYN telescope. This effort is 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 on to happen some of the time. Queued observing also enables many synoptic programs, which would be awkward or even impossible to carry out with classical scheduling methods. Saha aims to systematize the experience from this exercise and to construct a system that is capable of supporting larger groundbased queues that optimize such special purpose utilization.

Paul S. Smith, Assistant Scientist

Areas of Interest

Active Galactic Nuclei, Polarimetry

Recent Research Results

Optical and UV spectropolarimetry has proven to be one of the most powerful techniques in the investigation of the structure of Active Galactic Nuclei (AGNs). This technique has forcefully advanced the notion that the AGN ionizing flux does not emerge isotropically from the nuclear region, implying that our viewing perspective is an important factor in determining the differences observed between various types of AGNs. An obscuring torus of material prevents direct observation of the inner nuclear regions if the torus intersects our line of sight. Smith has been involved in several studies that have extended these ideas to various luminosity classes of AGNs (e.g., Hines, et al. 1995, ApJ, 450, L1; Wilkes, et al. 1995, ApJ, 455, L13). In addition, HST and groundbased spectropolarimetric studies of Seyfert 1 nuclei have emphasized that there are multiple scattering regions close to the broad-line region (BLR; Smith, et al. 1995, ApJ, 444, 146; Smith, et al. 1997, ApJ, 488, 202). Another successful technique used to probe the innermost structure of AGNs is to monitor their emission-line and continuum fluxes. A time delay between the brightening or fading of the ionizing continuum and the response of the line-emitting gas can be interpreted as the light travel time from the central ionizing source to the gas, thereby giving an estimate of the size of the BLR. Smith and his collaborators completed the first systematic, long-term spectrophotometric monitoring program of a well-defined sample of quasars. This project succeeded in detecting correlated variations between the continuum and emission-line fluxes and produced the first reliable observational estimates of the size of the BLR in quasars, extending previous studies of Seyfert nuclei to higher luminosity (Maoz, et al. 1994, ApJ, 421, 34; Kaspi, et al. 1996, ApJ, 471, L75).
Results from this program suggest that the size of the BLR roughly scales with the square root of the continuum luminosity of the AGN as expected from photoionization models. Smith collaborated with G. Schmidt and J. Liebert (U. of Arizona) in an HST project to resolve the remarkable double-degenerate binary LB 11146 (Schmidt, Liebert, and Smith, 1998, *ApJ*, in press). One of the white dwarfs is highly magnetic with a field strength of around 700 million Gauss and the other is a non-magnetic ($B < 30,000$ Gauss), apparently normal DA white dwarf. This system presents important implications related to models for stellar formation and/or common envelope evolution. The HST observations do not resolve the binary and give an upper limit of 0.025" for the separation of the stellar components, which implies a 90% likelihood that the white dwarfs are separated by < 2.3 AU—which makes it likely that there was material exchanged between stars in the past (though a true common envelope stage is not required).

**Future Research Plans**

Smith continues various observational projects that investigate the blazar class of AGNs. Programs include simultaneous VLBI radio and optical polarimetry of BL Lacertae objects to find correlations between their radio and optical synchrotron continuum emission. A polarization survey of a new sample of BL Lacs is in progress to study the possibility that radio and X-ray selected BL Lacs have the same parent population. A nearby AGN will be imaged using HST in an attempt to resolve the scattering regions around the nucleus. This particular object, Mrk 231, exhibits many properties similar to broad absorption-line quasars, and presents an opportunity to resolve some of the nuclear structures that may be present in higher-redshift objects. Smith will continue a long-term project with M. Corbin (U. of Arizona) to monitor the emission-line profiles of quasars with exceptionally broad emission lines.

**Service**

Smith’s primary service activity is to manage the KPNO telescope operators. These nine individuals are responsible for the nighttime operation of the 4-m, 2.1-m, and WIYN telescopes, and as such are the primary representatives of the observatory to visiting astronomers during their observing sessions. Smith’s duties include hiring, scheduling, and coordinating training of the operators. Another major task he undertook during 1998 was to help convert the compensation method for the operators from an hourly wage to an annual salary. This conversion is intended to assist in retaining operators and give them a career path within the observatory. Smith also assisted in executing the WIYN Queue Observing Experiment. This experiment is designed to test observing strategies that most effectively match TAC-approved WIYN observing projects to observing conditions. About sixty programs per year are serviced in this manner by NOAO under the policy that the highest-ranked proposals are given the highest priority within the WIYN Queue. The flexible schedule of the Queue allows for synoptic programs to be pursued and the ability to dynamically match image quality requirements of programs with observing conditions. Smith’s duties include observing for the WIYN Queue program, maintenance of the program’s public Web pages, and some general administration associated with the experiment. Roughly 120 nights are allocated to the Queue annually. In addition, Smith is the instrument scientist for the Hydra Multi-Object Spectrograph. Hydra is one of the two main instruments permanently mounted on the WIYN telescope.

**Jeff Valenti, Research Associate**

**Areas of Interest**

Valenti’s primary research interest is the study of stellar spectra at infrared, optical, and ultraviolet wavelengths. In particular, Valenti is interested in stellar magnetic fields, accretion onto T Tauri stars, mass loss from evolved stars, molecular line diagnostics in M dwarfs, and spectral line bisectors. Valenti participates in instrument development, observing campaigns, data reduction, and radiative transfer modeling.
**Recent Research Results**
Together with Christopher Johns-Krull, Valenti definitively measured the magnetic fields on flare stars, finding fluxes 100 times larger than what is seen on the Sun. With more than two years of data, they still see no magnetic variations, which has important ramifications for the underlying dynamo. Magnetic fields are believed to play a crucial role in accretion onto young stars. They have obtained one of the only magnetic field measurements for this important class of stars, and last month, obtained some exciting polarization data, which will help constrain the field geometry. Nikolai Piskunov and Valenti incorporated a molecular equation of state into their Stokes radiative transfer code used to model the effects of stellar magnetic fields.

Valenti completed an IUE spectral atlas of high and low mass pre-main-sequence stars. Several stars show unusual fluorescent emission by very hot molecular hydrogen. It is also clear now that accretion, not stellar activity, plays a key role in producing the UV continuum. Graham Harper and Valenti put together a radiative transfer code that handles departures from non-LTE, spherical geometry, outflows, and realistic scattering.

Valenti participated in the ground calibration of the Space Telescope Imaging Spectrograph. He also helped to recommission a Zeeman analyzer with very high spectral resolution \( R = 240,000 \) at McDonald Observatory. Since arriving at Kitt Peak, he has helped to characterize and improve the Phoenix infrared spectrometer.

**Service**
Valenti has mainly worked to characterize the Phoenix infrared spectrograph. He studied the behavior of the closed-cycle cooler, use of the CO absorption cell for wavelength calibration, localized nonlinearities in grating motion, and use of low noise reads to minimize read noise. He wrote a command summary for the instrument control software, and is currently helping incorporate new stepper motors and encoders into Phoenix. He intends to develop a suite of routines designed to improve observing efficiency.

**Lloyd Wallace, Astronomer Emeritus**

**Areas of Interest**
Stellar and Planetary Atmospheres, Minor Constituents in the Earth’s Atmosphere, Spectroscopy of Sunspots and Cool Stars

**Recent Research Results**
Wallace has completed the analysis of the hydrogen chloride line at 3.4168 microns in twenty-five years of solar spectra obtained at the McMath-Pierce telescope. D. Hall (now at Institute for Astronomy, U. of Hawaii) obtained the earliest spectra with a 20-m horizontal spectrograph; most of those from 1979 to the present were obtained by various observers with J. Brault’s (now at Aeronomy Lab., National Oceanic and Atmospheric Administration) Fourier transform spectrometer, and from 1993 to the present by W. Livingston with the 13.5-m vertical spectrograph. This line is the result of absorption in the Earth’s stratosphere by HCl that is produced mostly by decomposition of man-made chlorinated compounds in the troposphere. The analysis shows an overall rise in the HCl amount of a factor of three from 1971 to 1990. However, in subsequent years the rate of increase appears to have decreased by a factor of two, presumably because of the decreased production of these compounds.

**Future Research Plans**
Wallace is in the process of analyzing the spectra of cool stars in the 1.02-1.35 micron region obtained by K. Hinkle with the Fourier transform spectrometer at the 4-m telescope. This spectral region is particularly interesting because of the variety of molecular absorbers that have been identified: vanadium oxide (VO), titanium oxide and sulphide (TiO and TiS), zirconium oxide and sulphide (ZrO and ZrS), cyanogen (CN), and water (H2O). We are in the process of finding the agents responsible for the otherwise unidentified features. Wallace
is also continuing his analysis of the sunspot spectrum in the red and near infrared. Two new absorption bands have been discovered but the identity of the absorbers is a mystery.
Todd Boroson, Astronomer

Areas of Interest
AGN emission lines, AGN host galaxies and environments, stellar populations, optical instrumentation.

