NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

FY 1995 PROVISIONAL PROGRAM PLAN

June 29, 1994
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I. OVERVIEW

Nighttime Astronomy

It is certain that during the next decade astronomers will achieve major advances in our understanding of the structure and evolution in the universe. Over the next decade there will be an unprecedented increase in the power of optical and infrared telescopes. In the US, the first Keck telescope is already in operation, and the Gemini, Magellan, second Keck, Columbus, and MMT upgrade projects are all scheduled to achieve first light by the turn of the century. The VLT and Subaru will also be completed on a similar time scale. These telescopes will not only have larger aperture, they will be capable of substantially higher levels of performance than conventional telescopes now in operation. Active control of optical alignment and of the shape of the primary mirror combined with adaptive optics will routinely produce image quality of a few tenths of an arcsecond. The gains in throughput for some types of observations will exceed by an order of magnitude or more the performance of today’s 4-m class telescopes.

This new generation of large telescopes will be used primarily to explore the spectroscopic properties of sources, many of which were discovered by X-ray, gamma-ray, and infrared satellites, that are beyond the reach of today’s telescopes. The combination of spectroscopy of distant galaxies combined with morphological types obtained with HST will yield important constraints on models of the formation of galaxies. Fundamental problems, such as the determination of the age and scale of the universe, when and how large scale structure formed, how interactions influence the evolution of galaxies, and the frequency of formation of planetary systems around other stars, are likely to yield to solution when these powerful new facilities go into operation.

To ensure that the NOAO community can contribute fully to the major advances that we confidently expect during the next ten years, we must develop and support internationally competitive state-of-the-art facilities. Unfortunately, just as we have developed the technical capabilities to build far more powerful telescopes and instruments, the prospects for significant increases in funding have faded. At the same time as we are making an investment of half a billion dollars in capital for new telescopes in the US, our ability to fund instrumentation and operations of those telescopes at a level that would realize their full scientific potential is very much in doubt.

We believe a strong case can be made--and we will make it--that this major capital investment, which has been derived from state, federal, and private funds, represents such a qualitative change in the kinds of facilities available to astronomers that the NSF should provide an increase in funding in order to operate the Gemini telescopes effectively and to provide instrumentation for the large private telescopes. Even if NSF is able to respond favorably, it is still likely that NOAO will wish to alter its own priorities as new capabilities come on line. In order to embrace new opportunities, support for some existing programs, however excellent they may be, will have to be reduced or eliminated.

During the past year, all of the divisions of NOAO have worked to develop an outline of the program that we will carry out through the next decade. We must now fill in this outline with specific plans for each year. Those plans are being worked out and will be described when we submit the proposal to renew the cooperative agreement under which NOAO operates. In this program plan we describe briefly the decisions that we have already made and give a summary of our overall priorities. The program plan for FY 1995 is consistent with the detailed longer range plan that we are now developing and is designed to bring us one year closer to achieving our goals for the decade.
The common mission of all of the divisions of NOAO is to enable excellent research through the provision of scientific capabilities that are open on a competitive basis to all astronomers. By capabilities, we mean the combination of telescope, instrument, and reduction software— all of which must work together reliably and must match or exceed in performance the best facilities available elsewhere. In order to accomplish this mission, NOAO will change the activities and emphasis at its nighttime sites in order to make the most effective use of its already very constrained resources.

Overall, the priorities that we have set are: 1) support of US involvement with, and the use of, Gemini; 2) operation of the 4-m class telescopes; 3) maintaining an instrumentation program that is capable of producing instruments that are at least the equal of the best available anywhere in the world; because of resource constraints, we expect to concentrate on a few areas of excellence and will purchase other instruments or designs for them from other observatories; 4) operation of other telescopes. The other parts of the observatory, including the scientific staff and administrative support, will be sized in a way that is consistent with the overall program.

The emphasis at CTIO will be on operations. The engineering resources at the site will be devoted to improving telescope performance, with highest priority being given to the 4-m telescope. An extensive program has been initiated to improve the imaging performance of the telescope so that it does not compromise the natural seeing offered by the site. Steps already completed include ventilation of the dome, cooling of the oil and the primary mirror, and re-figuring the secondary mirror. Future steps include installing an active support system under the primary mirror, a wavefront sensor, and a tip-tilt secondary. (At KPNO the 4-m upgrade program began with installation of a new servo system and telescope control system in order to improve pointing and tracking. Implementing the upgrades in a different order at the two sites permits the exchange of proven designs and minimizes duplication of effort.) Upgrades to other CTIO telescopes will be undertaken if resources permit. One major goal of such improvements would be to increase reliability and lower maintenance costs. By making investments now in improved performance and reliability, CTIO is preparing for the advent of Gemini South. It is likely that CTIO staff will become heavily involved in Gemini work, since after this program of improvements they will have extensive experience in solving the kinds of problems that are likely to be encountered in the commissioning of the Gemini telescope on Cerro Pachon. Indeed, the modifications to the CTIO 4-m will permit early testing of the efficacy of many of the design features of the Gemini telescopes, including dome ventilation, cooling of the primary mirror to modify mirror seeing, and active wavefront sensing.

In the future, major instrumentation on the scale of Hydra, SQIID, and Phoenix will be built in Tucson for KPNO, CTIO, and if NOAO competes successfully, for Gemini. The construction of complex facility class instrumentation requires a technical group with a range of very high level capabilities. NOAO cannot within its current budget maintain that level of capability at two sites. The two sites will collaborate closely on developing a coordinated instrument plan and on conceptual design. For particular instruments, a staff member from CTIO may be resident in Tucson in order to serve as project scientist to oversee detailed design and fabrication. KPNO and CTIO have developed a coordinated plan for both optical and infrared instrumentation over the next several years. The outcome will be comparable capabilities, although not identical instruments, at the two sites. In the infrared, either two, or if NOAO submits a successful proposal, three medium resolution spectrometers will be built. In the optical, the first priority is development of either one or two mosaic imagers, depending on availability of funds. When that project is complete, the next priority will be construction of either one or two multi-object high-throughput spectrometers. The exact specifications will be determined after additional internal discussions and after seeing what approaches have been, or will be, adopted by other groups including Gemini.
The resources used for this combined instrumentation program will be the same as the resources now being devoted exclusively to KPNO. Therefore, the rate of delivery of instruments to KPNO will be halved unless we become substantially more efficient in our development of instruments. We are looking at options involving the reorganization of ETS, a change in the way we approach instrument design and fabrication, new technologies for increasing throughput, and replacing staff in a small number of key positions.

Because the instrumentation program in Tucson will now serve both CTIO and KPNO, the program will formally report to the NOAO Director or her designee. The level of this program will be decided through joint discussions between CTIO and KPNO. KPNO will no longer have the option of cutting the instrumentation program disproportionately in order to support continued operations of its telescopes.

One of the most difficult and contentious issues facing the observatory is that of the future of the small telescopes at CTIO and KPNO. These telescopes are well instrumented, the capabilities that they offer are, with very few exceptions, not duplicated in the university community, very important scientific results are being achieved with them, and they play an essential role in supporting the broad-based vitality of the US and Chilean astronomical communities. About three quarters of the papers published by users of KPNO and CTIO do not depend on data from the 4-m telescopes. However, the future of the small telescopes is threatened. The threat that is most widely recognized is the declining budget; it is unclear that KPNO and CTIO can continue to operate the full suite of available telescopes even at current budget levels. The problem at KPNO is particularly acute since the WIYN telescope is now coming on line. The second threat is even more serious. All of the NOAO telescopes are aging. Maintenance is becoming increasingly costly and difficult. The telescopes should be replaced with modern instruments that offer better performance at lower cost.

