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I. INTRODUCTION AND PLAN OVERVIEW

The purpose of the National Optical Astronomy Observatories is to advance US astronomy. Three components of the program accomplish that goal: NOAO provides major telescope facilities, encourages a strong internal research program, and develops new instrumentation and observing facilities. Astronomers recognize that observatories function as a system, with a range of telescope apertures and observational capabilities required for optimum use of the most scarce resources. As long as the performance of the telescopes remains competitive with that of newer instruments, the "beams" do not become obsolete; new problems can be continually addressed with modern instrumentation. A scientific staff active in research is an essential ingredient for identifying and following through on the key instrumentation needs of today and for having the vision to understand the problems that will drive demand for future capabilities. The excellence of the service provided to NOAO users depends on a dedicated, top quality scientific staff.

The National Observatories provide community-wide access to large and moderate aperture telescopes with state of the art instrumentation solely on the basis of scientific merit. NOAO is unique in offering observing time to the best ideas, regardless of institutional affiliation of the proposers. Facilities include an unparalleled combination of telescopes with state of the art instruments in both hemispheres and an array of unique solar telescopes.

Cost effectiveness must be judged on the quality and quantity of scientific output for the investment made in the institution. That output includes scientific publications, development of new instrumentation and training of students. Excellence in the observing program is maintained by a stringent peer review process and a high level of competition where fewer than one in three proposals can be granted time on the 4-m telescopes.

This demand is high because of the quality of the instrumentation developed which keeps NOAO telescopes at the forefront. Optical imaging and spectroscopy have been advanced by the implementation of large-format CCDs with high quantum efficiency and very low readout noise. Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory have provided users with optical fiber coupling of the wide-field focal planes to spectrographs, with reliably working systems winning high praise from users. The IR groups have made the benefits of the revolution in IR array detectors available to the broad community with imagers and spectrometers, as well as the simultaneous four-color imager (SQUID) and the Cryogenic Optical Bench (COB). Solar physics is experiencing a renaissance in magnetic field determination in terms of sensitivity and accuracy with near-infrared and other techniques, and in imaging quality through advances in adaptive optics. The approaching deployment of the GONG network will lead to a powerful database for helioseismological probing of the structure of the solar interior.

Given the high standards of review and reliable access to competitive instrumentation, the volume of use is then directly related to the amount of first-class science produced. The observatories support some 1,100 visits per year from over 100 different US institutions. That figure includes 780 visits by graduate students in US programs in the last five years. The observatories have supported in total 3,432 observing programs in that period that have led to more than 3,500 publications.

Another unique aspect of the National Observatories is the existence of a strong instrumentation infrastructure that permits innovative engineering for facility-class instrumentation. NOAO supports a large community of users, who have limited access to high-demand facilities. The instruments must be produced with a high level of reliability and versatility, so that data can be obtained with confidence for a variety
of observational programs. That mode of operation is complementary to highly experimental, support-intensive development at university observatories.

University consortia have found the operating environment of NOAO favorable for joint development of new telescope projects. The WIYN telescope program is making rapid progress toward first light by the end of 1993 with a new 3.5-m telescope at Kitt Peak, and the SOAR consortium continues planning for a comparable facility at CTIO. The very viability of NSO has depended on successful collaboration with the Air Force and NASA research efforts, NOAA, HAO, and other partners in pursuing the frontiers of solar physics.

The forward look for the night-time program is completely coupled to the Gemini Project. The Gemini Observatory is planned on a different model from existing facilities, in that it will not be a stand-alone operation with its own staff and infrastructure. It will rely on the national facilities of the partner countries for support, time allocation, and new instrument development. NOAO will be the focus for US participation in the operations phase for both telescopes, and the southern 8-m will be operated in close collaboration with CTIO. A vital NOAO is a key component of this strongly endorsed direction for US optical astronomy.

This program plan will summarize the major investigations to be undertaken by NOAO astronomers, highlight progress and completion milestones for major collaborative projects and instrumentation, note the functions of the US Gemini Project Office, and present the organization, plans and other information about the ongoing operations of the National Observatories. Important milestones for FY 1994 include:

- Completion of integration and test of all the GONG field stations.
- Deployment of 3 GONG field stations, with two operational.
- Analysis of first GONG merged dataset.
- Bringing the WIYN telescope to full readiness for scientific operation.
- Completion of modifications to Hydra fiber positioner and integration with bench spectrograph at WIYN.
- Polish and reinstallation of CTIO f/7.8 secondary for the 4-m telescope.
- Deployment of wavefront sensor for CTIO 4-m telescope.
- Initiation of modification to active primary mirror support system for CTIO 4-m telescope.
- Deployment of 4096 pixel square mini-mosaic CCD imagers at KPNO and CTIO.
- Deployment of Cryogenic Optical Bench IR imager at KPNO.
- Development of 1024 square InSb IR arrays with USNO and SBRC.
• Initiation of design and development of medium-resolution IR spectrometer for KPNO and CTIO.
• Completion of Mark II Correlation Tracker for Vacuum Tower Telescope at NSO/SP.
• Further progress on adaptive optics at NSO/SP.
• Completion of Video 10830 Å filtergraph for Solar Vacuum Telescope at Kitt Peak.
• Upgrade electronics for polarimetry with Near Infrared Magnetograph on McMath-Pierce telescope.

The budget request submitted to Congress by the President for FY 1994 is $31.21 M, an increase of 17.3% over the budget initially received for FY 1993. In the budget document, the request is presented as a 4.2% increase over an FY 1993 base budget that had been substantially restored through supplemental funding desired from the economic stimulus package. As of this writing, an increment to the base budget from that source of supplemental appropriations does not appear likely. A restoration of funding to the level proposed, however, should be considered essential to restore the health of the infrastructure and development programs of NOAO, which was seriously jeopardized by the 10% loss of purchasing represented in the FY 1993 base. The budget in this program plan is being presented as a base program at the FY 1993 level adjusted by 4.2% for inflation, and a series of increments that would restore the loss of capability incurred by the steadily declining budget.

The incremental funding, presented in the form of initiatives, is required to accomplish the Bahcall committee recommendations for repairing and strengthening the infrastructure. It is required for a strong instrumentation program, and it is required for reinvestment to bring about dramatic improvement in the scientific performance of the existing telescopes. For adequate representation of the US in the Gemini project and full communication with the US community, more support is needed for the US Gemini Project Office. A viable solar astronomy program now rests entirely on continuing support of key initiatives. For these reasons, the initiatives should not be considered as options, but as crucial and integral parts of a program necessary to keep US astronomy competitive.

II. SCIENTIFIC PROGRAM

A. Cerro Tololo Inter-American Observatory

J. Baldwin is continuing work with T. Storchi-Bergmann (UFRGS, Brazil) and A. Wilson (STScI) on the gas kinematics and abundances in the inner kpc of Seyfert galaxies. With R. Carswell (Cambridge U., England) and G. Williger (CTIO) he will obtain high-resolution echelle spectrograph observations of the absorption line systems in high-redshift QSOs. This includes observations of the intervening galaxies in front of the QSOs. Baldwin will also carry on a major program of ground-based optical and IR spectroscopy of a large sample of QSOs which are having UV spectra taken with HST. In the coming year he expects to spend considerable amounts of time on an HST and ground-based study of the Seyfert 2 galaxy NGC 3393. The HST spectra are being taken, so this project can move ahead. Baldwin is also a co-PI on another HST project to study the Orion nebula. This will include drawing on a large amount of ground-based spectroscopy of Orion obtained by Baldwin and G. Ferland (U. of Kentucky) over the past three years.
During the coming year, O. Eggen is assembling a sample of nearly two thousand GK giants with intermediate band, (R, I), DDO and Geneva photometry. Astrometric data is available for most of the stars. The 800 members of the old disk population in the sample should yield accurate luminosities, reddening values, and chemical abundances from calibrations of the photometric parameters. Less than one percent of the objects should be peculiar in the sense that the flux distribution is abnormal. The peculiarity is signaled by strong CH (and Ba II) and weak CH. The CH+ stars are all spectroscopic binaries, probably with white dwarf companions, whereas the CH- stars are not. A broad absorption band, centered near 3500 Å, is found in the CH+ stars whereas the CH- objects have a broad emission feature in the same region. The intensity of these absorptions and emissions are independent of the intensity of abnormal spectral features. The distribution of the (U, V) velocities is independent of the heavy element abundance, and should not appear to be random. Ten percent of the old disk stars show a CN anomaly, equally divided between CN strong and CN weak. Also, white dwarf candidates for membership in the Hyades supercluster, isolated on the basis of their proper motions, will be tested for total space motion derived from luminosities based on the well established, and tight color-luminosity relation for such stars. At least 35 degenerate members have been found amongst the known white dwarfs and there may be several additional double degenerate members. Eggen will also analyze the luminosity function of the Hyades cluster and supercluster.

During the next year, J. Elias's research will concentrate mainly in three areas. As part of the CTIO program of continued observations of SN 1987A, he will attempt 1-20 μm photometry and near-infrared images and spectroscopy of this unique object. The infrared photometric data are critical to a determination of the evolution of the bolometric luminosity of the supernova; data taken in 1992 show a clear flattening of the luminosity decline of this object, currently interpreted as due to the presence of ⁵⁷Co in the remnant. The second area is a program to be done in conjunction with P. Hacking, G. Neugebauer, and B.T. Soifer (California Inst. of Tech.) on a measurement of the luminosity function of infrared-luminous galaxies. This makes use of deep pointed observations by the Infrared Astronomical Satellite (IRAS) to produce a sample of faint 60 μm sources. Most of these (> 95%) are distant galaxies, which must be identified and whose redshifts must be measured in order to construct the luminosity function. The observational work is complete, and final reduction of the data and a careful assessment of the IRAS data will be undertaken. In a third area, working with R. Williams and other CTIO staff, Elias will obtain spectra of novae at various stages of development. One of the goals of the project is to see how dust formation correlates with other aspects of the spectral development of novae.

R. Elston's main area of research interest will continue to be the formation and evolution of galaxies, and the process of star formation within galaxies. In collaboration with D. Silva (KPNO), Elston will study nearby early type galaxies by looking at gross photometric properties and their resolved stellar populations. Following their detection of a luminous extended giant branch in M32 indicating the existence of a large intermediate age population in this galaxy, they will survey all the M31 group spheroids for similar populations, and plan to extend the survey to luminous elliptical galaxies as distant as the Leo group. They will also study the nature of radial color gradients in early type galaxies using near-IR photometry to try to disentangle the roles that changes in metallicity and the age of the stellar population play in these radial gradients. They have found that a combination of radial age, metallicity, reddening and or relative abundance gradients are needed. Elston is also pursuing another approach to the problem of galaxy formation and evolution by observing samples of faint field galaxies. He will compile a sample of K band selected galaxies reaching K=21. This sample should provide galaxies with redshifts well beyond z=1. The hope is to obtain redshifts for the brighter of these objects in the future, but also to study the colors and magnitudes of the objects to constrain early type galaxy evolution at z>1. Elston also plans to pursue the study of the most distant known galaxies with redshifts of z=2. With B. Jannuzi (Inst. for Advanced
Study) he has been measuring the ultraviolet and near-IR polarization of distant radio galaxies. They find that a number of these distant objects are polarized in both the optical and near-IR indicating that the continuum of these objects cannot be due entirely to starlight as is commonly assumed. Finally, to study the global processes which lead to violent star formation in galaxies Elston will study the interstellar medium of nearby "starburst" galaxies with P. Maloney (NASA, Ames) using near-IR spectroscopy, where they have also found evidence that these galaxies have generally "over pressurized" ISMs from the existence of diffuse molecular hydrogen emission which seems to pervade them.

D. Geisler plans to investigate detailed elemental abundances in a number of the most metal-poor Galactic globular cluster giants. Good high resolution, high signal-to-noise ratio data have been obtained for a large sample of cluster giants with the 4-m echelle and long camera. This study is in collaboration with Minniti (U. of Córdoba, Argentina), Peterson (U. of Arizona) and Claríá (U. of Córdoba, Argentina). Geisler will also continue his investigation of the metallicity distribution functions of the globular cluster systems in a variety of elliptical galaxies. For example, he has obtained extensive data on the important M87 system with Lee. A third area of research is the chemical composition of old, metal-poor open clusters. Together with Claríá and Minniti he plans to investigate their metal abundances with Washington photometry, while echelle spectra are being obtained in collaboration with G. Wallerstein and J. Brown (U. of Washington).

B. Gregory will work on the detailed optical, cryogenic and mechanical design of the Second Generation IR Imager which will use the $256 \times 256$ HgCdTe (NICMOS) detector from Rockwell, recently received. The optical design is complete and the mechanical design is well advanced. He is now concentrating on the specification and conceptual design, with J. Elias and R. Elston, of the Next Generation IR Spectrometer, designed to take advantage of the larger format detectors which are becoming available. It is hoped that this project will be defined and executed in collaboration with the KPNO scientific and engineering staff, producing an identical instrument for each hemisphere. Gregory will, in addition, continue to participate in the work on the optics of the 4-m telescope.

S.R. Heathcote will continue his work to investigate the kinematics of Herbig-Haro objects and associated "optical jets." These are believed to be the manifestations of collimated, high velocity outflows, driven by young pre main-sequence stars into their surroundings, and as such can provide important insights into phenomena occurring during the formation and early life of stars. Heathcote is completing a study of the HH 90/91 complex in collaboration with B. Reipurth and R. Gredel (European Southern Obs.). The poorer collimation together with the greater age derived from proper motion measurements of this complex suggest that it is at a more advanced evolutionary stage than HH 34 and HH 111. High resolution near infrared spectra will be obtained of this object. A multitude of $H_2$ emission lines should be detected which provide a new and very powerful tool for investigating physical conditions in HH objects. In conjunction with B. Reipurth, M. Roth (Carnegie Inst. of Washington), A. Noriega-Crespo (U. of Washington) and A. Raga (U. of Manchester, England), Heathcote will investigate the prototypical HH complex HH 1/2. Deep narrow band optical images have revealed the existence of a second jet making a substantial angle with the main outflow axis of the system. Both proper motion measurements and the comparison of the optical images with sensitive IR K-band images suggest that this side jet might be driven by VLA-2, a second faint radio continuum source near VLA-1 which drives the main HH 1/2 outflow. If these outflows can be shown to be collimated by accretion disks around their respective sources, then the misalignment of the flow axis implies that the two disks are not coplanar.

Instrumentation physicist, T. Ingerson will continue to pursue his work on several major ongoing instrumentation projects. One of them, CTIO's new Prime Focus Atmospheric Dispersion Corrector (PFADC) for the 4-m telescope is expected to become operational in 1994. This should be the first
operational corrector of this type in the world. He will continue to work in the area of fiber-fed instrumentation, improving the performance and efficiency of Argus, Cerro Tololo's Multiple Object Spectrograph and the fiber-fed, bench-mounted echelle spectrograph for the 1.5-m telescope. He has been instrumental in the development of a new standard system of "intelligent" controllers for these and other instruments, and under his direction efforts will be made to implement controllers of this type on all of CTIO's major instruments. These controllers support standard networking protocols and are integrated with the Arcon detector control system, insuring that instruments using them are controllable naturally from anywhere on the network. Ingerson will continue to serve as CTIO's scientific staff representative in the area of computer hardware, particularly in the area of computer networking. Therefore, his instrumentation efforts will be directed towards integration of all CTIO's communication systems with each other and with Arcon, telescope control and CTIO instruments.

A. Layden plans to perform follow-up observations on the local RR Lyraes. The purpose is to ensure that all stars with proper motions in the literature, or which are in the Hipparcos Input Catalog, have high quality abundances and radial velocities. Thus, more precise space velocities can be calculated for the kinematic investigation, and an improved statistical parallax solution can be performed, thus improving our knowledge of the absolute magnitude of the RR Lyraes and its dependence on metal abundance. In addition, Layden is collaborating with R. Zinn to study the kinematic and abundance distributions of RR Lyraes in the inner Galactic halo. These data will serve to test Zinn's findings which suggest that the older (bluer horizontal branch) globular clusters, which dominate the inner halo, have a faster net rotation than the younger clusters. Layden also plans to study the kinematics and abundances of halo RR Lyraes outside the solar circle and well above the Galactic plane, in order to test Majewski's surprising result that the "true halo" has a retrograde net rotation of ~50 km/s. Layden will also test the feasibility of searching for RR Lyraes in the deep inner halo/bulge field in which Morrison and Harding studied the field blue horizontal branch stars. The ratio of BHB stars to RR Lyraes in these fields is an indication of the relative ages of these populations. Eventually, spectra of the RR Lyraes will provide more information on the kinematics and abundance distribution of the halo as a function of Galactocentric distance. Layden also plans to study the kinematics and abundance distribution of the RR Lyraes in the Large Magellanic Cloud, in order to verify the result of Suntzeff, Schommer, Olszewski and Walker that the old, metal-poor component of the LMC has a much more flattened, disk-like spatial distribution than the halo of our Galaxy.

M.M. Phillips will continue to concentrate his research effort during FY 1994 on supernovae and novae. Since 1986, Phillips has collaborated with N. Suntzeff and M. Hamuy (CTIO) on a long-term program to obtain optical photometry and spectrophotometry of type I and II supernovae using CCD detectors on the 0.9-m, 1.5-m, and 4-m telescopes. The principal goal of these observations is to accurately determine the observable properties of type I and II supernovae from outburst to relatively late epochs (1-2 years after outburst). Such data should provide considerable insight into the nature of the progenitor stars. Moreover, as the case of SN 1987A has shown, the availability of high-quality light curves and spectra for individual supernovae will inevitably generate further advances in our theoretical understanding of these events. In a related project, Phillips, Hamuy, and J. Maza (U. de Chile) will also continue an observational program to test the utility of supernovae (both types Ia and II) as cosmological standard candles. Finally, Phillips plans to continue to participate in the long-term program led by Williams to follow the spectroscopic evolution of novae in outburst using the 1.5-m and 4-m telescopes. These data will be used to model the expanding envelopes and determine the characteristics of the outbursts.

R. Schommer and collaborators will continue to pursue questions concerning the large scale peculiar motions seen in southern hemisphere clusters of galaxies. Tully-Fisher relations, based on I band CCD
frames and Fabry-Perot Hα velocity fields, will be used to determine distances and peculiar motions for 13 clusters of galaxies in the redshift range of 5,000-7,500 km/s. The scale of these motions still has not been determined, but these and other recent cosmological observations require power on larger scale than the standard Cold Dark Matter simulations produce. This makes some astronomers very uncomfortable, requiring even reasonable theorists to introduce models with a non-zero cosmological constant. With Caldwell (Whipple Obs.), Walker (CTIO), and Graham (Carnegie Inst. of Washington), Schommer is obtaining photometric measures on identified variable stars in M83 (NGC 5236) in the Centaurus Group. This galaxy has had recent SN of type Ib (1983G) and II (1968L) and there have been 6 SN in the group, with distance estimates ranging from 2.4-4.8 Mpc. Approximately a dozen variables have been identified to date. Planetary nebula and luminosity fluctuation distances have been obtained for several members of this group of galaxies.

In the coming year, C. Smith will work with R. Kirshner (Harvard-Smithsonian), B. Blair (Johns Hopkins U.), K. Long (STScI), and F. Winkler (Middlebury Coll.) on supernova remnants (SNRs) in the nearby galaxy M33. Their spectroscopic survey of the SNRs identified by Long is being completed, confirming the remnant candidates, and further work on SNR evolution based on this sample is progressing, accompanied by the identification of a new set of SNR candidates in the outer regions of M33. With this larger sample of SNRs (now over 60), Smith et al. will better constrain models of SNR evolution and energetics. Winkler and Smith will continue work surveying the LMC to find new remnants having already identified several candidates. In order to better understand the broader-than-expected line widths in Balmer-dominated SNRs, Smith, Raymond, and Laming will study Galactic remnants, where their shocks can be studied in greater detail. Observations of several Galactic remnants will provide better constraints on the models which they are developing to explain the observed line widths. While Smith, Kirshner, Blair, Long, and Winkler continue to work on the sample of SNRs in M33, Blair, Long and Smith are pushing the identification of remnants to more distant galaxies such as M83. There, 40 candidates have been identified for which follow-up spectroscopic confirmation and analysis is planned. Smith also will be working with Raymond, J. Hester (Arizona State U.), and others studying the Vela SNR, which is one of the best examples of an evolved SNR. The optical observations and spectroscopy done at CTIO can be combined with high-resolution X-ray data to better understand the kinematics of shocks in middle-aged remnants such as Vela. Together with the supernova group at CTIO, Smith plans to continue the search for SNe in starburst galaxies and also is collaborating in attempts to study the transition from supernova to remnant by recovering very old SNe (or young SNRs) at sites of historical SNe.

N. Suntzeff plans to concentrate his research in three main areas: the metal abundances and kinematics of the stellar populations in the Large Magellanic Cloud, a complete survey of stellar populations in the Carina and Sculptor dwarf galaxies, and fundamental observations of southern hemisphere supernovae. The LMC project is designed to study the overall kinematics and stellar evolutionary history of that galaxy. Suntzeff is collaborating with A. Klemola (Lick Obs.), E. Olszewski (Steward Obs.), Schommer (CTIO), and E. Hardy (U. of Laval, Canada) on various projects. With Hardy, he plans to measure velocities for all the known carbon stars in the LMC with the Argus multi-fiber system to map out in greater detail than ever before the kinematics of the intermediate age population in the LMC. They will be able to map out the rotation of the LMC out to at least 8 degrees from the LMC center to study the nature of the disk rotation and bar perturbation, as well as the dark matter. With the other collaborators, he is studying selected regions in the LMC to try primarily to isolate the oldest population of stars. One of the most curious aspects of the LMC is that it evidently formed its initial population of stars in a rotating spheroid, in contradistinction to the barely rotating halo of the Milky Way. This conclusion is based on only 13 old clusters, and in order to make any more progress, individual field stars must be used. This project was begun on a field of stars near NGC 2257 that has been selected by color and lack of proper motion. Out
of 100 stars surveyed, about 50 are LMC members, and of those, about 15 are Population II stars. Five other fields will be surveyed with the Argus multi-fiber system. This data will allow the measurement of the velocity dispersions and metallicities of field stars which will be used to model the formation and evolution of the LMC. With Cudworth (U. of Chicago), and Stetson and Smecker-Hane (Dominion Astrophys. Obs.), Suntzeff plans to start a major survey of the stellar populations in the Sculptor and Carina dwarf galaxies. He has shown the data extant on the metallicity distributions in these galaxies is qualitatively consistent with very simple metal-enrichment models. If this is true, then these galaxies are the simplest evolving stellar aggregates that can be used to test metal-enrichment models. Suntzeff will propose to observe all the red giant branch stars above the horizontal branch (some 150 per galaxy) in these objects to produce a metallicity histogram which will be fit to theoretical models of chemical enrichment. Finally, Suntzeff will continue his work with Phillips, Hamuy, and Maza (U. de Chile) on the evolution of supernovae. These projects involve the gathering of basic photometric and spectroscopic data on supernovae. Hamuy and Maza are undertaking a program to discover SN out to z=0.15, while Suntzeff will be concentrating more on the measurement of the local supernovae.

A. Walker will continue his work on the zero-point calibration of the distance scale by obtaining spectroscopy and UBVI photometry for stars in the Galactic open cluster NGC 6664, which contains the Cepheid EV Sct, in a collaboration with D. Turner (St. Mary's U., Canada). Other distance scale related work includes measurement of the distance to NGC 5253, a galaxy which has produced two supernovae in the past century, by both the surface brightness method and the planetary nebula luminosity function method. With N. Caldwell (Whipple Obs.), J. Graham (Carnegie Inst. of Washington) and R. Schommer, Walker will continue an on-going project to discover and measure Cepheid variables in the Centaurus group of galaxies. This group has had a large number of recorded supernovae, and measured distances based on planetary nebulae and surface brightness fluctuations. Photometry and high dispersion abundance analyses will be carried out for several southern clusters which contain Cepheid variables in view of the sensitivity of the derived distances to the abundances, the latter which until now have been assumed solar. High precision B,V and I CCD photometry will be obtained for 130 RR Lyraes in four galactic globular clusters. That for NGC 4590 is a collaboration with C. Cacciari (Bologna). Some specific problems that the observations will be able to address are the accurate placement of the RR Lyraes in the HR diagram, for comparison with evolutionary tracks and with positions of instability strip edges and mode boundaries, and comparisons with theoretical light curves obtained from hydrodynamic models. Other RR Lyrae related work planned is a project with Y-W Lee (Yale U.) to determine abundances for all of the type ab RR Lyraes in the galactic globular cluster Omega Centauri. A complete sample of abundances for this unique cluster, in combination with newly available photometry, will allow comparison with HB evolutionary models, investigation of the magnitude-metallicity relation, and determination of the age of the cluster.

G. Williger, collaborating with J. Baldwin (CTIO), R. Carswell, M. Irwin, R. McMahon (Cambridge U., England) and C. Hazard (U. of Pittsburgh) will measure the Doppler parameter, H I column density and density and redshift distribution of Lyα forest systems at the earliest detectable epochs by observing the QSO 1202-074 (z = 4.7, m =18) with the 4-m telescope plus echelle spectrograph at 12km s⁻¹ resolution. This will also permit the strictest possible constraints to date on the Gunn-Peterson effect. In addition, they will evaluate the chemical evolution of proto-galaxies through examining the metallicity of a damped Lyα system at z = 4.5 along that line of sight. In collaboration with Baldwin and Hazard, Williger will use data obtained with the Argus multifiber spectrograph to probe superclustering in the early Universe along sightlines to a field of over twenty QSOs with z = 1.8 and m < 19.5 in a 0.5° x 1.0° area. This uniquely dense field of bright, high redshift QSOs offers an unprecedented opportunity to study the three dimensional distribution of QSO absorption systems, in particular metal absorption systems. Williger and
P. Hewett (Cambridge U., England) will measure directly the total mass (including dark matter) associated with galaxies by studying the amplitude and angular dependence with BV photometry of any overdensity of background QSOs around foreground galaxies. In a continuing program, Williger, S. Raychaudhury (Harvard-Smithsonian) and D. Lynden-Bell (Cambridge U., England) will complete photometric calibrations for the southern half of the APM Equatorial Galaxy Survey in a project which began in 1991. In theoretical work, Williger plans to collaborate with P. Petijean (Cambridge U., England) to combine his hydrodynamical code with Petijean's photoionization code in order to calculate redshift, $H\text{I}$ column density and Doppler parameter distributions resulting from self-gravitating models for Ly$\alpha$ forest absorbers.

**B. Kitt Peak National Observatory**

H. Abt is searching for binaries among the normal sharp-lined, A-type stars for the following reason. A large study being completed with N. Morrell (U. Nacional de La Plata, Argentina) involves obtaining rotational velocities and MK spectral types of 1700 A-type stars. Preliminary results show that all stars with rotational velocities greater than 150 km s$^{-1}$ have normal spectra, but the slower rotators can have either normal or peculiar. Thus, a parameter other than rotational velocity (and hence the occurrence of a diffusive separation of elements) must determine whether a star will be normal or peculiar. Is that parameter duplicity?

T. Armandroff will continue his studies of dwarf spheroidal galaxies, which to a greater or lesser extent, have larger velocity dispersions and mass-to-light ratios than expected if they consisted of only a simple old stellar population (like globular clusters). The fact that galaxies this small appear to contain significant amounts of dark matter has important implications regarding the composition of the dark matter and the contribution of dwarf galaxies to the mass density of the Universe. Armandroff is working to understand the very high mass-to-light ratios (50-100) measured for the Draco and Ursa Minor dwarf spheroidals, in collaboration with E. Olszewski (Steward Obs.) and T. Pryor (Rutgers U.). The present M/L values are based on velocities for about 20 stars per galaxy from the MMT. Armandroff et al. are using Hydra to observe about 300 giants in each galaxy. Velocities for samples of this size allow one to do more than simply compute the velocity dispersion and use King models to get the mass, yielding a M/L value; this traditional method has a number of pitfalls. Instead, they plan to use numerical techniques developed by Merritt (1992) to estimate the potential directly from the observed distribution of stars in radius and radial velocity. By avoiding binning, this technique makes the greatest use of the velocity data. Improved projected density profiles will be available for the modeling, as Armandroff et al. are obtaining such data using the 0.9-m and wide-field CCDs. The star counts from the 0.9-m will also allow a search for asymmetries in the stellar distribution, expected if these systems are experiencing strong tidal forces. The new core and tidal radii resulting from the 0.9-m data and the central surface brightness measurements that they are making with the Schmidt/CCD should alone yield a marked improvement in Draco and Ursa Minor’s mass-to-light ratios, as the present values are based on photographic star counts made by Hodge circa 1960.