Recent Research Results
Together with Salzer (Wesleyan), Gronwall (Wesleyan), Thuan (Virginia), Moody (BYU), Izotov (Kiev), and Kniazev (Special Astrophysical Obs.), Boroson has continued his work on samples of nearby emission line galaxies (KISS, the KPNO International Spectroscopic Survey). This long term objective prism survey with the Burrell Schmidt has yielded several hundred galaxy candidates with [O III] emission and over one thousand galaxy candidates with H-alpha emission over 100 square degrees out to a redshift of one-tenth. The discovery technique produces relatively complete sampling of the luminosity function out to substantial distances, and so the survey is well suited for studying both the luminosity function and the space distribution of these objects. Slit spectra of these candidates are now being obtained in order to identify objects of particular interest, including low luminosity objects with near-primordial abundances.

Future Research Plans
Boroson is beginning a new imaging study of QSO host galaxies using the WIYN telescope. The intent is to study a complete sample of objects by obtaining high spatial resolution images in two line-free bands in order to study morphology, luminosity, and color of the underlying stellar populations. Boroson is beginning a small-area survey aimed at identifying a sample of emission-line galaxies at a redshift of 0.5-0.6 analogous to the low-redshift sample from the KISS project described above. This survey would be made using the new CCD Mosaic Imager on the 4-meter Mayall telescope and several narrow-band filters. The goal would be to understand the evolution of the luminosity function over the redshift range spanned by the new sample.

Service
Aside from being instrument scientist for the new CCD Mosaic Imager now being commissioned, Boroson’s major service duties are associated with his position as US Gemini Project Scientist, Director of the NOAO Science Operations division (SCOPE), and associate director of NOAO. These duties include heading the office that has scientific and technical liaison responsibilities for the US community participation in the international Gemini project, as well as participating with the other national project scientists as the Gemini project scientist team. As the head of SCOPE, Boroson provides oversight and leadership for the expanded roles of this division, including the “before and after” activities for all the telescopes to which NOAO provides access. These activities range from proposal and TAC process support, and support of astronomers preparing proposals or observing programs, to data reduction, archives, and scientific outreach. In addition, Boroson serves on the Committee for Astronomy and Astrophysics, a National Research Council subcommittee of the Board on Physics and Astronomy and the Space Studies Board.

David S. De Young, Astronomer

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 Objects to starbursts in galaxies and the creation of megaparsec scale radio sources—the largest single coherent objects in the Universe. De Young's focus has been on the nature of the boundary between the outflow and the environment, for it is here that the momentum and energy transfer from the flow to the ambient medium, and it is this interaction that can reveal the characteristics of the outflow and hence constrain the nature of the object giving rise to it. Some of the results of this work have been an analytic description for the evolution of large scale structures seen in such boundaries; an explanation of the blue continuum seen in the central regions of some galaxy clusters in terms of jet induced star formation; a formulation of the relation between slow molecular outflows and fast moving collimated jets in proto-stellar and young stellar objects, and a model for the evolution of compact radio sources into large classical double sources that is consistent with observations from the parsec to 100 kiloparsec scale.

Future Research Plans
Galaxy Evolution - In collaboration with C. Norman (STScI) De Young plans an investigation of 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. In order to see if this model has any credibility, one needs a firm calculation which answers the following questions: is the hot debris, when mixed (or not) with the halo gas, thermally unstable? If so, is the instability damped or does it proceed to the nonlinear regime? Does the instability form dense sheets, filaments or clouds? Do these objects then persist and become gravitationally bound? This project requires complex and accurate modeling of the thermal conductivity in the context of time dependent numerical hydrodynamics, and the requisite algorithms are being developed. 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. The solution will require realistic modeling of a two phase ISM with radiative cooling, and the algorithms are now in hand to do this. 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 Chairman of the two KPNO telescope Time Allocation Committees, 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 airflow around and within various telescope structures to assist in evaluation of proposed designs for a new solar telescope for the National Solar Observatory. De Young also serves on the Board of Trustees of the Aspen Center for Physics and on the Executive and Steering Committees of the San Diego Supercomputer Center.

Buell T. Jannuzi, Assistant Astronomer

Areas of Interest
Observational Cosmology, Quasar Absorption Line Systems, Active Galaxies, Instrumentation for Surveys

Recent Research Results
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.

Lyman-alpha absorbers are observable from redshifts of zero to over 4, 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 ultra-violet spectra of quasars during the first four cycles of HST operations. The large and homogeneous catalogue of low redshift Lyman-alpha absorbers that resulted from this work (Jannuzi, et al. 1998, ApJS, 118, in press) is being used for a wide variety of studies. Recent results include evidence for clustering of some low redshift Lyman-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, edited by P. Petitjean and S. Charlot, Editions Frontier: Paris, p. 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 ($z = 0$) (Weymann, et al. 1998, ApJ, in press). Jannuzi is also leading a team which 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 groundbased telescopes, including the Gemini 8-m telescopes scheduled for completion at the turn of the century.

Together with Arjun Dey, Jannuzi is Co-PI of the NOAO Deep Wide-Field Survey, a deep optical (U,B,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; (2) Provide the astronomical community a sensitive multicolor database of objects from which samples may be selected for other interesting problems; (3) Furnish a database of interesting objects that can be investigated spectroscopically with the Gemini telescopes.


**Service**

Jannuzi is a member of the scientific staff of USGP/SCOPE. He also serves as the instrument scientist for all of KPNO's low to moderate resolution spectrographs. These include the R-C spectrograph and the Cryogenic camera used on the 4-m and the GoldCam spectrograph used on the 2.1-m (for more information see the Low-to-Moderate Resolution Optical Spectroscopy Manual for Kitt Peak). Jannuzi is also the project scientist for an upgrade of the camera and detector of the GoldCam spectrograph. Since 1997 Jannuzi has served as the coordinator 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 KPNO Time Allocation Committee. Jannuzi also 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 also a member of NOAO’s Instrument Projects Advisory Committee (IPAC).

**Tod R. Lauer, Associate Astronomer**

**Areas of Interest**

Cosmology: Large Scale Structure of the Universe, Distance Scale, Clusters of Galaxies, Deep Surveys; Normal Galaxies: Structure of Galaxies, Central Structure and Black Holes
Current and Near Term Research

In collaboration with M. Postman (STScI), Lauer has completed a deep near-IR imaging survey with the KPNO 4-m. This survey was designed to detect galaxy clusters out past a redshift of one, and thus serve as a basis for exploring how the largest structures in the Universe have evolved since the Universe was half of its present age. The survey covers 16 square degrees, contains one million galaxies, and is the deepest sampling of the Universe over such a large area. Lauer and Postman are now working on understanding the galaxy counts, correlations functions, and galaxy cluster catalogs generated from the survey as diagnostics of evolution of galaxies and structures sampled by the survey. The results show that the I-band survey is sensitive to structure evolution out to z~1, but that galaxy clustering has not evolved strongly since that time. As a member of the NOAO Deep Wide-Field Survey team, Lauer will be continuing work of this type.

In the coming year, Lauer and Postman, in collaboration with M. Strauss (Princeton), also hope to use NOAO observations of BCG to continue to search for the scale at which large scale galaxy bulk flows terminate. Lauer and Postman earlier used BCG to show that a bulk flow of galaxies appeared to exist on scales larger than would be expected under standard theories of galaxy formation. Bulk flows contain information about the distribution of matter in the Universe, thus the implication of the earlier Lauer and Postman work would be that the Universe remains inhomogeneous out to far larger distances than would be expected. The new work hopes to refine the earlier bulk flow measurement, as well as extending it deeper into space; the diameter of the volume being explored is about 1.5 billion light years.

Lauer also continues to use HST to study the makeup of nearby galaxies as part of a team effort chaired by D. Richstone (Michigan). Lauer has shown that the central structure of galaxies is very different than expected—the density of stars in the center appears to rise without limit, rather than leveling off to a constant value. This result may mean that black holes are common in the centers of galaxies; indeed a key goal of the Richstone team is to use HST to detect such black holes. To date the team has detected black holes in a number of galaxies, and hopes to use the new STIS on HST to increase their success rate.

Service

Lauer is editor of the NOAO Newsletter, the major vehicle of communication between NOAO and its community. The Newsletter is published on the NOAO Web Page and in hardcopy. Lauer also chairs selection of NOAO postdocs, and runs the Friday Lunch and joint NOAO/Steward colloquium series. Lauer is now assigned to the USGP/SCOPE division and a major component of his work in the coming year will be in support of this division’s activities. Presently Lauer is working on establishing an archive of Mosaic imaging data.