The scientific case for operating telescopes with a range of apertures and capabilities is compelling. Even when the Gemini telescopes are completed, there will be the equivalent of only one 8-m class telescope for the US community outside the handful of major universities that have built their own telescopes of comparable aperture. In order to use the Gemini telescopes most efficiently, it is necessary to do a great deal of preparatory and calibration work on telescopes with smaller aperture. There will be a need for surveys to select objects for spectroscopy with the Gemini telescopes; imaging and photometry do not in general require 8-m aperture. For many programs, calibrations of brighter objects can be obtained with smaller telescopes. All Gemini instrumentation will have to be fully commissioned either on a simulator or at a telescope before it is shipped to the remote sites, and existing telescopes can play an important role in commissioning and testing.

After assessing their requirements, both KPNO and CTIO believe that the optimum complement of instruments at each site, if they were to be developed ab initio, would be three 4-m class telescopes and a single wide-field 2-m class telescope for imaging surveys. The 4-m telescopes would be optimized for different science, including the infrared, and at least one at each site would be compatible with the Gemini specifications so that it could be used to commission instruments. Each would have a limited instrument capability in order to minimize instrument changes. Limited instrument changes combined with modern telescope design should dramatically lower operating costs. NOAO will seek partners to build the additional telescopes required to provide this suite of instruments and will offer to exchange observing time on its other facilities so that partners in such telescopes can have access to the full range of observing capability even though they are partial owners of a highly specialized facility.
KPNO and CTIO have both been examining what their posture should be concerning adaptive optics. We have decided to follow a phased program. The effective performance of adaptive optics depends first of all on optimizing the performance of the telescope itself. Therefore, the upgrades to the CTIO 4-m are an essential prerequisite. At KPNO, work requiring superb imaging will for the most part be carried out at the WIYN telescope. After optimizing telescope performance, the focus at CTIO will be on implementing tip/tilt capability. KPNO is seeking a partnership with an experienced group to fabricate a low-order adaptive optics system for the WIYN. KPNO has also contacted several groups about bringing adaptive systems to Kitt Peak in return for observing time. After evaluation at KPNO and possibly CTIO, the observatories will try to identify funds to purchase a tested system.

Gemini will have a major impact on NOAO. While the project is an international one that is managed independently of NOAO, Gemini expects that the partner countries will assume major responsibility for certain Gemini activities. In the construction phase, the partner countries are responsible for providing scientific input into the design requirements for the project, for evaluating the proposed designs, and for carrying out much of the technical work, including fabrication of instruments, writing of software, and construction of some major telescope subsystems. In the operations phase, the Gemini project itself will support observers at the telescopes. The partner countries will be responsible for much of the interaction with their communities both before and after the observations are made. Included among the tasks assigned to the partner countries are the operation of national telescope allocation committees, provision of the expert assistance needed by the users to prepare competitive proposals, building of all major new instrumentation, support for maintenance problems that cannot be handled by on site Gemini staff, and responding to requests for access to archived material. Much of this activity will take place within NOAO. In those cases where work, such as building instruments, is carried on outside of NOAO, then NOAO will be responsible to the international Gemini project for ensuring that the work is completed in a satisfactory manner. To the extent possible, we will use the same standards and approaches for the Gemini-related activities as for CTIO and KPNO. Such standardization will allow us to achieve economies of scale.

The demand for new instrumentation for the 8-m and 10-m telescopes is likely to exceed the availability of public and private resources, and it may not be possible for every observatory to maintain the full complement of technical experts required for competitive development in all areas. NOAO is prepared to act as a facilitator for technology sharing for the mutual benefit of all interested observatories. A cooperative approach to the implementation of new detectors, specialized electronics and optics systems is likely to be the preferable path for a maximum exploitation of the scientific capabilities of the new generation of telescopes.

Some decisions about management follow from the integration of the nighttime program. First, we will have to develop a common infrastructure, including common hardware, software, and interfaces; to the extent feasible, CTIO and KPNO will adopt standards that are common to Gemini as well. The instrumentation program in Tucson will now have to supply instruments to both CTIO and KPNO with no increase in the budget; we are making an effort to increase significantly the efficiency with which instrumentation is produced. While we have agreed that the instrumentation is now an NOAO program and that resources may be shifted from KPNO to CTIO and vice versa from time to time, we have decided that the support for telescope operations will be fixed to the sites. One can argue for giving higher priority to the operation of the small telescopes on either site. CTIO offers unique access to the southern hemisphere. KPNO's small telescopes are better instrumented and serve a larger proportion of US users. If resources are assigned to the sites in the same proportions as they are now, then the staffs of each site can determine the best way to respond to changes in budget, and if innovative ways are found to reduce operating costs at one site, that site will benefit--the funds saved will not be transferred to the other site.
Both KPNO and CTIO are actively seeking collaborations that would pay for some of the operations costs of the small telescopes in return for making time available for large programs such as the verification of MACHO candidates.

An important question that must be addressed over the next several years is what facility should be built for optical/infrared astronomy after the Gemini telescopes are completed. It is fair to say that no one knows what the specifications of such a facility should be, and in fact there are very few conceptual ideas that have been put forth. It is widely thought that the next major facility should be some kind of optical or infrared interferometer. Before selecting the balance between aperture of the separate telescopes and baseline, a number of technical issues must be resolved with prototype interferometers, and development work is now going on in several institutions. The ultimate choice of approach will also depend on when interferometry is initiated with the VLT and Keck telescopes and how successful those programs are. Any national or international facility would have to offer significant gains beyond what is available with Keck and the VLT.

NOAO plans to take two steps to support activities in planning for the future. First, sometime in the next two years, we will hold a small workshop of key people to explore what a major new groundbased facility might look like. Second, we will continue to support S. Ridgway's efforts in interferometry. He has already participated directly in interferometer projects in France and here in the US and has conducted experiments in linking telescopes interferometrically with fibers. He has also led several study committees on interferometry, including the interferometry panel of the Bahcall committee. He is currently spending nearly full time assisting with the preparation of the proposal for the CHARA array, which will be built by Georgia State.

Both CTIO and KPNO expect to iterate with their users committees concerning this plan and the specific program elements contained within it. We are committed, however, to a close integration of all of the nighttime program and believe that this is the way that NOAO can within a very constrained budget best serve its user community.

Solar Astronomy

With the imminent deployment of the NOAO Global Oscillations Network (GONG), and of its space counterparts on the SOHO satellite, solar astronomy enters a new era of solar exploration. These Solar Interior Observatories will observe the non-radial pulsations of the Sun around the clock with accuracies which are limited only by the random solar surface motions themselves. Although GONG is approved for an initial operation period of three years, it is constructed so that operation over one or two solar cycles is well within its capabilities. It will be unique in that respect. Together with the sophisticated inversion techniques now being developed within NSO/NOAO and elsewhere to derive the flows, temperatures and possibly magnetic fields in the solar convection zone, such an extended operation will open up the layers of the Sun responsible for the solar dynamo and for the solar activity cycle to detailed observations. It is not unreasonable to expect these observations to lead to detailed models of solar and stellar activity which may ultimately answer long-standing questions on the origin and predictability of solar activity and its impact on Earth.