S. Barden is instrument scientist for the Hydra multi-fiber positioner. This instrument is currently undergoing renovation designs for its permanent installation on the WIYN telescope. The move from the Mayall to the WIYN will take place during FY 1994 with completion of the commissioning taking place during the first half of FY 1995. With the planned development of a new fiber-fed echelle for the Mayall telescope, Barden plans to investigate the properties of double fiber scramblers in order to achieve ultra-precise radial velocity measurements. Improving the throughput efficiency of these scramblers is desired.
in order to improve the limitations in stellar seismology and in searching for planetary companions via radial velocity monitoring. Scientifically, Barden will plan to use the Hydra instrument to continue observations of selected stars in M71 and M13 to monitor their radial velocities. The goal of this project is to determine the binary frequency of the stellar samples. This information is required for theorists to understand the dynamical processes which halt core collapse within the centers of globular clusters. As binaries are discovered, followup observations are planned to determine the period and other orbital parameters which will help define the distribution of those parameters within this class of stellar population.

M.J.S. Belton plans to take his ongoing Halley research to the point where an improved rotational model is coupled to an improved determination of the shape of the nucleus. Belton will work with Dr. K. Meech on recently acquired ground-based (KPNO) and HST data on Chiron. He will analyze this data in the framework of the trapped ballistic dust coma model that he and Meech developed and published in 1990. Belton will continue his work with the Galileo project: The Ida encounter (August 1993) is expected to be accomplished and should lead to a comparative study with the earlier results from Gaspra. He also expects to complete the Gaspra shape modeling already in progress. In parallel with this will be the construction of a "radiation model" for the camera based on data acquired at the December 1992, Earth-Moon 2 encounter and the preparations for the Galileo "Low Gain Antenna" mission at Jupiter. Belton also plans to pursue his SMACS (Small Missions to Asteroids and Comets) "Discovery" program concept with a view to the preparation of a proposal in 1994.

B. Bohannan's research centers on observational studies of the evolution of massive stars, in particular comparison of their observational properties with theoretical calculations. Determination of basic stellar properties--temperature, gravity, mass, and surface element abundances--of luminous stars are critical to understanding stellar evolution at masses where mass loss rates may define the path taken as a star evolves from hydrogen to helium core burning and then on to supernova. Current investigations involve abundance studies of B supergiants in the Large Magellanic Cloud with E.L. Fitzpatrick (Princeton U.) and determination with P.S. Conti (U. of Colorado) of the properties of the Of/WN class of stars which have properties intermediate between the Of and WN types and which may indicate a possible direct evolutionary connection.

T. Boroson's recent research activities have concentrated on quasars and their host galaxies. Following the completion of a spectroscopic study, in collaboration with R. Green, of the Hβ-[O III] region in a large sample of quasars, these same workers are extending this type of study to higher redshift objects which can be studied in the UV. This work combines a template spectrum of the quasar I Zwicky 1, obtained with the Faint Object Spectrograph on the Hubble Space Telescope, with spectra of several dozens of objects obtained from KPNO telescopes. Results from the previous study have implications for a better understanding of what the important physical parameters are in quasars. Close to completion is a large project aimed at learning more about the stellar populations of the host galaxies of low redshift quasars. Off-nuclear spectroscopy, done in collaboration with J. Dunlop (Liverpool John Moores U.) and D. Hughes (Oxford U.), suggests that the quasar phenomenon is linked to some degree of global star formation in all quasar host galaxies. In contrast, radio galaxies observed in the same way show no evidence for a young stellar component. Finally, Boroson, J. Salzer (Wesleyan U.), and A. Trotter (Amherst College) have recently completed a study of extremely low luminosity emission-line galaxies. This work combined a narrow-band imaging survey to find such objects with a spectroscopic study of a large number of candidates using the Hydra multi-fiber spectrograph. The most surprising result from this project was the finding that the space density of low-luminosity star-forming galaxies is not a strong
function of redshift out to a few tenths—a result in disagreement with some of the studies aimed at interpreting the counts of faint blue galaxies.

In the coming year, D. Crawford expects to be active in photometric studies of open clusters. Those now on the list include IC 1805, IC 1848, NGC 1502, and NGC 6611. All of these contain very young OB type stars and are ideal for investigations of accurate zero-age main sequences as well as for definitive studies of interstellar reddening effects on photometric systems and on the ratio of total-to-selective absorption. Results in the literature are far from conclusive. In addition, work continues on synthetic photometry studies relative to standard photometric systems.

In 1994, D. De Young will continue research in two areas, both related to star formation. The first area involves the fate of gas which is ejected above the galactic plane. This material comes from the energetic debris of supernovae or from associations of young and massive stars. The conjecture is that the gas from these fountains and supersons bubbles cools as it moves into the galactic halo and then condenses to form dense clouds, and, eventually, stars. The energetic outflow portion of this picture is well understood through detailed calculations, but the subsequent possible condensation into clouds and stars is still completely obscure. In collaboration with C. Norman, a detailed examination of this condensation process will be made. The second and perhaps more difficult project involves a calculation of the outflow from young stellar objects. It is becoming clear from observations that these bipolar outflows are characterized by fully turbulent subsonic jets which strongly interact with their surrounding medium through entrainment in the turbulent boundary layer. No theoretical models now exist for such fully turbulent but anisotropic flows, and an ab initio formalism will have to be established to understand this process. Such an understanding will in turn place important constraints on the evolution of protostellar objects and very young stars.

With the commissioning of the Cryogenic Optical Bench, I. Gatley’s scientific focus has returned to the study of vibrationally excited molecular hydrogen. On the first visit to the telescope in 1993 he made molecular hydrogen images of the Orion nebula, the reflection nebula NGC 2023, and several Planetary nebulae. In the coming year studies will extend to the spiral arms of M51 and to the Galactic center. He also intends to map the photodisociation regions surrounding the HII region M17; the implementation of the fast infrared electronics will allow use of the 256 x 256 InSb detector to map the 3.3 μm dust emission. Comparison of the H$_2$ and 3.3 μm maps is important to a better understanding of fluorescent excitation, and M17 is the brightest example of the phenomenon presently known.

F. Gillett’s research goals for FY 1994 will be to study star formation regions in the 1-5 μm range in an attempt to further characterize the environment of forming stars. Examples to be studied include Mon R2 and B335.

R. Green has acquired echelle data from the 4-m for studying metal-line and Lyman-$\alpha$ systems. Extraction is laborious at best, but is now proceeding in collaboration with Don York and Jim Lauroesch at the University of Chicago, and Keliang Huang from Nanjing Normal University. Huang and Green were co-recipients of a Chretien Award from the AAS to pursue this analysis. A paper including deblended equivalent widths and curves of growth is nearly complete for the object MC3 1331+170. A parallel analysis is underway for the absorption complex in B2 1225+317. Huang and Green are writing a review paper on high-dispersion studies of quasar absorption-line systems. Osmer, Hall, Porter, Liu and Green are pursuing a multi-color survey of about a square degree of sky at high galactic latitudes, that should be complete to 23rd magnitude in V. Hydra time has been granted for confirmation of sources that are stellar but stand out in multi-color space from the stellar locus. The goal is to determine the evolution of
the quasar and Seyfert galaxy luminosity functions. In addition, they will obtain color data on faint galaxies as a function of magnitude, and work on the metallicity distribution of distant halo dwarfs.

K. Hinkle's principal activity in 1994 will be the construction and testing of the high resolution infrared spectrograph 'Phoenix.' Major optical components will be arriving late in calendar year 1993 and system integration and testing will continue through 1994 with first light for this instrument in late 1994. In preparation for the era of high resolution infrared spectroscopy with array detectors, Hinkle and L. Wallace will prepare and publish in 1994 a high resolution (R=150000) 1-5 μm spectral atlas of Arcturus as observed with the 4 meter Fourier transform spectrometer. In 1994 Hinkle also plans to continue his collaboration with J. Keady (Los Alamos Nat. Lab.) and P. Sada (New Mexico State U.) on the kinematics and structure of carbon-rich circumstellar shells. A focus of this work in 1994 will be on molecular hydrogen in carbon-rich circumstellar shells. Models of the circumstellar H₂ indicate that while vibration-rotation features are weak, most of the circumstellar mass is in H₂ and the H₂ S1 line is an excellent probe of mass-loss rate. Once the mass-loss rate has been measured using the H₂ line, it will then be possible to infer abundances relative to hydrogen from the circumstellar lines of other molecules. Hinkle will also be continuing his research with P. Bernath (U. of Waterloo) on circumstellar chemistry. Hinkle and Bernath have been interested in long chain-carbon molecules and will continue to search for the infrared signatures of the symmetric forms of these molecules. In 1994 Hinkle also plans to continue his research on the kinematics of peculiar late-type variable stars.

During FY 1994, G. Jacoby will continue his work on the extragalactic distance scale. Using the planetary nebula luminosity function, he will be deriving distances for galaxies up to twice as far as those in the Virgo cluster to (1) compare PNLF distances with those derived from Type Ia supernovae, and (2) to test the Great Attractor model. In addition, he will continue with his studies of the internal kinematics of galaxies using planetary nebulae as test particles to map the gravity fields. Concentrating on the nearby galaxy M31 where thousands of planetary nebula candidates now have been identified, a comparison will be made between the central bulge and the outer halo dynamics. Other planned work includes a continuation of the search for very young, dusty, planetary nebulae in the Galactic disk and the development of long period variables as standard candles.

R. Joyce's primary scientific objectives will be to continue the photometric and spectroscopic study of highly evolved stars, with a bias towards the C stars. The photometric work, while perhaps prosaic, nonetheless is one of the few, if not the only, systematic program to characterize the variability characteristics of stars undergoing extreme mass loss. Because of the periods of these objects (300-2500 days), occasional widely-spaced photometric nights are sufficient to determine periods for stars with very long periods or incomplete coverage. The spectroscopic program initiated last year was originally intended to search for possible abundance variations or isotopic carbon ratios which might be indicative of this phase. Based on the initial low-resolution spectra, the immediate focus is on the strong polyatomic bands of C₂H₂ and HCN, which are significantly enhanced over the bands of CH, CN, and C₂ found in relatively unobscured C stars. The extreme paucity of J and H band spectra of these, or most any other, stars will require further observations not only of the mass-losing C stars, but of a larger sample of controls, covering a range of [C/O] and temperature. An interesting sideline is provided by the discovery of at least four dwarf stars with carbon-rich optical features (Margon et al. 1984; Green, Margon, MacConnell 1991). This has significant implications for the assumption that all C stars are luminous post main sequence objects, and that faint C stars therefore lie in the distant galactic halo. JHK photometry suggests that these stars are faint at H, relative to J and K in comparison to recognized C giant stars. Recent IR spectroscopy of a number of faint high-latitude C stars, including two identified as nearby dwarfs, appears to show much weaker CO in the dwarfs. This would be consistent with the photometric colors and may support
the hypothesis of carbon deposition from an evolved companion. He plans to obtain more definitive observations on a wider sample of stars using the enhanced capability of the upgraded IR spectrometer.

T.D. Kinman will continue his work on the blue horizontal branch stars and RR Lyrae stars in the Galactic halo. A comprehensive pilot program (with Kraft and Suntzeff) showed that these stars could be discovered with good completeness among the Case AF stars (Burrell Schmidt Survey). This pilot program covered over fifty square degrees in two fields; one at the North Galactic Pole and another at the Anticenter. It is being extended to two additional fields at each of these locations. This should allow nearly 100 blue horizontal branch stars to be discovered which should (together with the RR Lyrae stars) be enough to delineate the shape of the outer halo with more accuracy than is currently possible. The color distribution of these horizontal branch and RR Lyrae stars is largely defined by metallicity and age, so it should be possible to make more definitive statements about the way that these two quantities vary in the outer halo and also on the run of spatial density of the halo with galactocentric distance.

T. Lauer's research plans for 1994 will be split into two major areas. The first area is continuing his program with Hubble Space Telescope research. In 1994, he expects to conduct research with a repaired HST. His primary research will be continued investigation into the structure of galactic nuclei and the search for central massive black holes. He will also be investigating the stellar populations of nearby galaxies, and the morphology of cosmologically distant galaxies. His second area of research is continuing his program with Marc Postman of STScI on investigating the Large Scale Structure of the Universe. In 1994 they expect to complete work on an improved distance indicator for measuring motion of the Local Group with respect to the 15,000 km/s Abell Cluster Frame. Work will begin on expanding the Frame to higher redshifts as well as analyzing the existing frame for further constraints on the formation of large scale structure.

In 1994, R. Lynds expects to continue being heavily involved in the reduction of data from the Hubble Space Telescope--data taken with the Wide-Field/Planetary Camera (WFPC) and later with WFPC-2 following the refurbishment mission.

P. Massey is continuing his studies of the massive star content of Galactic and Magellanic Cloud OB associations. His work so far has shown that the upper-mass cut-off of the IMF is roughly 80 solar masses, independent of the metallicity of the region. In addition, his data to date have shown that the slope of the IMF is significantly flatter in the Magellanic Clouds than in the Milky Way. In FY 1994 he will use multi-object spectroscopy already obtained with the KPNO 4-m and Hydra to demonstrate whether or not there is a gradient in the IMF slope within the Milky Way, as has been previously suggested in the literature, and whether this upper-mass cut-off remains invariant with other parameters of the star-forming region, such as size of the parent cloud. In addition, Massey is empirically determining the mass-luminosity relationship for high-mass stars by using high signal-to-noise data obtained with the KPNO Coude Feed spectrograph on known early-type binaries. These data allow refinement of orbital parameters for these systems, yielding masses. These masses can then be used to test mass-loss evolutionary models of massive stars.

K.M. Merrill’s current scientific research interests follow along two intimately interwined threads, the stellar content within regions of star formation and the diffuse environment with which they interact. As part of the SQIID Star Formation project with R. Probst, he will continue to process observations from the on-going census of nearby regions of star formation--places which are close enough and small enough in angular extent to be critically surveyed. Preliminary reductions have been combined with multi-faceted information by S. Strom and K. Strom into an emerging mosaic of the star formation process itself. At
birth stars are deeply shrouded within their stellar nurseries. We have been examining the stellar equivalent of day-care centers, where the residue of birth is still apparent, but the stars are more exposed (and therefore more amenable to detailed studies), and the differences which will accentuate with age are also clearly distinguishable. Guided by careful modeling, we have developed powerful discriminants based on simple broad bandpass J-H and K-H colors (which are "coincidentally" SQIID's strong suit!) to select objects for detailed study with other more powerful, but less panoramic, tools. We have already tracked down stellar nurseries where the oldest inhabitants are 500,000 years old. It appears that stars can form in small (order 10 to 100) groups and that larger regions might be a composite of many such groups. With I. Gatley, he will be examining the circumnebular environment of stars, using the Crogenic Optical Bench. COB is an excellent tool for isolating diffuse emission from the stellar "contaminant": longslit and multi-slit grism spectroscopy, and spatial mapping with wide-field frequency switching on and off emission lines are proving to be powerful discriminants. We have been employing 2 \mu m hydrogen emission, both atomic and molecular, as a probe of the distributed energy content (in the form of exciting UV photons and mechanical shocks) of active regions of star formation.

P. Osmer's research will concentrate on the evolution of quasars, in particular, of their space density, emission-line properties, and energy distributions. He will continue work on a deep, 4-m multicolor survey to investigate the space density of faint quasars with \( z > 3 \) and faint quasars/AGNs with \( z \) about 2. The recent determination by Warren, Hewett, and Osmer of the decline of the apparent space density of luminous quasars at \( z > 3.3 \) makes it important to see if fainter quasars follow the same behavior, as we may be seeing back to the epoch of quasar formation. The luminosity function of faint quasars/AGNs with \( z \) about 2 is important to the debate on density vs. luminosity evolution. The finding of an inflection point or similar feature in the luminosity function would allow a test of the widely used luminosity evolution models. The work on the evolution of the emission-line and continuum properties of quasars bears on the physical nature of the central regions and on the possible obscuration by dust in clouds along the line of sight to \( z > 3 \). Calculations by Fall, Pei, and others are now sufficiently advanced to permit a detailed prediction of how dust obscuration should redden the energy distribution in a magnitude-limited sample. Osmer, Porter, and Green will combine data they have on quasars with \( 0.1 < z < 4 \) with other recent results in the literature to see if the data provide evidence for either evolution or reddening.

M. Pierce is continuing the application of the Luminosity Line-width Relations in order to map the local distribution of late-type galaxies and examine the local departures from the Hubble flow. He is also completing the analysis of multi-epoch photometry of the resolved stellar population in Virgo Cluster galaxies with the goal of discovering variables stars and establishing the distance to the Cluster. Pierce will also continue the investigation of the incidence of strong interactions and mergers between member galaxies of clusters at moderate redshift (0.4 < \( z < 1.0 \)).

C. Pilachowski and Armandroff will continue their survey of heavy element abundances in Population II giants. Their survey will determine barium and europium abundances in a sample of nearly 100 metal poor giants to examine the relative contributions of the r- and s-processes of nucleosynthesis in the early phases of galactic chemical evolution. Pilachowski, C. Sneden (U. of Texas) and R. Kraft (U. of California, Santa Cruz) will continue a program to detect and measure sodium abundance variations in a large sample of globular cluster giants observed with the Hydra fiber positioner and multi-object spectrograph. Finally, with S. Saar (Center for Astrophys.), M. Pinsonneault (Yale U.), and J. Stauffer (Center for Astrophys.), Pilachowski will extend studies of the lithium abundance in stars in nearby clusters to the regime of the M dwarfs, particularly emphasizing young M dwarfs, as a diagnostic of stellar structure and evolution.
R. Probst will be occupied in commissioning the Cryogenic Optical Bench, a second generation IR camera stressing multiple spatial and spectral filtering modes. His personal use of the instrument will stress narrow band imaging and grism spectroscopy in regions of star formation for which I possess JHK imaging data from SQIID. As instrument scientist for the NICMOS 3 camera IRIM, he will lead technical efforts to characterize and improve its performance.

S. Ridgway will continue his collaboration with scientists from the University of Paris to develop and utilize fiber coupled infrared interferometry. This year they will work on the analysis and interpretation of observations obtained in FY93 of evolved stars. These observations will determine stellar angular diameters, which will be the basis for derivation of effective temperatures. Ridgway will also collaborate with S. Strom (U. of Massachusetts) in the utilization of the new Fast Two-Axis Secondary camera at the 2.1-m telescope to obtain high resolution infrared images of regions of active star formation in Taurus. These images will be analyzed for stellar multiplicity and improved statistics for the initial mass function at intermediate masses.

In 1994, A. Sarajedini plans to continue his research on blue stragglers in Galactic globular clusters. His observing run at CTIO in July will provide photometric data on enough blue stragglers to allow the construction of the first photometrically complete luminosity function for these enigmatic stars. The various features of this luminosity function will undoubtedly shed light on the origin and evolution of blue straggler stars. In addition, he has proposed to use the CTIO 4-m telescope to obtain membership information for several apparent red horizontal branch stars in certain globulars; these stars are thought to be the progeny of blue stragglers. If these stars are cluster members, the theory of horizontal branch morphology will need to be modified to account for their existence. If, on the other hand, these stars are NOT members of the cluster, stellar evolution theory will need to provide highly-efficient mass-loss mechanisms to transform a relatively massive star, such as a blue straggler into a much less-massive blue horizontal branch star. Finally, he plans to study the ages of the dwarf spheroidal galaxies in the Local Group so that they can be compared with Galactic globular clusters. The results of this project have wide-reaching implications for scenarios of galaxy formation.

During FY 1994, D. Silva will be working on three major projects. First, in collaboration with Todd Boroson and Richard Elston, he will continue to obtain high quality radial gradient data for the twelve brightest Virgo ellipticals ("the Virgo Project"). At this writing, UVRJK images for all twelve galaxies, H band images for the five brightest, and CO 2.36 μm spectra for the four brightest have been obtained. Their FY 1994 goal is to analyze and publish the existing data and obtain good radial spectra in the 3500-6500 Å range to study in detail the nature of the stellar populations near the main sequence turnoffs in these galaxies. Second, with Elston, Silva will continue his effort to study the resolved stellar populations near and above the giant branch in nearby early-type galaxies and spiral bulges. The chief goal of this project is to establish the presence or absence of intermediate-age AGB stars. During FY 1994, they plan to obtain JHK images with subarcsec resolution for NGC 1023, NGC 3031 (M81), and NGC 5128 (Cen A). They also plan to obtain high resolution near-IR images for a sample of M31 globulars to search for intermediate-age AGB stars. Third, Silva and Mike Pierce, will conclude their deep, wide-field, multi-band imaging survey of the known z = 0.4 galaxy clusters. Their goal is to classify the galaxies in these clusters in terms of their stellar populations to study the effects of environment on galaxy evolution. The achieved field-of-view is large enough that a direct cluster/field galaxy population comparison can be made. During FY 1994, they will image the last two clusters in their sample and publish their analysis of the clusters Cl0024+1630 and Abell 370.
L. Wallace's first research project is the identification of the features in the sunspot spectrum from 8 to 21 μm as seen with the solar FTS. The whole region is crowded with shallow lines. The short wavelength end is dominated by SiO and I have extended the SiO identifications to about 10.8 μm. The longer wavelength part is mostly unidentified except for a few OH and water vapor rotational lines. The objective is to identify as much as possible in order to find new molecular constituents. A second program is the production, with K. Hinkle (KPNO), of an atlas of the spectrum of Arcturus from 1 to 5 μm obtained with the 4-m FTS at extreme Doppler shifts (January/February and June/July). We would combine them with atmospheric absorption spectra obtained from the Solar FTS to produce a clean Arcturus spectrum corrected for atmospheric absorption.

In FY 1994, M. Wise will continue his study of the intracluster medium (ICM) in clusters of galaxies. These investigations are being done in collaboration with C. Sarazin (U. of Virginia) and will include detailed modeling of the X-ray spectra from these objects and incorporate the effects of radiative transfer due to cold material in the cooling cores. A primary goal of this work will be to supplement and extend these models with data obtained from the ROSAT imaging and ASCA X-ray spectroscopy missions. In addition to the X-ray regime, Wise will continue several ongoing cluster programs at other wavelengths. These include optical investigations of polarized light in clusters with B. McNamara (Center for Astrophys.), R. Elston (CTIO), and B. Jannuzi (Inst. for Advanced Study). This project will attempt to determine the origin of the blue light seen in many centrally dominant galaxies in cluster cooling flows. In addition, Wise and C. Walker (U. of Arizona) plan a program of sub-mm observations to constrain the amount of cold dust present in these objects. Finally, Wise and C. Sarazin (U. of Virginia) will continue a program to investigate the nature of the interstellar medium (ISM) in nearby bright ellipticals using ROSAT X-ray imaging data.

C. National Solar Observatory

R. Altrock will work on solar-cycle studies of the solar corona, using data from the SP Emission-Line Coronal Photometer (ELCP). This will include investigation of the variation of activity and rotation as a function of latitude and various periodicities in activity. Efforts to understand the implications of, and to refine knowledge of, overlapping solar cycles as observed in the corona will be continued. Studies of the variation of Fe XIV and Fe X coronal fluxes and their relationship to other global solar parameters will be performed. ELCP data will be searched for transients, and correlations with chromospheric, upper-coronal (from space-based instruments), and possibly solar-wind and geomagnetic data will be investigated. In particular, collaboration will continue with HAO on a study of transients as observed with the ELCP and the HAO Mark III K-Coronameter. Observations will begin with the full-limb "One-Shot" coronagraph after modifications to add a CCD camera are complete. He will continue work on the design and construction of a new space-based system to observe interplanetary disturbances, called the Solar Mass Ejection Imager (SMEI). Studies of coronal mass ejections will begin with data from the new Miniature Advanced Coronagraph (MAC I) CCD prominence-eruption patrol instrument. An investigation of the spatial and temporal variations of coronal temperature will be done.

K. Balasubramaniam will continue to be actively involved with S. Keil in the Solar Activity Initiative. The program will involve acquisition and interpretation of the data acquired under the Initiative program during the 1991, 1992, and 1993 observing runs at the Vacuum Tower Telescope, Hilltop facilities, the Evans Facility, and particularly the NSO/JHU-APL Vector Magnetograph. The goal is to look for signatures of active region development that give rise to eruptive situations, such as flares, separate from, and in
conjunction with, the magnetic field evolution. Such signatures could be changes in physical parameters such as velocity, temperature, pressure, proper motions, etc., or a combination of these.

J. Brault will work on mountain software to make the output of the new McMath-Pierce FTS data collection system smoothly compatible with the CD-ROM archive currently being implemented for existing data extending back to 1976; full reduction facilities, including improved and merged versions of GRAMMY and DECOMP, are planned for the Sun workstation already installed at the FTS. The possibility of connecting the archive itself to one of the major data network systems, such as NASA's Astrophysics Data System, will also be pursued. Brault will also continue his work with the IUPAC Working Group on Unified Wavenumber Standards, with the emphasis this year on internal standards for emission spectra. High quality spectra of an electrodeless lamp have already been obtained for the 2-0 sequence of vibration-rotation bands of CO, up to 14-12. When these have been calibrated using the laser wavenumbers of the 2-0 band itself, they will make available several hundred very high-quality standards (absolute accuracy a few times 10^-6 cm\(^{-1}\)) in the region around 4000 cm\(^{-1}\). Work also continues on the selection of good working standards in Ar I for use with hollow cathode light sources; although of slightly lower precision, they will still improve the accuracy of wavenumbers from such sources in the visible and near infrared by an order of magnitude, thus overcoming some of the uncertainties (primarily due to pressure shifts) that long plagued the old IAU wavelength standards.

R. Dunn will continue to work on all aspects of the adaptive mirror program for the Sacramento Peak Vacuum Tower Telescope.

T. Duvall will be working on several projects: i) preparing an instrument for an expedition to the South Pole in October 1994, ii) extending our understanding of the time-distance diagram of helioseismology through analysis of data, and iii) analyzing the data from the high-degree seismometer.

M. Giampapa's research program will focus on the structure of the outer atmospheres of low-mass dwarf stars. This work will be based primarily on pointed ROSAT X-ray observations and McMath-Pierce H\(\alpha\) observations of selected M dwarf stars. He will infer, through multi-component fits, the temperature structure of the corona in active and quiescent dwarf stars, as well as deduce emission measures and derive loop parameters in the context of stellar coronal loop models. Preliminary analysis suggests that the coronae of low mass dwarfs are highly extended (relative to the stellar radius). This property may be a distinguishing feature of the kind of dynamo that operates within the stellar interior. The H\(\alpha\) data will be utilized to infer chromospheric structure which, again, preliminary results suggest could be quite extended. He will further explore the utility of the He I triplet features, \(\lambda 5876, 10830\), for the estimation of active region area coverages on solar-type stars. This work will be based on a combination of atmospheric modeling and calibration observations of solar active and comparison quiet regions. The latter will be obtained with the McMath-Pierce Fourier Transform Spectrometer.

J. Harvey plans to reduce his involvement in developing the GONG project instrument as the production instruments are deployed in 1994. He will continue to study the solar interior using helioseismology observations obtained at South Pole and with the High-Degree Helioseismometer on Kitt Peak. The work is in collaboration with T. Duvall (NASA), F. Hill (NSO), and S. Jefferies and M. Pomerantz (Bartol Res. Foundation). He will also participate in the construction and testing of a new instrument to be used at South Pole early in FY 1995. The main scientific goals are: the temporal variations of solar oscillations over the solar cycle, exploration of the high frequency part of the oscillation spectrum, and local seismic imaging using a newly-developed analysis technique. Harvey also plans to work with synoptic data obtained at the Vacuum Telescope on Kitt Peak. The new 10830 Å video filtergraph should be in
operation providing a unique new look at the solar chromosphere. An ONR-funded project directed by R. Howard will explore early detection and characterization of coronal mass ejections from the solar disk.

K. Harvey will continue her research in two areas: (1) Collaborative studies with the Soft X-ray Telescope on board Yohkoh. Of special interest is a study of X-ray bright points and their association with the evolution of the underlying photospheric magnetic field and with their chromospheric counterparts, observed in He I 10830 and Hα. Additional research areas will be coronal holes observed in He I 10830 compared with those in soft X-rays, and coronal mass ejections and their disk sources. (2) A study of solar irradiance in terms of magnetic structures observed in the photosphere. Use will be made of the NSO full-disk magnetograms to define objectively magnetic network elements and active regions to determine (a) a mapping function with Ca II K intensity, He I 10830, and (b) the variation of the magnetic flux in these structures as a function of the cycle to establish their relative contributions to the total solar irradiance.