Catherine A. Pilachowski, Astronomer

Areas of Interest

Stellar Seismology, Stellar Compositions, Stellar Evolution and Nucleosynthesis, the Origin of the Elements in the Milky Way

Recent Research Results

Pilachowski, in collaboration with C. Sneden, R.P. Kraft, and E. Langer, is continuing to investigate abundance variations in globular clusters. Their previous work in M13 established the role of proton-capture nucleosynthesis in changing the relative abundances of neon, sodium, magnesium, and aluminum in stars on the giant branch. All M13 giants are affected to a varying degree by proton-capture nucleosynthesis and mixing, and the mixing of nucleosynthesis products to the surface is occurring at an earlier evolutionary phase than previously predicted. Research on globular clusters is an area where WIYN and Keck can provide complementary data, to mutual advantage. Time on Keck is too scarce to sample the number of stars needed to understand abundance
variations in globulars, but Keck data can follow up on specific targets identified from WIYN data to provide detailed analyses of many important elements. Without the WIYN data and the large numbers of stars that can be obtained, it is difficult to draw meaningful conclusions from the Keck data. Their work continues with observations of sodium abundances in M3, M15, and M19 from WIYN Hydra data.

Pilachowski, Tim Beers, Chris Sneden, and Rob Cavallo are using a new technique, that of low resolution spectroscopy of the O I triplet at 7772Å, to determine oxygen abundances in extremely metal poor stars ([Fe/H]<-2.5) identified in the Preston-Beers survey. Since the lines are closely spaced in wavelength, we can work on the blended feature at lower resolution without significant penalty in precision, and obtain spectra of fainter stars than would be accessible with a high dispersion spectrograph. They are investigating whether the oxygen excess observed at higher metallicity extends (or even increases) to lower metallicity. The composition of the lowest metallicity stars is probably dominated by the production of elements in a small number of supernovae explosions of relatively massive stars. The [O/Fe] ratio is sensitive to the mass of the progenitor supernova. The dispersion in the [O/Fe] ratio in extremely metal poor stars may well constrain the dispersion (or lower limit) of the masses of supernovae contributing to the chemical enrichment of Milky Way at its earliest phase.

**Future Research Plans**

Pilachowski, in collaboration with S. Barden, M. Giampapa, F. Hill, C. Keller, and J. Harvey, is working to detect and study acoustic oscillations in Procyon. They obtained 12,888 spectra during a 35-night observing run on the Kitt Peak Coude Feed telescope. Analysis of the observations is underway.

Pilachowski, in collaboration with Mark Giampapa, Jeff Valenti, and Sam Barden, is investigating possible variation in line bisectors in solar type stars using very high resolution spectroscopy ($R = 240,000$) on the Coude Feed Telescope.

**Service**

Pilachowski serves as Project Scientist for the ALPS++ Project to develop a new database and proposal management system for observing time proposals for both KPNO and CTIO. This effort is important not only to lighten the workload involved in handling proposals, but also to allow us to undertake easily the new tasks facing NOAO, including changing observing styles, telescopes, and instrumentation, and public access to independent observatories. In addition, she is responsible for support of the KPNO electronic proposal submission process for KPNO. Pilachowski, with Mark Giampapa (NSO), is responsible for the support of high resolution spectroscopy on KPNO telescopes. Pilachowski is also 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. Pilachowski continues to serve as a member of and Secretary to the WIYN Consortium Board of Directors, and she serves on the Council of the American Astronomical Society. She actively serves the broader community, participating on numerous advisory committees and review boards.

**Francisco G. Valdes, Scientist**

**Areas of Interest**

Cosmology, gravitational lensing, stellar spectroscopy, astronomical software

**Recent Research Results**

Recent work has centered on spectroscopy of a very broad sample of stars of various spectral types, temperatures, and abundances. This collection of stellar spectra will form a unique library, since it covers a larger variety of stars at higher resolution than any existing collection; the atlas will be made available to the astronomical community and public at large. The research use of this library will be for modeling stellar populations
in galaxies and for developing software that will be able to determine the temperature, mass, and composition of stars from large future spectroscopic surveys.

**Future Research Plans**
The observations and preparation of the library of stellar spectra is a continuing multi-year project. Valdes will participate in the NOAO Wide-Field Survey using the new NOAO CCD Mosaic camera. This survey is an effort by many of the NOAO scientific staff to utilize the powerful imaging capabilities of the Mosaic camera to provide data over a large region of the sky to the community and for various research programs of the participants. Valdes will study these data to measure masses of galaxies and clusters of galaxies which distort the images of distant galaxies by the gravitational bending of the passing light.

**Service**
Valdes is responsible for the development of forefront astronomical software for CCD and spectroscopic astronomical data. This software involves new techniques and complex programs to deal with the increasingly complex astronomical data produced by advanced astronomical instruments. The end-product is to extract the maximum astronomical information from the observations made at the telescopes. The software is required by users of NOAO instruments as well as other observatories in the United States and abroad. Support of this software involves assisting astronomers in the application of the programs and consultation about the best methods to use. This assistance is given to many NOAO staff, visitors, and astronomers from smaller institutions. Valdes is currently developing the data reduction software for the NOAO CCD Mosaic camera, a new forefront camera being built by NOAO to image a very large region of the sky in a single exposure.
Taft Armandroff, Associate Astronomer

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

Recent Research Results
Armandroff has been studying the dwarf spheroidal galaxies of the M81 group, in collaboration with Caldwell (SAO), Da Costa (Mt. Stromlo), and Seitzer (Michigan). This study was motivated by the opportunity to increase the number of galaxies defining the properties of dwarf spheroidals, and by the fact that the different environment of the M81 dwarfs compared to those of the Galaxy allows a study of how dwarf spheroidal properties change with environment. They obtained HST WFPC2 images through the F555W and F814W filters of two M81 group dE’s: BK5N and a new system found by them in a CCD survey with the Burrell Schmidt, F8D1. The resulting color-magnitude diagrams show the upper two magnitudes of the red giant branch. Surface brightness and total magnitude measurements indicate that BK5N and F8D1 have similar central surface brightness (24.5 and 25.4 mag/arcsec² in V, respectively), but F8D1’s larger length scale results in it being 3 magnitudes more luminous than BK5N. BK5N lies on the relation between central surface brightness and absolute magnitude defined by Local Group dwarf ellipticals, but F8D1 does not. F8D1 is more luminous for its central surface brightness than the relation predicts, similar to the large low surface brightness dwarf galaxies found in Virgo. The mean color of the giant branch is used to establish the mean abundance of each galaxy. F8D1, the more luminous galaxy, is significantly more metal rich ([Fe/H] ~ -1.0) than BK5N ([Fe/H] ~ -1.7). Both BK5N and F8D1 lie on the relation between absolute magnitude and metal abundance defined by Local Group dwarf ellipticals. However, as regards the relation between central surface brightness and metal abundance, BK5N again follows the Local Group dwarfs, while F8D1 deviates significantly from this relation. This suggests that the total amount of luminous matter is more fundamental in controlling metal enrichment than the surface density of luminous matter. Armandroff et al. also discuss the intermediate age stars, and note one globular cluster in F8D1. This research was recently published in the Astronomical Journal (February 1998).

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. Work is currently underway on a detailed study of the M31 dwarf spheroidal companion And II, using HST/WFPC2 and WIYN CCD imaging to construct a color-magnitude diagram that reaches below the horizontal branch. HST observations of And III are expected shortly. From these data, Armandroff hopes to learn whether these two galaxies resemble their Galactic counterparts as much as And I does (see Da Costa, Armandroff, Caldwell, Seitzer 1996, AJ, 112, 2576).

Service
Armandroff serves as project scientist for the NOAO optical/UV instrumentation program. In this capacity, he coordinates all optical instrumentation development efforts and serves as a member of the Instrument Projects Advisory Committee (IPAC). Armandroff is a member of the team developing and commissioning the 8K x 8K CCD Mosaic Imagers for KPNO and CTIO. Armandroff participates in the group overseeing construction of a version of the Hydra multi-fiber positioner for the CTIO 4-m, and the group designing a tip/tilt imager for WIYN. He also serves on the “Kitchen Cabinet” for KPNO operations.
Samuel C. Barden, Scientist

Areas of Interest
Stellar Physics and Dynamics, Binary Stars, Spectroscopic Instrumentation

Recent Research Results
Barden has undertaken a collaborative effort with M. Giampapa and C. Pilachowski to observe the long term behavior of absorption line bisectors in the stars recently detected to have possible planetary companions. It is quite possible that line bisector modulations due to stellar pulsations could in some fashion mimic the behavior of an orbiting body when observed at relatively low resolution. Higher resolving powers (R = 100,000) than those used to detect the low level radial velocity motions are needed to see if indeed the behavior can be accounted for by modulations in the shape of the absorption lines rather than by true reflex motions of the star. This project has received funding through the NASA Origins program to carry out observations with the McMath-Pierce Solar Telescope facility.