The National Solar Observatory is currently developing a long range plan (the so-called Future Directions Plan or FDP), which capitalizes on this new capability. The FDP combines a program of high quality basic research in solar astrophysics with one of research in the strategically important topics of global change.
and Sun induced hazards on the Earth. It is a well focussed program that defines the need for solar instrumentation, observations, theory and modelling from a set of specific goals based on the desire to understand and predict solar variability. It is a program that requires the cooperation and participation of the entire solar astronomy community, as is the case already in the GONG program and as will be the case for the PSPT/RISE (Precision Solar Photometric Telescope/Radiative Inputs from the Sun on the Earth) program. It also is a program which places the use of the NSO telescopes and the development of its instrumentation in a new perspective. The result of the FDP will therefore be to give new emphasis to the traditional mission of NSO: (1) basic research in solar astrophysical processes, (2) leadership in its discipline and (3) support of its user community in the form of cutting edge observational and data analysis capabilities.

The NSO Future Directions Plan has the following four specific goals and proposed programs towards those goals:

**Goal 1: Understanding of the Solar Activity Cycle.**

- Implementation of GONG and operation for one or two 11-year solar cycles.
- Continuation and refinement of observation of solar surface flows and magnetism.
- Development of a computer model of the solar cycle using these observations.
- Testing of this solar cycle model on observations of sun-like stars.

**Goal 2: Understanding the Coupling of the Solar Interior to the Surface Behavior and the Prediction of Solar Irradiance Changes.**

- Make high quality observations of the very outer layers of the solar convection zone.
- Relate these to the observed solar surface behavior.
- Determine the origin of the solar irradiance changes.
- Develop a model of the solar surface magnetic field behavior.
- Testing this model with surface observations at very high angular resolution.

**Goal 3: Understanding the Coupling of the Solar Surface Behavior to the Solar Envelope and the Prediction of Solar Transient Events.**

- Determination of the mechanisms that control the topology of the coronal magnetic fields.
- Research into the mechanisms responsible for chromospheric and coronal heating.
- Development of a model for coronal transients and solar flares.

**Goal 4: The Exploration of the Unknown.**

- An essential component in a strongly programmatic effort like this one. The primary tool for carrying out the FDP is helio-seismology. A clear case can be made that this technique resulted from purely "curiosity driven" research.
- An example is the exploration of the as yet unknown IR spectrum of the solar corona and of solar flares.
From these goals and programs the FDP defines a prioritized list of solar instrumentation capabilities. NSO is fortunate to already have the broad range of telescopes and many of the instruments needed to start carrying out the observational programs. The FDP clearly defines, however, where these facilities need to be improved and optimized. Especially in the areas of theory, computer modelling, and observations at far-UV and X-ray wavelengths, cooperative programs with other research groups are necessary. Initial steps have already been taken for cooperative programs with the High Altitude Observatory.

One of the capabilities called for in the FDP is a large aperture (2-m to 4-m class) telescope capable of high-angular resolution observations, solar IR observations, solar-stellar observations, and if possible, solar coronal observations. The last large solar telescope funded by the NSF is the Kitt Peak McMath-Pierce telescope, which goes back to the early 1960s. The prominent Sac Peak Vacuum Tower Telescope, funded by the USAF, celebrates its 25th anniversary in 1994. Elsewhere in the USA, solar astronomers also work with old equipment. This stands in sharp contrast to the approximately fifteen 8-m class telescopes currently under construction in the world for nighttime astronomy. A good case can be made for a modern large aperture solar (-stellar) facility. Within its limited resources, NSO is currently developing and comparing concepts for an upgrade of the McMath-Pierce facility to a 4-m aperture with a 2-m to 4-m aperture reflecting coronagraph (LRC) that would also be capable of far-IR solar disk observations. Both facilities would be good solar-stellar facilities, and the LRC might turn out to be the lowest emissivity telescope in the world for nighttime observation. When the concept studies are complete they will be compared with the LEST facility, and one concept will be selected for the preparation of a major proposal.

Milestones for FY 1995

- Beginning of WIYN telescope scientific operations.
- Installation of f/14 IR secondary on CTIO 4-m.
- Commissioning of active primary mirror support system for CTIO 4-m.
- Implementation of two new large-format CCDs under ARCON at CTIO.
- Completion of Aladdin demonstration project with USNO, SBRC to produce 1024 square InSb IR arrays.
- Implementation of mini-mosaic 4K x 4K CCD array.
- Experiments with high-resolution imaging at KPNO Diffraction-limited imaging at 3 µm on the 4-m with COB Tip-tilt imaging on the 2.1-m with COB Possible collaborations with Starfire Optical Range.
- Completion of mechanical fabrication for high-resolution IR spectrograph, Phoenix.
- Commissioning of Hydra/MOS on the WIYN telescope.
- Fabrication of new correlation tracker for Sac Peak Vacuum Tower Telescope.
- Begin fabrication for Near-Infrared Magnetograph-2 for McMath Pierce Telescope.
- Major new release of IRAF (2.11); integration of GUI and scientific applications.
II. SCIENTIFIC PROGRAM

The key to a successful national observatory is a world-class scientific staff. It is the scientific staff, working with the user community, that defines the future of the observatory. To carry out their own forefront research, the staff creates the new capabilities on which that research depends. The scientific staff is the backbone of a strong instrumentation effort, which is the essential component in ensuring that NOAO continues to provide internationally competitive facilities.

<table>
<thead>
<tr>
<th></th>
<th>Payroll</th>
<th>Non-Payroll</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTIO</td>
<td>1,355</td>
<td>122</td>
<td>1,477</td>
</tr>
<tr>
<td>KPNO</td>
<td>1,850</td>
<td>242</td>
<td>2,092</td>
</tr>
<tr>
<td>NSO/SP</td>
<td>589</td>
<td>31</td>
<td>620</td>
</tr>
<tr>
<td>NSO/T</td>
<td>703</td>
<td>47</td>
<td>750</td>
</tr>
</tbody>
</table>

A number of important scientific results have been achieved by the NOAO staff during the past year. The evidence for large scale flows out to redshifts of 15,000 km/s presented challenges our basic ideas about the nature of large scale structure. Plans are in progress to extend the survey to twice the redshift. CTIO has become a leading center for the discovery and observation of supernovae, with important applications to the extragalactic distance scale. NSO staff continue to be leaders in helioseismology, using data to model the structure in the solar convection zone. Pioneering observations in the infrared are leading to a better understanding of the structure of solar magnetic field.

It is impossible in a brief document to do justice to the sweep of scientific activities pursued at NOAO. An appendix to this document lists the research plans and publication records for individual members of the scientific staff.

In the areas that we have chosen to emphasize, the instrumentation developed under the leadership of the scientific staff leads the world. The multiple-object spectrograph Hydra is far superior to any other now available to US astronomers. The suite of optical and infrared detectors now deployed at NOAO is the best offered at any observatory in the world, and a major new IR-array development program is being carried out in partnership with the Navy. The WIYN telescope, which takes advantage of several new technologies in order to preserve the intrinsic image quality of the site, is expected to go into regular service in the next year. Deployment of the GONG network will be also be initiated in the next 12 months.

There are, however, a number of issues that must be addressed if we are to maintain the quality and vitality of the scientific staff. The first issue of concern is the increasing demand of the service load. The size of the scientific staff supported with NSF funds has been reduced steadily over the past decade. The responsibilities of the scientific staff for support of the operation of existing telescopes, for interfacing with the user community, and for leading the instrumentation program have not been reduced commensurately. We must work to establish a better balance between time available for research and the time committed to supporting observatory operations.
An increasing number of the scientific staff are supported on funds obtained from NASA and other agencies. These outside funds have been particularly important in contributing to the scientific vitality of NSO and KPNO and in enabling these two divisions to establish strong post doctoral programs. However, individuals on soft money do not in most cases contribute significantly to the support of observatory operations and the user community.