F. Hill plans to continue collecting data using the High-\ell Helioseismograph at the Kitt Peak VIT. In collaboration with researchers at the Astrophysical Institute of the Canaries, the University of Colorado, and the University of Cambridge, he will analyze the data to infer the horizontal velocity field in the solar convection zone. Hill plans to analyze the data that will be available from the GONG prototype and field instruments to continue development of the merging algorithm for GONG. Hill will also test the GONG data reduction pipeline and quantify any systematic errors resulting from the data processing. Hill will use the GONG data to develop inversion methods and to infer the internal solar rotation rate. Hill will also work with the SOI personnel to develop methods of measuring frequencies from high-degree power spectra.

R. Howard will continue his collaboration with Prof. K. R. Sivaraman of the Indian Institute of Astrophysics. This project is aimed at measuring the positions and areas of every sunspot on the daily Kodaikanal white-light plates from 1904 to the present. The measurements should be completed during this period. Also Howard will continue his collaboration with R. Komm and J. Harvey in the analysis of Kitt Peak Vacuum Telescope data. A second post-doctoral fellow will join the group at the start of FY 1994. This project will continue to be centered on the study of large-scale velocity fields of small-scale magnetic features. In the next year studies will be carried out in an attempt to define better the diffusion constant of the supergranulation velocity field. In addition, Howard will continue his studies of plages and sunspots in an effort to define parameters for, and set limits on, the activity dynamo process from its surface manifestations. A portion of this work will be carried out in collaboration with Dr. Sydney D'Silva of the Tata Institute of Fundamental Research in Bombay. Work next year will continue to emphasize the separation of magnetic polarities in regions as a parameter of activity and dynamic behavior.

S. Jefferies will continue the current South Pole Helioseismology program on into 1994 with the development of a new observing instrument and preparation for a field trip at the end of the year. The purpose of the new experiment is to measure the properties of acoustic modes with frequencies above the atmospheric cut-off frequency, to examine the wave properties of the solar atmosphere, and to obtain data at a phase of the solar cycle previously not studied. Observations will be made in both intensity and velocity. The velocity data will be the first imaged observations obtained from a single instrument that are without diurnal interruption.

H. Jones will continue collaboration with colleagues at NASA GSFC (J. Davila, S. Jordan, R. Thomas, J. Brosius, W. Thompson, and W. Neupert) in analyzing the SERTS-4/Spectromagnetograph data set to quantify the mechanisms for forming He lines in the solar chromosphere and transition region. V. Andretta, a doctoral student from Naples, has joined this collaboration as part of his dissertation
research. Jones organized and conducted a coordinated observing program and analysis workshop for the comparison of several magnetographs in FY 93 and will continue and expand this work in FY 94.

S. Keil will analyze the large data base obtained using the NSO/SP Vacuum Tower Telescope and Vector Magnetograph on the pre-activity development of solar magnetic regions. The relationship between velocity shear and magnetic instability will be investigated. Three-dimensional MHD codes will be used to compute coronal fields using the observed photospheric fields as inputs. Soft X-ray images from Yohkoh will be used to verify the calculations.

R. Komm will continue his collaboration with R. Howard and J. Harvey in the analysis of high-resolution magnetograms obtained with the NSO Kitt Peak Vacuum Telescope. This project is centered on the study of large-scale velocity fields of small-scale magnetic features and, after investigating average velocities and their solar cycle behavior, is now focused on residual velocities in longitude and latitude. Among other topics, possible correlations between residual velocities will be investigated.

J. Kuhn will complete two new IR camera systems using Rockwell HgCdTe NICMOS 3 and TCM arrays. A small, medium-resolution, imaging FTS system will also be completed. A project to build a high-resolution, imaging IR Fabry-Perot filter was started in collaboration with several NSO scientists. The IR systems will continue to be used at the VTT and Evans Facility for magnetometry and photospheric and coronal photometry. The fast IR system will be used for solar speckle observations during the next year. The RISE project should also get started in earnest this year. Kuhn plans to begin testing large format CCD camera and filter systems for these precision photometric instruments. Collaborative night-time projects to study the diffuse light in galaxy clusters and to find evidence of dissolving galaxies were continued with colleagues from Hamilton University, Michigan State University, Wyoming Infrared Observatory and Haverford College.

J. Leibacher will be pursuing studies of He 10830 oscillations, magnetic field interactions with the oscillation signal, high-\(l\) ridge analysis and time series modeling.

C. Lindsey and S. Jefferies are working with D. Braun (who will be joining NSO from the U. of Hawaii in September 1993) to develop a new area of solar diagnostics called local subsurface helioseismology. This concept is based on the possibility of applying computational holographic techniques to small-scale solar oscillations to examine subsurface magnetic structure. The data base for the ongoing project includes the NSO-Bartol-NASA South Pole Observations of 1987, 1988 and 1990. Acoustic power maps made from these observations show surface features that suggest the occurrence of subsurface magnetic flux tubes crossing the solar equator to connect active regions in the southern and northern active-region bands. This work will continue. In addition, Lindsey is working with J. Jefferies on a project to model solar chromospheric structure based on submillimeter observations made from the James Clerk Maxwell Telescope, on Mauna Kea, Hawaii. They will apply new LTE techniques they have developed for handling the statistics of radiative transfer in inhomogeneous media for this project.

W. Livingston plans to continue his basic monitoring of the solar spectral irradiance: Spectrum line variability of Ca K and He 10830. Line bisector variations over the solar cycle (5000 to 6300 Å observations made with the FTS). At a lesser pace, Livingston will continue the atmospheric trace-gas measurements (CO\(_2\), CO, CH\(_4\), HCl, etc). This work is done in collaboration with L. Wallace of KPNO. The new IR grating will allow observations of the stratospheric line of HCl, and the data frequency for this line will now become monthly. Livingston will use the dewar "Baboquivari" and its InSb diode to
measure magnetic fields in collaboration with S. Solanki and others. In connection with the proposed 4-m upgrade he expects to participate with ETS in mirror seeing tests and other seeing-related experiments.

D. Neidig is co-investigator on the USAF Space Weather And Terrestrial Hazards (SWATH) mission, and will be heavily involved in mission planning and in assembly of the SWATH coronagraph. The latter instrument, in addition to acquiring data on coronal structures and mass ejections, will be used in observations of space debris in size ranges unobtainable from the ground. Work will continue in analysis of the spatial variation of the electron acceleration spectrum in solar flares, using high speed optical imaging and hard X-ray data on white-light flares. Attempts to acquire a high-quality, universal spectrogram of a white-light flare, using the Vacuum Tower Telescope, will continue as opportunity permits. The Multiband Patrol (MBP) will be put into regular operation in support of flare studies. A statistical analysis of a data base (approximately 800 cases), including flare activity and parameters derived from vector magnetograms, will apply multivariate discriminant analysis in order to precisely determine the role of magnetic shear in flare prediction models.

L. November is applying new methods developed for precise in situ calibration of polarization optical systems to relevant problems, and plans to complete initial work on the "geometric analogy." His work will be in the following areas: (1) A number of polarimeter designs can be calibrated uniquely using a rotating entrance polarizer alone. The solution will be applied to the calibration of the liquid crystal polarimeter. It is hoped that this instrument will be completed and will be making useful solar observations this year. (2) A general representation for isotropically depolarizing optical elements was developed for which a depolarization and Jones operator is recovered with three input-independent polarization states, as can be obtained by the rotation of a single polarized source. Several design ideas for automatic calibration of the SP/VTT will be studied this year using this principle. (3) It is possible to recover the individual matrix operators in a serial system consisting of rotating elements from measurements of the combined system alone. This solution to the inverse problem for a serial-element optical system represents an analytic approach to the Sole filter problem. Numerical simulations will be carried out on this problem. (4) The "geometric analogy" is an underlying theoretical theme of this work. It is pointed out that the natural transformation group for the Stokes' parameters arises as a consequence of the condition of quantum observability of the dual-element wave function alone, without referring to spatial characteristics for the light-state wave function. This is the subject of a theoretical work soon to be submitted. The theory makes specific predictions for resonators, e.g. etalons, which could be tested. This work will continue during the next year.

M. Penn plans three research projects for this next year. First will be a measurement of the transmission of acoustic waves into sunspots using molecular absorption lines to measure the internal sunspot oscillations. Next, by using the two Fe XIII near-infrared coronal emission lines, the coronal density will be measured and related to loop structure and coronal rain. Finally, in collaboration with J. Kuhn, oscillations in the magnetic flux of sunspots will be studied using polarimetry of Fe absorption lines at 1.5 microns.

D. Rabin will study the structure of the magnetic field in the deep photosphere using the Near Infrared Magnetograph (NIM). The scientific goals include characterizing the spatial and statistical properties of flux tubes, and measuring the vector magnetic field in and around sunspots. In collaboration with T. Ayres (U. of Colorado) and G. Kopp (Meadowlark Optics), Rabin will use the newly-installed infrared grating at the McMath-Pierce main spectrograph, and the 256 × 256 infrared array camera, to study thermal inhomogeneity in the temperature minimum region (the 4.7 μm vibration-rotation bands of the CO molecule are a sensitive thermal probe of the photosphere-chromosphere transition). Rabin will pursue
aspects of the McMath-Pierce upgrade project (led by W. Livingston) connected with characterizing and improving the internal seeing of the telescope, particularly in the infrared.

R. Radick will concentrate on developing a low-order corrector for the NSO/Sac Peak solar adaptive optics system. This item, which is intended primarily to correct slowly varying aberrations present in the Vacuum Tower Telescope, will feature either a phase diversity/neural network phase measurement scheme or a more conventional Shack-Hartmann sensor. Its development will involve cooperation and coordination with associates at both the USAF Phillips Lab in Albuquerque and LP ARL. He will also continue to pursue concept definition activities for a near-infrared solar imaging interferometer with associates at the Phillips Lab and UNM.

G. Simon will continue his collaborations with N. Weiss (U. of Cambridge), A. Title (Lockheed), P. Brandt (Kiepenheuer Inst.), and G. Ginet (Phillips Lab.) on kinematic modeling of magnetoconvection at the solar surface. The model will be used to clarify the role of vortex motions in the surface velocity pattern, and to show how sunspots and plage regions decay in the presence of supergranulation and mesogranulation flow fields. Simon will be a member of an NSO/Sac Peak team which hopes to fly a series of three solar satellites during the next five years. He will also continue as a team member of the SOHO/MDI mission, scheduled for a 1995 launch. G. Simon and L. November are engaged in an ambitious two-year program with P. Brandt (Kiepenheuer Institut fuer Sonnenphysik (KIS)) to study the evolution of mesogranulation and magnetic fields. They plan two or three long observing programs with simultaneous and sequential observations from the Canary Islands and at Sac Peak. Each run will last 15 hours per day, for two weeks. In the Canaries the team will use both the KIS Vacuum Tower Telescope and the Swedish Solar Observatory. Success depends on the ability to see granulation, so that local correlation techniques can be used to identify the motions of mesogranules and supergranules.

R. Smartt will continue to work on problems concerned primarily with the solar emission corona, as well as the development of prototype reflecting coronagraphs. With Z. Zhang (Nanjing U.), he will carry out further studies of the interaction of post-flare loops, with emphasis on the relationship between the interaction as observed in the coronal emissions and the associated Hα emission. He will also be involved in ongoing studies of data recorded at the 11 July, 1991, total solar eclipse. In a joint program with Institut d’Astrophysique, reflecting coronagraph technology development continues at NSO/SP. Smartt will be involved in oversight of the design of a third coronagraph in this program that will employ a super-polished objective mirror of 55-cm aperture. In a similar capacity, he will be responsible for the construction of a small white-light coronagraph as part of a space-borne instrumentation package.

J. Zirker will continue his collaboration with O. Engvold (U. of Oslo) and S. Martin (California Inst. of Tech.) on the formation and magnetic regularities of solar prominences. This will involve joint observing runs at Big Bear and Sac Peak, and occasional meetings to review and interpret the data. Engvold and Zirker have separate plans to collaborate on the fine structure of prominences and the inferences they give on prominence magnetic fields. S. Koutchmy (Paris) and Zirker will continue work on the fine-structure of the corona and on attempts to confirm the current ideas on the heating of the corona. Zirker may get involved in the analysis of 1994 eclipse observations that Koutchmy is planning. P. Cargill (U. of Maryland) and Zirker may undertake a simulation of the evolution of a coronal current sheet, in order to find new diagnostics (X-ray and microwave spectra) for these elusive objects.
III. US Gemini Project Office

The importance of the US Gemini Project Office (USGPO) to NOAO was underscored by the AURA Board when they passed a resolution at their April Board of Directors meeting, making the USGPO a scientific division of NOAO on a par with CTIO, KPNO and NSO. The new division is led by the US Gemini Project Scientist, currently F. Gillett in acting capacity, preceded by R. Green and P. Osmer. The purpose of the USGPO is facilitating the scientific participation of the US astronomy community in the Gemini Project. The office does that through establishing two-way communication with the community on technical and scientific issues, through providing oversight and advice to the Gemini Project, through advocating and representing US interests in Gemini, and through coordinating the efforts of US institutions providing subsystems such as instruments to the Project.

The national Gemini Project offices in the other major partner countries typically have four people devoting full-time to the effort. An effective mix is two scientists, a national Gemini Project Manager, and an administrative assistant. The astronomers cover the tasks of communication and outreach, review of scientific materials for the Gemini Project, choosing and convening national scientific advisory committees, and interacting directly with the Project through the Gemini Science Committee and other advisory roles with the Gemini Project Scientist. The US Project Manager must have a strong engineering and technical background; that person identifies US providers of subsystems for the Project, acts as contract manager as requested for successful US institutions providing instruments and other technical packages, and reviews technical materials and presentations. The administrative assistant must produce the materials distributed to US astronomers and provide the logistical arrangements for US astronomers and engineers supporting the Project on advisory committees. The current staffing includes J. Gallagher, supported for an interim term by AURA as Associate US Gemini Project Scientist, L. Daggert as US Gemini Project Manager, and P. Wiggins coordinating administrative support.

A separate line in the budget table of this program plan shows the costs of supporting the US Gemini Project Office. Primary expenses are for salaries and for the travel expenses of the US scientific and technical committee members. Some additional cost is ascribed to NOAO staff that work with Gemini on a regular basis to review designs for specific subsystems. Because these NOAO staff are in Tucson, the Gemini Project team relies heavily on them to help work out the details of how to refine the scientific requirements and how to translate those requirements into technical specifications. By international agreement, salary support for scientists involved with Gemini and their travel expenses cannot be charged directly to the Gemini Project budget. It is likely that FY 1994 will see the hiring of a full-time US Gemini Project Scientist, US Gemini Project Manager and administrative assistant. NOAO could not absorb those costs within the FY 1993 budget envelope without a significant reduction in capability elsewhere in the program.

The USGPO has supported scientists serving on the (international) Gemini Science Committee at its meetings in Tucson and Victoria, Canada, and participants on the six Instrument Working Groups, charged with defining the scientific performance specifications and identifying potential providers of the instruments listed in the initial implementation plan. The US community also participates in the Gemini technical standards committee and in national project office meetings that have focused on the allocation of work packages to the partner countries. The USGPO, with the addition of the Associate US Gemini Project Scientist, will expand its outreach activities with a display and discussion session at the Berkeley AAS meeting and with a similar plan for the winter meeting after the primary mirror PDR. The USGPO has solicited expressions of interest in building instruments for Gemini and plans to facilitate
collaborations among interested groups at universities, national centers, and industry-based research organizations. The USGPO will also provide input to the operations plans for the Gemini Observatories and help define the role of NOAO and the US community during the operations phase. A successfully met objective will be to see a well-informed, involved and supportive US astronomy community behind the Gemini Project.

IV. MAJOR PROJECTS

A. Global Oscillation Network Group (GONG)

The Global Oscillation Network Group (GONG) is an international project to conduct a detailed study of the internal structure and dynamics of the closest star by measuring resonating waves that penetrate throughout the solar interior – Helioseismology. To overcome the limitations of current observations imposed by the day-night cycle at a single observatory, GONG is developing 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 is also establishing a distributed data reduction and analysis system to facilitate the coordinated analysis of these data. The primary analysis will be carried out by a dozen or so scientific teams, each focusing on a few specific categories of problems. Membership in these teams is open to all qualified researchers.

The project got underway officially in FY 1987. Since then, a breadboard version of the Doppler analyzer has been built and thoroughly tested, yielding excellent results. A prototype instrument was then built and began producing useful engineering data in FY 1990. Since then, refinements have been made to the prototype, improving the quality of the data, and increasing the level of automation and reliability of the systems. A project to develop data reduction and analysis software for the network has proceeded in parallel with the instrument development. Software for the data-reduction pipeline has also gone through "breadboard" and "prototype" phases, using data from the prototype instrument to test and optimize algorithms. Both the instrument development plan and the reduction and analysis software plan were submitted for peer review in 1993 with gratifying results.

The project has revised its long-range plan to attempt to deal with the absence of capital funding at the levels anticipated in the original proposal to the NSF. This has forced a departure from the originally proposed approach that called for subcontracting the actual production of major systems for the instrument. Much of this work is now occurring in house. Further, in order to get the network on the air in a timely manner, the development and production phases of the project have, of necessity, overlapped; while refinements are still being made to the prototype Doppler imager, the construction of many field-instrument components has proceeded. While this strategy involves some calculated risks, it will likely allow the project to field an excellent network of instruments in the shortest possible time.

The project continues to hold its annual meetings, but with adjustments to allow the format to evolve as the project moves from one phase to another. Starting with the April 1991 meeting, the format became less of a review of project developmental plans for the instrument and reduction software, stressing instead the scientific aspects of the project. The 1992 meeting was hosted by the High Altitude Observatory/National Center for Atmospheric Research and was called "GONG 1992: Seismic Investigation of the Sun and Stars." It was attended by more than 100 participants. The venue for the 1993 meeting was Tucson and consisted primarily of project presentations, science team meetings, and scientific talks.
If funding is delivered on schedule, FY 1994 will see completion of instrument production activities and all of the stations will have been integrated and tested at a staging area several kilometers north of the NOAO building. By the end of FY 1994, two field stations will be operational, and a third deployment will be in progress.

During 1994 the prototype instrument will also continue to take data routinely with daily visits by a non-expert attendant, thus simulating actual field operations as closely as possible. As in the past, the oscillation data obtained will be made available to GONG’s science teams in support of their various pre-network developmental activities.

The development of the data reduction and analysis system will also be completed in 1994. The last acquisitions for the Data Management and Analysis Center (DMAC) will be installed early in the FY, and the facility will be operational in time to verify the first field data tapes later that summer. Reduction of results from the partial network will be underway by year’s end.

Specific FY 1994 tasks will include the following:

- Complete integration of field instrument components
- Conduct a deployment readiness review
- Deploy first field station at Big Bear, California
- Deploy station at Mauna Loa, Hawaii
- Deploy first antipodal station at Teide, Canary Islands
- Analyze first merged data
- Continue routine operation of the prototype instrument
- Continue operating site-survey instruments at remaining sites

Looking forward to GONG network science operations in June 1994, the long-range plan calls for the following milestones:

| GONG Long-Range Milestones |
|----------------------------|
| December 1994 | Begin network operations |
| December 1997 | Cease network operations |
| November 1998 | Complete initial data reduction |

The anticipated long-term funding requirements in 1993 dollars are as follows:

| Fiscal Year | 1994 | 1995 | 1996 | 1997 | 1998 |
|------------|------|------|------|------|------|
| Funding (M$) | 2.60 | 2.10 | 2.10 | 1.47 | 1.69 |

These numbers are predicated on the restoration of the FY 1993 funding, as noted in the Budget section.
B. 3.5-m Mirror Project

|                      | Thousands of Dollars |
|----------------------|----------------------|
|                      | Payroll | Non-payroll | Total  |
| General              | $10K    | $40K        | $50K   |
| Startup support      | $43K    | $10K        | $53K   |
| Total                | $53K    | $50K        | $103K  |

During the past year the project has focused on activities related to completing the final grind and polish to the specified aspheric surface, upgrading the mirror support system, and preparations for the Phase IV 3.5-m mirror system acceptance test. This mirror is cast borosilicate glass and has been the source of experiments for grinding, polishing, and testing at NOAO since 1989. Past work on this mirror has resulted in the development of mechanical supports, thermal control system and in-telescope figure control. FY 1994 will see the completion of this multi-year project with the installation of the 3.5-m primary mirror system in the WIYN Telescope.

The project is divided into four phases: at present we are just completing Phase III. During Phase I the mirror blank was ground and polished to a 1/15-wave RMS sphere to facilitate optical testing from its center of curvature. The mirror was then aluminized, and the mirror support, thermal control, figure control and the temperature monitoring systems were built and installed into the mirror cell.

During Phase II system tests were conducted to develop and test the thermal control and active support systems. System performance was verified in both vertical and horizontal orientation.

At the start of Phase III, the mirror cell assembly was removed from the polishing table. Most the 960 thermal sensors attached to the mirror were removed. Passive polishing supports were fitted to the mirror cell, but the thermal control system was left intact. This approach made it possible to thermally stabilize the mirror after each polishing session. By sealing the mirror cell to the mirror, the mirror could be pressurized during polishing. This novel approach significantly reduced the quilting normally introduced while polishing a structured mirror.

Polishing of the 3.5-m primary mirror at the Steward Observatory Mirror Lab is completed. The work was a joint effort involving SOML and NOAO personnel. The final figure achieved over the clear aperture is superb: 22.9 nm RMS and 310 nm peak-to-valley. The largest remaining aberration is astigmatism. With astigmatism removed, the final figure achieved is 15.7 nm RMS and 188 nm peak-to-valley.

Preparations for Phase IV tests include installation of sixty-six redesigned axial supports, modifications to the final thermal control system, final modifications to the cell and general painting. Phase IV will be the final acceptance test. The polished mirror will be installed in the mirror cell, and a final series of tests will confirm the performance of the mirror and its support systems. Following the acceptance tests, the mirror will be shipped to Kitt Peak to be aluminized. After coating, the mirror will be assembled in its cell for installation in the telescope.
In FY 1994, the following work is planned for the 3.5-m Mirror Project:

1) Complete the Phase IV tests.
2) Publish the Phase IV test reports.
3) Install the mirror and cell on the telescope.
4) Complete mirror and telescope integration test.
5) Complete the system Operation and Maintenance manuals.

C. WIYN

NOAO has joined together with the University of Wisconsin, Indiana University and Yale University to build on Kitt Peak a new 3.5-m telescope utilizing a borosilicate honeycomb mirror cast at the University of Arizona Mirror Laboratory. The new telescope (known as the WIYN telescope for Wisconsin-Indiana-Yale-NOAO) is designed for use with optical fibers for multi-object spectroscopy, with a relatively fast focal ratio (about f/6.3) and a field-of-view of a full degree (15 arcmin uncorrected). The WIYN telescope will also be instrumented for CCD imaging. WIYN is devoting substantial effort to producing a telescope of superb image quality, with an enclosure designed to minimize dome seeing and on a site known to provide excellent seeing. The error budget for WIYN is planned to allow image quality as good as 0.5 arcsec when seeing permits. When the seeing is good, the WIYN telescope will be capable of high spatial resolution imaging with good image sampling.

Two Nasmyth foci will be available, one equipped for multi-object fiber spectroscopy with a wide field corrector, and the other available for a CCD imaging camera and other university instrumentation. Instrumentation for the WIYN telescope is being provided both by NOAO and by the universities. NOAO will provide the fiber-positioner, the multi-object spectrograph, and a large format CCD for imaging. NOAO will maintain facility instrumentation provided with the telescope. The universities will be responsible for university instruments which will not be generally available.

Time on the telescope will be shared among the members of the consortium, according to the financial contributions of the four partners. At least 40% of the time is expected to be allocated to NOAO for use by the astronomical community. NOAO's portion of the telescope time will be used for survey and synoptic programs efficiently done with multi-object spectroscopy. Observations will typically be obtained by the Observatory staff, rather than by individual astronomers assigned nights on the telescope. The telescope will provide the dedicated resources needed for studies of distant clusters of galaxies, selected samples of stars in nearby galaxies and in star clusters, and the physical environments of galactic nebulae. This new facility will therefore allow NOAO's community to pursue larger programs than are often considered feasible on Kitt Peak's other telescopes due to oversubscription. The telescope will also provide ground-based support for space astronomy.

During FY 1993 the project will essentially complete construction of the facility, and the commissioning phase will begin early in FY 1994. The polishing of the primary mirror has been completed by the Steward Observatory Mirror Laboratory, and the mirror is scheduled to be installed in the telescope in early FY 1994, followed quickly by the remaining optics.

During the commissioning phase in FY 1994, the WIYN telescope will be brought to a state of operational readiness for scientific operations. The major work will include:
• Installation of the telescope optics (December 1993)
• Completion of the telescope control system (January 1994)
• Alignment and collimation of the telescope optics (January 1994)
• Pointing and tracking tests (March 1994)
• Thermal testing (through June 1994)
• Commissioning of the WIYN Imager (September 1994)
• Final commissioning the Hydra fiber positioner and multi-object spectrograph (October 1994)

Regular scientific operations should begin early in FY 1995.

D. SOAR

The SOAR Telescope Project, consisting of the University North Carolina, Columbia University, and CTIO has completed its initial technical design work, culminating in the Technical Description (SOAR Technical Report Number 8). Issues addressed include the optical support structure (the top end, with a rectangular support for the secondary mirror assembly), the azimuthal support structure (the bottom half), and mirror supports to provide the active optics capability. The secondary mirror will itself be activated to move about the neutral center of curvature at 5 Hz or possibly more rapidly. This will not affect the focus, but will correct for windshake and the lowest order image motions produced by the atmosphere. Temperature control of the thin meniscus has also been studied by Barr, as detailed in SOAR Technical Reports 1 and 8. The near-zero CTE values of the ULE glass means mirror figure changes are negligible as the ambient temperature changes. Mirror seeing may be avoided by also utilizing the low thermal conductivity of ULE glass and the known thermal history during nights of good seeing. Briefly, the mirror will be cooled during the day to a temperature at or slightly below the temperature expected at the start of observing. An hour or two before the actual observing the front of the mirror will be heated slightly, and the front surface and the ambient air will then cool at about the same rates.

Recent technical studies have focused on the fabrication of the primary mirror. The raw ULE glass has been produced at Corning's Canton, New York plant. Each of the 26 boules has been tested for mean, vertical, and radial variations in the coefficients of thermal expansion. The first fabrication step was to select pairs of boules to be vertically fused to produce the necessary 20-cm thick stacks. A study was done (SOAR Technical Report Number 10) to determine the optimum selection of boule pairs to minimize CTE variations. While they are small, typically a few billionths of a cm per degree, proper selection minimizes the stresses in the mirror produced by polishing the primary at room temperature and operating it twenty degrees colder. The contract to fuse 24 boules into 12 stacks was signed, and the work completed during 1992. The next step will be to cut the cylindrical boules into hexagonal shapes, and fuse the stacks laterally into a plano blank. The plano will then be mounted onto a spherical ceramic sag mold and heated until the plano assumes the proper shape. SOAR Technical Report Number 11 studied and solved the optimal placement of the stacks for the hexing process. The hexing, lateral fusing, and sagging to produce the primary mirror blank, should be undertaken during 1993.

During FY 1994 work will continue on the axial and lateral primary mirror supports. G. Schwesinger will study the design and performance of a lateral outer-edge support which greatly reduces deflections in the primary mirror at off-zenith pointing, and Larry Barr will continue design work on the axial supports for the primary. Fund raising efforts at both University of North Carolina and Columbia University will continue until the funds required for the construction of the telescope have been obtained.
E. Other Telescopes at CTIO

C2t Telescope (Harvard/IOA)
The Harvard University-Institute of Astronomy, Cambridge consortium (C2t) to build and operate a 4-m telescope on Cerro Pachon is proceeding ahead. The C2t project wishes to retain as much observing time and control over their telescope as possible, and therefore they will pay CTIO/NOAO for the use of all services and the local infrastructure. No agreements nor MOUs have been signed yet, however CTIO astronomers are enthusiastic about the possibility of having CfA/IOA astronomers as neighbors and colleagues. Most of the present C2t effort is being directed to the fund-raising of approximately $25M, which is what is needed to build the telescope and endow operating costs. Harvard was successful in obtaining a commitment of $3M to the project a year ago, and both Universities are actively pursuing other sources of funds.