Service
Hydra/CTIO: Barden serves as co-project scientist with Robert Schommer from CTIO in the production of a multi-fiber positioner, Hydra/CTIO, which is based on the same concept as Hydra/WIYN. He is supervising and participating in the fiber cable construction and assembly, and in laboratory testing and evaluation of the robotic fiber positioner. The Hydra/CTIO project is nearing completion with delivery of the working instrument for use on the Blanco 4-meter telescope at the start of FY 1999. Barden will reside in Chile during the expected three-month commissioning period immediately following delivery of the instrument.

Gemini CCD Controllers: Barden is project scientist for the Gemini CCD controllers. The goal is to deliver controllers for use on the Gemini optical instruments by the end of FY 1998.

US Community Liaison for Gemini Optical Instruments: Barden serves as the US Community liaison for the optical instruments being fabricated for the Gemini telescopes. In this role, he attends and participates in the design reviews for both GMOS and HROS. He is expected to assist at some level in the integration and testing of these instruments as well as in the on-telescope commissioning.

Volume-Phase Holographic Gratings: Barden is PI of a one-year NSF grant to evaluate the performance of eight gratings. The goal is to explore the viability of a new technology grating for astronomical applications. These gratings diffract light by a thin layer in which fringes due to index of refraction modulations form the grating rather than by surface discontinuities as in classical gratings. These new gratings offer the potential for high diffraction efficiencies, versatility which cannot be obtained with surface relief gratings, and large grating dimensions. Barden is collaborating with Co-I's at Kaiser Optical Systems, Inc., a company which currently produces small volume phase gratings. At the end of the grant period, some of the test gratings will be made available to the US astronomical community through the NSF for implementation into astronomical instruments. Barden is also a Co-I in the development of a volume phase holographic grism which will be implemented in the LDSS spectrograph at the Anglo-Australian Observatory for observations of the Southern Hubble Deep Field.

High Efficiency Spectrograph: Barden is involved in the development of conceptual ideas for a “high efficiency spectrograph,” which KPNO is considering as a potential replacement for the aging R-C spectrograph at the Mayall 4-meter. Barden is exploring new technology gratings and optics in an attempt to simplify and enhance the spectrograph’s efficiency.

Committees: Barden currently serves on the “Kitchen Cabinet,” which provides counsel to the KPNO director. His role with the Gemini CCD controllers also involves him in the Gemini Optical Instruments Science
Jonathan Elias, Astronomer

Areas of Interest
Star Formation and Evolution, Magellanic Clouds

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 dust forms. 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 data from the Infrared Space Observatory (ISO) 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 Doug 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 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 HST. The collaborators have been assigned HST time to observe the globular cluster systems around five distant giant ellipticals. In addition, M31 globular clusters will be observed from the ground in order to improve the calibration of the V-H color.

Service
Elias's service activities during the last year have been in several areas. He has served as project scientist for the Gemini Near-Infrared Spectrometer since 1995, and transferred from Chile to Tucson in January 1996 as a consequence. This position also entails service on the Gemini Infrared Instrumentation Science Working Group and the NOAO Instrument Projects Advisory Committee. In addition, he is NOAO project scientist on two projects that are currently in the planning stages: a joint project with the University of Florida to build a wide-field near-infrared imagers/multi-slit spectrometers, and a project to build a copy of the Gemini Near-Infrared Spectrometer for joint use by SOAR and Gemini South.
Kenneth H. Hinkle, Associate Support Scientist

Areas of Interest
Circumstellar and Interstellar Matter, Molecular Spectroscopy, Peculiar Stars, Instrumentation

Recent Research Results
During the past year Hinkle has worked extensively on the high resolution infrared spectrograph Phoenix. While this instrument is in regular use by KPNO visitors, several components needed modification before commissioning as a facility instrument. As part of this effort a paper was published documenting the instrument (SPIE 3354 in press). A number of observing runs have been undertaken to characterize the instrument. These runs have produced data or partial data sets for a number of projects. While most of the data is still not fully reduced, and one of the commissioning projects underway is the development of optimized reduction software, some early results have been published. With co-investigators B. McCall and T. Oka (U. Chicago) and T. Geballe (Gemini), Hinkle has collaborated in a program to measure the abundance of the ion H3+ in the interstellar medium. H3+ is formed as cosmic rays ionize molecular hydrogen. H3+ then reacts via a proton hop route to produce the wide variety of complex molecules observed by radio astronomers. H3+ is not easy to detect due to its symmetry, reactivity, and the nature of the spectrum. The first detection of H3+ in the diffuse interstellar medium was reported (1998 Science 279 1910) using Phoenix spectra. An additional article by McCall, et al. on H3+ is in the 1998 Faraday discussion. In the last year Hinkle also completed a number of papers on projects not related to Phoenix. With R. Joyce, L. Wallace, M. Dulick (NOAO) and D. Lambert (Texas) Hinkle has submitted to AJ a paper on medium resolution spectra of cool stars, particular those of S-type, in the 1.0-1.3 micron region. Unidentified features were searched for in a spectral region where sulfur compounds have been identified. Previously identified bands from exotic molecules like TiS and ZrS were confirmed but no strong new bands were seen. With M. Meyer (Arizona), S. Edwards (Smith), and S. Strom (Massachusetts), a paper has been submitted to ApJ on spectral classification in the H band. With L. Wallace a paper has been published (1997 ApJS 111 445) on spectral classification in the K band. Hinkle and T. Lebzelter (Vienna) published a paper (1997 AJ 114 2686) on the pulsation velocities of AGB variables as measured in the K and H bands. In the area of instrumentation, Joyce (NOAO), Hinkle, Meyer (Arizona), and Skrutskie (Massachusetts) have published (SPIE 3354 in press) an article on the use of a thermal blind infrared array in a warm spectrograph.

Future Research Plans
For three years Hinkle, F. Fekel (Tennessee State) and R. Joyce (NOAO) have been observing on a quarterly basis a group of late-type binary stars, which include interacting symbiotic pairs, with the Coudé Feed telescope and the IR NICMAS array. Visual spectroscopy of interacting binaries is confused by (hot) emission from the accretion disk. The infrared spectrum is dominated by radiation from the cool star in the system. A few of the symbiotic systems now have well defined orbits from the Coudé Feed data and as expected the results are considerably improved over visual data. Another motivation of this project is a planned extension of the object list using Phoenix to include, for instance, very highly reddened massive binary systems. Hinkle has also engaged in a search for several circumstellar organic molecules using Phoenix. With M. Kress (NASA Ames) and P. Bernath (U. Waterloo), Hinkle is looking for various symmetric organic molecules of interest in the early solar system, for example methane, ethane, and allene, as well as the pure carbon chain molecules. Initial problems with astigmatism in Phoenix hindered this research. Work by Hinkle and others at NOAO to improve the image quality should make Phoenix very productive in searching for circumstellar and interstellar lines. Hinkle and collaborators B. Hrivnak (Valparaiso) and S. Kwok (Calgary) plan to use the Phoenix spectrograph to explore the velocity structure and ionization structure of the circumstellar shells of post-AGB stars. These shells show considerable spatial structure and are intermediate between the complex spatial structure of planetary nebula and the simple geometry of AGB mass loss. With L. Wallace (NOAO) and J. Vanti (NOAO) Hinkle is investigating rotation, magnetic field, and temperature determinations from high resolution K band.
spectra of M dwarfs. In 1999 Phoenix will be taken to CTIO. Hinkle is looking forward to extending his work on late-type variables to the southern sky. His collaborators on AGB variables are J. Hron and T. Lebzelter (Vienna). Several papers on northern field Miras are in preparation with Hron and Lebzelter, and work is planned on a number of important southern objects.