Several other factors may begin to affect recruiting negatively. While NOAO has continued to have good success in hiring its first choice candidates at the junior faculty level, this situation may not persist unless these problems are addressed. The major issues are:

1) Surveys continue to show that NOAO salaries are well below the salaries at AURA member institutions. The discrepancy has traditionally been greatest at the level of full astronomer (equivalent in rank to full professor), but in order to match offers from other institutions we are now offering salaries to entry-level scientific staff that are comparable to what people who have been here for four or five years are earning. An overall upward adjustment in salaries is likely to be required. Such adjustments are difficult to make when NOAO is consistently level-funded with no correction for inflation.

2) The continued questioning of the future of the observatory and its programs as represented by the Faber letter, the attacks on the Gemini project, and the current survey of the McCray committee have made it more difficult to recruit junior faculty. Every candidate interviewed this year expressed reservations about coming to NOAO because of its uncertain future.

3) The best young observational astronomers look first to organizations that can offer substantial access to telescopes. With the projected completion of several large telescopes, NOAO's positions are becoming less competitive in this regard. To some degree we have been able to remain competitive because of the superb instrumentation on the several small telescopes operated by CTIO and KPNO. If some or all of these telescopes are closed because of budget pressures, the opportunities for staff (as well as community) research will be severely diminished, and it will become increasingly difficult to recruit outstanding young people.

This year, NOAO offered an early retirement incentive to members of the scientific staff. A key part of this incentive is providing an emeritus program that permits retired staff to continue to conduct research programs with the same opportunities and level of support as are available to salaried scientific staff. The definition of the emeritus program was worked out in close collaboration with the scientific staff and has been approved by AURA and the NSF. To date, four of the eleven eligible staff members have opted for retirement. The offer remains open for 18 more months.

Other staff changes include the following:

**CTIO**

Two staff departures are scheduled. Doug Geisler will leave at the end of the year concluding a 10 year term at CTIO, first in a Research Associate position and most recently as an Assistant Astronomer. Chris Smith will finish his three year post-doctoral appointment in November. Because of the very tight budgets, these two positions plus the other post-doctoral position, vacant since Gerard Williger departed in February 1994, will not be filled immediately. During FY 1995, we expect to fill the vacancy created by William Weller's departure with a specialist in optics to work on the 4-m telescope upgrades program and other optical programs.
KPNO

FY 1995 will see several changes in the scientific staff at KPNO. David Silva moved from his postdoctoral position in October 1993, to become Assistant Scientist, with responsibility for supporting KPNO user science with the WIYN telescope. David De Young completed his years of service in NOAO administration to return to full-time scientific staff activity. Matt Johns will leave his base at NOAO and his position as WIYN Project Scientist to work with the Magellan Telescopes Project. Current postdoctoral research associates Heather Morrison, Michael Pierce, and Michael Wise will complete their terms and move to other academic appointments. Both Heather and Mike Pierce will take up tenure-track faculty positions. Buell Jannuzi will join the scientific staff in January 1995, as a Hubble Fellow, and will take the position of Assistant Astronomer in late spring. Stéphane Charlot, who works on spectral synthesis of high-redshift galaxies, will come as a postdoctoral research associate at the beginning of FY 1995. Paola Sartoretti will join us as a postdoc, working with Bob Brown of STScI and Michael Belton of KPNO on solar system and planetary problems. An assistant scientist position is being filled to improve the optical imaging telescope performance and scientific system results. We mourn the passing of Alain Porter, whose productive career in supernovae, galaxy clusters, and quasars was cut tragically short.

NSO

Compared to the major changes which took place in the NSO scientific staff in FY 1994, FY 1995 promises to be a rather quiet and stable year. FY 1994 saw the replacement of John Leibacher as the NSO Director by Jacques Beckers, the retirement of Jim Brault and Bill Livingston, and the transition of Bob Howard to a half-time position. A number of post-doctoral scientists supported by NOAO/NSO and by NSO’s partners joined the NSO/Tucson staff: Doug Braun (SPRC), Sydney D’Silva (NSO), Yuhong Fan (ONR), Yeming Gu (SPRC), and Christoph Keller (Swiss Science Foundation). At NSO/Sac Peak Vladimir Airapetian joined the staff as a long term visitor supported by Los Alamos National Laboratories. In FY 1995 we expect to fill the vacancy created by Brault’s retirement with an Assistant Scientist. Christoph Keller will assume the NSF funded post-doc position being vacated by Sydney D’Silva.

III. US GEMINI PROGRAM (USGP)

The US Gemini Program (USGP) is the focus for US activities in support of the Gemini project. The USGP is a scientific division of NOAO, as are CTIO, KPNO, and NSO. It is led by the US Gemini Project Scientist, T. Boroson. The purpose of the USGP is to facilitate 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.

A separate line in the budget table of this program plan shows the costs of supporting the US Gemini Program. 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. In addition, a number of NOAO staff scientists and engineers assist the USGP in preparing material for its activities. Currently,
the USGP includes three staff members, the US Gemini Project Scientist, T. Boroson, F. Gillett, and a Technical Administrator, K. Wood. L. Daggert serves part-time as US Gemini Project Manager. Recruitment is in progress for a full-time US Gemini Project Manager.

A major activity in FY 1995 will be the procurement and management of the Gemini instruments that have been allocated to the US. In the current plan, pending approval by the Gemini Board in May 1994, five instrumentation work packages are slated for the US. These include an IR Imager (allocated to the University of Hawaii), an IR Spectrometer, IR arrays and controllers, a Mid-IR Imager, and the Optical detectors and acquisition imagers. It is likely that some of these will be designed and constructed at NOAO and that some will be done outside of NOAO, probably at universities. The USGP has the task of organizing and managing the procurement in a way that encourages wide community involvement, open competition, and guarantees the delivery of instruments to Gemini that meet the requirements of the project and the partner countries. Furthermore, these instruments must be delivered for a fixed price, which will require material funds or subsidies that amount to 30-40% of the cost of the instruments. The USGP will act as a management interface between the international project and the selected builders of the instruments.

The USGP has supported scientists serving on the (international) Gemini Science Committee (GSC) at its recent meetings in Tucson and Cambridge, England, and on the US Science Advisory Committee, which helps the USGP develop a US position on issues with scientific implications. As the instrument work proceeds, the GSC will establish working groups to provide scientific oversight of the instrument design and fabrication efforts. The USGP will support US participation in these committees in areas of optical instrumentation, infrared instrumentation, and adaptive optics and acquisition and guiding. An important new area of concentration for scientific input will be operations, as the focus begins to change from the construction phase to the operations phase of the project. It is expected that operations will provide an opportunity for innovative approaches as great as the design of the telescope itself. The USGP will continue its outreach efforts with displays at national meetings and colloquia on the project status at astronomy departments throughout the nation. It is also hoped that a series of regional meetings can be used effectively to increase community involvement in 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 half 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. A prototype instrument has been 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. Papers have already appeared in the scientific literature utilizing data from the GONG prototype. While some final refinements are still being made to the prototype station, the construction of field instruments is in full swing and rapidly nearing completion. The data-reduction-pipeline and data-distribution systems are now routinely processing and distributing prototype data to the project staff and a growing number of community users. Refinements are being made to assure that they both will be able to keep up with the observing cadence of the full network.

Work on the land grading, foundations, utilities, and fencing for the field sites began in 1994. Contractors will have begun or completed work at Tenerife and Learmonth, and possibly Mauna Loa and Big Bear, by September 1994. The remaining work at all sites will be completed in 1995. FY 1995 should also see the deployment of the field instruments, the first network data, and the initiation of pipeline data processing.