Sao Paulo Telescope
Several astronomical groups in Brazil have been interested in locating a telescope at CTIO in recent years because of the lack of excellent photometric sites in Brazil. Encouraged by the State of Sao Paulo, IAGE of the University of Sao Paulo entered into negotiations with CTIO more than three years ago to place a 2-m class telescope on AURA property which was to be designed and fabricated by Zeiss of East Germany, and funded by a swap of coffee beans for technology. The collapse of East Germany ended this initiative. However, the project has re-surfaced in recent months due to the strong interest of the IAGE astronomers, and the apparent willingness of the state of Sao Paulo to consider funding such a telescope. The basic telescope specifications have not been decided yet, and IAGE has been discussing possible designs with European firms. Informal contacts have been made between the CTIO Director and astronomers at IAGE about the possibility of locating the telescope on Cerro Pachon. The University of Sao Paulo would want to operate the telescope in the ‘Mauna Kea’ style, where they pay for all services. Nothing concrete has been decided upon regarding the operation of such a telescope at CTIO, however an agreement is likely to be made more realistic by Brazilian participation in the Gemini Project. All discussions to this point have been very preliminary.
V. INSTRUMENTATION

A. Cerro Tololo Inter-American Observatory

| Instrumentation | Payroll | Non-payroll | Total |
|-----------------|---------|-------------|-------|
| Active Primary Mirror Supp. System | 40      | 26          | 66    |
| Second Generation IRS* | 182     | 46          | 228   |
| Death of Tolnet    | 47      | 29          | 76    |
| Arcon 3C/6A + 2 spares | 33      | 43          | 76    |
| Arcon/Sun Interfaces (3) | 7       | 30          | 37    |
| Mini Mosaic      | 57      | 10          | 67    |
| **Total**        | **366** | **184**     | **550** |

* This is a two-year+ collaborative project; money is FY 1994 request for one instrument; manpower is for CTIO only, for FY1994 - FY 1995.

CTIO's FY 1994 instrumentation plans are concentrated in three main areas: improving the imaging performance of the 4-m telescope, fabricating and installing new array controllers, and beginning a joint CTIO-KPNO project to build a second-generation infrared spectrometer. The latter project also requires duplication of the f/15 secondary recently completed for the KPNO 4-m telescope.

4-m Telescope Image Improvements

In FY 1991, a major program was begun at CTIO to improve the thermal environment of the 4-m telescope by removing heat sources and facilitating air flow in the dome. During the course of this work, which is essentially completed, it became clear that the 4-m telescope optics themselves are not currently capable of producing an image quality comparable to the characteristics of the site (median seeing of 0.6-0.7 arcsec FWHM). Hence, in June of this year, the f/7.8 secondary mirror will be shipped to the USA for re-figuring. During FY 1993, we are also building a Shack-Hartmann image analyzer and modifying the f/7.8 secondary mount to provide for more efficient alignment and monitoring of the secondary once it has been re-figured. As the final step in this program, we propose in FY 1994 to modify the existing primary mirror support system to provide for active control of the primary mirror figure. This last project in particular will benefit work at other foci as well.

New Array Controllers

The design of a new-generation array controller was actively begun at CTIO approximately three years ago. After successful testing of two prototype controllers on the Curtis Schmidt telescope, the first copies of the Arcon 3A controllers destined to replace the ten-year old VEB controllers will be entering into routine service on the 0.9-m and Curtis Schmidt telescopes during the present semester. During the remainder of FY 1993 (and probably stretching into the first half of FY 1994), we plan to produce (in-house) six copies of a slightly upgraded version of the controller, Arcon 3B. In FY 1994, we propose to
carry out a final production run of six controllers, Arcon 3C, which should be enough to satisfy all of our present detector controller needs. For Arcon 3C, we plan to have as much of the work as possible done by contract; in-house personnel will be involved only to supervise production and acceptance testing.

Second-Generation Infrared Spectrometer/4-m f/15 Secondary
The Second Generation IR Spectrometer is a joint CTIO-KPNO project. Specifications have been developed jointly with the KPNO IR Group, and the conceptual design will be done jointly until the point is reached at which detailed design and fabrication can be divided up among the participants. CTIO is expected to take the lead at the initial stages of the project, with the goal of preparing a final conceptual design for review toward the beginning of FY 1994. Manpower resources are expected to come from CTIO (both in FY 1994 and 1995) and from the KPNO IR group (FY 1995). The Second Generation IRS will work at f/15, and the 4-m must therefore be upgraded to include an f/15 secondary prior to completion of the project. The NICMOS Imager currently being built at CTIO would be able to make use of this secondary as well. This new secondary mirror is a capital-intensive project which requires NOAO resources freed by the WIYN project (FY 1994 and 1995) in addition to the regular CTIO instrumentation budget.

In addition to the above-mentioned projects, initiative resources would allow existing infrared instrumentation at CTIO to be transferred to modern control systems, and two lower-priority, capital-intensive improvements to carried out:

Death of Tolnet
IR photometry and the current Infrared Spectrometer at CTIO are controlled via "Tolnet", a network of Data General 16-bit Eclipse computers which were installed in the 4-m telescope building in the late-1970s. These computers are antiques which Data General no longer supports. The IR instruments are the last major applications that make use of Tolnet; if they could be converted to more modern computers, we would be able to reduce the support burden on the mountain staff as well as eliminate a major heat source in the 4-m telescope building.

Backup La Serena-Tololo Microwave Link
CTIO staff and visitors have come to rely very heavily on the fast link between La Serena and Tololo, both for problem debugging, data transfer, and electronic communication. A recent failure of the microwave system has pointed out the importance of providing a backup system. Rather than buying a full set of spares for the existing system, we propose the purchase a completely independent 23 GHz channel. The new system would increase the available bandwidth, in addition to providing a nearly full backup capability at considerably less cost.

A key element of the above-described program is the demonstrated desire and willingness of the CTIO and KPNO staffs to make infrared instrumentation at the two sites more compatible. The most efficient and logical way to bring state-of-the-art IR instrumentation on-line nearly simultaneously at both KPNO and CTIO is to pool the technical resources at both sites. The Second-Generation IRS and the f/15 secondary for the CTIO 4-m are important steps in this direction. It should be noted that the plan for the Second Generation Infrared Spectrograph contemplates the use of detector electronics developed at KPNO for both the KPNO and CTIO instruments. This presents a new challenge, since for this to work effectively will require a much greater degree of collaboration in support areas (documentation, training, response to problems, etc.) than has been achieved before between KPNO and CTIO. Of course, this style of instrumentation production will be an absolute necessity for Gemini.
B. Kitt Peak National Observatory

1. KPNO Optical/Ultraviolet

The Optical/Ultraviolet (O/UV) Instrumentation Group has placed its emphasis for the last five years on the development of multiple object fiber-linked spectroscopy. The successful implementation of the Hydra automated fiber positioner and bench spectrograph places KPNO at the leading edge of fiber-fed spectroscopy.

A second major focus of the O/UV group has been the acquisition, testing, and implementation of the best available CCDs. This program has been advanced in three ways. First, the O/UV CCD group has a worldwide reputation which encourages vendors to make new CCDs available for characterization before they are released to the general community. We acquired two excellent Tektronix 2048 × 2048 chips early on in Tektronix's fabrication program for that state-of-the-art device. Second, involvement with the development program undertaken with Tektronix for the Space Telescope Imaging Spectrograph has yielded a number of devices which have been available on the KPNO telescopes. Third, significant improvements in CCDs for spectroscopy have been realized from the successful foundry run at Ford Aerospace (now Loral Fairchild), made in collaboration with CTIO and Steward Observatory, which yielded devices with 15 μm pixels in 3K × 1K, 800 × 1200, and 2048 × 2048 formats. Thinning and packaging are in progress with new AR coatings and UV sensitizing resulting in 80% efficiency from 3500 Å to 7000 Å. Connected to this effort is the upgrade of old CCD controllers to a modified version of the CTIO transputer-based array controllers. With these systems in place around the start of FY 1994, a significant improvement in readout speed should be achieved with no increase in noise.

The program proposed for FY 1994 maintains O/UV's emphasis on improving the imaging capabilities at KPNO while at the same time laying the groundwork for the next round of spectrograph improvements. The largest project is a continuation of the development of a mosaic imager for use at the 4-m prime focus and at the 0.9-m telescope. A new corrector for the 4-m prime focus will enable this mosaic to take advantage of the improved image quality over a large field. As the current fiber positioner and bench spectrograph will be modified for use at the WIYN telescope, a new high-dispersion fiber fed spectrograph is being investigated for the 4-m telescope.
Summary of KPNO O/UV Projects

| Project                        | Payroll | Non-Payroll | Total  |
|-------------------------------|---------|-------------|--------|
| CCD Mosaic Imager             | 250     | 20          | 270    |
| CCD Development               | 87      | 8           | 95     |
| 4-m Prime Focus Corrector     | 11      | 10          | 21     |
| Fiber R&D                     | 6       | 12          | 18     |
| New 4-m Fiber Spectrograph    | 73      | 25          | 98     |
| Gold Cam 2                    | 100     | 10          | 110    |
| O&M                           | 52      | 13          | 65     |
| **Total**                     | **579** | **98**      | **677**|

**CCD Mosaic Imager**

The long term goal for CCD imaging is the development of an 8K x 8K array, constructed as a 2 x 4 mosaic of 4K x 2K CCDs. The first step toward this goal is the fabrication of a four-chip (each 2K x 2K) mini-mosaic. There are three reasons for building a mini-mosaic: 1) as a technology demonstration of our ability to mount a number of chips together in a way that can be extended to a larger array; 2) to be a useful instrument in its own right; and 3) as a prototype for testing many of the peripheral aspects of the mosaic, such as controllers, dewar design, and data processing.

A prototype version of the mini-mosaic has been tested at the 0.9-m and 4-m telescopes, and it is expected that two high-quality arrays will be finished in early FY 1994, one for use at KPNO and one for use at CTIO. Preliminary design work on the dewar, shutter and filter assembly, and guider has begun for the large mosaic. After a detailed design study and some experience with the mini-mosaic has been acquired, the project will undergo a review by an outside committee. Following a successful review, we will contract for a new run of CCDs with Loral Fairchild and for thinning and packaging services with Lesser (Steward Obs.). The large mosaic will be shared with CTIO on an annual basis. The project should be completed by the middle of FY 1995.

**CCD Development**

Although we have not finished the 3K x 1K and 800 x 1200 chip characterization, the thinned CCDs are starting to arrive with some regularity. Two 800 x 1200 chips have been sent to CTIO and one has been put into the Cryogenic Camera. Three 3K chips are ready for disbursement. Our current expectation is that by the end of FY 1993, KPNO, NSO, and CTIO have adequate supplies of these chips.

In FY 1994, most of the CCD Development work will be in support of the mosaic project and the new Harcon controllers. For the mosaic, a number of 2K chips must be characterized, and, following another foundry run, we will begin on the 2K x 4K CCDs. The new controllers require new microcode to run the existing complement of CCDs, and this will be a good opportunity to look carefully at how we can increase the speed of readout.
4-m Prime Focus Corrector
This proposal, which is a continuation of a FY 1993 proposal is intended to upgrade our CCD imaging capability at the prime focus of the 4-m telescope. We have completed studies to modify the doublet and triplet designs. Only marginal improvements could be achieved. We are left with no recourse other than to design a new corrector. A contract has been signed with R. Bingham (U. College, London) to provide several designs, preliminary versions of which we expect to see before the end of FY 1993. Evaluation and detailed design work will follow, and we will be ready to purchase glass and contract for construction of the elements in FY 1994. The full capital funding for this project must come from the initiatives restoration.

Fiber R&D
A modest level of continuing support is required for evaluating new commercial products and beginning an investigation of fiber scramblers.

New 4-m Fiber Spectrograph
We are proposing a new, fiber-fed, cross dispersed spectrograph for the KPNO 4-m telescope to replace the bench spectrograph being moved to WIYN in 1994. The spectrograph would utilize a single object fiber and several sky fibers fixed in the focal plane of the 4-m and should be capable of spectral resolutions of a few thousand up to 100,000. The scientific motivation is to provide a new capability at the 4-m telescope to address programs which require high spectral resolution, moderate resolution and broad spectral coverage, and/or stability for precise velocity measurements. The stability and high dispersion capability will allow studies of stellar seismology, detections of planetary systems, and work related to other stellar physics problems where very accurate line strengths and velocity measurements are required. In its medium resolution cross-dispersed mode, the new spectrograph will allow high signal-to-noise spectroscopy over a very large wavelength range of moderately faint objects.

A design study is underway in FY 1993 leading to a concept design. This will include a feasibility study of grism cross dispersion and an evaluation of camera options to provide the range of dispersions desired. In FY 1994, we plan to develop a detailed design with most fabrication in FY 1995.

Gold Cam 2
In FY 1993 we have begun work to design a new camera for the Gold Spectrograph. It has been obvious since a 3K x 1K CCD was put into GoldCam that this instrument is the one with the poorest match between optics and detector. We are unable to use more than about 2000 (30 mm) of the 3072 spectral pixels because the line profiles become strongly skewed outside of this range. There is a long standing astigmatism problem with the higher dispersion gratings, and this has become more noticeable because observers use these gratings more frequently now that they can cover a significant wavelength range with them.

We are looking at designs for both a long camera which would be used for higher dispersion work than the current camera permits (and would accept a universal dewar), and a short cryogenic camera which would cover an octave in wavelength on a Ford 3K x 1K CCD. These designs are still to be finalized, but they are both relatively simple (all surfaces are spherical) and we would like to begin fabricating the first one (probably the long camera) in FY 1994.
2. Overview of the KPNO Infrared Program

We have just completed our first five years of experience with IR arrays at KPNO. This enterprise has been highly successful. We have staged the implementation of this technology in such a way as to provide immediate scientific results, have made the paradigmatic shifts required to "think infrared," have invested in the hardware needed for efficient operation of the new instrumentation, and have planned for upgrades based both on improvements in technology and on improvements in our understanding.

The program is now approaching maturity. The next five years will see continued rapid growth, including:

- Upgrade of existing array-based instrumentation to a detector format size of $256 \times 256$, with further upgrades to larger format to follow;
- Installation of fast electronics and related upgrades in computer hardware and software required for 3-5 $\mu$m operation and for the use of larger format arrays;
- Development of $1024 \times 1024$ InSb detectors in collaboration with USNO;
- Deployment of a high resolution ($R=100,000$) spectrograph;
- Sharply improved image quality through wavefront correction;
- Design and construction of a medium resolution spectrometer with CTIO.

Recent Program Highlights

- The facility camera SQIID is now operational at the 4-m telescope, employing a new f/15 secondary mirror and closed-cycle refrigeration,
- The detector research and development effort has successfully deployed state of the art high quantum efficiency HgCdTe and InSb detector arrays,
- In a collaborative arrangement with Tony Tyson of Bell Telephone Laboratories, the facility camera IRIM was upgraded to a $256 \times 256$ HgCdTe NICMOS III array,
- The detector removed from IRIM, being of superior cosmetic quality, was installed in the grating spectrometer CRSP, providing a very substantial improvement for that instrument,
- The Cryogenic Optical Bench was commissioned using a $256 \times 256$ InSb detector array,
- The optical and mechanical design for the high resolution ($R=100,000$) long-slit spectrometer was completed,
- The Fast Two-Axis Secondary (FTAS) project at the 2.1-m telescope used tip-tilt wavefront correction to demonstrate a factor of two improvement in image size.
Future Plans

Detector upgrades for all existing array-based instrumentation
The facility camera IRIM was recently upgraded to a 256 × 256 HgCdTe Nicmos III array, while the Cryogenic Optical Bench employs a 256 × 256 InSb detector array. Now that such high quantum efficiency, large format detectors are available it is also appropriate to upgrade the detector in CRSP as a short-term measure (preceding the construction of a next generation medium resolution spectrograph, scheduled to occur towards the end of the forward look period, as described below). The optics in CRSP can take full advantage of the larger format in the dispersion direction, but not in the spatial direction; we are extremely fortunate to have in hand an engineering grade 256 × 256 InSb whose functional area fills this illumination pattern of CRSP, allowing a very cost-effective upgrade path. A further necessary step in such an upgrade program is in the fast electronics and computer capabilities required to support the very high resultant data rate.

Fast electronics and related computer upgrades
Development of fast electronics was begun in FY 1990, and the prototype was available and working in the L channel of SQIID by the end of FY 1991. The latest generation of high quantum efficiency arrays strains the older KPNO IR data system intolerably. For example, the old data system requires 60 seconds to archive a single frame, yet the longest integration time possible at broadband K is now only 10 seconds. Fast processing electronics are a major component essential for operation in the thermal infrared, for rapid data acquisition, for fast guiding, and for more sophisticated adaptive optics. Faster electronics will also be needed for full exploitation of the multiple-read noise reduction algorithm, essential for efficient spectroscopy. Continued development work and upgrade in this crucial area will proceed as rapidly as resources allow, so that all IR instruments at all KPNO telescopes can be operated efficiently, with electronics based on a common design.

Deployment of a high resolution (R=100,000) spectrograph, PHOENIX
The experience gained at KPNO with CRSP, a low- and medium-resolution array spectrometer employing an SBRC 58 × 62 InSb array, amply demonstrates the power of IR arrays for spectroscopy. The High Resolution Spectrometer, PHOENIX, uses a compact collimator/camera system based on a modification of the Ebert-Fastie concept. In keeping with our commitment to modular design, the PHOENIX foreoptics are modeled on the Cryogenic Optical Bench, and will accept an f/15 beam, in common with the other IR instruments. The optical and mechanical design for the high resolution (R=100,000) long-slit spectrograph PHOENIX is now complete, and construction will begin in the second half of FY 1993. This instrument will continue the strong tradition of high resolution IR spectroscopy begun at KPNO with the 4-m FTS, and because of the improvements in detector technology, will provide much greater sensitivity.

Sharply improved image quality through wavefront correction
Infrared astronomers are becoming increasingly aware of the potential of adaptive optics for image improvement. The recent demonstration of diffraction limited imaging at 2-5 μm at Haute Provence, a mediocre site, has shown that this potential will be realized within the near future. The 2 μm window is a particularly good place to work, because the background from both atmospheric airglow and thermal emission is relatively low.

The KPNO infrared program entered this field with a development program that began with relatively simple modifications to existing facilities and instruments. The first step was adaptive correction to image motion through simple tilt correction, which reduces the 2 μm image diameter by a factor of 2 under typical Kitt Peak seeing. The experiment is proceeding at the 2.1-m telescope. A CCD camera is used to
provide a continuous position readout for a reference star in the field. The required brightness of the reference source depends on atmospheric conditions, but is sufficiently faint that the image stabilization option will be of wide applicability. The error signal is used to close a fast guiding loop with the existing 2.1-m two-axis IR secondary. A new camera module for the Cryogenic Optical Bench will allow its use with FTAS in FY 1994.

It is too early to predict accurately how the generalization to higher order wavefront correction will proceed at KPNO. One possibility is through the addition of a segmented secondary and with improved wavefront measurement. Implementation of the fast guiding would require installation of suitable mirrors, first at the 2.1-m and later at the 4-m. A focal ratio in the range f/60 to f/120 would be appropriate for this small secondary. An upgrade of the fast processing electronics would be required for rapid centroiding and generation of the error signal to drive the mirror tilt in two axes. The longer term developments should also include deployment at the 4-m of the tilt correction system, and incorporation of higher order corrections through active control of a segmented mirror. Following the model of other successful IR development programs, development of a mirror with 10-20 actuators might be undertaken jointly with a commercial vendor, especially one with experience in adaptive optics for Defense programs. Real-time correction of several higher order (Zernike) terms would then be possible, and the goal of diffraction limited imaging could be more closely approached.

**Design and construction of a medium resolution spectrometer with CTIO**

Major savings in non-recurring engineering costs and infrastructure can be realized if the same instrument can be operated at multiple sites. At KPNO the work needed to allow IR operation at a common focal ratio of f/15 at the 1.3-m, 2.1-m and 4-m telescopes is now complete, and identical closed-cycle refrigeration will soon be available at all three telescopes. A scheme is now under consideration to make similar modifications at CTIO. This will allow us to use copies of the same instrument at KPNO and CTIO. Discussions of a suitable choice for an identical pair of IR instruments have identified among the user communities a common desire for a new medium resolution spectrometer. Work on the optical design will proceed at CTIO simultaneous with the necessary telescope modifications. The mechanical packaging and construction will take place in Tucson.

**Detector development with USNO**

A series of meetings between representatives of USNO and NOAO during 1992 identified areas of common interest in the development and deployment of IR focal plane detectors for use in astrometry. USNO brings to this discussion vast experience in astrometry, while NOAO has expertise in the development, characterization, and utilization of various IR detector technologies in astronomy.

InSb was identified as the detector material appropriate to satisfy our mutual goals, because of its high quantum efficiency, excellent cosmetic quality, low dark current, low read noise, and absence of after-images of the kind seen in HgCdTe array detectors (the other readily available high QE material). The present maximum array format of 256 × 256 was deemed too small for typical applications in astrometry. Formats of 1024 × 1024 will be required.

As part of a pilot program based on existing 256 × 256 detectors, observations were made at both the 4-m and 1.3-m telescopes at KPNO. These observations demonstrated that the present generation of IR cameras at KPNO provide stable, reproducible, sensitive infrared observations suitable for astrometry.

We have now entered into a jointly funded collaboration between USNO and NOAO for a detector development program with Santa Barbara Research Co. to produce 1024 × 1024 InSb arrays within two
years. Santa Barbara Research Co. is the leader in the field of InSb detector array development for astronomy. NOAO has a long and mutually advantageous relationship with SBRC in the specification, deployment and optimization of these detectors. The first generation 58 × 62 array was pioneered at NOAO just a few years ago. Very recently, the newly developed 256 × 256 InSb array was put into service at KPNO with great success. Extrapolating along the technology baseline provided by these earlier efforts, SBRC and NOAO are now convinced of the feasibility of a development program for 1024 × 1024 InSb array detectors. This is the format size identified by USNO as that required for a mature astrometry program. The detector development effort will be modeled after that conducted by NOAO in the successful development of the science grade PtSi array.

Advanced Mirror Coatings
The performance of all the IR instrumentation is affected by the reflectivity and emissivity of the telescope optics. The optical design of the telescope system, the intrinsic properties of the mirror coating, the contamination of the mirror surfaces by dust and other residues, and the deterioration of the mirror surfaces are all important factors in determining the system emissivity, and thus the ultimate performance. In the thermal IR, notably around 4 μm and 11 μm (and perhaps even in the K band), the thermal emission of the telescope system is the dominant source of background at the detector.

The long-term plan is to pursue a program to evaluate the performance of telescope mirror coatings. In FY 1991 we initiated the effort by applying an advanced coating to the optics of an existing 33 cm f/15 low-background configuration telescope adapted so that it can be attached to the top-surface of the IRIM and CRSP, storing the telescope in the 1.3-m dome, and making measurements of the 33 cm telescope emissivity, zenith sky emissivity, and 1.3-m telescope emissivity at 4 μm each time the IRIM or the CRSP is mounted on, or removed from, the 1.3-m under clear weather conditions. Use of the 33 cm telescope for these tests allows us to isolate sources of background emission in the telescope, recoat the mirrors, change coatings, and make mirror cleaning and scattering tests (all of which would be rather impractical with the 1.3-m telescope itself) while at the same time providing a realistic approximation to a real telescope environment and configuration, and a comparison baseline with the aluminum coatings on the 1.3-m.

The initial coating is thorium fluoride/silver/chromium, which the NOAO coating lab is able to produce. The prescription has been in use at the 4-m FTS for several years. If the testing indicates substantially improved durability and performance of advanced coatings, it will be important to develop the capability to lay down silver undercoated with copper and overcoated with sapphire and tantalum oxide, the preferred prescription in the NOAO-supported study at the Optical Sciences Center to develop an IR optimized, broad wavelength, improved durability mirror coating.

Gemini
The KPNO Infrared Program is well positioned to meet the requirements of the NOAO 8-m telescopes. The fast guiding and coatings endeavors are directly applicable to the design of an "infrared optimized" telescope. By virtue of the Cryogenic Optical Bench approach to instrument construction, the present generation of KPNO instruments can be regarded as prototypes for the 8-m telescopes. The long-term effort will be in the area of diffraction-limited observations, with associated adaptive optics, fast electronics, and rapid guiding. High resolution spectroscopy can benefit significantly from a successful adaptive optics program because of the small angular slits required to achieve high spectral purity. A plan including development of sharply improved image quality and spectroscopy is therefore operationally justified and will be aggressively pursued. Given our sturdy programmatic expertise, it would be a wise
investment for Gemini to underwrite a substantial effort in IR astronomy at KPNO, and we will continue attempts to foster a close relationship.

| FY 1994 Program                        |Thousands of Dollars |
|----------------------------------------|---------------------|
|                                        | Payroll  | Non-Payroll | Total |
| Continue PHOENIX                       | Hinkle   | 292         | 60    | 352   |
| Design Medium Res. Spectrometer        | Joyce/Hinkle| 11         |       | 11    |
| Fast Two-Axis Secondary (FTAS)         | Ridgway  | 26          | 5     | 31    |
| Upgrade CRSP Detector                  | Joyce    | 52          | 2     | 54    |
| COB Improvements                       | Merrill  | 160         | 20    | 180   |
| Closed Cycle Cooler Upgrades           | Fowler   | 26          | 5     | 31    |
| Operations and Maintenance             | Fowler   | 141         | 40    | 181   |
| Detector R&D                           | Gatley   | 156         | 35    | 191   |
|                                        |          |             |       | 864   | 167   | 1,031 |

* Reduced relative to previous five year plans to actual levels of support for FY 1993

C. National Solar Observatory

NSO's primary instrumental goal continues to be the ongoing development of the principal instruments at each site: adaptive optics at Sacramento Peak, and infrared systems at Kitt Peak.

The resources to begin "new" projects must come from the wedge of resources that results from the completion of "old" projects, and potentially new resources. Thus, the NSO plan anticipates a span of at least two or three years in order to identify start times and levels of effort for future activities. Such an approach also naturally supports the development of a self-consistent long-term program.

It should be noted that NSO pursues a scientific program which is the result of a partnership between the NSF and a number of other agencies and groups, primarily the AFSC/PL, NASA, NOAA, LPARL, and HAO. All of these partners contribute funding of one sort or another to the program. Nearly all of these activities impact the NSF-supported program. The discussions here are limited to projects which receive at least partial support from NSF.

1. Sacramento Peak

Adaptive Optics

The development and installation of an Adaptive Optics system at the NSO/Sacramento Peak Vacuum Tower Telescope (VTT/SP) continues into FY 1994 as NSO's highest priority project. Many fundamental physical processes on the Sun occur at angular scales of less than one arcsec. For example, the interaction of surface convection and magnetic fields, and buildup and release of flare energy, and the emergence and
decay of sunspots all involve processes at the subarcsec scale. The addition of an effective AO system to the VTT promises to enhance significantly the ability to observe and measure these effects by providing diffraction-limited resolution for extended periods.

This program was based primarily on an AO system developed by the Lockheed Palo Alto Research Laboratory (LPARL), and tested at the VTT/SP, in a joint LPARL/NSO program. The LPARL AO mirror consists of a matrix of independently-controlled, sub-aperture mirror elements. Optimization of the AO system by R.B. Dunn, NSO/SP, during 1992 resulted in a video record that demonstrates the ability of such an AO system to provide substantial correction to the wavefronts from an extended source such as the Sun. In a parallel program, NSO/SP has undertaken the development of an AO system (under R.B. Dunn) based on a very thin, continuous-surface mirror controlled by an advanced computer-controlled system, coupled with a novel Wavefront Sensor (WFS). This new system offers the possibility of improved performance in several technical areas.

The success of the LPARL project has greatly increased interest and demand for a system on the VTT. While considerable progress has been made over the last few years, funding has been extremely limited. At the present time only a small staff is available to assist R. Dunn in this project, namely an optical engineer, electrical engineer and an instrument maker. In addition to Dunn, part-time help in programming is also available. Non-payroll funds, which in the past have been supplied by PL/GPSS, are predicted to be minimal in 1994. Near-term objectives for the NSO/SP AO system include completion of the Correlation Tracker and subsystems, completion of the optical system for the LCD Wavefront Sensor, testing and debugging of the Reconstructor, further progress on the WFS camera control electronics, and reassembling of the Fizeau Interferometer and its associated computer and software (this instrument will be used to test the 61 actuator face plate mirror).

Mirror-Advanced Coronagraph
Work continues on optimizing the performance of the second prototype reflecting coronagraph (MAC II) based on a 15-cm aperture, zerodur super-polished objective mirror. In particular, a special CCD camera has been acquired. Also, a new filter system is under test that should provide better discrimination between the coronal-line emission and the continuum background. Further, a second optical channel will be incorporated to allow simultaneous measurements at two wavelengths. Tests will be carried out in an attempt to obtain images in the near infrared Fe XIII (10747 Å). These developments and tests will provide invaluable input for optimizing the design of MAC III, based on a 55-cm aperture, super-polished objective mirror. Additional optical design work has been carried out on MAC III, with a further refinement still required. In parallel, initial mechanical design work has been carried out. Requests for quotes on the extremely challenging technology of the super-polished objective mirror have been distributed to potential vendors. Completion of all details of the complex optical design, acquisition of the primary objective mirror, and substantial progress in the mechanical design of this instrument are planned for the next year.