Service
Hinkle's service activities include being project scientist for the Phoenix spectrograph. This project started in 1991 and has accounted for nearly full-time effort by Hinkle since then. The Phoenix project is a major observatory contribution to the community. Phoenix now allows high resolution (R = 100,000) spectroscopy in the 1-5 micron infrared to much fainter limiting magnitudes than previously possible. Phoenix will ultimately serve a larger community than Kitt Peak. Current plans call for use of this instrument at CTIO in early 1999 and with Gemini as well as on Kitt Peak. Hinkle has done a large part of the program management for Phoenix, has provided the astronomical input, and has resolved many engineering and optical design issues. Hinkle did the optical assembly and oversaw the mechanical assembly. Hinkle is now in charge of bringing the instrument to complete user readiness as well as supporting user runs. Hinkle also maintains FTS spectra dating back to 1976 in an archive. Spectra are available upon request. Hinkle and collaborators are continuing to publish atlases based on this and other archival material making these spectra more readily available to the community. Since Phoenix is a Gemini instrument, Hinkle serves on the Gemini infrared instrumentation working group. Hinkle is also the 2.1-m telescope scientist.

K. Michael Merrill, Associate Support Scientist

Areas of Interest
Star Formation, Young Stellar Objects, Interstellar Medium, Circumstellar Envelopes, Late Stellar Evolution, Infrared Instrumentation, Data Acquisition and Reduction

Recent Research Results
Merrill and Gatley have recently discovered a striking correlation between the results of two very different approaches to the study of the ionized gas in the Galactic center. Specifically, the dynamical model by Lacy, et al. 1991 (ApJ 380, L71), based on observations of the neon 12.8 micron line, isolates a one-armed Keplerian spiral structure that is also prominent in Merrill and Gatley's images of the reddening of the ionized gas, based on KPNO 1.3-meter COB Brackett alpha and gamma emission line images. They will deploy capabilities unique to KPNO to study the "central engine" buried within the Galactic center, which is otherwise hidden from conventional optical techniques by massive extinction. Observations at both high angular resolution to get spatial details (provided by the DLIRIM real-time shift and add facility which produces diffraction-limited images at the 4 meter telescope) and high spectral resolution to get the kinematics (provided by the Phoenix spectrograph) will be required to scry the truth from the tangle in the Galactic center. These observations will significantly improve the database for ionized gas kinematics and star counts, providing a stringent test for the "central engine." Furthermore, because the Lacy spiral shows up as a distinct feature in the extinction map, one can confidently predict that the kinematic profiles at Brackett alpha and Brackett gamma will show differential extinction which will make it possible to tie the kinematic and the imaging experiments together.

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 his 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 arc minutes 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 a region of star formation covering a wide range in distance, total mass, and age.

Service
As an Infrared Imaging Scientist at KPNO, Merrill oversees the IR imagers and attendant visitor support at KPNO, including instrument set-ups and observer checkouts, and is the point of contact on performance issues for both proposers and the TAC during the proposal cycle. He is project scientist for the KPNO SQIID upgrade to 512 × 512 InSb and actively involved with the shake-down and deployment of new IR instrumentation. As the responsible scientist 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. As package scientist for the next generation Gemini/NOAO Array Controller project and responsible scientist for the Aladdin InSb 1024 × 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. Merrill continues as advisor to Gemini for IR instrumentation—detectors, array controllers, limiting performance and observation techniques. Merrill has been an active participant in outreach activities within the local schools, including teaching classes and coaching Science Olympiad teams, and at scientific meetings.
Jacques Beckers, Director, NSO

Areas of Interest

Recent Research Results
Beckers is undertaking the feasibility study of a large aperture solar telescope (CLEAR), including a survey of sites for its location and the development of techniques for remote sensing of atmospheric turbulence.

Future Research Plans
Beckers will complete the solar telescope feasibility study. On the basis of the site survey results, he will do research into the physics of daytime seeing at lake sites.

Service
Beckers is Director of the National Solar Observatory, Editor of the journal *Experimental Astronomy*, a member of the USRA Astronomy and Space Science Council and of the Advisory Board of the Center for Astronomical Research in the Antarctic (CARA).

Michael Dulick, Assistant Scientist

Areas of Interest
Molecular Spectroscopy, High-Resolution Fourier Transform Spectrometry, Study of Molecules of Astrophysical Interest

Future Research Plans
Dulick plans to use the McMath FTS to record laboratory spectra of diatomics in the infrared and visible to aid in the assignment of sunspot spectra. A significant portion of the analysis will entail the development of an effective internuclear potential model for the electronic states of transition-metal diatomics in order to utilize information derived from low-temperature laboratory spectra in predicting the high-temperature spectra of sunspots. Dulick will also participate in projects to upgrade the detectors and data collection system for the FTS.

Service
Dulick serves as the NSO FTS Instrument Scientist for visiting investigators funded under the NSF Chemistry grant for Laboratory Fourier Transform Spectroscopy, with specific duties that include providing assistance in the experimental design and setup and the instructional use of the instrument.

Richard Dunn, Astronomer

Areas of Interest
High Resolution Imaging, Instrumentation

Future Research Plans
Dunn plans to continue his work on improving the quality of resolution at the Vacuum Tower Telescope. He will also continue to consult on the upgrade to the Solar Observing Optical Network (SOON).
Mark Giampapa, Associate Astronomer

Areas of Interest
Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results
Giampapa and his colleagues, S. Baliunas (SAO) and R. Radick (AFRL), are in the process of completing a survey of chromospheric Ca II H and K line emission in the numerous solar counterparts in the solar-age and solar-metallicity open cluster M67, using the WIYN telescope with the Hydra multiobject spectrograph. The results will indicate the range of potential amplitudes of the solar cycle through observations of about 100 Sun-like stars. This is critical to know in view of the impact of solar variations on long-term global climate changes. Giampapa and his collaborators expect to submit for publication in early FY1999 the results of this unique solar-stellar program.

M. Giampapa and his collaborators plan to repeat their initial survey of magnetic activity in the many Suns in M67 in order to begin an investigation of long-term variability analogous to what would be expected from cycle-like modulations of chromospheric activity. In addition, Giampapa and his colleagues in the solar-stellar community will explore the prospects of establishing a long-term program of measurement of cycle properties in solar analogs at a large-aperture telescope. As a member of the SONG (Stellar Oscillations Network Group), Giampapa and his colleagues expect to complete during FY99 the reduction and analysis of the 30-day Procyon observing campaign. A positive result will open a new vista for the experimental study of stellar interiors through the techniques that have been so successfully employed in helioseismology as exemplified by the GONG program. S. O'Brien (former REU student; U. of Arizona graduate) and Giampapa will submit for publication the results of their long-term monitoring program of spectroscopic variability in T Tauri stars. Their analysis has disclosed persistent, periodic variability in the mass outflow/inflow regions of these precursors to Sun-like stars and solar systems. In collaboration with C. Pilachowski (NOAO), S. Barden (NOAO/KPNO), J. Valenti (NOAO/KPNO) and D. Deming (NASA/GSFC), Giampapa is leading an effort to measure line bisectors in stars that have been reported to have Jupiter-like companions. The results will illustrate the potential contribution of intrinsic stellar atmospheric motions to apparent Doppler shifts that could be misinterpreted as being due to planetary companions. This investigation is supported by a grant from the NASA Origins of Solar Systems Program.

Service
Giampapa serves as the Science Branch Chief for the Tucson site of the National Solar Observatory. In this role, he has overview responsibilities for the scientific and instrument development activities at NSO/T. Giampapa is chairman of the Tucson site Project Review Committee (PRC) and serves as a member of the full NSO PRC. He is a member of the NSO Management Team and also serves on the NSO/Kitt Peak TAC where he advises on proposals for the use of the solar-stellar spectrograph at the McMath-Pierce facility. He is the Program Scientist for the McMath-Pierce nighttime program which is currently operated with grant funds contributed by Principal Investigators. Giampapa is the Instrument Scientist for the SOLIS Integrated Sunlight Spectrometer (ISS).

Other activities include educational outreach through participation in the REU program and through teaching a class in Laboratory Astronomy to non-science majors at the University of Arizona where he is an Adjunct Astronomer and Lecturer in Astronomy. In addition, Giampapa serves as a member of the editorial boards for the journals Solar Physics and New Astronomy Reviews, and a member of the Advisory Board for the Astronomical Society of the Pacific Conference Series.
Jack Harvey, Astronomer

Areas of Interest
Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results
Recent research by J. Harvey has focused on the solar magnetic field as the driver of solar activity. In particular, the polar magnetic field is a particularly interesting and important component. For example, recent studies of cosmic rays have suggested that the heliospheric magnetic field is not symmetric about the ecliptic in the sense that the south pole appears to be stronger. Our observations from Kitt Peak have shown that, indeed, the south pole field is stronger. Furthermore, the amount of activity in the form of coronal mass ejections and new active regions is much higher in the south. This asymmetry is being investigated. J. Harvey is also continuing his helioseismic studies mainly under a NASA grant and concentrating on the background spectrum. This was once thought to be uninteresting compared with the strong oscillation modes used to probe the solar interior, but now we know that there is an intimate and important connection between the two.