The unpredictability of budgets continues to be a problem for project scheduling. The FY 1994 budget was $250 K less than requested, forcing a two-month delay in the schedule for the first station deployment. The proposed FY 1995 budget is barely sufficient to field all six stations. Any decrease will force the deployment of some of the stations into FY 1996. Moreover, the FY 1994 budget was not announced until late March. Given the cost of deployment and the long lead times required for shipping, such a delay in FY 1995 is also a threat to the schedule, even if the budget number itself is adequate.

Anticipating the possibility of these problems, the project has recently changed its deployment strategy. The original approach called for deploying the first two stations close to home at Big Bear and Mauna Loa. This would allow us to gain experience with relatively short supply lines and ready access to our full resources. However, this requires the deployment of four stations before three of them would be at the 120° longitude increments required to provide minimal 24-hour coverage opportunities that might allow scientific work to begin. It is our view that further delaying the beginning of even limited science operations is unacceptable. Thus, we will deploy the first three stations at 120° increments.

In order to do this as rapidly as possible and with the least short-term cost, we will “deploy” the Big Bear station temporarily in its current location at the “Farm” here in Tucson. This station will be commissioned in September or October of 1994. It will be moved to Big Bear after the other five stations have been deployed. The second station will be deployed at El Teide on Tenerife, probably in December, depending on the vagaries of ship schedules and weather. The third station will be deployed to Learmonth in January or February 1995, subject to the same considerations. Site survey data show that this subnetwork has the potential to improve the 1/day sidelobes by a factor of about 40 over a single site. This should provide a meaningful improvement in the scientific inferences drawn from such data. (It should be noted that the addition of the remaining three sites will improve the 1/day sidelobes by yet another factor of seven.)

This shift in strategy is not without its risks. The first “real” deployment will take place many thousands of miles from Tucson, at a time when there is the potential for occasional ice storms. The second deployment is at Learmonth, where summers are renowned for their heat and occasional cyclones. Nevertheless, on balance we believe these risks are manageable and warranted.

The schedule for the deployment of the remaining three stations, plus the relocation of Big Bear, will depend on both the amount and timing of the FY 1995 budget. At the moment, the order is likely to be Cerro Tololo, Udaipur, Mauna Loa, and then Big Bear. We will have to delay shipping the fourth (CTIO) station until after the budget announcement. If that occurs as late as March, as it did this year, it is
unlikely that work would begin there until May. Thus, the precise schedule of the remaining deployments will be highly dependent on both the timing and amount of the FY 1995 budget. Some stations might have to be pushed back into FY 1996.

Specific FY 1995 tasks will include the following:

- Continue routine operation of the prototype instrument
- Complete the preparation of the field sites
- Conduct a pre-deployment review
- Temporarily operate the Big Bear station from Tucson
- Perform DMAC end-to-end tests
- Deploy the El Teide Station
- Deploy the Learmonth Station
- Move the Prototype station to the Farm
- Integrate the CTIO, Udaipur, and Mauna Loa stations
- Deploy the additional stations as funding permits
- Process data from a three (or more) site network
- Continue operating site-survey instruments at selected sites

Looking forward to GONG network science operations in early 1995, the long-range plan calls for the following milestones:

**GONG Long-Range Milestones**

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1994</td>
<td>Begin network installation</td>
</tr>
<tr>
<td>March 1995</td>
<td>Begin three-site network operations</td>
</tr>
<tr>
<td>August 1995</td>
<td>Begin six-site network operations</td>
</tr>
<tr>
<td>August 1998</td>
<td>Cease network operations</td>
</tr>
<tr>
<td>August 1999</td>
<td>Complete initial data reduction</td>
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</table>

The anticipated long-term funding requirements in inflated dollars (3% model) are as follows:

<table>
<thead>
<tr>
<th></th>
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<td>1.81</td>
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**Budget Section**

The GONG project will begin the deployment of the network field stations in September or October of 1994. In the past the project had some flexibility to deal with fluctuations in budget figures from target values and the three to six month delays in actually knowing what the budget figure is. This flexibility stemmed largely from the tactic of delaying major capital purchases until the end of the fiscal year. Now that we are in the end game, this flexibility has largely evaporated. The proposed FY 1995 budget is sufficient to permit the deployment of all six stations, if no major problems are encountered. The cost of
the deployment effort in travel and shipping is $460 K. In FY 1994, the uncertainty in the project’s budget ranged over $550 K and was not resolved until more than half way through the month of March.

We feel cautiously confident about proceeding with the deployment of three stations during the October 1994 to March 1995 period, based on conservative budget projections. However, if those projections are realized, no further stations could be deployed until the beginning of FY 1996 (October 1995). With the advice and consent of the GONG Scientific Advisory Committee, we have accepted the higher risk of deploying two remote stations (Tenerife, Canary Island and Learmonth, Western Australia) as the first two completely dismantled and reassembled stations in order to guarantee that some limited science operations can begin during FY 1995 with a three-site 120° spaced subnetwork. The amount and timing of the FY 1995 project budget will determine when the remaining stations will be deployed.

B. WIYN

NOAO is collaborating with the University of Wisconsin, Indiana University and Yale University to build the new 3.5-m WIYN telescope on Kitt Peak. The telescope is designed for optical imaging and multi-object spectroscopy with optical fibers, with a relatively fast focal ratio (about f/6.3), and a corrected field of view of a full degree (15 arcmin uncorrected). The WIYN Project has placed a high priority on achieving superb image quality with the telescope. The enclosure and mount are designed to minimize dome seeing through rapid ventilation and thermal control. The site (the southwest ridge of Kitt Peak) is known to provide excellent seeing. The optics are polished to produce images a factor of ten better than can be produced by the KPNO 4-m telescope. The primary mirror is designed with active mirror supports to maintain the superb figure. The error budget for WIYN is planned to allow image quality as good as 0.5 arcsec when seeing permits. 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 in part for survey and synoptic programs efficiently done with multi-object spectroscopy and for wide field imaging with good spatial resolution. Observations will be obtained primarily by the Observatory staff through queue scheduling and service observing, 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. The construction phase will be completed in FY 1994, and commissioning will continue into FY 1995. The optics were installed in April, 1994, with First Light occurring in May. During the commissioning phase in FY 1994 and FY 1995, the WIYN telescope will be brought to a state of operational readiness for scientific operations. The major work will include:

• Completion of telescope commissioning (December 1994).
• Commissioning of the Hydra Fiber Positioner (November 1994).
• Commissioning of the Imaging Camera (January 1995).
• Commencement of shared risk science observing (March 1995).
• Commencement of regular scientific observing (January 1996).
• Training of maintenance staff.

C. SOAR

Columbia University has withdrawn from SOAR, which is a project to build a 4-m telescope on Cerro Pachon. The University of North Carolina is continuing its fund-raising efforts and has already identified at least one possible new partner in this project with CTIO. Until fund-raising efforts have been successful, we will not present further milestone tables.

D. Other Telescopes at CTIO

C^t Telescope (Harvard/IOA)
Most of the present Cambridge-Cambridge (C^t) effort continues to be directed to fund raising of approximately $25 M, which will be needed to build the telescope and endow operating costs. Cambridge University (UK) has renewed its commitment to seeking funds for this project with the arrival of R. Ellis as the new Plumian Professor of Astronomy in charge of the Institute of Astronomy there.

Sao Paulo Telescope
IAGE astronomers continue to show interest in locating a 1.8-m telescope at CTIO. CTIO has forwarded a preliminary set of cost estimates for provision of basic services for this telescope.