CCD Implementation
This is seen as an ongoing effort by the Observatory to continue to provide state-of-the-art detectors to the community. Many existing instruments that are only film-based will need to have CCD capabilities added. New instruments using CCD technology will have to be integrated into the existing system architecture. The general advance of this technology also requires that we look continuously at new detector designs and implement them when appropriate. Part of this ongoing effort is to explore current controller technology. This will include an interim program of using existing NSO/SP MDA controller systems for running the larger format arrays. While these controllers have excellent characteristics for
handling the old, smaller-format RCA arrays, they are quite inadequate for providing optimum performance of the newer, large-format devices. To improve readout speed and create the capability of handling multiple independent camera systems, NASA-based, commercially-available controllers with widely-configurable capabilities are also being investigated.

**MARK II Correlation Tracker**

This project is intended to capitalize on the parallel research efforts now underway concerning new Correlation Tracker designs. Various institutions are working currently on hardware implementations, PC versions, and VME-based versions for balloon flights. After several of these programs have reached a reasonable state of completion, and based on their comparative performance, a consensual plan will be developed to produce an advanced, but technically simpler, version of a universal correlation tracker system. Of the different approaches to second-generation systems of this type, the absolute difference algorithm appears to have the most promise, based on simplicity and response time, but critical measurements will be required to confirm this provisional assessment.

**Multiple Aperture Telescope System**

Many solar observations can be made effectively with relatively small-aperture telescopes. In fact, certain seeing conditions can result in superior angular resolution using a small-aperture system, compared with that of much larger telescopes. Further, for certain programs, the availability of large blocks of observing time of limited resolution might prove more valuable than high-resolution observations on large-aperture telescopes of limited access. Consistent with this viewpoint, an optical Multiple Aperture Telescope System (MATS) is proposed for the NSO/SP Vacuum Tower Telescope. The 76-cm aperture of the VTT/SP will be divided into six 32-cm apertures to form six separate optical beams, each with its own scale, offset guiding, correlation tracker and rastering capability. With this system, any of the sub-telescopes could be used to observe at any position on the Sun. Each would have its own particular optical table and focal plane instrument(s). This system will therefore have the enormous advantage of being able to run multiple experiments simultaneously, where extremely high-angular resolution is not essential, thus multiplying the potential scientific return of the VTT.

2. **Kitt Peak**

**McMath-Pierce Infrared Program**

The long-term program to enhance the infrared capabilities at the McMath-Pierce facility continues with a combination of city and mountain support. Under the direction of A.K. Pierce, the 13-m vertical spectrograph underwent a major upgrade: the visible grating turret was replaced by a dual visible/infrared turret attached to a completely new spectrograph top. During FY 1994, the infrared grating will be used to pursue two long-standing scientific objectives: spatially resolved carbon monoxide spectroscopy at 4.6 \( \mu \text{m} \) and imaging magnetometry using the 12 \( \mu \text{m} \) atomic emission lines.

The Near Infrared Magnetograph (NIM) is a unique instrument to map the true magnetic field strength in the deep solar photosphere using the McMath-Pierce Telescope, the vertical spectrograph, and the Zeeman-sensitive line Fe I 1.565 \( \mu \text{m} \). The 128 \( \times \) 128 InSb array camera from Amber Engineering has been upgraded to a 256 \( \times \) 256 array. Anamorphic transfer optics are installed and performing to specification; the baseline data acquisition system and user interface are complete.

One major goal of the infrared program during 1994 will be to upgrade the NIM data system so that polarimetry can be accomplished at video rates. The modified data system, based on VME hardware and
VX-Works software, will be in large part a copy of existing GONG hardware (which is already optimized for a 256 x 256 array). A second goal will be to begin the design and breadboard fabrication of NIM-2, an imaging vector magnetograph based on a Fabry-Perot spectral isolator rather than a grating spectrograph. Using the same infrared camera system as NIM, NIM-2 will complement rather than replace NIM: the existing instrument will excel in spectral resolution and, therefore, magnetic discrimination; NIM-2 can offer much better time resolution. The NIM-2 project is partially supported by a grant from NASA.

The infrared program will work with the McMath-Pierce upgrade project to measure seeing in the infrared.

Video 10830 Å Filtergraph
The proposed joint NASA/GSFC and NSO video 10830 Å Filtergraph is designed to improve the time resolution and geometric integrity of time sequences of images at the Vacuum Telescope on Kitt Peak. The instrument will be used to study active-region evolution and rapid, flare-associated transients. The instrument is a unique design that allows high-sensitivity measurements of equivalent width, Doppler shift, and line-of-sight magnetic field, using the He I 10830 Å line. The instrument will be able to run simultaneously with the Spectromagnetograph.

Conceptual design studies were conducted during FY 1991 and in early 1992. Long lead-time optics were purchased. In 1993 using an optical design by J. Harvey, design engineers at NASA/GSFC, Laboratory for Astronomy and Solar Physics, are finishing complete technical drawings for the instrument which should be fabricated at NOAO in 1993. The data system has been purchased, and the plan is to acquire initial test data late in calendar year 1993.

Solar-Stellar Cross Dispersion
A preliminary design using a 60° prism for the cross-dispersing element and a SAIC/Ford Aerospace 1024 x 3072 CCD rectangular array has been developed by R. Dunn. This spectrograph-detector combination will produce 24 orders on the chip with approximately 1.4 times the spectral coverage of our present system at 2.8 times the dispersion. As an example, we will be able to obtain high-resolution spectra extending from 3900–7200 simultaneously with the 1024 x 3072 array and cross-dispersed echelle.

The installation of the prism cross-disperser, along with the extensive modifications to the grating turret and to the current CCD mount that will be required, are planned for 1993. Thus, the actual cross-dispersing of the spectrograph is planned to follow the successful installation and initial operation of the large-format CCD array.

McMath-Pierce 4-m Upgrade Study
A 4-m, all-reflecting solar telescope would foster new science in the infrared between 1 and 20 μm. At 12 μm, where seeing is significantly better than in the visible, a diffraction limit of 0.75 arcsec would ensure the direct measurement of non-sunspot magnetic fields in the high photosphere. Asteroseismology would become feasible for solar-type stars as faint as V=7. It is proposed that the existing McMath-Pierce Facility can be increased to a 4-m aperture system. The telescope superstructure would remain unchanged and most instruments would need only slight modification. Internal image quality would be preserved by use of liquid-cooled, actively supported, aluminum-based mirrors. A feasibility study by L. Barr has been completed. He has made an analysis of how to support the 6-m alt-azimuth feed and the 4-m concave. A preliminary cost estimate is in hand which includes a quote from the potential mirror manufacturer. One result of Barr's work is the general improvement in imaging that may be expected from temperature-controlled mirrors.
As a proof of concept, we propose a project to demonstrate the improvement for solar observations afforded by active control of a cooled aluminum mirror, and solar adaptive optics in the mid-IR – the "Better Mc." We would replace the existing 1.6-m image forming mirror with a new mirror made of cast aluminum which is forged and cryogenically cycled, with active control of the mirror figure in an isothermal environment with a new mirror of the same diameter. In conjunction with the large-format infrared arrays being procured by NOAO, this system will yield a dramatically improved McMath-Pierce Facility for infrared solar physics today at the same time that it provides the pathfinding experience that we would need before proceeding with a proposal for a full 4-m upgrade.

South Pole
The South Pole is a site that provides observing conditions that cannot be matched elsewhere on Earth. The unique observing conditions at the site allow the measurement of the properties of solar oscillations with minimal contamination by systematic errors. We will extend our polar helioseismology program by obtaining new and unique observations during the 1994/95 austral summer. Our program will simultaneously observe the full solar disk using wings of the Hα and Ca II K Fraunhofer lines. These line wings are formed at different heights in the solar atmosphere. The wings of the Ca II K-line are formed near the temperature minimum region while the Hα line wings are formed higher in the atmosphere. The Hα line will be used for Doppler velocity and intensity studies while the Ca II K-line will be used for intensity only. Both sets of observations will be made with an angular resolution of 4 arc seconds using CCD cameras sampling at video rates (60 Hz). The observed images will be integrated over 20-second intervals before being digitally recorded on high-density magnetic tape.

The velocity data will be especially unique in that they will be the first imaged observations obtained from a single instrument that are without diurnal interruption. The intensity data will complement our previous intensity observations and will provide information on the oscillations at a phase of the solar cycle previously not studied.

These data will promote some important advances in the field of helioseismology. These include determinations of: the physics of the acoustic oscillations with frequencies above 4 mHz, the wave properties of the solar atmosphere, the variation of the acoustic oscillations with the solar activity cycle, and the sub-surface structures of magnetic features. This information will be used to test and refine solar models, which in turn will lead to improvements in the theory of stellar structure and evolution.

Kitt Peak Vacuum Telescope Control Upgrade
This project, which was first proposed in 1990, is to upgrade the 20-year-old control and guiding systems of the NSO/KPVT. Maintenance of these aging systems is becoming difficult and many of the spare components are no longer available. The guider no longer functions properly in some operational modes, as well as operating poorly through light clouds. The new control and guiding systems will be integrated with modern computer hardware and software. Much of the hardware and software development for this project can be applied directly to the upgrade of the McMath-Pierce Telescope control and guiding systems which will follow. The existing limb guiders at the KPVT will be replaced with linear CCDs. The limb guider translation stage control will be upgraded to distributed processors which interface to the servos on the #1 and #2 mirrors. Control of the Littrow spectrograph grating, shutters, lens focus, as well as telescope control console and handpaddles will be handled by another layer of distributed processors. These processors will interface with a Sun computer which will host the GUI. This upgrade will eliminate the DEC PDP 11/73 and CAMAC.
KPVT Flare Buffer
Summing several video frames in the instruments for the KPVT improves signal-to-noise ratios and slows the data rates sufficiently for on-line reduction. However, strong evidence indicates that for brief periods, many transient solar events exhibit time variations over milliseconds which provide important clues concerning the processes which accelerate and transport high-energy particles. On these occasions, it would be desirable to retain raw data at the highest possible frame rate. The flare buffer will make use of off-the-shelf hardware to record at least a portion of the raw video frames in a first-in, first-out buffer mode which can run continuously until frozen by a software, or observer-activated, signal. The hardware for this instrument will be purchased in calendar year 1993.

Sacramento Peak FY 1994 Projects*

| Project Title                        | Thousands of Dollars |
|--------------------------------------|----------------------|
|                                      | Payroll | Non-payroll | Total  |
| Adaptive Optics                      | 143     | 18          | 161    |
| Mirror-Advanced Coronagraph          | 51      |             | 51     |
| CCD Implementation                   | 46      | 7           | 53     |
| Mark II Corr. Tracker               | 18      | 5           | 23     |
| Multiple Aperture Tele.              | 22      | 5           | 27     |
| **Total**                            | **280** | **35**      | **315**|

Tucson FY 1994 Projects*

| Project Title                        | Thousands of Dollars |
|--------------------------------------|----------------------|
|                                      | Payroll | Non-payroll | Total  |
| McMath-Pierce Infrared Program       | 78      |             | 78     |
| Video Filtergraph                    | 15      |             | 15     |
| Solar-Stellar Cross Disperser        | 5       |             | 5      |
| South Pole                           | 15      |             | 15     |
| KPVT TCP Upgrade                     | 142     |             | 142    |
| Video Flare Buffer                   | 15      | 37          | 52     |
| **Total**                            | **269** | **37**      | **307**|

* NSF support only.
D. Central Computer Services

The computer facilities run by CCS in the Tucson office complex serve three general needs for NOAO-Tucson: data reduction and analysis for the scientific staff and visitors, general computing for all staff members, and IRAF development and support. Our distributed computing strategy for Tucson implements a combination of central, shared facilities, and a variety of desktop facilities including workstations and modern, smart terminals. Computing systems are linked with real or virtual Ethemets, transmitted by wire in Tucson, optical fiber on Kitt Peak, and leased-line between Tucson and Kitt Peak.

In FY 1992-FY 1993 we completed an extensive improvement program to our central computing facilities, replacing older high-maintenance systems with modern low maintenance ones, achieving concurrently a major upgrade of capabilities. In FY 1994 and subsequent years, we will continue our program of upgrades for increased performance with reduced maintenance and operating costs.

Thus, in FY 1994 we will replace one of the servers for the Science Workstation Network, Ursa, at a cost of $80K.

IRAF Development

IRAF (the NOAO Image Reduction and Analysis Facility) is a portable software system used for astronomical data reduction and analysis, general image processing and graphics, and astronomical software development. The IRAF software, first released several years ago, is now in heavy use within the NOAO observatories, at several hundred sites in the world astronomical community, and within the NASA astrophysics community.

During FY 1994, work will continue on IRAF systems software and scientific applications. Projects to be worked on during 1993 include a general mosaicing task, components of the new display interfaces and images structure projects (particularly graphics and image display support for X-Windows) and the IRAF CCD Environment (ICE) used to acquire CCD data at KPNO.

Kitt Peak Telescope and Instrument Control Systems

The "Mountain Programming Group" (the part of CCS that develops software for instrument and telescope control) will continue major projects that were begun during previous years. Among the instrument-related work, integration of new CCD controllers, being developed at CTIO, into existing Kitt Peak systems will be particularly important.

In the hardware area, as detectors in both the IR and visible become larger, the data acquisition and reduction computers on Kitt Peak must keep pace. During 1992-1993, a substantial number of new computers were added to the mountain (in some cases replacing obsolete systems). During 1994, the configuration of these machines will be further refined.

Funds for these activities, including salaries for the mountain programming group, are included in the budget for KPNO O&M.
VI. TELESCOPE OPERATIONS AND USER SUPPORT

A. Cerro Tololo Inter-American Observatory

The long-term project on Tololo to clean up the thermal environment of the 4-m telescope is nearing completion. The console room has been moved from inside the dome to the ground floor, and the flotation oil is being cooled. Large vents were cut in the dome, and moving panels installed so that during observing passive air flow can flush the inside of the dome of warm air. Measurements of image size are about to begin with the completion of a camera that will document image quality. However, one fallout of this effort, from the Shack-Hartmann and shearing interferometer tests, has been the realization that the 4-m R-C f/7.8 secondary mirror has a substantial matching error that degrades image quality at the Cass focus. In June 1993 the R-C secondary is being withdrawn from service to be refigured by Kodak via ion polishing. It is not due to be returned to Chile until November 1993, and the 4-m telescope will be largely devoted to IR astronomy and prime focus imaging during that interval. The six month absence of the mirror will prevent Cass spectroscopy from being done, but the improved images should make the interruption worthwhile.

In late FY 1993 CTIO is scheduled to finally receive the new atmospheric dispersion corrector (ADC) for the 4-m prime focus, which should deliver images less than 0.3 arcsec over a 50 arcmin field for zenith distances less than 60 degrees, over the entire visible wavelength range. This multi-purpose corrector will be in general use for both imaging and fiber-fed spectroscopy. The new CCD TV acquisition cameras designed and fabricated by CTIO should be in place on all Tololo telescopes by the early part of FY 1994. The new ‘Arcon’ CCD controllers are now being fabricated, and will be installed with dedicated CCDs and dewars on most of the telescopes during FY 1994, replacing the old VEB controllers. With their fast, quad readouts, on-line arithmetic capabilities, and greater reliability they will relieve the mountain maintenance burden. Finally, during FY 1994 we plan to have Exabyte tape drives hooked up to the Sun workstations at each of the telescopes, and we will be implementing a new system of motor controllers on most of the major instruments using S-bus and the Suns.

A new aspect of user support at CTIO has been added during FY 1993, which is the assignment of a systems manager/IRAF specialist on Tololo at all times. Thus, every afternoon and evening at the telescopes there is available for help and consultation by all astronomers an observer support person who will assist with the computer setup, IRAF data reduction, and file management.

B. Kitt Peak National Observatory

KPNO continues to develop ways to improve the quality and quantity of data delivered by the site. These efforts include many projects to improve the image quality at the telescopes, several of which are long term, as well as new techniques in data management and observing strategies. Seeing improvements are beginning at the 4-m, where cooling of the oil is underway. The summer shutdown in 1993 will be the longest in history for this telescope and will include replacing the servo system and general electronic upgrades. It is important to note that the length of this shutdown is due exclusively to the lack of resources now available as a result of the continuous decline in the KPNO budget over the last nine years. Optical alignment at this and the other telescopes is also being done through regularly scheduled "fine tuning" of telescope optics every six months. In addition to the regular instrumentation programs described elsewhere, several efforts are underway to provide an integrated, long term plan for improving and synchronizing telescope operations and user support. First, an overall plan for CCD chip acquisition and implementation
has been developed. Another effort is underway to refine the interface between the forthcoming new CCD controller software and IRAF, and a similar activity is planning the integration of the massive data stream from the proposed $2 \times 2$ mosaic into the overall reduction and analysis structure. Finally, active investigations of new modes of observing and data archiving are taking place. Past workshops have been held on this subject, and a current experiment in implementing "key projects" and archiving is being carried out by the IR group. During the summer shutdown of 1993, an experiment in queue scheduling will take place at the 0.9-m, the 2.1-m and the Coude Feed telescopes. Depending on the outcome of this experiment, queue scheduling may continue into the regular fall season with the 0.9-m and the 2.1-m telescopes. Coupled with this effort will be the implementation of a primitive data archiving system to preserve all CCD images taken with the KPNO telescopes. In conjunction with this, development of techniques for electronic submission of observing proposals is underway.

C. National Solar Observatory

The new $1024^2$ CCD arrays will be integrated into the observing system, first using the present CCD controller, and then a new enhanced, faster acquisition system. The new system will be a JPL CCD controller able to read CCD’s up to 2 million pixels/second into an image processing and display computer, which will be limited by storage rates and the array itself. The Adaptive Optics system at the VTT continues in development with the integration of the Correlation Tracker optical system on the AO bench and installation of the main wavefront detection optics in the large vertical tube above the AO bench. The testing of the thin entrance window continues.

Fine tuning for our recently installed VME telescope control system will continue. In addition to the $1024^2$ CCD arrays being installed at the ESF, a linear 2048 CCD will be installed at the Littrow Spectrograph (LSG). Also, a new observing port has been installed on the LSG which will allow more flexibility in the synoptic program setups. A dedicated video camera will be installed in the Universal Spectrograph Hα slit jaw camera.

Upgrading of the ancient DEC PDP 11/73 Telescope Control System (TCS) at the KPVT will begin in FY 1994 if restored funding is available. The system will be replaced by distributed processors linked to a host Sun Sparcstation. This upgrade will allow the PDP, FORTH environment, and CAMAC to be retired at the KPVT.

It is anticipated that the McMath-Pierce TCS will be upgraded after the completion of the work at the KPVT.

VII. OPERATIONS AND FACILITIES MAINTENANCE

The table below identifies the funding for the various sites in support of their facilities operation and maintenance requirements. The text which follows highlights those major maintenance projects that are expected to be undertaken in FY 1993. These projects are also included as part of our (five-year) Long Range Plan for facilities maintenance.
Operations and Facilities

|                      | Payroll | Non-Payroll | Total  |
|----------------------|---------|-------------|--------|
| CTIO                 | 2,517   | 1,890       | 4,407  |
| KPNO                 | 3,538   | 1,205       | 4,743  |
| NSO - Support        | 1,104   | 523         | 1,627  |
| USAF Support for Sunspot | (600)   | (600)       |        |
| NSO - Tucson         | 402     | 108         | 510    |
| NASA Support for Vacuum Tel. | (32)   | (32)        |        |
| **Total**            | 7,561   | 3,094       | 10,655 |

A. Cerro Tololo

A systematic program of maintenance on many of the important components of the CTIO infrastructure will continue during FY 1994. It will consist of painting the smaller telescope domes and extending the installation of guard rails on the road up Tololo to the more exposed sections of the road. New switching and control hardware will be installed on the emergency diesel electric generator on Tololo to better facilitate a smooth transition in power sources when there is a power outage on the mountain, so as not to affect observations or computer processes underway. A renovation of the Volkswagen 'Beetle' fleet on Tololo is scheduled, as is replacement of a substantial segment of corroded water pipe in the system which brings water from the quebrada to the summit. The telephone plant will also be modified to permit more lines to the mountain.

In La Serena a long-term project to remodel and renovate many of the US hire residences, which were almost all constructed in the late 1960s and early 1970s, will have been completed in FY 1993. Routine maintenance, particularly painting, should be all that is necessary on these houses in the near future. In order to eliminate an increasing amount of particulate matter that we are experiencing from the compound well, a new filtration system will be installed. An important maintenance item that is needed but cannot be done without additional funds is the purchase of a small electric generator for the La Serena compound. Although there have been relatively few power outages in the city in the last three years, we still do experience them, and all work involving computers and motors must shut down.

The most significant maintenance item for FY 1994 will be the completion of the new telescope operations and user support building on Tololo. This building, which is located immediately off the summit below the 4-m building, will house all the labs, offices, shops, and library that formerly occupied the 4-m building. As part of the thermal isolation of the telescopes, these will be removed from the telescope buildings and transferred to the new Telops structure. Construction is proceeding slowly because of the recent budget cuts, however, the building should be finished and occupied during FY 1994 if some funding is restored.
**B. Kitt Peak**

It was planned in FY 1990 that the next large scale improvement to the Kitt Peak telescopes would be the multi-year upgrade of the 4-m. Recent layoffs at Kitt Peak have delayed this work, and in FY 1994 the major maintenance effort will be a continuation of the upgrade of the 4-m telescope. The most significant effort in this regard will be installation of a ventilation system for the dome; the detailed design for this will depend upon the analysis of the CTIO ventilation program and the results of numerical modeling. In addition, work on the building lighting and thermal environment control system will continue. A major effort at this telescope in FY 1993 will be implementation of a closed cycle cooling system and cooling of the bearing oil.

Activity at the NSO/Kitt Peak facilities is expected to include the planning of a program to overhaul the McMath and a 4-m conversion feasibility study for the McMath.

In addition, limited resources are expected to allow continued upgrade of the telecommunications facilities, an increased emphasis on the training of the technical staff, seeing improvements at all telescopes, replacement of old TV acquisition and leaky memory equipment with state-of-the-art devices, expansion of the Administrative Building to allow space for the WIYN telescope staff (with funding from the university partners in WIYN), and other miscellaneous improvements to the telescopes as time allows.

A long list of deferred work remains. Unless sufficient funds are made available, a sample of major work that will be deferred includes the replacement of a section of the sewer line, implementation of a phased replacement program for the power line, construction of a clean room atmosphere for the 4-m aluminizing chamber, and a very expensive upgrade of the 4-m rotator/guidar.

**C. NSO/Sacramento Peak**

In spite of minimal funding and insufficient staffing levels, many infrastructure improvements have been accomplished in the past five years. These range from large, several months long, projects to smaller single craftperson jobs. Major improvements include installation of four boilers, painting of the Tower, Main Lab and IDL, installation of UPS’s at the Main Lab and all telescope facilities, reroofing of IDL, VTT and emergency generator buildings, snow roof replacement at trailers, hazardous waste remediation, fire alarm installation, as well as several office and building renovations. Primarily these have been completed by our current staff within operating budget constraints.

Facility Maintenance continues to be reactive in style due to low budgeting. This trend will continue until progress is made in staffing and renovating Observatory infrastructure. Major deferred projects include completion of road repaving, re-roofing of relocatables, VOQ and Facilities Maintenance, painting of redwoods and relocatables, replacement of LPG and Water mains on Observatory Loop, upgrade of underground storage tanks, and completion of housing furnace replacements. As a reactive group, priorities on these projects will continue to be dictated by circumstances and funding.

The New Mexico State Legislature has appropriated an additional $125,000 for the construction of a Visitors Center at NSO/SP. Combined with the original $150,000 appropriated last year, NSO/SP has $275,000 to begin the project. It is expected that detailed planning and selection of an architectural and engineering firm will be completed in FY 1994. Partners for this project include NSO/SP, US Forest Service, Astronomical Research Consortium (ARC) and the New Mexico Department of Tourism. A grant
request has been submitted for matching funds from the Intermodal Surface Transportation Enhancement Act.

D. NOAO Tucson Headquarters

The decision on relocation of the NOAO headquarters has not yet been made. Therefore, for FY 1994, the Central Facilities Operations (CFO) department will again allocate resources based upon the same strategy adopted in FY 1993. That is, if relocation is likely, all large-cost and multi-year improvement projects such as HVAC and electrical power upgrades will be deferred. However, if instead it is determined that the headquarters building will be expanded, or remain status quo, the start-up of those projects will be included in this year's resource allocation.

Several projects will proceed in FY 1994, regardless of the relocation question. They are the continued replacement of vehicles in the NOAO Tucson motor pool (a minimum of two vehicles are needed this year), and the design/implementation of an energy management program to help stabilize, and hopefully reduce our electric utility expenditures. Included within the design is the replacement of our shops' area bay lighting with more energy efficient fixtures, and the strategic placement of a number of motion detectors. Other low cost energy improvements will be undertaken as they are identified as well.

The reason for moving ahead on energy management is that for FY 1994, unless some procedure-only changes, implemented in FY 1993 are effective, it is estimated that our annual utility costs will be approximately $340K. Our power company, Tucson Electric Power, narrowly escaped bankruptcy this past year, and future rate increases, well in excess of inflation, are expected. Large, principally fixed-cost items, such as electric utilities, and telecommunications are quickly eroding the funds available for CFO to properly maintain our facilities.

Provided sufficient funds are available, in FY 1994 we will also continue to make small upgrades to our telephone equipment; consider implementing voice messaging; make limited purchases of more costly energy management controls; and reinforce portions of the CAS building floors along with new carpeting.

Projects that will need to be deferred to future years include; upgrade of the headquarters building fire alarm system; re-paving of the maintenance yard; replacement of the coatings lab foam roof; replacement of large areas of tile and carpeting; exterior painting of the headquarters building; the purchase of major energy management equipment; construction of a bicycle parking area; and parking lot fence and gate improvements.
VIII. SCIENTIFIC STAFF AND SUPPORT

|                          | Payroll | Non-Payroll | Total |
|--------------------------|---------|-------------|-------|
| CTIO                     | 1,338   | 137         | 1,475 |
| KPNO                     | 1,631   | 243         | 1,874 |
| NSO - Sunspot            | 598     | 31          | 629   |
| NSO - Tucson             | 646     | 48          | 694   |
| US Gemini Offices Support| 450     | 50          | 500   |
| Central Offices           | 106     | 0           | 106   |
| **Total**                | 4,769   | 509         | 5,278 |

A. CTIO

Several scientific staff departures occurred during FY 1993 whose effects will cause FY 1994 to be a transition year for the observatory. First, Victor Blanco retired from the CTIO staff after 26 years of total dedication to Cerro Tololo, having served 13 of those years as Director. And then, R.E. Williams left CTIO at the end of his second term as Director to re-locate in the US, accepting an appointment at STScI in Baltimore. During the search period for a new Director, Mark Phillips has been appointed as Acting Director. Because of the very tight budgets recently, no new staff members have been hired during the past year, and in fact, Blanco’s position and that of one of the current departing post-docs will not be filled for the foreseeable future. Judy Cohen (California Inst. of Tech.) will be coming to CTIO as a long-term visitor during FY 1994.

B. KPNO

FY 1994 continues to provide a rich scientific atmosphere at KPNO, primarily through the post-doctoral program. In addition to one new hire in this program through the KPNO normal recruitment process, six additional post-doctoral appointees are present at KPNO through programs funded by outside sources. Two of these have received the prestigious Hubble Fellowships resident at KPNO, and it is a reflection of the attractive nature of KPNO as a scientific institution that these individuals have chosen to carry out their fellowships here. This brings the total number of post-doctoral fellows at KPNO in FY 1994 to ten, including six funded from non-NSF sources. In addition, the KPNO visiting scientist program will be supporting both long term and short term visitors, especially in the area of interferometry. This program provides considerable enrichment of the scientific atmosphere at KPNO for a minimal cost.
C. NSO

Yuhong Fan (U. of Hawaii) will be joining NSO/T to work on magnetic field emergence and coronal heating, and Christoph Keller (Zurich) will be joining NSO/T to work on high-spatial resolution observations of the Sun employing speckle techniques. They will be supported by NSF and ONR.

Greg Kopp will be completing a three year post-doctoral position at NSO/T and joining Meadowlark Optics of Longmont, Colorado.