Future Research Plans
During FY 1999 Harvey will concentrate on the SOLIS and GONG upgrade projects. Scientific research will focus on studies of the polar magnetic field, intranetwork magnetic fields, the chromospheric magnetic field, and the evolution of solar activity. This work is supported in part by a grant from the ONR (of which J. Harvey is the PI) and is in close cooperation with a post-doctoral fellow, Dr. J. Worden. He will also continue his research in helioseismology through collaborations with Dr. S. Jefferies and T. Duvall. He is collaborating with members of the recently launched TRACE satellite team to study small-scale solar activity.

Service
J. Harvey performs observatory service as Chair of the NSO/KP TAC and NSO Scientific Personnel Committee, Instrument Scientist for the GONG project, Telescope Scientist for the KP Vacuum Telescope, and Project Scientist for the SOLIS project. He expects to continue with those responsibilities. In the outside community he serves on NASA and NSF review panels and is a member of the editorial board of the journal Solar Physics. He is participating in two proposals for future solar space missions.

Frank Hill, Scientist

Areas of Interest
Helioseismology, Asteroseismology, Fluid Dynamics of the Solar Convection Zone, the Solar Activity Cycle, Digital Libraries

Recent Research Results
Hill continues to perform research in helioseismology. Currently he is focusing his efforts on improving the estimates of the parameters that describe the features (peaks, ridges, rings) in the solar acoustic spectrum. These parameters are the fundamental data for helioseismology and provide the foundation on which rest all inferences about the solar interior. Consequently, Hill is working on advanced time-series analysis including multi-tapers and wavelet denoising with P. Stark (UC Berkeley), R. Komm, Y. Gu, and S. Jefferies; and with R. Howe on detailed calculations of the spatial leak structure arising from the non-orthonormality of spherical harmonics on a partial sphere.

Service
Hill serves as the GONG Data Scientist, developing algorithms for the reduction and analysis of data for global helioseismology. He serves as the NSO Digital Library Scientist, using an NSF Space Weather Program grant to place NSO data on-line and accessible over the Internet. This service is now available at the URL
http://www.nso.noao.edu/diglib. Hill typically supervises six staff members, currently three scientists, one programmer, and two data technicians. Hill is a member of the NOAO Stellar Oscillation Network Group (SONG) Steering Committee, the IAU Commission 12 Organizing Committee, the IRIS helioseismology network Scientific Committee, and the NASA Space Physics Data System Solar Physics Discipline Team. Hill is a member of the NSO Telescope Allocation Committee. He continues as a participant in Project Astro.

Robert Howard, Astronomer

Areas of Interest
Observational Study of Surface Active-Region and Sunspot Orientations and Velocities as Diagnostics of Sub-Surface Conditions Related to the Dynamo Process in the Sun

Recent Research Results
Studies of the Mount Wilson data sets have shown recently that the surface rotation of the magnetic axes of active regions is directed, on average, toward the average orientation in each hemisphere (not toward the east-west orientation). The average orientation is a tilt of a few degrees, with the leading portion of the regions equatorward of the following portions. It is not clear why this tendency for motion of the axis toward the average values should exist. It may signal a preferred orientation of subsurface source magnetic flux ropes. Earlier theoretical work which explained the average orientation as due to the effect of the Coriolis force on rising flux tubes is now in some doubt.

Future Research Plans
Howard will continue studies of surface characteristics of solar active regions as diagnostics of sub-surface flux tube dynamics. This work promises to shed light on the dynamo process that is believed to operate near the base of the solar convection zone. These studies are being carried out in part in collaboration with P. Gilman (HAO, Boulder, CO), and K. R. Sivaraman and S. S. Gupta (Indian Institute of Astrophysics, Bangalore, India). This project involves the analysis of measurements of the positions and areas of all of the sunspots on the daily Kodaikanal (India) white-light, full-disk photographs of the Sun—a series which started in 1906. Analysis of these data, in conjunction with similar data from Mount Wilson measured several years ago, will continue during the next year. The Kodaikanal and Mount Wilson data sets have been combined into one large data set. In order to do this, optical aberrations in the Kodaikanal data were identified and corrected for. Using the combined data set, rotation rates and meridional motions of these spots will be examined, and the results from the observations at the two sites will be compared. Other work by Howard utilizes the Mount Wilson sunspot data set and the Mount Wilson magnetic active region data set, put together by Howard several years ago. These studies will center on effects, such as the Coriolis force and magnetic tension in the subsurface flux loops, that govern the orientations and motions of the magnetic field lines that emerge to form active regions.

Service
Howard provides editorial assistance for all NSO documents (quarterly reports, newsletter input, etc.). As a service to the community, he serves as co-editor of the journal Solar Physics.

Stuart Jefferies, Associate Scientist

Areas of Interest
Solar/Stellar Oscillations, Image Restoration and Reconstruction, Interferometry

Recent Research Results
Jefferies and N. Meunier (Meudon Observatory) continued developing a technique to improve the accuracy with which the solar oscillation power spectrum can be modeled. Their research shows that many of the
oscillation measurements reported in the literature to date, are contaminated by systematic offsets. Inversions of these biased data will lead to incorrect inferences about the Sun's internal structure.

Jefferies and C. Toner continued to look for oscillatory signals at the solar limb. Theoretical calculations predict that for intensity observations, both the p-mode and g-mode signals should peak near the limb. An analysis of Ca II K-line intensity data, obtained at South Pole, suggests that g-modes may be visible. A preliminary analysis of a small amount of intensity data obtained by MDI suggests that the signal should be at least a factor of ten clearer in the MDI data. The detection of g-modes would allow a more accurate probing of the deep solar interior.

Jefferies, G. Severino and Th. Straus (Capodimonte Observatory, Napoli, Italy) studied the solar background signals and their interaction with the solar oscillation signals. Accurate measurement of the non-oscillatory components of the background signal will provide information on solar convection. Preliminary work shows that incorrect background estimation will affect the precision of the p-mode measurements.

Jefferies and J. Benson (US Naval Observatory, Washington DC) worked on developing an algorithm for analyzing the data from the Naval prototype Optical Interferometer. This device is routinely used to measure visibility amplitudes and closure phase for stellar objects at optical wavelengths.

Jefferies, R. Garcia (Service d’Astrophysique, France), H. Shibahashi and Y. Osaki (U. of Tokyo) studied the high-frequency region of the power spectrum of solar velocity observations obtained by the GOLF experiment on board SOHO. They explained why the observed spectrum shows mode-like structure above the acoustic cut-off frequency for the solar atmosphere (this was not expected for unimaged observations).

Jefferies, J. Christou (Starfire Optical Range, New Mexico), K. Hege and M. Cheselka (U. of Arizona) continued the development of an iterative algorithm to solve the blind deconvolution problem. This is a problem in which the observer has incomplete knowledge of both the object of interest and also how his observation has been degraded. The algorithm now solves the problem in both the image domain and the Fourier domain. Tests are underway to measure the improvement in the estimation of the low-spatial frequency components of the restorations.

**Future Research Plans**
Jefferies plans to continue with the above mentioned projects until closure.

**Service**
Jefferies coordinates the internal reviewing of papers.

**Christoph Keller, Associate Astronomer**

**Areas of Interest**
Solar Magnetic Fields (Observations and Interpretation), High-Precision Imaging Polarimetry (Visible and Near-Infrared), Image Reconstruction Techniques (Speckle Imaging and Phase-Diversity), Telescope and Instrument Design, Detector Development (Polarimetry, Hyper-Spectral Imager), Astero-seismology

**Recent Research Results**
Extremely precise linear polarization measurements have opened a new window to solar research. These techniques developed by Keller give new insight into atoms and molecules and their radiation in the solar atmosphere and properties of weak, turbulent magnetic fields. In particular, magnetic field strengths below 1 G can be measured, compared to the limit of about 100 G for Zeeman-effect based observations in the visible and
near-infrared. Speckle polarimetry reconstructions of magnetic elements in the quiet sun have provided the first statistically relevant sample of fluxtubes, the building blocks of solar magnetic fields outside of sunspots.

Future Research Plans
Keller will use the McMath-Pierce telescopes to investigate solar magnetic fields in the quiet Sun, in particular weak and turbulent fields, by using the Zurich Imaging Stokes Polarimeter I and II and the Near-Infrared Magnetographs (NIM) 1 and 2. The new NIM 2 instrument will be used to get extensive vector magnetic field data. Further observations of scattering polarization will be used to deduce spatial and temporal variations of the turbulent magnetic field of the Sun. Observations with the Sacramento Peak VTT will be used to study the dynamics of magnetic elements. Keller is a co-investigator for two successful NSF proposals to obtain rapid image sequences and to obtain diffraction-limited time sequences using phase-diversity reconstruction techniques. The design of SOLIS components will use a major fraction of Keller's time during the next three years.