Southern Spectroscopic Survey Telescope
Very preliminary discussions have been held with astronomers from the University of Texas about the possibility of locating a southern version of the SST at CTIO. Such discussions will continue at a preliminary level while work on building the northern SST continues.

Gemini
Though Gemini is not a part of NOAO, CTIO staff have become involved in scientific, technical and administrative activity in support of this project. In particular, work on the site preparation for the southern telescope is now under way on Cerro Pachon. During FY 1995, work will continue on the construction of the access road to the new dormitory area, installation of the commercial power line and provision of water to the summit area. Work will also begin on the excavation of foundations for the telescope support building and enclosure. An existing prefabricated dormitory building "the 20 unit dorm" will be moved to Cerro Pachon from Cerro Tololo for use by the construction crew; work will also begin on construction of a separate six-unit dormitory for eventual use by night workers on Pachon (astronomers, telescope operators, support personnel).
V. INSTRUMENTATION

A. KPNO/CTIO Instrumentation Program

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<td>(T. Boroson, I. Gatley)</td>
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<td>(I. Gatley)</td>
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<td>Miscellaneous Projects</td>
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<tr>
<td>(T. Armandroff, S. Barden)</td>
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<tr>
<td>Total</td>
<td>1,881</td>
<td>423</td>
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Overview

Enlarging the perspective of the KPNO instrumentation program to provide outstanding instrumentation to all of the NOAO nighttime programs (KPNO, CTIO, and ultimately Gemini as well) is a step which is crucial to the future of NOAO. The scientific staff has devoted much thought to the best approach to achieving this goal. We believe that the best instruments are built by people who care passionately about the instruments and who are involved closely in the design, fabrication, and commissioning of them. A model which has instruments conceived at one site but built at another leads to a substantial risk of mediocre performance and failure. A better model has instruments conceived through collaboration and consensus, built, commissioned, and used in Tucson and on Kitt Peak, and then redeployed in a timely way at CTIO and Gemini. In this way, the southern hemisphere sites of NOAO obtain outstanding instruments which work, are well understood, and are supportable with limited technical resources. This approach also offers the advantage of more frequent new instrumentation at all NOAO sites. Examples of this approach include the transfer of SQIID (after upgrade to larger format InSb detectors) to CTIO and the sharing of the high dispersion Phoenix spectrometer with Gemini and CTIO. To make this model a reality requires standardization of the observing environment among the sites, including focal ratios, array controllers, and ancillary equipment. That such standardization is becoming reality is very encouraging.
The program outlined below includes both the joint KPNO/CTIO instrumentation program and the KPNO-specific program. By FY 1996, we plan to identify some resources for instrument and telescope upgrades that are under the control of the KPNO Director, just as CTIO has retained a site-specific engineering group.

The details of specific FY 1995 projects are described below:

Detector Development
The Aladdin Project to build 1024 × 1024 InSb arrays began in FY 1993 as a collaboration among NOAO, the US Naval Observatory, and the Santa Barbara Research Corporation. The Project is now well underway, with the first production run of arrays in the summer of 1995. The Project schedule is as follows:

• Readouts will be available in April 1994. This phase will allow us to estimate the yield of readouts, which is widely believed to be the most critical part of the project.

• InSb material characterization will be complete by fall 1994. This step is accomplished by making 256 × 256 arrays from the material samples.

• The first 1024 hybrids will be produced in the fall of 1994.

• These 1024 arrays will be characterized by June 1995.

• The first production run of arrays will occur in the summer of 1995. This demonstration run will complete the program as presently planned. The production run will establish the yield (thereby price), and provide detectors for the NOAO and USNO programs. Further production runs can produce detectors for the community. A committee chaired by Todd Boroson was formed to oversee the project, and that committee has charged Boroson to proceed to establish a procedure for distribution of the arrays to the community. Such distribution will require support from the NSF and/or other sources of funds.

NOAO has also undertaken a vigorous program of CCD development through foundry runs and collaboration with M. Lesser (Steward Obs.). This program has produced a large number of CCDs of various sizes and properties which are still in processing or characterization. We expect characterization and deployment of the mini-mosaic and 3K × 1K CCDs to continue through the end of FY 1994. We expect to receive sufficient 2K × 2K devices to build two 4K × 4K mini-mosaics, one for WIYN and one for CTIO. Most of the effort in FY 1995 will likely be devoted to 2K × 4K devices for the full 8K × 8K mosaic imager. If not enough 2K × 2K CCDs are available to complete the mini-mosaics, we may be able to build the second (or third) mini-mosaic from two 2K × 4K CCDs.

Detector Implementation
With new detectors becoming available in both the optical and the infrared, we must plan to move quickly to get these arrays onto telescopes at both KPNO and CTIO.

Both KPNO and CTIO will want to deploy 1024 × 1024 (or at least 512 × 512) pixel IR imagers as early as possible, though detectors are unlikely to be available prior to FY 1996. Note that the upgrade from 256 × 256 HgCdTe to 512 × 512 InSb requires new analog electronics, including a preamp, clock drivers,
and A/D converters. KPNO will plan with high priority early in FY 1996 to upgrade the Cryogenic Optical Bench with a large format detector. These detectors are unlikely to be available early enough in FY 1995 for work to be done that year. CTIO should also work with the KPNO IR staff to develop a feasible upgrade path to make a large format imager available as soon as possible in the southern hemisphere. Of critical importance is the need to plan a common and cost effective means to build the necessary electronics for all the large format detectors we will want to implement.

The infrared imager SQIID, which now contains low-QE PtSi arrays, should be upgraded as soon as possible to larger format detectors with higher QE. An upgrade to four 512 x 512 InSb arrays should occur as soon as possible after the arrays become available (the SQIID optics are not designed for 1024 x 1024 arrays but can take good advantage of the 512 x 512 arrays). The 512 x 512 arrays are quadrants of partially successful 1024s. The electronics needs for the SQIID upgrade should be considered in the context of requirements for Phoenix and COB, and, because SQIID has four channels, this task is quite challenging.

Under the present schedule, the earliest we could sensibly upgrade SQIID is in the Spring of 1996 (following the detector production run in the Summer of 1995). SQIID would then return to service at KPNO in fall 1996 and could be available for transfer to CTIO in early 1997. Consistent with this schedule, KPNO proposes that the scientific staff of CTIO and KPNO work together to propose a key project for IR imaging of local group galaxies in both the northern and southern hemispheres. SQIID could be used to image M33 from KPNO in fall 1996 and then the LMC from CTIO in 1997. When the 8-m Gemini telescope on Cerro Pachon becomes available, it may be appropriate to designate SQIID for use there.

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. This imager would be usable at the KPNO and CTIO 4-m telescopes and the KPNO 0.9-m. The first step toward this goal is the fabrication of a four-chip (each 2K x 2K) mini-mosaic. We have built a thick mini-mosaic and tested it at the 4-m and 0.9-m. This has demonstrated the technology to package and mount these chips and has given us experience with the controllers and data processing. Significant progress is being made on the thinning and packaging of the mini-mosaic chips and the remaining technical challenges have been overcome. The dewar hardware (which now contains the prototype mosaic) is ready to receive the finished detector. We expect to deploy at least one thinned mini-mosaic before the end of FY 1994. A foundry run of 2K x 4K chips took place at Loral Fairchild in mid FY 1994. Preliminary design work on the dewar, shutter, filter assembly, and TV guider for the 8K x 8K mosaic also took place in FY 1994. We expect an external design review of the mosaic project to take place before the end of FY 1994. Following that, the FY 1995 work will largely focus on detailed design and construction of the dewar, shutter, filter assembly, and TV guider.