IX. PROGRAM SUPPORT

|                          | Payroll | Non-Payroll | Total  |
|--------------------------|---------|-------------|--------|
| NOAO Director’s Office   | 503     | 96          | 599    |
| Indirect Cost Credits    |         | (340)       | (340)  |
| Central Administrative Services | 1,083 | 333         | 1,416  |
| Central Computer Services | 717     | 216         | 933    |
| Central Facilities Operations | 498   | 798         | 1,296  |
| Engineering and Technical Support | 1,112 | 482         | 1,594  |
| Public Information Office | 100     | (7)         | 93     |
| Management Fee           |         | 490         | 490    |
| **Total**                | 4,013   | 2,068       | 6,081  |

A. NOAO Director’s Office

The NOAO Director is responsible for providing scientific leadership for NOAO, determining priorities, allocating resources, budgeting and planning. The scientific divisions reporting to the Director are CTIO, KPNO, NSO, and the US Gemini Project Office, each headed by an Associate Director of NOAO. The US Gemini Project Office is led by the US Gemini Project Scientist, currently Fred Gillett in acting capacity. The Deputy Director of NOAO, P. Osmer, was on leave from NOAO serving as Acting Project Scientist for the Gemini 8-m Telescopes Project through November 1992, then enjoyed a reprieve from most administrative responsibilities through summer 1993, to concentrate on his research program.

The NOAO Director, S. Wolff, has also been Acting Gemini Project Director since June 1992. From the inception of that appointment until February 1993, she was on leave from NOAO, and R. Green served as Acting NOAO Director. On her official return to NOAO, R. Green became Acting Deputy Director. The status of the Director’s Office is expected to remain the same through the summer of 1993.
The three observatory Associate Directors of NOAO did not wish to renew their appointments at the expiration of their current terms. External searches were conducted for new directors of CTIO and NSO, with public announcement of the results anticipated for June. AURA advised NOAO to conduct an external search for a permanent US Gemini Project Scientist, which will be carried out over the summer. The issue of KPNO Director will be addressed after that of US Gemini Project Scientist is settled.

Five infrastructural units report to the NOAO Director. They are Central Administrative Services, Central Computer Services, Central Facilities Operations, Engineering and Technical Services, and Publications and Information Resources. Activities and supervision of the Tucson switchboard and copy center are the responsibility of the NOAO Director's office. This office manages funds for the AURA Observatories Visiting Committee and the NSF Foreign Telescope Travel Funds, as well as administering the Research Experiences for Undergraduates program at the observatories.

B. Central Administrative Services

CAS provides support services in the areas of financial management, procurement, human resource administration, shipping and receiving, property control, and contract administration.

The CAS Manager is responsible for establishing and implementing financial and administrative standards and procedures throughout NOAO. He also monitors performance against the approved budget and advises the Director of potential problems.

The accounting department provides full bookkeeping, data processing, disbursement, payroll, and financial reporting services for the AURA Corporate Office, Gemini, WIYN and all NOAO units except for certain transactions occurring in Chile. The latter are performed by CTIO’s La Serena and Santiago business offices and reported monthly to accounting for inclusion in consolidated records and reports. The accounting department budget includes the cost of liability and fidelity insurance for all NOAO activities.

The human resources department develops, implements, and coordinates personnel policies and programs for NOAO. It is responsible for recruitment, relocation assistance, wage and salary administration, equal opportunity employment and affirmative action, and employee benefits for all NOAO staff other than local hires in Chile.

The procurement department provides contracting, purchasing, expediting, and shipping/receiving services for Gemini, WIYN and all NOAO units except local purchases by NSO at Sunspot, New Mexico and CTIO in Chile. It also arranges for export of supplies and equipment purchased in the US for shipment to CTIO and other overseas destinations. In addition, it provides travel and clerical support to CTIO visitors, including the CTIO Telescope Allocation Committee and Users Committee, and serves as CTIO's main communications link to the US.

C. Central Computer Services

CCS is responsible for policy development with respect to computer languages and hardware acquisition, for planning for the application of new and developing technology within the NOAO, for monitoring the state-of-the-art in computer applications to astronomy, and for the development of major software systems for application to data reduction and analysis.
CCS personnel provide support for data reduction and analysis, operate and maintain the NOAO Tucson offices’ computers and their operating systems, and provide general-purpose programming support for scientific, engineering, and some administrative activities. CCS personnel also support the telescope and instrument control computers and data reduction systems on Kitt Peak, as well as the associated development projects in Tucson.

The CCS staff will continue to support the distribution of IRAF (Image Reduction and Analysis Facility) software to over 1,000 community sites around the world. Several ports are in progress at NOAO, or in the community with NOAO collaboration, to make IRAF available on the newest and most cost-effective workstation-style computers.

D. Central Facilities Operations

CFO provides all the basic facility type support services required for the daily operation of the NOAO Tucson headquarters buildings. Those services include, but are not limited to, the operation/maintenance and repair of nine buildings which total in excess of 120,000 s.f., mail and general supplies distribution, telecommunications system management, security, safety, motor pool shuttle service and supervision of contracted groundskeeping, and custodial services. Other efforts include major and minor modifications to the NOAO Tucson facilities, and construction support for specific programs, as required. CFO also provides architectural and civil engineering support to programs at the Tucson headquarters, as well as to NSO Sacramento Peak and Kitt Peak facilities upon request.

E. Engineering and Technical Services

ETS is organized into: a) project style groups that have long-term assignments to specific project objectives, and b) general services groups that provide limited, short-term services on a first-come-first-serve basis. Support for general services is budgeted initially in ETS but is subsequently billed to the NOAO divisions making use of the general services group. General services also maintains basic equipment and facilities for use by people assigned to the project groups. This office also operates the NOAO coatings lab. General services include the engineering manager’s office and those engineering specialists who are not assigned to a project group. Costs related to the project groups are shown within the division where the projects actually occur.

F. Public Information Office

The Public Information Office is responsible for producing press releases, responding to requests for information from the media and from the general public, and supporting visits to Kitt Peak by educational and media groups. The office maintains the NOAO photo collection, which produces and sells images at cost to the general public. The PIO staff provides displays and representation for NOAO at national and international meetings, and oversees the production of NOAO brochures. The office maintains a speakers bureau and is in charge of educational outreach programs.

The manager of PIO oversees the Kitt Peak Museum and Visitor Center. The Museum is beginning the construction of an addition that will house a 16-inch telescope, and is renovating many of its exhibits. A volunteer program has been instituted at the Museum. Volunteer docents act as tour guides, store workers, and help at special events such as public evenings and eclipse days. The Museum has started several local
outreach programs, including visits to schools both on and off the Tohono O’odham Reservation, star parties at national parks facilities, and collaborative activities with other museums.

X. RESEARCH EXPERIENCES FOR UNDERGRADUATES PROGRAM

The Research Experiences for Undergraduates Program (REU) was established by the National Science Foundation (NSF) to attract students to careers in science and engineering by providing opportunities for undergraduates to participate in scientific research experiences. NOAO plans to provide funding for twelve research assistants from an award by the NSF for the 1994 NOAO REU Site Program. The program award will cover salary and transportation expenses for the students.

The 1994 NOAO REU students will carry out collaborative research projects with scientists on topics ranging from the nature and origin of solar and stellar activity to galaxies and cosmology at NOAO research facilities in Tucson, Arizona, and at Sacramento Peak, New Mexico. Students will be recruited for the program through the distribution of posters and applications to a broad spectrum of colleges and universities. Announcements will be sent to over 700 astronomy, physics, engineering, mathematics, and natural science departments throughout the United States and Puerto Rico. In an effort to attract students from underrepresented areas, primarily women and minorities, NOAO will utilize specific mailing lists, including the Historically Black College List generated by the NSF and a list of American Indian Science and Engineering Society affiliates, to reach these groups. Applications for REU positions will follow a review process that begins with a graded assessment of all candidates by a designated staff member based on quality of references, application content, and relevance to NOAO projects. The evaluation will then be distributed to REU project advisors for individual selection of candidates. Staff members will be encouraged to consider strongly the background of each student in conjunction with their overall application grade and specific interest and aptitude for a project area. Staff members wishing to participate in the NOAO REU program submit proposals to the NOAO Director. Selection is based on the scientific merit of the proposals and on their effectiveness in providing a wide range of research experiences for the participating students.

In Tucson, at the facilities of Kitt Peak National Observatory, REU students will be involved in a broad range of research topics including stars and stellar systems, galaxies and cosmology. At the National Solar Observatory in Tucson, REU students will participate in a complementary program of the study of dynamo processes as they occur in the solar interior and solar-type stars. REU students at the National Solar Observatory on Sacramento Peak will join in an integrated research effort designed to develop models of the processes that lead to the build-up and release of energy in solar active regions.

A small sample of REU project proposals by NOAO scientific staff follows. NOAO tries to select proposals where significant progress can be made during the summer and from which a publication is likely to result.

- Numerical simulations of airflow over solar facilities at Kitt Peak and Sacramento Peak using 3-D code on the San Diego Cray computer.

- Data reduction, literature and data archival searches, and the development of an explanation for the dynamical history and star formation of an unusual Sbc galaxy, NGC 3310.
• Determination of the lithium abundance in stars in the very young cluster NGC 2264 from high resolution spectra.

• Reduction of helioseismic data obtained at the geographic South Pole in 1990, including the development of a code to correct for image defects in a commercial software package.

• Data analysis of deep, wide-field imaging of $Z = 0.4$ clusters using IRAF and FOCAS tools.

• Collecting, correlating, and analyzing multi-wavelength data from simultaneous observations of active galactic nuclei with IUE, EUVE, ROSAT, and ground-based telescopes.

The REU student will have an unparalleled opportunity to participate in original research with the NOAO scientific staff along with access to state-of-the-art instrumentation and extensive library collections for astrophysical research. Students and staff will participate together in weekly scientific meetings during which two NOAO staff members give half-hour summaries of a major research or technical topic, tours of various observatory sites and facilities, and weekend social events. Tours of facilities at Kitt Peak, Sacramento Peak, Apache Point Observatory, the Very Large Array, and the University of Arizona’s Steward Mirror Laboratory will be planned for students. A Summer Student Research Presentation session will be held at both sites to allow each student the opportunity to give a brief talk to the NOAO scientific staff on a topic related to their research project. In addition to providing an exciting research environment that includes the latest observational and computational tools, NOAO is equally concerned with creating an enjoyable social environment. Shared offices and housing, formal and informal get-togethers, and recreational activities, such as scientific luncheons, barbecues, pool parties, and weekend hikes, will be arranged for the REU students. To encourage students to present papers and posters, based on their REU experience, at scientific meetings and conferences, NOAO will retain a portion of the 1994 REU award for travel assistance to such events after the close of the program.

While the 1994 NOAO REU students may work principally on one research project in close collaboration with a scientific staff member, the total program of lectures, tours, and mutual interactions among the students and staff within the professional and social environment provided by NOAO will, in fact, serve to expose the REU student to not just one topic, but to many facets of modern astronomical research.

XI. BUDGET

The budget and staffing tables given in Appendix 6 show staffing and funding for observatory operations and for GONG. In preparing these tables, we have assumed 4.2% inflation over the approved budget of $26.6M for FY 1993 in defining the base level for FY 1994. Since the President’s budget projected that inflation figure from a base substantially enhanced by supplementary funding in FY 1993, the total request level of $31.2M is met from additional functions that would be revived with a restoration of funding. The 6.7% cut mandated for FY 1993 has brought the loss of purchasing power of the NOAO budget to over 30% relative to that of FY 1984. Substantial restoration is required for a vital program. The following subsections define in more detail the restored funding initiatives for each division of NOAO. Taken together, they would move NOAO in a strongly positive direction.
A. Cerro Tololo Inter-American Observatory

1. One of the actions taken in response to the FY 1993 budget cut of 6.7% was to give up the scientific staff position vacated by Victor Blanco on his recent retirement. The CTIO scientific staff is currently seriously overextended. More than 50% of the CTIO tenure-track staff are eligible for a sabbatical leave at the moment, which they cannot take because of the effect it would have on observatory operations. If funding were restored, replacement of the lost position would be a high priority.

2. The original air bag support system for the 4-m telescope has been found to be easily adaptable to an active support system. Most of the design work has been done to convert the old system, however, the fabrication and installation requires funding which the present budget does not permit.

3. CTIO does not have a large supply of good, working CCDs. The actual chips are available, however the work needed to characterize them, put them in dewars, and bring them on line at the telescopes requires additional resources that we do not have. We have three state of the art detectors on the shelf waiting for attention: a STIS 2048 CCD, a Loral 1200 × 800 chip, and a NICMOS 256 square device. None of these are in use at the telescopes! The requested funds would enable us to re-hire two Chilean technicians who were laid off in the recent budget cuts, who could devote themselves to bringing the new chips on line.

4. Both Gemini 8-m telescopes and the KPNO 4-m will have f/15 secondary mirrors for the IR. It is imperative for the collaboration and compatibility of CTIO in IR instrumentation with Gemini and KPNO that we acquire such a mirror. CTIO currently has only an f/30 IR secondary, and acquisition of an f/15 secondary for the CTIO 4-m is only possible if higher than level funding is achieved.

5. The current motor controls on the CTIO telescopes are a historical mix of different systems. Filters are controlled by one computer, and shutters and grating changes by other computers. The entire system is archaic and needs to be modernized. Restoration would enable us to implement a new motor control system for all of the CTIO spectrographs.

6. The new Tololo operations center, which will house the labs and offices for observer support, the machine shop, library, and lunch room was to be built in two phases. The first phase of construction, now underway with FY 1993 funds, involves the ground floor offices. The second floor, which will house labs and for which the exterior framing has been done, cannot be completed if funding remains level.

7. The microwave link between La Serena/Tololo and the outside world has certain failure points which bring the system down from time to time. A Super High Frequency (SHF) module could be installed using the same fibers, which would serve as a back-up transmitter/receiver and would double our current bandwidth. This project is capital intensive, requiring almost no manpower.

B. Kitt Peak National Observatory

Scientific Staff Augmentation - Impact of US Gemini Project Office

Since the US Gemini Project Office has become a full division of NOAO, it is not appropriate to list it directly as an initiative dependent on restored funding. The annual costs of such a division are estimated to be around $500K for the full-time efforts of two senior scientists, a program manager, and administrative support. The restored funding shows the two senior scientists replaced in the KPNO
scientific staff, the program manager as a senior engineer in ETS, and the administrative support restored to NOAO. The balance of the USGPO budget is for non-payroll, primarily travel support of US scientists on Gemini advisory committees.

The major thrusts of Kitt Peak improvements are in telescope performance and in new operating modes such as queue scheduling and service observing. Ventilating the 4-m dome represents an example of a necessary upgrade to mitigate the problems of dome seeing, which currently limit telescope imaging performance. The site seeing program is to establish a reasonable goal for the telescope system performance by establishing the free air seeing delivered to the top of the dome.

The other infrastructural enhancements are for increased mountain staffing to support the WIYN telescope as it comes on line, provide extra manpower for the increased needs of queue scheduling, and begin the regular storage of copies of Kitt Peak data. For support of remote observing and queue scheduling, as well as vastly increased efficiency in troubleshooting of detectors and systems, a microwave link from the mountain to the downtown headquarters would be installed.

Two other major initiatives would proceed with funding in addition to the amount of the budget request. One is a project to establish a thermal control system for the 4-m primary mirror assembly. The goal is to allow the mirror temperature to be set at a level close to equilibrium with the predicted mountain night-time air temperature to avoid the image distortion from mirror seeing. The other project is a major updating of the read/write multiplexing system that is the basis for control of guider-rotator functions on the 4-m telescope. The purpose is to replace 1960s technology that is demonstrating an increasing failure rate and to remove major sources of heat load from the telescope area.

C. National Solar Observatory

Kitt Peak Instrumentation, Operations, and Safety

Survey and overhaul of McMath-Pierce electrical system
The McMath-Pierce Solar Telescope Facility recently celebrated its thirtieth anniversary. This event was both a joyous celebration and a sobering reminder that the basic electrical systems within the telescope are in need of a major upgrade in order to ensure that the facility remains operational and competitive. The first task is to survey the facility to develop a plan for the upgrade followed by the swift implementation of the developed improvements.

Modify #3 mirror mount to allow safe handling
The removal of the #3 mirror for realuminizing is accomplished at the present time by placing a band around the mirror while it is still in place in the McMath-Pierce optical tunnel. This procedure is not only hazardous to the mirror itself but presents a safety hazard for the maintenance crew. A mirror cell or band that could be left in place and easily attached to a crane would solve this problem and remove any hazard.

Guard to prevent fall from Vacuum Telescope elevator
Implement the existing plan to enclose the elevator to remove the possibility of an accidental fall occurring.
Upgrade of the Telescope Control Systems at the McMath-Pierce and Kitt Peak Vacuum Telescopes

Upgrade the twenty to thirty year old control and guiding systems to ensure that the facilities remain operational and competitive. The current systems are difficult to maintain with many of the parts no longer available and lacking spares. The guiding system requirements at the two facilities are similar enough that the system developed for one may be copied with slight modification and applied to the other. Lessons learned from the recent Telescope Control System (TCS) upgrades to the NSO/Sacramento Peak Tower Telescope, KPNO 2.1-m telescope and Coudé feed upgrades and the ongoing 4-m Mayall telescope upgrades will be applied in order to take full advantage of the knowledge gained from engineering and software development already completed. These upgrades are not possible within the NSO base even in the best of times. Given the present and anticipated reductions additional NOAO resources are required to carry out the necessary upgrades.

McMath-Pierce 4-m Upgrade: The "Better Mc" Daytime solar seeing monitors

An extensive engineering study was conducted in FY 1991 and FY 1992 on the feasibility of upgrading the McMath-Pierce telescope to 4-m class aperture. In anticipation of this upgrade and towards further proving the feasibility of the upgrades, NSO and NOAO ETS have recently proposed a series of engineering tests in the areas of cooling a large (1.5-m) actively figure controlled aluminum mirror, and quantifying daytime solar telescope seeing on Kitt Peak. The proposed series of tests would address the questions: how good a day time site is Kitt Peak, and can a large aluminum mirror be produced at reasonable cost, actively figure controlled, and when placed in a solar beam, sufficiently cooled to eliminate mirror seeing? This program will provide a significantly improved solar capability at the current aperture whether or not the 4-m Upgrade is pursued.

D. Global Oscillation Network Group

The GONG project has encountered some cost increases in fiscal years 1992 and 1993. While fractionally small, these have totaled about $160K and will lead to about a three-month delay in fielding the network, as well as an increase in the overall project cost by more than $400K. If the FY 1993 budget does not accommodate a recovery of the $160K, the three-month delay and associated cost increases could be avoided by a $160K increase in the FY 1994 GONG budget to $2.76M. In addition, a contractor default required renegotiating with a new supplier for a critical optical component, leading to an increase in cost to the project of about $90K.

E. Central Computer Services

Mountain Programming
Expeditious installation of modern TCS hardware and software at the NSO and the smaller KPNO telescopes.

Downtown Computing
Upgrades to the file servers supporting staff computing and the computers and file servers supporting visitors. The development of the mini- and the maxi-mosaics and the 1024 square IR arrays are going to swamp our network disk storage and tax the computing resources as well.
F. Engineering and Technical Services

The detector development program is for the benefit of all the NOAO observatories, and is placed in the instrumentation program of ETS. The amount of $150K is earmarked for CCD development, and would be a joint effort with Mike Lesser at Steward Observatory. The goal is to thin and package a number of devices for the large mosaic project, as well as dedicated use for spectrographs of the three divisions. The InSb array development program is a joint activity with USNO Flagstaff and Santa Barbara Research Corporation to develop 1024 square devices. A number of 512 square working devices should be available to NOAO from this effort.

The other initiatives are to replace key technical positions lost in the recent cutback.
## APPENDIX 2

### NOAO Management

| Name           | Position and Details                              |
|----------------|---------------------------------------------------|
| S. Wolff       | Director, NOAO/Gemini Project Director            |
| P. Osmer       | Deputy Director, NOAO                             |
| R. Green       | Acting Deputy Director, NOAO                      |
| J. Leibacher   | Associate Director, NOAO                          |
|                | NSO                                               |
| M. Phillips    | Assistant Director, CTIO                          |
| F. Gillett     | Acting US Gemini Project Scientist                |
| R. Barnes      | Assistant to the Director, KPNO                   |
| G. Blevins     | Manager, Central Administrative Services          |
| L. Daggert     | Manager, Engineering & Technical Services         |
| J. Dunlop      | Manager, Central Facilities Operations            |
| Y. Estok       | Assistant to the Director, NOAO                   |
| S. Grandi      | Manager, Central Computer Services                |
| G. Gallaway    | Administrative Manager, NSO/Sacramento Peak      |
| J. Kennedy     | Assistant to the Director, NSO                    |
| K. Meyers      | Public Information Officer                        |
| R. Smartt      | Deputy Director for NSO/Sacramento Peak           |
| J. Tracy       | Controller, Central Administrative Services      |
APPENDIX 3

NOAO SCIENTIFIC STAFF

Wolff, Sidney - Director, NOAO/Acting Gemini Project Director
Green, Richard - Acting Deputy Director, NOAO/Astronomer, Tenure

Cerro Tololo Inter-American Observatory

Phillips, Mark - Assistant Director, Tenure
Baldwin, Jack - Astronomer, Tenure
Blanco, Victor - Astronomer, Tenure
Eggen, Olin - Astronomer, Tenure
Elias, Jay - Associate Astronomer, Tenure
Heathcote, Stephen - Associate Astronomer, Tenure
Suntzeff, Nicholas - Associate Astronomer, Tenure
Walker, Alistair - Associate Astronomer, Tenure
Schommer, Robert - Associate Astronomer, Tenure
Elston, Richard - Associate Astronomer, Tenure
Geisler, Douglas - Assistant Astronomer
Gregory, Brooke - Support Scientist
Ingerson, Thomas - Support Scientist
Layden, Andrew - Research Associate
Smith, R. Chris - Research Associate
Williger, Gerard - Research Associate

Kitt Peak National Observatory

De Young, David - Associate Director, NOAO for KPNO/Tenure
Osmer, Patrick - Deputy Director, NOAO/Tenure
Abt, Helmut - Astronomer, Tenure
Belton, Michael - Astronomer, Tenure
Boroson, Todd - Astronomer, Tenure
Crawford, David - Astronomer, Tenure
Gatley, Ian - Astronomer, Tenure
Jacoby, George - Astronomer, Tenure
Kinman, Thomas - Astronomer, Tenure
Lynds, Roger - Astronomer, Tenure
Pilachowski, Catherine - Astronomer, Tenure
Ridgway, Stephen - Astronomer, Tenure
Wallace, Lloyd - Astronomer, Tenure
Massey, Phillip - Associate Astronomer, Tenure
Armandroff, Taft - Assistant Astronomer
Lauer, Tod - Assistant Astronomer
Bohannan, Bruce - Scientist
Johns, Matt - Scientist
Barden, Samuel - Associate Scientist
Joyce, Richard - Support Scientist
Hinkle, Kenneth - Associate Support Scientist
Probst, Ronald - Associate Support Scientist
Merrill, Michael - Associate Support Scientist
*O’Neil, Earl - Senior Associate, Research
*Porter, Alain - Associate, Research
Ajhar, Edward - Research Associate
*Morrison, Heather - Research Associate
*Muller, Beatrice - Research Associate
Pierce, Michael - Research Associate
*Samarasinha, Nalin - Research Associate
Sarajedini, Ata - Research Associate
Silva, David - Research Associate
*Veilleux, Sylvain - Research Associate
Wise, Michael - Research Associate

National Solar Observatory

Leibacher, John - Associate Director, NOAO/Director
Smartt, Raymond - Deputy Director/Astronomer, Tenure
Brault, James - Physicist, Tenure
Dunn, Richard - Astronomer, Tenure
Harvey, Jack - Astronomer, Tenure
Howard, Robert - Astronomer, Tenure
Jefferies, John - Astronomer Emeritus
Kuhn, Jeffrey - Astronomer, Tenure
Livingston, William - Astronomer, Tenure
Pierce, Keith - Astronomer Emeritus
Zirker, Jack - Astronomer, Tenure
Giampapa, Mark - Associate Astronomer, Tenure
November, Laurence - Associate Astronomer
Rabin, Doug - Associate Astronomer, Tenure
Hill, Frank - Scientist
Toner, Clifford - Assistant Scientist, GONG
Kopp, Greg - Research Associate
Penn, Matthew - Research Associate
*Altrock, Richard - PL/GSS, Astrophysicist
*Balasubramaniam, Karatholuvu - Assistant Scientist
*Duvall, Tom - NASA Astrophysicist
*Harvey, Karen - Visiting Astronomer, SPRC
*Jefferies, Stuart - Bartol Research Associate
*Jones, Harrison - NASA Astrophysicist
*Keil, Stephen - PL/GSS Astrophysicist
*Komm, Rudolf - ONR Research Associate
*Lindsey, Charles - Visiting Astronomer
*Neidig, Donald - PL/GSS Astrophysicist
*Radick, Richard - PL/GSS Astrophysicist
*Simon, George - PL/GSS Senior Scientist

US Gemini Project Office

Gillett, Fred - Acting US Gemini Project Scientist/Astronomer, Tenure

Central Computer Support

Sharp, Nigel - Associate Support Scientist - CCS
Valdes, Francisco - Associate Support Scientist - CCS
Wolff, Richard - Project Scientist - CCS

* not supported by NSF
APPENDIX 4
Cerro Tololo Inter-American Observatory

Scientific Staff: Primary Fields of Interest and 1992 Publications

J. Baldwin - Active Galactic nuclei; quasars; H II regions.

Baldwin, J.A., Pérez, G., Gregory, B., Weller, W., Wilson, R., Noethe, L. 1992, ESO Conference and Workshop Proceedings No. 42, ed. M.-H. Ulrich (Garching, ESO), p.247, "Retrofitting New Technology to an Old Telescope"

Storchi-Bergmann, T., Wilson, A.S., Baldwin, J.A. 1992, ApJ, 396, p.45, "The Ionization Cone, Obscured Nucleus and Gaseous Outflow in NGC 3281 - A Prototypical Seyfert 2 Galaxy?"

O. Eggen - Photometry and astrometry; dynamical evolution of the Galaxy.

Eggen, O.J. 1992, AJ, 103, p.1302, "The Pleiades Supercluster in the FK5"

Eggen, O.J. 1992, AJ, 103, p.1381, "Photometry of F-K Type Bright Giants and Supergiants. I. Intermediate Band and H $\beta$ Observations"

Eggen, O.J. 1992, AJ, 104, p.275, "Asymptotic Giant Branch Stars Near the Sun"

Eggen, O.J. 1992, AJ, 104, p.1482, "The Hyades Supercluster in the FK5"

Eggen, O.J. 1992, AJ, 104, p.1493, "The Sirius Supercluster in the FK5"

Eggen, O.J. 1992, AJ, 104, p.1906, "HR 1614 and the Dissolution of a Supercluster"

Eggen, O.J. 1992, AJ, 104, p.2141, "The Kinematics of Young Disk Population Supercluster Members"

J. Elias - IR photometry and instrumentation; star formation; stellar mass loss.

Suntzeff, N.B., Phillips, M.M., Elias, J.H., DePoy, D.L., Walker, A.R. 1992, ApJ, 384, L33, "The Energy Sources Powering the Late-Time Bolometric Evolution of SN 1987A"

R. Elston - Galactic evolution.

Elston, R., Silva, D.R. 1992, AJ, 104, p.1360, "The Extended Giant Branch in M32"
McCarthy, P.J., Elston, R., Eisenhardt, P. 1992, ApJ, 387, L29, The Lyα/Hα Ratio in the High Redshift Radio Galaxy

Schmidt, G.D., Elston, R., Lupie, O.L. 1992, AJ, 104, p.1563, "The Hubble Space Telescope Northern-Hemisphere Grid of Stellar Polarimetric Standards"

D. Geisler - Abundances and properties of stars and star clusters in the Galaxy and nearby galaxies.

Cellone, S.A., Forte, J.C., Geisler, D. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.404, "Structure and Colors of Dwarf Elliptical Galaxies in the Fornax Cluster"

Geisler, D., Friel, E.D. 1992, AJ, 104, p.128, "The Metallicity Distribution of G and K Giants in Baade's Window"

Geisler, D., Suntzeff, N.B., Mateo, M., Graham, J. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.422, "Metal Abundances of Magellanic Cloud Clusters"

Geisler, D., Minniti, D., Claria, J.J. 1992, AJ, 104, p.627, "Washington Photometry of Globular Cluster Giants: The Most Metal-Poor Clusters"

Geisler, D., Claria, J.J., Minniti, D. 1992, AJ, 104, p.1892, "Washington Photometry of Open Cluster Giants: Nine Old Disk Clusters in the Third Galactic Quadrant"

Harris, G.L.H., Geisler, D., Harris, H.C., Hesser, J. 1992, AJ, 104, p.613, "Metal Abundances from Washington Photometry of Globular Clusters in NGC 5128"

McWilliam, A., Geisler, D., Rich, R.M. 1992, PASP, 104, p.1193, "Abundance Analysis of Three Giants in the Metal-Poor Globular Cluster NGC 2298"

B. Gregory - Low temperature physics and infrared instrumentation.

Baldwin, J.A., Pérez, G., Gregory, B., Weller, W., Wilson, R., Noethe, L. 1992, ESO Conference and Workshop Proceedings No. 42, ed. M.-H. Ulrich (Garching, ESO), p.247, "Retrofitting New Technology to an Old Telescope"

S. Heathcote - Interstellar medium; planetary nebulae, Herbig-Haro objects; star formation; supernovae, polarization of active galactic nuclei.