Service
Keller is the telescope scientist for the McMath-Pierce telescopes. He provides observing support at the McMath-Pierce facility, is involved in the design and implementation of new instruments such as the Near-Infrared Magnetograph 2 and the Solar Optical Long-term Investigations of the Sun (SOLIS). He leads the real-time software and hardware team for SOLIS and co-leads the Vector-Spectromagnetograph efforts. Keller is a member of the Project Review Committee, the NOAO Exploration of Technology group, and the Search Committee for the next NSO director.

John Leibacher, Astronomer

Areas of Interest
Helioseismology, Atmospheric Dynamics

Recent Research Results
The first results from GONG are beginning to emerge, ranging from the thermodynamics and kinematic structure of the solar interior, to the effect of spatial inhomogeneities on the p-modes, to the atmospheric response of the resonant and non-resonant sound waves.

Future Research Plans
Leibacher will be devoting the majority of his efforts to assuring GONG's technical and scientific success. He will also continue work on techniques of time series analysis and chromospheric oscillations. Ideas about the observational signature of the convective excitation of p-mode oscillations and the detection of gravity modes will be pursued with data from GONG as well as the SOI/MDI instrument onboard the SOHO spacecraft.

Service
Leibacher serves as the Director of the Global Oscillation Network Group program. He serves on the editorial board of the journal Solar Physics, and chairs the Goddard Space Flight Center's Space Sciences Visiting Committee and the AAS Solar Physics Division's Hale Prize Committee.

Haosheng Lin, Assistant Astronomer

Areas of Interest
Solar Irradiance Variations, Infrared Measurements of Solar Magnetic Fields
Future Research Plans

H. Lin will continue to work on the construction and implementation of the Precision Solar Photometric Telescope (PSPT) for the RISE project. Lin completed the PSPT prototype, and installed it at Observatory of Rome in Italy in 1996. Daily high photometric precision full-disk data in the Ca II K wavelength, and in the blue continuum at 4096 Å are now available to the solar community. This is the beginning of the process to build up a database spanning over a solar cycle for the studies of the total solar irradiance variations observed from satellite experiments. In the short term, Lin is interested in using these data for the study of the energy balance of active regions and the continuum contrast of the faculae and network elements; he will also search for brightness structures that may be related to large scale flow on the Sun.

Lin also plans to continue his work on infrared measurements of solar magnetic fields. He constructed a polarization analyzer that is tunable from 1 to 2 microns, and integrated it with the IR array system at Sac Peak. This new IR capability at Sac Peak now allows us to measure solar magnetic field over a broad range of solar features. Lin used this new IR polarimeter to obtain new data on the intra-network magnetic fields, simultaneous photospheric and chromospheric level vector magnetic fields using the Fe I 15648 Å and He I 10830 Å lines, and filament magnetic field using also the He I 10830 Å line. He will continue to explore the potential of this new instrument, including coronal magnetic field measurement using the infrared Fe XIII line at 10746 Å and 10797 Å lines.

William Livingston, Astronomer Emeritus

Areas of Interest
Solar Magnetic Fields, Solar Rotation, Solar Spectrum Variability with Time (Sun-as-a-Star), IR Spectrum Atlases

Recent Research Results

Working with Nadege Meunier (graduate student from Meudon, France), Livingston made high sensitivity magnetic scans of the solar disk using the favorable IR line of Fe at 1.5648 micron. The aim is to detect and measure weak magnetic fields, a project well-suited to solar minimum. They employ a 300 hz polarization modulator which practically eliminates seeing noise. Modeling of the data by Sami Solanki (Zürich) suggests that perhaps over half of the Sun's surface flux goes undetected by ordinary magnetograms (Astronomy & Astrophysics, 1998, 331, 771-781).

With Binxun Ye (Beijing), Livingston has devised a new way to measure rotation right at the heliographic poles. The spectrograph slit is positioned about 5 arcsec inside the limb and, with the spectrograph fixed (not turning as is usual to track the heliostat fed image), the Sun's pole is allowed to slide past the slit. They observe the CO fundamental lines at 4.6 microns with a nearby water vapor line as a wavelength reference. CO offers the advantage of sampling only the quiet Sun. By being at the extreme limb, the influence of super granular motions (a confounding noise in Doppler measurements) is suppressed. One result is that occasionally the Sun displays no rotation at the extreme pole (Solar Physics, 1998, 179, 1-15).

Livingston continues his long-term monitoring of the Sun's irradiance spectrum. In collaboration with O.R. White (HAO/NCAR), they have a continuous record since 1974 of the behavior of chromospheric Calcium H and K, Helium 10830, H-alpha 6562, Calcium 8542, photospheric Carbon 5380, Beryllium 3131, and various Iron lines. Some long-term secular trends have been discovered indicating subtle alterations in the solar output. The ISS (solar high dispersion spectrometer) of SOLIS will eventually take up this program on a daily basis. The present aim is to overlap ISS and the present 13.5-m spectrograph data streams so they can be tied together.

He also makes 2-3 observations per year with the 1-m FTS. This archive goes back to 1980 and is an attempt to track spectrum line asymmetry arising from the average convective motions of the 3 million plus granules on
the disk. It could be that the weak fields mentioned above suppress in a variable way granular convection, possibly another link in the Sun-Climate relation.

**Future Research Plans**
Livingston plans to continue with the above programs, especially the spectrum monitoring.

**Service**
Livingston acts as the resource person for phone queries and other requests for solar information. He is helping Turkish astronomers prepare for the August 11, 1999, total eclipse, including a post-eclipse international meeting on eclipses.

**Douglas Rabin, Astronomer**

**Areas of Interest**
Magnetic Fields and Atmospheric Structure

**Recent Research Results**
D. Rabin has been investigating the three-dimensional structure of the solar atmosphere, from the base of the photosphere to the inner corona. The importance of understanding this structure springs from the growing realization that classical one-dimensional models of stellar atmospheres may fail at a basic level because the "average" conditions embodied in the model exist almost nowhere in the actual, highly inhomogeneous atmosphere. Rabin's work with T. Ayres (U. of Colorado) and T. A. Clark (U. of Calgary) supports this concept through direct measurements of the temperature field in the solar chromosphere, using vibration-rotation lines of the carbon monoxide molecule in the infrared near 4.8 microns. Rabin studied and reported on the prospects for measuring magnetic fields in the low corona using the Zeeman effect. Based on these results, Rabin and C. Keller (NSO) initiated a search for magnetic fields using the ZIMPOL polarimeter at the NSO Evans Facility coronagraph. The sensitivity reached in the initial observing run, although insufficient to detect a Zeeman signal, was encouraging and will be improved with a modified instrumental setup.

**Future Research Plans**
In the coming year, Rabin plans to continue research on the temperature minimum region using infrared spectroscopy in collaboration with visible imaging and spectroscopy (K. Sivaraman, Indian Institute of Astrophysics) and ultraviolet spectroscopy (T. Ayres and F. Hill). Rabin and Keller will continue their attempt to measure coronal magnetic fields with improved sensitivity. Rabin and Keller will study weak photospheric magnetic fields using the Near Infrared Magnetograph. Rabin and D. Jaksha (NSO) will continue to develop a large-format infrared camera based on an Aladdin array (resulting from the NOAO/USNO collaboration) and an NOAO-developed array controller.

**Service**
Rabin leads the solar infrared effort on Kitt Peak and is PI of the NASA-supported Near Infrared Magnetograph project. He is co-leader of the SOLIS Vector Spectromagnetograph team. He serves on the NSO/Kitt Peak Telescope Allocation Committee and Project Review Committee. He serves on the organizing committee for the proposed NSF Solar Magnetism Initiative and the advisory committee for the NSF Radiative Inputs from the Sun to Earth (RISE) program. Rabin also served as Chair of the NOAO Post-Tenure Review Committee, which recently developed recommendations on a review policy and procedures for NOAO tenured staff.
Thomas Rimmele, Associate Astronomer

Areas of Interest
Adaptive Optics, Small-Scale Magnetic Fields, Active Region Dynamics, Helioseismology

Recent Research Results
Rimmele has recently published results from high resolution observations of umbral fine structure. He found evidence for oscillatory magnetoconvection in a sunspot light bridge. Oscillatory convection in strong magnetic fields has been predicted by theoretical models but never observed before. Rimmele collaborates with P. Goode and L. Strous (NJIT), and Tuck Stebbins (JILA) studying the excitation of solar oscillations. Their observations show that acoustic power is generated in intergranular lanes and give a detailed description of the mechanism responsible for the conversion of convective energy into acoustic energy. They are also able to show that the acoustic energy is fed into the resonance modes of the Sun.