**Wide Field Imaging**

In order both to utilize the full field of the 8K x 8K mosaic imager and to improve delivered image quality at the 4-m prime focus, a new corrector and atmospheric dispersion corrector are required. In this project, KPNO is adopting the new CTIO corrector design with reoptimization for the scientific needs at KPNO. The reoptimization is necessitated by the desire for somewhat wider field and narrower simultaneous wavelength coverage. The reoptimization is being done in FY 1994 through contract work by R. Bingham (U. College, London). We expect to finalize the design, order glass, and place a polishing contract by the end of FY 1994. The work in FY 1995 will primarily involve supervision of that contract and mechanical design work for support of the corrector/ADC.
High Spatial Resolution Imaging Projects

The Cryogenic Optical Bench (COB) was originally designed to obtain a wide field of view, with some compromise in spatial resolution. In FY 1994-1995, COB will be modified via installation of new camera module to a 4-m plate scale of 0''.12 arcsecs/pixel. This sampling will allow near diffraction-limited images at a wavelength of 3 μm at the 4-m telescope, using a "shift and add" algorithm combined with the fast readout (IR speckle imaging). The instrument will be returned to service at the original plate scale in November 1994. The new camera module will be designed to accommodate a 1024 x 1024 pixel detector, when it becomes available.

The IR development project to utilize the 2.1-m telescope for high spatial resolution tip-tilt imaging in the infrared (FTAS) continues to offer opportunity for substantial gains in IR imaging. One possibility is to couple COB with FTAS. The FTAS camera itself is scheduled for use at CTIO for six months. A collaboration with the Starfire project is also a possibility, in which the FTAS dewar and a high quantum efficiency detector might be contributed to the project.

One of the highest priority items to result from the NOAO 2000 program was a desire for image improvement via tip-tilt (and low-order) correction. The initial goal of this effort would be a tip-tilt CCD imager, but low-order correction and the possibility of feeding spectrographs are eventual goals. In order to deploy an instrument in this area, and in order to gain technical and astronomical experience, we have begun discussions with the Dominion Astrophysical Observatory to deploy a tip-tilt (or possibly somewhat more sophisticated) correction imager at the 4-m and/or 2.1-m and/or WIYN. The NOAO effort would be collaborative, and we would take the lead in interfacing the corrective system to our telescope(s), CCD dewar(s), and control system(s). Since this system will likely work to wavelengths as long as ~2 μm, we plan to collaborate with the IR Program to interface an IR detector to the system as well.

Multi-Object IR Spectroscopy

Following an experiment with the Cryogenic Optical Bench to obtain multiple spectra in a single field with a slit mask, the KPNO staff plans to develop a low dispersion IR spectrometer with broad wavelength coverage (J, H, K, and L) capable of multi-object spectroscopy. A concept for such a grating spectrometer (GRASP) was developed in FY 1994, and we will begin detailed design work in FY 1995 as the Phoenix design effort winds down. The concept involves four fixed channels, one for each atmospheric window, separated by dichroics onto fixed gratings. Each channel could initially utilize a separate 512 x 1024 pixel detector. The instrument would also have a camera mode in which the gratings are replaced by flat mirrors. It may also be possible to obtain a factor of three higher spectral resolution by subdividing each spectral window with additional fixed gratings. The spatial dimension is used for long slit spectroscopy and multi-object spectroscopy.

High Resolution Spectroscopy

Design work for the high resolution IR spectrometer Phoenix will be complete by the end of FY 1994, and mechanical fabrication will be completed by the end of FY 1995. Our plan calls for 1024 x 512 InSb array for the instrument, if available. Electronics for Phoenix must be designed and built beginning in FY 1995, including a new preamp, clock drivers, and A/D converters, and a board must be added to the Wildfire array controller as well.

During FY 1994 some effort was also spent on a concept development for 4-m fiber-fed, cross dispersed, high/moderate resolution optical spectrograph. The spectrograph would utilize a single object fiber and several sky fibers fixed in the focal plane of the 4-m and will be capable of spectral resolutions of a few thousand up to 100,000. Much of the infrastructure remaining at the 4-m from Hydra/Bench will be
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Miscellaneous Instrument Upgrades

Following the installation of a 3K x 1K CCD in the 2.1-m GoldCam spectrograph, the limitations of using a camera designed for a smaller detector became unacceptable. We are unable to use more than about 2000 of the 3072 spectral pixels because the line profiles become strongly skewed outside this range. We have been pursuing a solution to this problem via the design of a new spectrograph camera. A design is nearing completion and is expected to be put out for fabrication in FY 1994. In FY 1995, we will complete fabrication and integrate the new camera with the spectrograph, replacing the original camera.

Another priority that arose from the NOAO 2000 effort is a significantly higher efficiency low/moderate resolution spectrograph for the 4-m(s). Since such a spectrograph would likely use one or more advanced technologies that O/UV does not have substantial experience with, we would like to form a study group of scientists and engineers to examine available technologies and approaches pursued by other observatories during FY 1995. The group would meet regularly for discussions, and some resources will be needed to explore some possible design approaches. One direction for careful scrutiny is the use of adaptive optics to feed spectrographs.

A modest level of continued support is also required to evaluate scramblers for the 4-m Fiber High-resolution Spectrograph and new commercial products.

The modification of Hydra and the Bench Spectrograph for optimal use at the WIYN Telescope is the KPNO O/UV group's largest project in FY 1994. In FY 1995, the remaining tasks will likely be testing, debugging, optimization, and documentation. It is also likely that we will explore interfacing a NICMASS IR camera to the Bench Spectrograph in FY 1995, potentially leading to a near-IR multi-object capability (in collaboration with the University of Massachusetts).
### B. Cerro Tololo Inter-American Observatory

**FY 1995 Projects**

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**Background**

CTIO's future is dominated by the impending arrival of the southern Gemini telescope. Our current planning assumption is that a large fraction of our ETS personnel will inevitably be drawn in to help support the Gemini commissioning phase starting in 1998 or 1999. This means that unless more resources are made available to CTIO, we have only the next three to four years to get our existing telescopes and instruments into the condition they will have to remain in until the middle of the next decade.

We are therefore, as a matter of urgency, meshing our near-term priorities into a program which puts the imaging performance and general maintainability of the 4-m telescope as the first priority. Additional work is planned for the IR instrumentation and ARCON/CCD improvement programs. Any remaining development resources would be used to make what (few) improvements we can to the smaller telescopes—more or less in order of aperture size.

**Projects Continuing from FY 1994**

There will be quite a few projects continuing into FY 1995. We intend during FY 1995 to close the gap between planned projects and projects completed by focussing our resources more sharply on the highest
priority items. The two largest continuing projects will be the f/14 Secondary and the Active Primary Mirror Support System--both for the 4-m.

The f/14 secondary was planned as a two-year project and will receive an additional $15 K for non-payroll expenditures in FY 1995. Other carry-overs will probably include the commissioning of a new spectrograph camera and CCD for the Cassegrain spectrograph on the 1.5-m telescope (in collaboration with STScI), and various small upgrades to the Schmidt telescope (in collaboration with U. of Michigan).

New FY 1995 Projects

F/14 Tip-Tilt Implementation
With the commissioning of the active primary mirror support system in early FY 1995, we will have completed a three-year program of renovation of the 4-m optics, which in itself has followed on a multi-year program of improvements to the telescope’s thermal environment. At that point we expect to reach our goal of regularly achieving optical images at close to the 0.6-0.7 arcsec FWHM median site seeing.