Gredel, R., Reipurth, B., Heathcote, S.R. A&A, 266, p.439, "An Optical/Infrared/Millimetre Study of HH 90/91"

Hamuy, M., Walker, A.R., Suntzeff, N.B., Gigoux, P., Heathcote, S.R., Phillips, M.M. 1992, PASP, 104, p.533, "Southern Spectrophotometric Standards. I."
Heathcote, S.R., Reipurth, B. 1992, AJ, 104, p.2193, "Kinematics and Evolution of the HH 34 Complex"

Morse, J.A., Hartigan, P., Cecil, G., Raymond, J.C., Heathcote, S.R. 1992, ApJ, 399, p.231, "The Bow Shock and Mach Disk of HH 34"

Reipurth, B., Raga, A.C., Heathcote, S.R. 1992, ApJ, 392, p.145, "Structure and Kinematics of the HH 111 Jet"

Reipurth, B., Heathcote, S.R., Vrba, F. 1992, A&A, 256, p.225, "Star Formation in Bok Globules and Low-Mass Clouds. IV. Herbig-Haro Objects in B335"

Reipurth, B., Heathcote, S.R. 1992, A&A, 257, p.693, "Multiple Bow Shocks in the HH34 System"

M. Phillips - Supernovae; novae.

Hamuy, M., Walker, A.R., Suntzeff, N.B., Gigoux, P., Heathcote, S.R., Phillips, M.M. 1992, PASP, 104, p.533, "Southern Spectrophotometric Standards. I."

Phillips, M.M., Wells, L.A., Suntzeff, N.B., Hamuy, M., Leibundgut, B., Kirshner, R.P., Foltz, C.B. 1992, AJ, 103, p.1632, "SN 1991T: Further Evidence of the Heterogeneous Nature of Type Ia Supernovae"

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R. Schommer - Star clusters; Magellanic Clouds; distance scale; Galaxy dynamics.

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Bothun, G., Schommer, R.A., Williams, T.B., Mould, J.R., Huchra, J.P. 1992, ApJ, 388, p.253, "Peculiar Velocities of Field Spirals Near and Beyond the Great Attractor"

Chu, Y.-H., Kennicut, Jr., R.C., Schommer, R.A., Laff, J. 1992, AJ, 103, p.1545, "30 Dor B: A Supernova Remnant in a Star Formation Region"

Schommer, R.A., Olszewski, E.W., Suntzeff, N.B., Harris, H.C. 1992, AJ, 103, p.447, "Spectroscopy of Giants in LMC Clusters. II. Kinematics of the Cluster System"

Schommer, R.A., Olszewski, E.W., Aaronson, M.A. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.485, "On Main Sequence Distances and the Local Distance Scale"
Suntzeff, N.B., Schommer, R.A., Olszewski, E.W., Walker, A.R. 1992, AJ, 104, p.1743, "Spectroscopy of Giants in LMC Clusters. III. Velocities and Abundances for NGC 1841 and Reticulum and the Properties of the Metal-Poor Clusters"

N. Suntzeff - Stellar abundances and populations.

Anthony-Twarog, B., Twarog, B.A., Suntzeff, N.B. 1992, AJ, 103, p.1264, "CCD Strömgren Studies in NGC 6397"

Drake, J.J., Smith, V.V., Suntzeff, N.B. 1992, ApJ, 395, L95, "Sodium, Aluminum, and Oxygen Abundance Variations in Giants in the Globular Cluster M4"

Geisler, D., Suntzeff, N., Mateo, M., Graham, J. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.422, "Metal Abundances of Magellanic Cloud Clusters"

Hamuy, M., Walker, A.R., Suntzeff, N.B., Gigoux, P., Heathcote, S.R., Phillips, M.M. 1992, PASP, 104, p.533, "Southern Spectrophotometric Standards. I."

Langer, G.E., Suntzeff, N.B., Kraft, R.P. 1992, PASP, 104, p.523, "λ3883 CN Band Strengths for 238 Metal-Poor Halo Giants: Evidence for Chemical Differences Between Globular Cluster and Halo Field Giants"

Mateo, M., Suntzeff, N.B., Nemec, J., Terndrup, D., Weller, W., Irwin, M., McMahon, R. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.455, "The Stellar Population and Internal Kinematics of the Sextans Dwarf Spheroidal Galaxy"

Phillips, M.M., Wells, L.A., Suntzeff, N.B., Hamuy, M., Leibundgut, B., Kirshner, R.P., Foltz, C.B. 1992, AJ, 103, p.1632, "SN 1991T: Further Evidence of the Heterogeneous Nature of Type Ia Supernovae"

Schommer, R.A., Olszewski, E.W., Suntzeff, N.B., Harris, H.C. 1992, AJ, 103, p.447, "Spectroscopy of Giants in LMC Clusters. II. Kinematics of the Cluster Sample"

Suntzeff, N.B., Phillips, M.M., Elias, J.H., DePoy, D.L., Walker, A.R. 1992, ApJ, 384, L33, "The Energy Sources Powering the Late-Time Bolometric Evolution of SN 1987A"

Suntzeff, N.B. 1992, IAU Symp. 149, ed. B. Barbuy, A. Renzini (Dordrecht, Kluwer), p.23, "Population II in the Milky Way Galaxy and the LMC"

Suntzeff, N.B. 1992, ASP Conference 30, ed. B. Warner (Provo, Brigham Young U.), p.161, "RR Lyrae Variables and the Population II in the Large Magellanic Cloud"

Suntzeff, N.B., Schommer, R.A., Olszewski, E.W., Walker, A.R. 1992, AJ, 104, p.1743, "Spectroscopy of Giants in LMC Clusters. III. Velocities and Abundances for NGC 1841 and Reticulum and the Properties of the Metal-Poor Clusters"
A. Walker - CCD photometry instrumentation, stellar evolution, distance scale.

Hamuy, M., Walker, A.R., Suntzeff, N.B., Gigoux, P., Heathcote, S.R., Phillips, M.M. 1992, PASP, 104, p.533, "Southern Spectrophotometric Standards. I."

Schaefer, B.E., Landolt, A.U., Vogt, N., Buckley, D., Warner, B., Walker, A.R. 1992, ApJS, 81, p.321, "The Photometric Period of the Recurrent Nova T Pyxidis"

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Walker, A.R. 1992, AJ, 103, p.1166, "The LMC Cluster GLC 0435-59 (Reticulum): Photometry of the RR Lyraes, and a Color-Magnitude Diagram"

Walker, A.R. 1992, ApJ, 390, L81, "The Absolute Magnitudes of LMC RR Lyrae Variables, and the Ages of Galactic Globular Clusters"

Walker, A.R. 1992, AJ, 104, p.1395, "The LMC Cluster NGC 1466: Photometry of the RR Lyraes, and a Color-Magnitude Diagram"

Walker, A.R. 1992, PASP, 104, p.1063, "A BV Color-Magnitude Diagram for the Galactic Globular Cluster NGC 1851"

R. Williams - Novae; accretion disks; emission-line formation; LMC abundances.

Smette, A., Surdej, J., Shaver, P.A., Foltz, C.B., Chaffee, F.H., Weymann, R.J., Williams, R.E., Magain, P. 1992, ApJ, 389, p.39, "A Spectroscopy Study of UM 673 A & B: On the Size of Lyman-Alpha Clouds"

Saizar, P., Starrfield, S., Ferland, G.F., Wagner, R.M., Truran, J.W., Kenyon, S.J., Sparks, W.M., Williams, R.E., Stryker, L.L. 1992, ApJ, 398, p.651, "A Multiwavelength Study of Nova QU Vulpeculae 1984"

Szkody, P., Williams, R.E., Margon, B., Howell, S.B., Mateo, M. 1992, ApJ, 387, p.357, "TT Crateris: A Long-Period, Double-Lined Dwarf Nova"

Williams, R.E. 1992, ApJ, 392, p.99, "Incorporation of Density Fluctuations into Photoionization Calculations"

Williams, R.E. 1992, AJ, 104, p.725, "The Formation of Novae Spectra"

G. Williger - Large scale structure in general and QSO absorption in particular, both observationally and theoretically. Cataclysmic variables and accretion disks.
Williger, G.M., Babui, A. 1992, ApJ, 399, p.385, "Pressure-Confined Lyα Clouds: Simulation Results versus Observations"
APPENDIX 4

Kitt Peak National Observatory

Scientific Staff: Primary Fields of Interest and 1992 Publications

H. Abt - Stellar spectroscopy; binary stars; stellar rotation; stellar classification.

Abt, H.A. 1992, DeskTop Publishing in Astronomy and Space Sciences, ed. A. Heck, "American On-Line Publications Tests and Long-Range Plans"

Abt, H.A. 1992, PASP, 104, p.235, "What Fraction of Literature References are Incorrect?"

Morrell, N., Abt, H.A. 1992, ApJ, 393, p.666, "Spectroscopic Binaries in the alpha Persei Cluster"

Abt, H.A. 1992, Scientometrics, 24, p.441, "Publication Practices in Various Sciences"

Abt, H.A., Willmarth, D.W. 1992, IAU Coll. 135, "Duplicity Among Solar-type Stars"

T. Armandroff - Stellar populations, globular clusters, dwarf spheroidal galaxies.

Armandroff, T.E., Da Costa, G.S., Zinn, R. 1992, AJ, 104, p.164, "Metallicities for the Outer-Halo Globular Clusters Pal 3, 4, and 14"

Da Costa, G.S., Armandroff, T.E., Norris, J.E. 1992, AJ, 104, p.154, "The Metal Abundance and Age of the Globular Cluster Ruprecht 106"

Massey, P., Armandroff, T.E., Conti, P.S. 1992, AJ, 103, p.1159, "IC 10: A ‘Poor Cousin’ Rich in Wolf-Rayet Stars"

Caldwell, N., et al. 1992, AJ, 103, p.840, "The Dwarf Spheroidal Companions to M31: Surface-Brightness Profiles"

S. Barden - Spectroscopic instrumentation and binary stars.

Barden, S.C., et al. 1992, Fibre Optics in Astronomy II, ed. P.M. Gray, ASP Conference Series, p.185, "Hydra - Kitt Peak Multi-Object Spectroscopic System"

Barden, S.C., et al. 1992, Fibre Optics in Astronomy II, ed. P.M. Gray, ASP Conf. Series, p.223, "Observational Performance of Fiber Optics - High Precision Sky Subtraction and Radial Velocities"

Barden, S.C. 1992, Fibre Optics in Astronomy II - Conference Overview"
Welty, A.D., et al. 1992, AJ, 103, p.1673, "BF Orionis: Evidence for an Infalling Circumstellar Envelope"

M. Belton - Planetary astronomy.

Belton, M.J.S. 1992, Planetary Report, 12, p.14, "Small Missions to Asteroids: The Threat Future Exploration"

Belton, M.J.S., Delamere, A., 1992, Proc. Asteroids, Comets, Meteors 1991 Symp., ed. E. Bowell et al., Lunar and Planetary Institute, Houston, "Low Cost Missions to Explore the Diversity of near Earth Objects"

M.J.S. Belton, et al. 1992, Science, 257, p.1647, "Galileo Encounter with 951 Gaspra: First Pictures of an Asteroid"

M.J.S. Belton, et al. 1992, Science, 255, p.505, "Lunar Impact Basins and Crustal Heterogeneity: New Westerin Limb and Farside Data from Galileo"

M.J.S. Belton, et al. 1992, Adv. Space Res. 12, No. 9, p.91, "Imaging of Venus from Galileo: Early Results and camera Performance"

M.J.S. Belton 1992, Icarus, 97, p.307 (Book review), "Uranus"

Lellouch, E., et al. 1992, Icarus, 98, p.271, "The Structure, Stability, and Global Distribution of Io's Atmosphere"

B. Bohannan - Stellar spectroscopy, basic astrophysical data, astrophysical instrumentation and data reduction.

T. Boroson - Quasars and active galaxies; stellar populations; galaxy kinematics; instrumentation.

Boroson, T.A., Green, R.F., ApJS, 80, p.109, "The Emission Line Properties of Low Redshift QSOs"

Peterson, B.M., et al. 1992, ApJ, 392, p.470, "Steps toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. III. Further Observations of NGC 5548 at Optical Wavelengths"

Boroson, T.A., Meyers, K.A., ApJ, 397, p.442, "The Optical Properties of IR-Selected and Mg II Broad Absorption Line Quasars"

Mazzarella, J.M., Boroson, T.A., ApJS, 85, p.27, "Optical Imaging and Long-Slit Spectroscopy of Markarian Galaxies with Multiple Nuclei. I. Basic Data"
Boroson, T.A., ApJL, 399, p.L15, "Evidence Against Some Orientation Effects in Radio Quiet QSOs"

D. Crawford - Stellar photometry and galactic structure.

D.S. De Young - Theoretical astrophysics; active galaxies and QSOs, galaxy clusters; astrophysical plasma processes and hydrodynamics.

De Young, D.S. 1992, ApJ, 386, p.464, "Galaxy-Driven Turbulence and the Growth of Intracluster Magnetic Fields"

De Young, D.S. 1992, Testing the AGN Paradigm, ed. S. Holt, S. Neff, C.M. Urry, (New York: AIP), p.431, "Compact Steep Spectrum Radio Sources and the Nuclear Environment"

De Young, D.S. 1992, STScI Proc. Symposium on Astrophysical Jets, ed. D. Burgarella, M. Livio, C. O’Dea, (Baltimore: STScI) p.9, "Jet Interaction with Rotating Disks: A Measure of Unification"

I. Gatley - Studying infrared emission lines from vibrationally excited molecular hydrogen.

Kastner, J.H., et al. 1992, ApJ, 398, p.552, "Variations in the Near Infrared Surface Brightness Distribution of the Bipolar Nebula OH231.8+4.2"

Weintraub, D.A., et al. 1992 ApJ, 391, p.784, "Near-Infrared Polarized Images of a Nebula around T Tauri"

Hyland, A.R., et al. 1992, MNRAS, 257, p.391, "Star Formation in the Magellanic Clouds. IV Protostars in the Vicinity of 30 Doradus"

Hurt, R.L., et al. 1992, AJ, 105, p.121, "Maffei 2 Revealed: The Infrared Morphology of a Hidden Galaxy"

Hillenbrand, L.A., et al. 1992, ASP Conf. Series 35, Massive Stars: their Lives in the Interstellar Medium, ed. J.P. Cassinelli, E. B. Churchwell, p.141, "Identification of New Candidate Herbig Ae/Be Stars in Extremely Young Clusters: M8, M16, M17, M42, NGC 2264"

Ellis, T., et al. 1992, SPIE Proc., 1765, p.94, "The Simultaneous Quad-color Infrared Imaging Device (SQIID): A Leap Forward in Infrared Cameras for Astronomy"

F. Gillett - Study star formation regions in the 1-5 μm range.

Backman, D.E., Gillett, F.C. Whitteborn, F.C. 1992, ApJ. 385, p.670, "Infrared Observations and Thermal Models of the Beta Picotoris Disk"
R. Green - Studies quasars to gain understanding of both their intrinsic properties, such as the energy production mechanisms, spatial distribution of material, the ionized broad line region, and evolution of the population; and of distant absorbing material and its chemical evolution with cosmic time in comparison with the fossil record of halo stars in the Galaxy.

Boroson, T.A., Green, R.F. 1992, ApJS, 80, p.109, "The Emission Line Properties of Low Redshift QSOs"

Bahcall, J.N., et al. 1992, ApJ, 397, p.68, "The Ultraviolet Absorption Spectrum of the Quasar H1821+643 (z=0.297)"

Rauch, M., et al. 1992, ApJ, 390, p.387, "The Lyman Alpha Forest of 0014+813"

Wesemael, F., et al. 1992, AJ, 104, p.203, "Studies of Hot B Subdwarfs. VIII. Stromgren Photometry of Hot, Hydrogen-Rich Subdwarf Candidates in the Palomar-Green and Kitt Peak-Downes Surveys"

Grauer, A.D., Green, R.F., Liebert, J. 1992, ApJ, 399, p.686, "On the Pulsational Stability of the Pre-White Dwarf Star PG 1707+427"

K. Hinkle - High resolution infrared spectroscopy, especially applied to circumstellar and interstellar matter and peculiar stars.

Hinkle, K.H., Bernath, P.F., 1992, Proc. Conf. on Astronomical Infrared Spectroscopy, ed. S. Kwok, "Infrared Spectroscopy of Pure Carbon Molecules in Circumstellar Shells"

Hinkle, K.H., Fekel, F., Ridgway, S.T. 1992, ASP Conference Series 32, Complementary Approaches to Double and Multiple Star Research, ed. H. McAlister W.I. Hartkopf, "Infrared Spectroscopic Observations of Long-Period Binaries"

Ridgway, S.T., Hinkle, K.H. 1992, ESO Conference Proc., Progress in Telescopes and Instrumentation Technologies, ed. M.-H. Ulrich, "Strategies for Very High Resolution Infrared Spectroscopy"

Hinkle, K.H., Fekel, F., Johnson, D. Scharlach, W.W.G. 1992, ASP Conference Series 26, Cool Stars, Stellar Systems, and the Sun, ed. M. Giampapa, J. Bookbinder, p.458, "The Unique Triple Symbiotic System CH Cygni"

Sada, P.V., Hinkle, K.H., Keady, J.K. 1992, ASP Conference Series 26, Cool Stars, Stellar Systems, and the Sun, ed. M. Giampapa, J. Bookbinder, p.468, "Temporal Variations in the Circumstellar Shell of IRC+10216"

G. Jacoby - Studies various aspects of planetary nebulae, the extragalactic distance scale, galaxy stellar dynamics and stellar populations.
Dopita, M.A., Jacoby, G.H., Vassiliadis, E. 1992, ApJ, 389, p.27, "A Theoretical Calibration of the Planetary Nebula Distance Scale"

Margon, B., et al. 1992, AJ, 103, p.924, "The Near-Infrared Counterpart to a Variable Galactic Plane Radio Source"

Balick, B., et al. 1992, ApJ, 392, p.582, "Stellar Wind Paleontology. II: Faint Halos and Historical Mass Ejection in Planetary Nebulae"

Jacoby, G.H., et al. 1992, PASP, 104, p.599 "A Critical Review of Selected Techniques For Measuring Extragalactic Distances"

R. Joyce - The study of evolved late-type stars, with emphasis on carbon stars.

Woodward, C.E., et al. 1992, BAAS, 24, p.1189, "Infrared Temporal Observations of Nova Cygni 1992"

T. Kinman - Galactic structure and evolution.

Kinman, T.D. Carretta, E. 1992, PASP, 104, p.111, "Delta-S Metallicities of 35 Field RR Lyrae stars and the Nature of BB Virginis and AR Herculis"

Stavely-Smith, L., Davies, R.D. Kinman, T.D. 1992, MNRAS, 258, 334, "HI and Optical Observations of Dwarf Galaxies"

Kinman, T.D. 1992, ASP Conf. Series, Variable Stars and Galaxies, ed. Brian Warner, Chelsea MI, p.19, "The Stars of Spectral types A and F as probes of the Galactic Structure"

T. Lauer - Extragalactic observational astronomy.

Holtzman, J.A., et al. 1992, AJ, 103, p.691, "Planetary Camera Observations of NGC 1275: Discovery of a Central Population of Compact Massive Blue Star Clusters"

Lauer, T.R., et al. 1992, AJ, 103, p.703, "Planetary Camera Observations of the M87 Stellar Cusp"

Lugger, P.M., et al. 1992, AJ, 104, p.83, "The Nucleus of M32 at 0.2 arcsec Resolution"

Lauer, T.R., et al. 1992, AJ, 101, p.552, "Planetary Camera Observations of the Central Parsec of M32"

Campbell, B., et al. 1992, AJ, 104, p.1721, "Hubble Space Telescope Planetary Camera Images of R136"

Lauer, T.R., Postman, M. 1992, ApJ, 400, p.L47, "The Hubble Flow From Brightest Cluster Galaxies"
R. Lynds - Cosmology.

Holtzman, J.A., et al. AJ, 103, p.691, 1992, "Planetary Camera Observations of NGC 1275: Discovery of a Central Population of Compact Massive Blue Star Clusters"

Lauer, T.R., et al. AJ, 103, p.703, 1992, "Planetary Camera Observations of the M87 Cusp"

Campbell, B., et al. AJ, 104, p.1721, 1992, "Hubble Space Telescope Planetary Camera Images of R136"

P. Massey - Studies star formation and the evolution of massive stars.

Massey, P., Jacoby, G. 1992, Astronomical CCD Observing and Reduction Techniques, ed. S. Howell, ASP Conf. Series, p.240, "CCD Data: The Good, The Bad, and The Ugly"

Parker, J.W., et al. 1992, AJ, 103, p.1205 "The Stellar Content of LH9 and 10 (N11) in the LMC: A Case for Sequential Star Formation"

Massey, P., Armandroff, T.E. 1992, AJ, 103, p.1159, "IC10: A ‘Poor Cousin’ Rich in Wolf-Rayet Stars"

K.M. Merrill - The star formation process as revealed by stellar content within regions of recent star formation and the diffuse environment with which they interact.

Ellis, T., et al. 1992, SPIE Proc., 1765, p.94, "The Simultaneous Quad-color Infrared Imaging Device (SQIID): A Leap Forward in Infrared Cameras for Astronomy"

Hurt, R.L., et al. 1992, AJ, 105, p.121, "Maffei 2 Revealed: The Infrared Morphology of a Hidden Galaxy"

P. Osmer - Quasars: surveys, space density, and spectral properties.

Osmer, P.S. 1992, ESO Conf. Proc. No. 42, Progress in Telescope and Instrumentation Technologies, ed. M.-H. Ulrich (ESO:Garching), p.35, "The Gemini Project: Overview"

Hall, P.B., et al. 1992, BAAS, 24, p.1136, "First Results of a Deep Multicolor Survey for Quasars"

Osmer, P.S. 1992, Gemini Project Doc. SPE-PS-G0001, "Gemini Science Requirements, Version 1.1"

M. Pierce - Observational cosmology with particular interest in the determination of the Hubble Constant and the determination of the properties of galaxies at moderate redshifts.
Pierce, M., et al. 1992, PASP, 104, p.599, "A Critical Review of Selected Techniques Used for Measuring Extragalactic Distances"

Pierce, M., Lavery, R., McClure, R. 1992, AJ, 104, p.2067, "High-Resolution Imaging of Distant Clusters I. Close Pairs, Interactions and the 'Butcher-Oemler Effect' at Z = 0.4"

Pierce, M., McClure, R., Racine, R. 1992, ApJ, 393, p.523, "High Resolution Imaging of Virgo Cluster Galaxies. I. The Distance Based on the Brightest Stars in NGC 4571"

Pierce, M., Ressler, M., Shure, M. 1992, ApJ, 390, p.L45, "An Absolute Calibration of Type Ia Supernovae from Photometry of the Brightest Stars in IC 4182"

Pierce, M., van den Bergh, S. 1992, PASP, 104, p.408, "The Intrinsic Colors of Supernovae of Type Ia"

Pierce, M., Shaya, E. Tully, B. 1992, ApJ, 391, p.16, "Nearby Galaxy Flows Modeled By the Light Distribution"

Pierce, M., Tully, B., Shaya, E. 1992, ApJS, 80, p.479, "Nearby Galaxy Flows Modeled By the Light Distribution"

Pierce, M., Tully, B. 1992, ApJ, 387, p.47, "Luminosity--Line-Width Relations and the Extragalactic Distance Scale. I. Absolute Calibration"

C. Pilachowski - Stellar evolution, stellar abundances, nucleosynthesis, stellar spectroscopy, spectrograph design, new generation telescopes.

Pilachowski, C., 1992, AJ, 103, p. 1668, "Giants"

R. Probst - The construction and commissioning of infrared array cameras, and their application to problems of star formation.

Dougados, C., et al. 1992, High Resolution Imaging by Interferometry, ESO Conf. Proc. #39, J.M. Beckers, F. Merkle, ed., p. 33, "Sub-arcsec near-infrared imaging of the BN-IRC2 region in Orion"

Craine, E.R., et al. 1992, Seventh Cambridge Workshop, Cool Stars, Stellar Systems, and the Sun, ASP Conf. Ser. 26, ed. M.S. Giampapa, p. 585, "A new catalog of cool dwarf stars"

Duquennoy, A., et al. 1992, IAU Colloq. #135, Complementary Approaches to Double and Multiple Star Research, ASP Conf. Ser. 32, ed. H.A. McAlister, p.540, "Interferometric imaging of nearby low-mass spectroscopic binaries. I. KPNO observations"

Probst, R. G., Merrill, K. M., Gatley, I. 1992, BAAS, 24, p.796, "The KPNO star forming regions project"
S. Ridgway - Infrared astronomy.

Christou, J.C., et al. 1992, High Resolution Imaging by Interferometry II, ed. J.M. Beckers, F. Merkle, ESO Conf. and Workshop Proc. No. 39, (ESO, Garching), p.83, "Z CMa Resolved - a 0.10" Variable Binary Star"

Dougados, C., et al. 1992, (ibid), p.115, "Sub-arcsec Near-Infrared Imaging of the BN-IRC2 Region in Orion"

Dyck, H.M., Benson, J.A., Ridgway, S.T. 1992, (ibid), p.753, "Scientific Progress with IRMA"

Coude du Foresto, V., Ridgway, S.T. 1992, (ibid), p.731, "FLUOR: A Stellar Interferometer Using Single Mode Fibers"

Ridgway, S.T. 1992, (ibid), p.653, "Recent Scientific Results from Multi-Telescope Interferometry"  
Ridgway, S.T., Keady, J.J. 1992, J. Astr. Francais, 39, p.23, "Recent Results on IRC+10216"  
Ridgway, S.T., et al. 1992, AJ, 104, p.2224, "The Infrared Angular Diameter of Omicron Ceti Measured near Maximum Light with a Michelson interferometer"  
Ridgway, S.T. 1992, ibid, p. 19, "Visible and Infrared Imaging Interferometry from Space"  
Ridgway, S.T. 1992, ibid, p.85, "Space Interferometry Science Working Group"

Duquennoy, A., et al. 1992, ibid, p.540, "Interferometric Imaging of Nearby Low-Mass Spectroscopic Binaries I: KPNO Observations"  
Coude du Foresto, V., Ridgway, S.T., Mariotti, J.-M. 1992, Targets for Space Based Interferometry, ESA SP-354, p.219, "Integrated Optics for an Interferometric Link"  
Ridgway, S.T. 1992, ibid, p.19, "Visible and Infrared Imaging Interferometry from Space"  
Ridgway, S.T. 1992, ibid, p.85, "Space Interferometry Science Working Group"

Dyck, H.M., Benson, J.A., Ridgway, S.T. 1992, AJ, 104, p.1982, "The Infrared Angular Diameter of alpha Orionis"  
Coude du Foresto, V., et al. 1992, Comtes Rendus de l'Academie des Sciences, 315, p.1641, "De l'Optique Integree pour l'Interferometrie Astronomique"

Ridgway, S.T. 1992, A Lunar Ultraviolet-Optical-Infrared Synthesis Array, ed. J.O. Burns, S.W. Johnson, N. Duric, NASA Conf. Pub. 3066, p.132, "Science Objectives for Ground and Space-Based Optical/IR Interferometry"
Ridgway, S.T., Hinkle, K.H. 1992, High Resolution Spectroscopy with the VLT, ed. M.-H. Ulrich, ESO Conf. and Workshop Proc. No. 40, (ESO, Garching), p.213, "Strategies for Very High Resolution Infrared Spectroscopy"

A. Sarajedini - Globular clusters and stellar populations of our Galaxy.

Bailyn, C. D., et al. 1992, AJ, 103, p.1564, "Evolved Stars in Omega Centauri. I. Radial Distribution of Blue Subdwarfs"

Chaboyer, B., et al. 1992, ApJ, 388, p.372, "The Effect of Helium Diffusion on the Ages of Globular Clusters"

Chaboyer, B. Sarajedini, A., Demarque, P. 1992, ApJ, 394, p.515, "Ages of Globular Clusters and Helium Diffusion"

Sarajedini, A. 1992, AJ, 104, p.178, "CCD Photometry of the Globular Cluster NGC 5897: Morphology of the Color-Magnitude Diagram"

D. Silva - Extragalactic stellar populations problems with an emphasis on studying the ages and chemical compositions of early-type galaxies to probe their formation and evolution.