Future Research Plans
Rimmele is involved in the adaptive optics program at NSO. In particular, he is developing techniques for wavefront sensing for extended objects. Working with the Air Force Research Laboratory (AFRL), he is developing the active optics system at the VTT/SP, which corrects optical aberrations that vary on slow time scales and also serves as a test bed for further development of adaptive optics. He is planning to build a low-order (~20 modes) adaptive optics system within the next two years as an intermediate step toward a full-up adaptive optics system. The low-order AO system will provide diffraction limited imaging during reasonable seeing conditions. Rimmele will continue his efforts to perform observations at the highest spatial resolution, using frame selection techniques, in order to study the properties and the dynamics of small-scale magnetic elements.

Service
In an ongoing effort, Rimmele is working with R. Radick (NSO/SP/AFRL) and R. Dunn (NSO/SP) on improving optical performance of the VTT/SP. This effort is expected to be completed in FY 1997. Rimmele is developing narrow-band filter capabilities for the VTT using Fabry-Perots and participates in an ongoing effort to upgrade CCD detectors at NSO/SP. Rimmele serves as Chair of the Sac Peak site Project Review Committee (PRC) and is co-investigator for the CLEAR design study.

Raymond Smartt, Astronomer

Areas of Interest
Coronal and Prominence Dynamics; Coronagraphic Instrumentation and Narrow-Band Tunable Filters

Recent Research Results
Coronal Loop Interactions (CLI) are observed in the emission of the two visible coronal lines, 530.3 nm (FeXIV; T ~ 2 × 10^6 K) and 637.5 nm (FeX; T ~10^6 K), the images recorded with the NSO/SP 20-cm Emission-Line Coronagraph. Similar events are also observed with the Soft X-Ray Telescope on YOHKOH, and with the Extreme Ultraviolet Imaging Telescope on SOHO. Together these data provide critical information about certain MHD processes occurring in the solar corona, and the role of CLIs in coronal heating. The visible coronal data are uniquely important because of their relatively high angular resolution. With V. Airapetian (CSC/GSFC) and Z. Zhang (U. of Nanjing), Smartt has investigated the appearance of cool plasma material (H-alpha emission) at a CLI site. It is interpreted as a consequence of a radiative instability that occurs in the optically-thin, confined plasma volume of a CLI, following an initial interaction and subsequent cooling. As the temperature falls, radiative cooling becomes much more efficient than cooling by conduction (initially the conductive cooling time is much shorter than the radiative time), which is the condition for the onset of the instability. This can cause a low-pressure condition, resulting in a plasma inflow from the surface to the site. At still lower temperatures, recombination of hydrogen ions becomes more efficient, producing H-alpha emission,
and the radiative instability ceases. The confined plasma volume then tends to an overpressured state, and loses energy most efficiently by plasma flows along field lines back to the surface, which is observed, and with velocities similar to those predicted.

Future Research Plans
Apart from further work on CLI analysis, Smartt will investigate the properties of the prominence-corona transition region (PCTR) in the case of quiescent prominences. It is generally thought that the PCTR can be characterized by a thin sheath surrounding such prominences, where the temperature rises abruptly from $T \sim 10^4 \text{K}$ to $\sim 10^6 \text{K}$ or more, and some observations support this picture. But other observations suggest that coronal temperatures can be present in the vicinity of the skeletal structure within the prominence, as defined by the complex magnetic field interior to the prominence. The properties of active prominences will also be investigated, especially with regard to their formation. Joint experiments to investigate CLIs in EUV lines are planned with the CDS instrument of SOHO, but these await sufficient solar activity to produce major post-flare-loop systems. Work will continue on the mirror-objective coronagraph (MAC) program, specifically the design and construction of MACIII, provided additional funding is available for its completion.

Service
Smartt is a member of the NSO Scientific Personnel Committee, the core planning group for the Sunspot Visitor Center, with specific responsibility for scientific exhibits, and Chair of the NSO/SP Telescope Allocation Committee. Apart from his role with the further development of MACIII, he is working on the development of a tunable, narrow-band, liquid-crystal Fabry-Perot etalon (under construction at CSIRO). He is a Co-I on the LASCO instrument of SOHO, as well as on two planned SOHO experiments. Finally, he continues to provide assistance, both directly and as a consultant, on various aspects of optical instrumentation refurbishment and development at NSO/SP.

Clifford Toner, Assistant Scientist

Areas of Interest
Global and Local Helioseismology, and Image Restoration

Future Research Plans
The detection and measurement of solar g-modes is of significant importance in the study of the internal structure of the Sun. Unlike p-modes, g-modes are expected to have large amplitudes in the deep interior of the Sun. This makes them significantly more sensitive to the structure of the Sun's central regions than the p-modes, and, potentially, a very powerful diagnostic of those parts of the Sun. A recent calculation by T. Toutain predicts that the g-mode signal in intensity should peak very close to the solar limb. Toner plans to continue his work with S. Jefferies developing a technique which differentiates the signal in a narrow annulus very close to the limb from the signal in an adjacent (interior) annulus in order to remove the solar background "noise" signal and thus enhance the probability of detecting g-modes. Toner will also be working with S. Jefferies and N. Meunier developing and testing a multi-dimensional fitting algorithm for the measurement of solar acoustic mode parameters. Toner will then port this code to a parallel processor machine.

Service
Toner performs observatory service as Assistant Data Scientist for the GONG project.
APPENDIX 4
NATIONAL OPTICAL ASTRONOMY OBSERVATORIES
FY 1997 USER STATISTICS

VISITOR TELESCOPE USAGE

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<th>NSO(^4)</th>
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\(^1\) Table reflects the number of observers/users physically present at each observatory for the fiscal period. Multiple visits by a single observer/user are counted separately. This table does not include NOAO staff.

\(^2\) During the fiscal year 1997 a total of 176 observing programs were carried out by visitors and the NOAO staff at Cerro Tololo. Visiting astronomers were assigned 90.2% of the scheduled telescope time and the remaining 9.8% was assigned to the staff.

\(^3\) During fiscal year 1997 a total of 259 observing programs were carried out by visitors and the NOAO staff at Kitt Peak. Visiting astronomers were assigned 84% of the scheduled telescope time and the remaining 16% was assigned to the staff.

\(^4\) During fiscal year 1997 a total of 172 observing programs were carried out by visitors and the NOAO staff at the National Solar Observatory. Visiting astronomers were assigned 22% of the scheduled telescope time and the remaining 78% was assigned to the staff.
### Table I
**FUNDING BY SOURCE**

(Amounts in $1,000)

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<th>FY-1998 Budget(a)</th>
<th>FY-1997 Expense</th>
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<td>(450)</td>
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<td>ESIE Division: Teacher Enhancement Program</td>
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<td>94</td>
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<td>GOALI: KOSI</td>
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### Table la

**STAFFING SCHEDULE**  
(In Full Time Equivalents)

<table>
<thead>
<tr>
<th></th>
<th>FY-1999 Budget</th>
<th>FY-1998 Budget(a)</th>
<th>FY-1997 Expense</th>
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Table II
SUMMARY OF ASTRONOMY DIVISION FUNDING BY COST CATEGORY
(Amounts in $1,000)

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STAFFING SCHEDULE
(In Full Time Equivalents)

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<th></th>
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|                        | 10.00      | 63.02                             | 417.36                          | 411.86         | 395.39         | 379.36                      |
|                        | 69.35      | 379.36                            | 411.86                          | 395.39         | 379.36         | 361.36                      |
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**SCIENTIFIC STAFF AND SUPPORT**

(Amounts in $1,000)

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|                                 |            | 40.00                                | 20.55                         | 10.00          | 0.00           | 0.00                        |
|                                 |            |                                      | 97.05                         | 92.25          | 85.45          |                             |
Table V

OPERATIONS AND MAINTENANCE
(Amounts in $1,000)

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(In Full Time Equivalents)

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#### OPERATIONS AND MAINTENANCE BY COST CATEGORY

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#### STAFFING SCHEDULE

**(In Full Time Equivalents)**

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(a) Includes all Director's Offices (NOAO, KPNO, CTIO, NSO), funds held by Directors not yet distributed to specific programs, recruitment, insurance, administrative services, freight to Chile, committee and observer travel support, and indirect cost and miscellaneous credits.
Table VII
NON-NSF FUNDED PROGRAMS
(Amounts in $1,000)

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STAFFING SCHEDULE
(In Full Time Equivalents)

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