Silva, D.R., Cornell, M.E. 1992, ApJS, 81, p.865, "A New Library of Stellar Optical Spectra"

Elston, R., Silva, D.R. 1992, AJ, 104, p.1360, "The Extended Giant Branch of M32"

L. Wallace - Radiative transfer problems in planetary atmospheres, tracking the changes in the amounts of the gases in the earth's atmosphere, and the spectroscopy of bright stars.

Wallace, L., Livingston, W. 1992, Geophys. Res. Lett., 19, p.1209, "The Effect of the Pinatubo Cloud on Hydrogen Chloride and Hydrogen Fluoride"

Wallace, L., Livingston, W. 1992, NSO Tech. Report #92-001, "An Atlas of a Dark Sunspot Umbral Spectrum from 1970 to 8640 inverse centimeters (1.16 to 5.1 microns)"

M. Wise - Intracluster medium in clusters of galaxies and the interstellar medium in early-type galaxies with an emphasis on the X-ray emission and spectra of these objects.

Wise, M.W., Sarazin, C.L. 1992, ApJ, 395, p.387, "Using Electron Scattering to Probe the Environment of Cluster Cooling Flows"

Wise, M.W., Sarazin, C.L. 1992, BAAS, 24, p.1290, "X-ray Absorption by Cold Gas in Cluster Cooling Flows"
APPENDIX 4

National Solar Observatory

Scientific Staff: Primary Fields of Interest and 1992 Publications

R. Altrock – Long- and short-term studies of the variation of the solar corona.

Altrock, R.C. 1992, Encyclopedia of Science and Technology. 7th Edition, Vol. 16 (McGraw-Hill), p.607, "The Solar Corona"

Altrock, R.C., Gilliam, L.B., Henry, T.W. 1992, Solar-Geophysical Data, Part 1 no. 559-570, ed. H.E. Coffey, "Sacramento Peak Coronal Line Synoptic Maps, 1991"

Altrock, R.C., Gilliam, L.B., Henry, T.W. 1992, Solar-Geophysical Data, Part 1 no. 559-570, ed. H.E. Coffey, "Coronal Line Emission (Sacramento Peak), 1991"

Guhathakurta, M. et al. 1992, ApJ, 388, p.633, "Coronal Density and Temperature Structure from Coordinated Observations Associated with the Total Solar Eclipse of 1988 March 18"

Jackson, B.V. et al. 1992, IAU Colloquium 133, Eruptive Solar Flares, ed. B.V. Jackson (Kluwer), p.322, "Considerations of a Solar Mass Ejection Imager in a Low-Earth Orbit"

Koutchmy, S. et al. 1992, A&AS, 96, p.169, "Coronal Photometry and Analysis of the Eclipse Corona of July 22, 1990"

K. Balasubramaniam – Physics of solar active region evolution, solar magnetic and velocity fields.

West, E.A., Balasubramaniam, K.S. 1992, SPIE 1746, Polarization Analysis and Measurement, ed. D.H. Goldstein and R.A. Chipman, p.281, "Crosstalk in Solar Polarization Measurements"

J. Brault – High resolution and laboratory spectroscopy.

Mount, G.H., Sanders, R.W., Brault, J.W. 1992, AO, 31, p.851, "Interference Effects in Reticon Photodiode Array Detectors"

Nave, G. et al. 1992, J. de Physique 2, p.913, "Precision Fe I and Fe II Wavelengths in the Red and Infra-Red Spectrum of the Iron-Neon Hollow Cathode Lamp"

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## APPENDIX 5
### NATIONAL OPTICAL ASTRONOMY OBSERVATORIES
#### USER STATISTICS

**FY 1992**

### VISITOR TELESCOPE USAGE

|                     | CTIO² | KPNO³ | NSO⁴ | NOAO Totals |
|---------------------|-------|-------|-------|-------------|
| Visiting Observers  | US    | Foreign | US | Foreign | US | Foreign | US/Foreign |
| Astronomers        | 120   | 44    | 371  | 38       | 95 | 26       | 586       |
| Graduate Students   | 37    | 8     | 136  | 8        | 6  | 1        | 179       |
| Other (technicians, | 0     | 8     | 28   | 3        | 17 | 9        | 45        |
| research assistants, etc.) | | | | | | | |
| Total Visitors      | 157   | 60    | 535  | 49       | 118| 36       | 810       |
| Institutions        | 59    | 26    | 94   | 29       | 49 | 23       | 202       |

1. The figures in this table reflect 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 fiscal year 1992, a total of 219 observing programs were carried out by visitors and the NOAO staff at Cerro Tololo. Visiting astronomers were assigned 72% of the scheduled telescope time and the remaining 18% was assigned to the staff.

3. During fiscal year 1992, a total of 322 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 1992, a total of 133 observing programs were carried out by visitors and the NOAO staff at the National Solar Observatory. Visiting astronomers were assigned 80% of the scheduled telescope time and the remaining 20% was assigned to the staff.

### VISITOR REDUCTION FACILITIES USAGE

**FY 1992**

| NOAO Tucson* |
|--------------|

|                     | Number of Institutions | Visiting Scientists | Totals |
|---------------------|------------------------|---------------------|--------|
|                     | Ph.D. | Student | Other |        |
| PDS Microdensitometer | 6     | 39      | 2     | 41     |
| Grant Comparator 2 axis | 10    | 23      | 26    | 52     |
| VAX and Workstation Computing Facilities | 77    | 160     | 44    | 227    |

* The numbers in the table above reflect duplicated usage of NOAO Tucson reduction facilities by visiting scientists. NOAO staff are not included in these figures.
### APPENDIX 6

#### NOAO FY-1994 Provisional Program Plan

**TABLE I**

**FUNDING BY SOURCE**

(Amounts in Thousands)

| Source                                           | Scientific Staff & Support | Instrumentation | Operations & Maintenance | Total FY-1994 | Total FY-1993(1) | Total FY-1992 |
|--------------------------------------------------|---------------------------|-----------------|--------------------------|--------------|-----------------|--------------|
| NSF FUNDING                                      |                           |                 |                          |              |                 |              |
| Observatory Operations                           |                           |                 |                          |              |                 |              |
| Cerro Tololo Inter-American Observatory          | 1,475                     | 550             | 4,407                    | 6,432        | 6,359           | 6,788        |
| Kitt Peak National Observatory                   | 1,874                     | 1,708           | 4,743                    | 8,325        | 8,386           | 8,782        |
| National Solar Observatory                      |                           |                 |                          |              |                 |              |
| Sunspot                                          | 629                       | 315             | 1,627                    | 2,571        | 2,616           | 2,986        |
| USAF Support                                     |                           |                 |                          |              |                 |              |
| Tucson                                           | 694                       | 307             | 910                      | 1,511        | 1,426           | 1,574        |
| NASA Support                                     |                           |                 |                          |              |                 |              |
| Global Oscillations Network Group                |                           |                 |                          |              |                 |              |
| U.S. Gemini Project Office                       | 500                       |                 |                          | 500          | 445             |              |
| 3.5 Meter Mirror Project                         | 103                       |                 |                          | 103          | 677             | 1,596        |
| Central Offices                                  |                           |                 |                          |              |                 |              |
| Director's Office                                | 61                        | 66              | 599                      | 726          | 795             | 803          |
| Indirect Cost/Miscellaneous Credits              |                           |                 |                          | (340)        | (453)           | (1,083)       |
| Publications & Info. Resources                   | 93                        | 93              | 129                      |              |                 | 101          |
| Central Administrative Services                  | 1,416                     | 1,416           | 1,361                    | 1,567        |                 |              |
| Central Facilities Operations                    | 1,296                     | 1,296           | 1,255                    | 1,407        |                 |              |
| Central Computer Services                        | 45                        | 117             | 933                      | 1,095        | 1,146           | 1,118        |
| Central Engineering & Technical Services         | 1,594                     | 1,594           | 863                      | 809          |                 |              |
| Management Fee                                   |                           |                 |                          | 490          | 475             | 475          |
| **Total Base Budget**                            |                           |                 |                          | 5,278        | 27,780          | 28,768       |
| **Total NSF Budget**                             |                           |                 |                          | 3,420        |                 |              |
| **Non-NSF Budget**                               |                           |                 |                          | 5,618        | 18,196          |              |
| **Total Budget**                                 |                           |                 |                          | **664**      | **29,679**      | **30,476**   |

#### STAFFING SCHEDULE - BASE BUDGET

(In Full Time Equivalents)

| Source                              | NSF Funded - Base Budget | Non-NSF Funded |
|-------------------------------------|--------------------------|----------------|
| **Total**                           | 58.30                    | 18.75          |
| NSF Funded - Base Budget            | 85.25                    | 17.25          |
| Non-NSF Funded                      | 314.78                   | 17.25          |
| **Total**                           | **458.33**               | **500.03**     |

(1) FY-1993 Program Plan, Revision I
### TABLE I

**FUNDING BY SOURCE**

(Amounts in Thousands)

| NSF FUNDING | Scientific Staff Support | Operations & Instrumentation | Total FY-1994 | Total FY-1993(1) | Total FY-1992 |
|-------------|--------------------------|-------------------------------|---------------|------------------|--------------|
| **Observatory Operations** |                          |                               |               |                  |              |
| Cerro Tololo Inter-American Observatory | 1,475 | 4407 | 6,432 | 6,359 | 6,788 |
| Kitt Peak National Observatory | 1,874 | 4,743 | 8,325 | 8,386 | 8,782 |
| **National Solar Observatory** |                          |                               |               |                  |              |
| Sunspot | 629 | 1,627 | 2,571 | 2,616 | 2,986 |
| USAF Support | (600) | (600) | (600) | (600) | (600) |
| Tucson | 694 | 510 | 1,511 | 1,426 | 1,674 |
| NASA Support | (32) | (32) | (31) | (31) | |
| **Global Oscillations Network Group** |                          |                               |               |                  |              |
| Tucson | 2,600 | 2,600 | 2,240 | 2,376 | |
| **U.S. Gemini Project Office** |                          | 500 | 500 | 445 | |
| **3.5 meter Mirror Project** |                          | 103 | 103 | 677 | 1,596 |
| **Central Offices** |                          |                               |               |                  |              |
| Director's Office | 61 | 66 | 726 | 795 | 803 |
| Indirect Cost/Miscellaneous Credits | (340) | (340) | (453) | (1,083) | |
| Publications & Info. Resources | 93 | 93 | 129 | 101 | |
| Central Administrative Services | 1,416 | 1,416 | 1,361 | 1,567 | |
| Central Facilities Operations | 1,296 | 1,296 | 1,255 | 1,407 | |
| Central Computer Services | 45 | 117 | 933 | 1,095 | 1,146 |
| Central Engineering & Technical Services | 1,594 | 1,594 | 863 | 809 | |
| **Management Fee** | 490 | 490 | 475 | 475 | |
| **Total Base Budget** | 5,278 | 5,766 | 16,736 | 27,780 | 27,089 | 28,768 |
| **Initiatives** | 340 | 1,620 | 1,460 | 3,420 | |
| **Total NSF Budget** | 5,618 | 7,386 | 18,196 | 31,200 | |
| **Non-NSF Budget** | 664 | 2,590 | 1,708 | |
| **Total Budget** | 31,864 | 29,679 | 30,476 | |

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**STAFFING SCHEDULE - BASE BUDGET**

(In Full Time Equivalents)

| NSF Funded - Base Budget | 58.30 | 85.25 | 314.78 | 458.33 | 461.83 | 782.78 |
| Non-NSF Funded | 18.75 | 17.25 |
| **Total** | 458.33 | 480.58 | 800.03 | |

(1) FY-1993 Program Plan, Revision I
## TABLE II

**SUMMARY OF NSF FUNDING BY COST CATEGORY**

### BASE BUDGET

(Amounts in Thousands)

| NSO          | CTIO | KPNO | Sunspot | Tucson | GONG | US Gemini Office | 3.5M Mirror | Central Offices | FY-1994 | FY-1993 | FY-1992 |
|--------------|------|------|---------|--------|------|------------------|-------------|----------------|---------|---------|---------|
| Personnel Costs | 4,221 | 6,612 | 1,982 | 1,318 | 1,700 | 450              | 53          | 4,236          | 20,572  | 20,188  | 19,324  |
| Supplies & Materials | 1,086 | 840  | 248    | 113   | 142   | 50              | 50          | 494            | 2,973   | 3,057   | 4,449   |
| Utilities & Communications | 368   | 259  | 275    |        |       |                 | 515         | 1,417          | 1,373   | 1,309   |         |
| Purchased Services | 440   | 141  | 24     | 14    | 170   | 300             | 1,089       | 981            | 1,187   |         |         |
| Domestic Travel | 52    | 129  | 15     | 47    | 515   | 127             | 460         | 361            | 253     | 314     |         |
| Foreign Travel  | 140   | 80   | 5      | 13    | 20    | 12              | 270         | 258            |         |         |         |
| Equipment      | 125   | 264  | 6      | 528   | 196   | 50              | 1,141       | 1,032          | 2,083   |         |         |
| Management Fee | 490   | 490  | 490    |        |       |                 | 490         | 475            |         |         |         |
| USAF & NASA Support | (600) | (32) | (632)  |        |       |                 | (631)       | (631)          |         |         |         |
| **Total**     | 6,432 | 8,325| 1,971  | 1,479 | 2,600 | 500             | 103         | 6,370          | 27,780  | 27,089  | 28,768  |

### STAFFING SCHEDULE - BASE BUDGET

(In Full Time Equivalents)

| Scientists     | 15.00 | 23.00 | 6.00 | 8.25 | 1.00 | 3.25 | 5.25 | 61.75 | 62.75 | 65.00 |
|----------------|-------|-------|------|------|------|------|------|-------|-------|-------|
| Engineers & Scientific Programmers | 19.00 | 23.50 | 7.00 | 2.50 | 15.50 | 0.75 | 0.50 | 15.15 | 83.90 | 84.15 |
| Administrators & Supervisors | 10.00 | 6.00  | 4.00 | 2.00 | 1.00 |      | 12.50 | 35.50 | 35.50 | 34.50 |
| Clerical Workers  | 24.00 | 4.25  | 3.10 | 1.00 | 1.00 | 0.25 | 34.13 | 67.73 | 68.23 | 74.53 |
| Technicians | 33.50 | 38.00 | 9.00 | 7.50 | 15.00 | 1.00 | 17.30 | 121.30 | 122.30 | 128.30 |
| Maintenance & Service Workers | 41.00 | 29.00 | 10.15 |      |      |      | 8.00  | 88.15 | 88.15 | 96.30 |
| **Total**      | 142.50| 123.75| 39.25 | 21.25 | 33.50 | 4.25 | 1.50 | 92.33 | 461.63 | 482.78 |
### TABLE III

**SCIENTIFIC STAFF & SUPPORT**

**BASE BUDGET**

(Amounts in Thousands)

|                      | CTIO | KPNO | Sunspot | Tucson | US Gemini Office | Central Offices | Total FY-1994 | Total FY-1993 | Total FY-1992 |
|----------------------|------|------|---------|--------|------------------|----------------|---------------|---------------|---------------|
| **Personnel Costs**  | 1,338| 1,631| 598     | 646    | 450              | 106            | 4,769         | 4,645         | 4,229         |
| **Supplies & Materials** | 42   | 77   | 13      | 21     | 5                | 7              | 153           | 148           | 126           |
| **Purchased Services** | 1    | 33   | 5       | 2      | 62               | 27             | 41            | 78            | 68            |
| **Domestic Travel**   | 5    | 56   | 8       | 15     | 50               |                | 134           | 129           | 98            |
| **Foreign Travel**    | 62   | 50   | 5       | 10     |                  |                | 127           | 131           | 125           |
| **Equipment**         | 27   | 27   |         |        |                  |                | 54            | 50            | 138           |
| **Total**             | 1,475| 1,874| 629     | 894    | 500              | 106            | 5,278         | 5,181         | 4,784         |

### STAFFING SCHEDULE - BASE BUDGET

(In Full Time Equivalents)

|                      | Scientists | Engineers & Scientific Programmers | Clerical Workers | Technicians | Total |
|----------------------|------------|------------------------------------|------------------|-------------|-------|
|                      | 14.00      | 21.00                              | 6.00             | 0.75        | 58.30 |
|                      | 1.00       | 1.50                               | 1.00             | 0.25        | 3.75  |
|                      | 1.50       | 1.50                               |                  | 1.50        | 60.55 |
| **Total**            | 16.50      | 21.00                              | 8.25             | 0.80        | 60.55 |
## NOAO FY-1994 Provisional Program Plan

### TABLE IV

**INSTRUMENTATION BASE BUDGET**

(Amounts in Thousands)

|          | CTIO | KPNO | Sunspot | Tucson | NSO | 3.5M | Central Offices | Total FY-1994 | Total FY-1993 | Total FY-1992 |
|----------|------|------|---------|--------|-----|------|----------------|--------------|--------------|--------------|
| Personnel Costs | 366  | 1,443| 280     | 270    | 1,700| 53   | 117            | 4,229        | 4,206        | 4,504        |
| Supplies & Materials | 103  | 243  | 35      | 37     | 142  | 50   | 160            | 610          | 610          | 1,606        |
| Utilities & Communications |        |      |         |        |      |      |                |              |              |              |
| Purchased Services | 81   | 8    |         |        | 170  | 50   | 610            | 610          | 1,606        |              |
| Domestic Travel   | 7    | 40   | 66      | 113    | 33   | 39   |                |              |              |              |
| Foreign Travel    | 2    | 20   |         |        | 22   | 3    | 21             |              |              |              |
| Equipment         | 5    | 528  |         |        | 533  | 524  | 357            |              |              |              |
| **Total**         | 560  | 1,708| 315     | 307    | 2,600| 103  | 183            | 5,766        | 5,991        | 7,621        |

### STAFFING SCHEDULE - BASE BUDGET

(In Full Time Equivalents)

|                     | 1.00 | 0.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
|---------------------|------|------|------|------|------|------|------|------|
| Scientists          |      |      |      |      |      |      |      |      |
| Engineers & Scientific Programmers | 7.50 | 13.25| 4.00 | 1.50 | 15.50| 0.50 | 1.50 | 43.75|
| Administrators & Supervisors | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |      |      |      |
| Clerical Workers    | 1.00 | 1.00 | 1.00 | 1.00 |      |      |      |      |
| Technicians         | 4.00 | 13.00| 1.00 | 4.00 | 15.00| 1.00 | 38.00| 43.60|
| **Total**           | 11.50| 26.25| 5.00 | 5.50 | 33.50| 1.50 | 2.00 | 85.25|

|                     | 93.85|      |      |      |      |      |      |      |
|                     |      | 93.60|      |      |      |      |      |      |


TABLE V
OPERATIONS & MAINTENANCE BY COST CATEGORY
BASE BUDGET
(Amounts in Thousands)

| Cost Category                | CTIO   | KPNO   | Sunspot | Tucson | Total FY-1994 | Total FY-1993 | Total FY-1992 |
|-----------------------------|--------|--------|---------|--------|---------------|---------------|---------------|
| Personnel Costs             | 2,517  | 3,538  | 1,104   | 402    | 4,013         | 11,574        | 11,337        | 10,591        |
| Supplies & Materials        | 941    | 520    | 200     | 55     | 494           | 2,210         | 2,299         | 2,717         |
| Utilities & Communications  | 368    | 259    | 275     | 55     | 515           | 1,417         | 1,373         | 1,304         |
| Purchased Services          | 358    | 100    | 19      | 12     | 300           | 789           | 288           | 30            |
| Domestic Travel             | 47     | 66     | 7       | 32     | 61            | 213           | 199           | 177           |
| Foreign Travel              | 78     | 28     | 27      | 3      | 12            | 121           | 119           | 112           |
| Equipment                   | 98     | 232    | 6       | 6      | 196           | 554           | 458           | 1,588         |
| Management Fee              | 490    | 490    | 490     | 490    | 490           | 490           | 490           | 490           |
| USAF & NASA Support         | (600)  | (32)   | (632)   | (631)  | (632)         | (631)         | (631)         | (631)         |
| Total                       | 4,407  | 4,743  | 1,027   | 478    | 6,081         | 16,736        | 15,917        | 16,363        |

STAFFING SCHEDULE - BASE BUDGET
(In Full Time Equivalents)

| Category                                | Scientists | Engineers & Scientific Programmers | Administrators & Supervisors | Clerical Workers | Technicians | Maintenance & Service Workers | Total |
|-----------------------------------------|------------|-------------------------------------|-------------------------------|------------------|-------------|-------------------------------|-------|
|                                          | 1.00       | 11.50                               | 10.00                         | 23.00            | 28.00       | 41.00                         | 114.50|
|                                          | 2.00       | 10.25                               | 6.00                          | 4.25             | 25.00       | 29.00                         | 76.50 |
|                                          |            | 3.00                                | 4.00                          | 1.60             | 8.00        | 10.15                         | 26.75 |
|                                          |            | 1.00                                | 1.00                          | 2.00             | 3.50        | 8.00                          | 7.50  |
|                                          |            |                                    |                               |                  | 89.53       | 314.78                        | 307.93|
|                                          |            |                                    |                               |                  |             |                               | 328.63|
TABLE VI

OPERATIONS & MAINTENANCE BY COST TYPE
BASE BUDGET
(Amounts in Thousands)

|                           | CTIO  | KPNO | Sunspot | Tucson | Central Offices | Total FY-1994 | Total FY-1993 | Total FY-1992 |
|---------------------------|-------|------|---------|--------|----------------|---------------|---------------|---------------|
| Engineering & Technical Services | 859   | 1,425| 188     | 50     | 1,594          | 4,116         | 3,522         | 4,051         |
| Telescope Operations      | 808   | 880  | 553     | 245    |                | 2,486         | 2,590         | 2,602         |
| Mountain Operations       | 894   | 1,713| 676     |        |                | 3,283         | 3,137         | 3,543         |
| Central Facilities - Tucson/La Serena | 742   | 268  |         |        | 1,296          | 2,306         | 2,253         | 2,421         |
| Central Computer Services |       |      | 933     | 933    |                | 933           | 1,009         | 943           |
| Administration            | 1,104 | 457  | 210     | 215    | 1,675          | 3,661         | 3,433         | 2,858         |
| Publications & Information Resources | 93    |      | 93      |        | 129            | 101           |               |               |
| Management Fee            |       |      | 490     | 490    |                | 475           | 475           |               |
| USAF & NASA Support       |       |      |         |        | (600)          | (32)          | (632)         | (631)         |
| Total O&M                 | 4,407 | 4,743| 1,027   | 478    | 6,081          | 16,736        | 15,917        | 16,363        |

STAFFING SCHEDULE - BASE BUDGET
(In Full Time Equivalents)

|                           |       |       |         |          |                |               |               |               |
|---------------------------|-------|-------|---------|---------|----------------|---------------|---------------|---------------|
| Engineering & Technical Services | 15.50 | 16.00 | 3.00    |         | 23.65          | 58.15         | 51.55         | 53.05         |
| Telescope Operations      | 25.00 | 15.00 | 8.00    | 5.00    |                | 53.00         | 55.00         | 57.00         |
| Mountain Operations       | 28.00 | 33.00 | 10.75   | 0.50    |                | 72.25         | 71.25         | 75.80         |
| Facilities                | 24.00 | 4.25  | 1.00    |         | 12.50          | 41.75         | 41.75         | 46.75         |
| Central Computer Services | 22.00 | 3.25  |         |         | 11.25          | 14.50         | 14.00         | 15.75         |
| Administration            |       | 2.00  |         |         | 42.13          | 75.13         | 74.30         | 80.28         |
| Total                     | 114.50| 76.50 | 26.75   | 7.50    | 89.53          | 314.78        | 307.93        | 328.63        |
### TABLE VII

NON-NSF FUNDING
(Amounts in Thousands)

| NSC | CTIO | KPNO | Sunspot | Tucson | Central Offices | Total FY-1994 | Total FY-1993 | Total FY-1992 |
|-----|------|------|---------|--------|----------------|--------------|--------------|--------------|
|     |      |      |         |        |                | 1,161        | 326          | 11           |
| Personnel Costs | Supplies & Materials | Utilities & Communications | Purchased Services | Domestic Travel | Foreign Travel | Equipment | Total |
| 600 | 64   |       | 664     | 934    | 744            | 2,590        | 1,708        |

### STAFFING SCHEDULE
(In Full Time Equivalents)

|          | Scientists | Engineers & Scientific Programmers | Clerical Workers | Technicians |
|----------|------------|-----------------------------------|------------------|-------------|
| Total    | 7.00       | 1.50                              | 10.25            | 18.75       | 17.25       |
| Initiative                                                                 | Scientific Staff Support | Instrumentation | Operations & Maintenance | Total FY-1994 |
|---------------------------------------------------------------------------|--------------------------|----------------|--------------------------|---------------|
| Cerro Tololo Inter-American Observatory                                   |                          |                |                          |               |
| Increase Scientific Staff                                                | 90                       |                |                          |               |
| 4-m Primary Active Support System                                         |                          |                |                          |               |
| Implement New CCD's                                                       |                          | 85             |                          |               |
| 4-m f/15 Secondary Mirror                                                |                          | 50             |                          |               |
| Spectrograph Motor Controls                                              |                          | 75             |                          |               |
| Differential for Peso Inflation & Dollar Exchange Rate                   |                          | 90             |                          |               |
| Tololo Operations Building                                               |                          |                |                          |               |
| La Serena-Tololo Microwave Link Upgrade                                  |                          |                |                          |               |
| Kitt Peak National Observatory                                           |                          |                |                          |               |
| Scientific Salaries to Offset Support to US Gemini Office (3 FTE)        | 250                      |                |                          |               |
| 4-m Prime Focus Corrector                                                |                          | 40             |                          |               |
| Kitt Peak Site Seeing Survey and Monitors                                |                          | 100            |                          |               |
| Ventilate 4-m Dome                                                       |                          |                |                          |               |
| Expand Telescope Operator Pool for Queue Scheduling                      |                          | 175            |                          |               |
| Expand Kitt Peak Support for WIYN Operations                             |                          | 36             |                          |               |
| Implement Initial Data Archiving System                                  |                          | 85             |                          |               |
| Implement Kitt Peak-Tucson Microwave Link                                |                          | 169            |                          |               |
|                           |                          |                |                          |               |
| National Solar Observatory                                               |                          |                |                          |               |
| Sunspot - Adaptive Optics Development Program                            |                          |                |                          |               |
| Tucson - Start McMath-Pierce Performance Upgrade                          |                          |                |                          |               |
| Tucson - Start Upgrade of McMath-Pierce Telescope Control System         |                          |                |                          |               |
| Sunspot - Facilities Improvements (paving, gas & water mains, heaters)   |                          |                |                          |               |
|                           |                          | 500            | 275                      | 775           |
| Global Oscillations Network Group                                       |                          |                |                          |               |
| Maintain Deployment Schedule and Mitigate Contractor Default             | 250                      |                |                          | 250           |
| Central Offices                                                          |                          |                |                          |               |
| Director's Office                                                        |                          |                |                          |               |
| Secretarial Salaries to Offset Support to US Gemini Office               |                          |                |                          | 35            |
| Central Computer Services                                                |                          |                |                          |               |
| Augment Kitt Peak Programming Group                                      |                          |                |                          | 55            |
| Hardware Upgrades for Large-format Array Data                            |                          |                |                          |               |
| Central Engineering & Technical Services                                 |                          | 80             |                          |               |
| Detector Development                                                     |                          |                |                          | 350           |
| Opto-Mechanical Engineer Salary to Offset Support to US Gemini Office    |                          |                |                          | 100           |
| Optical Engineer                                                         |                          |                |                          | 46            |
| Electrical Designer                                                      |                          |                |                          | 56            |
| Electronics Technician                                                    |                          |                |                          | 39            |
|                           |                          |                |                          | 430           |
|                           |                          | 331            |                          | 761           |
| Total Initiatives                                                        | 340                      | 1,620          | 1,460                     | 3,420         |
| Initiative                                                                 | Scientific Staff Support | Instrumentation | Operations & Maintenance | Total FY-1994 |
|---------------------------------------------------------------------------|--------------------------|----------------|--------------------------|--------------|
| Kitt Peak National Observatory                                           |                          |                |                          |              |
| Cool 4-m Primary Mirror                                                  |                          |                |                          |              |
| Modernize 4-m Interface Electronics                                      |                          |                |                          |              |
| National Solar Observatory                                               |                          |                |                          |              |
| Scientific Staff Salary Support to Offset Cost of New Director            | 130                      |                |                          |              |
| Tucson - Complete Upgrade of McMath-Pierce and Kitt Peak                 |                          |                |                          |              |
| Vacuum Telescope Control Systems                                          |                          |                |                          |              |
| Tucson - Complete McMath-Pierce Performance Upgrade                       |                          |                |                          |              |
| Total Additional Initiatives                                             | 130                      | 767            | 1,110                    | 2,007        |