We are also in the process of adding an f/14 focus to the telescope. One goal of that project is to make our IR instrumentation compatible with the KPNO 4-m (f/15) and Gemini (f/16). But the new secondary is also being installed with piezo-electric actuators in place to make it "tip-tilt ready." In FY 1995 we plan to push with high priority toward actually implementing this tip-tilt capability for IR imaging and spectroscopy and also for optical imaging. This will give CTIO the only major IR tip-tilt capability in the southern hemisphere. This is the logical extension of the program to improve the imaging capability of the telescope. The emphasis needs to be on the near IR (JHK) because this is where tip-tilt achieves the greatest proportional gains in image diameter for a 4-m telescope with good seeing.

The tip-tilt implementation consists of adding a guider box at the Cassegrain focus, which will have reimaging optics and a fast CCD camera in the straight-through position. These will be preceded by a 45° dichroic, which will direct light to any of three sideport instruments. Two of these instruments will be the existing IR imager and IR spectrometer, while the third will be an existing optical CCD imager. In the interests of getting on the air as quickly as possible we will start with a very simple manually operated system for switching between sideports.

The fast CCD camera will work at about 100 Hz. It will be an upgraded version of our existing CCD-TV acquisition cameras. This upgrade is also essential to the 4-m Control System Improvements and CCDTV Autoguiding projects described below, as well as to the 4-m Image Analyzer project which is currently underway. Since this camera upgrade is key to several projects, we plan to contract out most of the electronics design work during FY 1994.

4-m Control System Improvements
The other area, besides image quality, where the 4-m telescope obviously needs basic improvements and upgrading to its infrastructure is in its control systems. Although the control software and the computer in which it runs is modern, almost everything else dates from when the telescope was commissioned 20 years ago. Not only is the performance well below today's standards, but it is no longer possible to get spare parts for basic elements such as encoders and drive servos.

In FY 1995 we plan to start a three-year upgrade program, which will culminate in duplicating the recent upgrades made to the KPNO 4-m drives. During FY 1995 we want to convert to the KPNO GUI user interface and to make some basic improvements to our autoguider and to the control program in order to
make the autoguider much easier to use. We view the improvements to the autoguider as being the highest priority step we can take to improve the performance of the telescope for long exposures with instruments that do not use the tip-tilt system. The present autoguider (a ten-year old leaky memory system) is unacceptably sloppy and therefore produces considerable blur in an integrated image, and it also takes much too long to set up on a new guide star. We will switch over to an upgraded version of our CCD-TV acquisition camera for the autoguider (see the following project description), and install software that will pre-position the guide probe while the telescope is slewing to the next object.

Also in FY 1995 we will begin to purchase parts for the conversion to the KPNO-style servo systems and programmable logic controller. Fabrication of the new electronics systems will occur over FY 1996 and FY 1997. The new equipment will either be installed in two pieces, partly in FY 1996 and partly in FY 1997, or possibly in one major effort in FY 1997; we will not be able to decide between those two possible schedules until we review manpower allocations toward the end of FY 1995. During the crucial stage of tuning the servos we will get direct assistance from the engineers who carried out this work at KPNO.

CCD-TV Autoguiding
The acquisition cameras that we presently use in most locations consist of a CCD system which sends an analog signal to a frame grabber in a PC; the PC runs the frame grabber and calculates the optimum black-white windows used when the picture is displayed for the observer. During FY 1994 we have had an outside contractor design a dual-memory board, which will take over functions presently carried out in software in the PC and will also replace the frame grabber. We then will be able to work with a signal which has been kept digital from the CCDs A/D converter all the way to the display monitor in front of the observer, producing a significantly improved signal:noise ratio at a given frame rate and the ability to go to much higher frame rates. This will provide the basis for both a high-speed (100 Hz) guiding system for the tip-tilt application described above, and also for lower speed (1-8 Hz) autoguiding. Since the PC will no longer have to shuffle images in and out of a frame grabber, it will be available to centroid the star image and generate error signals for either application.

The present project will replicate this autoguiding system onto nine of the CCD-TV cameras presently in use at CTIO. Thus it will be available at all of the 4-m foci and at the 1.5-m and 0.9-m telescopes. This will require a significant (17 manweek) software effort to develop the autoguiding algorithm as well as to provide a variety of cursors, regions of interest and other features. But the replication costs for retrofitting our existing cameras are then very low, which in addition to its superior performance and applicability to other projects, is an important justification for this solution to our autoguiding problem.

Upgrade IR Imager to 512 x 512 Array
Our new 256 x 256 HgCdTe Imager is being designed so that we can very easily upgrade it to use a 512 x 512 InSb array. It will only be necessary to install a new detector mount, which will incorporate a field flattener lens. Such an upgrade would restore CTIO to a leadership position in southern hemisphere IR astronomy, since we can potentially offer this type of detector years before any other southern observatory. We hope to acquire the 512 x 512 array from the NOAO Aladdin project.

The 1024 x 1024 Aladdin arrays are actually four independent 512 x 512 arrays. Thus, even if the yield of 1024 x 1024 arrays is low the yield of fully functional 512 x 512 quadrants should be quite high. More detailed knowledge of the yield should be available by late FY 1994. After Al Fowler's group at NOAO finishes characterizing the Aladdin arrays, they will be released to KPNO and CTIO for deployment on telescopes. At this time it is expected that the IR Group at KPNO will start developing an upgrade to the
WILDFIRE control system, which will allow the control of these arrays in astronomical instruments. We would expect this controller upgrade to occur in parallel for KPNO and CTIO as it did during the very successful deployment of the $58 \times 64$ InSb arrays several years ago.

By producing this detector mount we will be in a position immediately to deploy one of these arrays on a telescope when it becomes available. Given the current status of the Aladdin project it seems very possible that this could happen during FY 1995. Even if arrays do not become available until FY 1996 it is certainly better to be ready to implement the array in our dewar rather than run the risk of having this state of the art detector sit "on the shelf" when we finally do receive one.

**Implementing New CCDs and Controllers**

We expect to have 10-11 of our new ARCON CCD controllers in service at CTIO by the end of FY 1995, one at KPNO, and a stockpile of 1-2 additional systems waiting for future CCD implementations. Two of the boards (the Voltage/Temperature Control and Video Processor cards) in each of these systems will be interim versions, which we know how to improve significantly. We feel that it is important to maintain a modest program of continuing ARCON development over the long-term in order to ensure that our CCD detector systems remain competitive. The first step in such a program will be to replace these two interim boards with newly designed ones. We will construct 15 copies of each of the boards, which includes 13 ARCON systems and two spares of each board.

We expect to bring up a minimum of two additional CCDs on ARCON controllers during FY 1995. These ideally would be a red-optimized $1000 \times 3000$ Loral CCD for use on the 4-m low-resolution spectrograph, and a $2 \times 2$ mosaic for use at the 4-m prime focus. Most of the mechanical effort for this project is to make a bigger head for the dewar, which will hold the $1000 \times 3000$ CCD at the prime focus of our Air Schmidt spectrograph camera. Besides offering important improvements in the quality and size of the CCDs available at the 4-m, these two additional systems will finally permit us to retire the last of our worn-out VEB CCD controllers. (Perversely, the last telescope to use a VEB will be the 4-m, because that is where we use the widest variety of CCDs). Unfortunately, the new CCDs do not presently exist, but in a worst case we will convert existing smaller CCDs over to ARCONs just to remove the reliability problems with the VEBs.

**Smart Motor Controllers**

We are systematically changing our old motor control hardware, which over the past decade was based mostly on Camac, to a new generation of Smart Motor Controllers. These use off-the-shelf Standard Bus cards and chassis to which we add a more durable box and connectors. During FY 1995, we will produce and populate four more of these standard units and begin to switch over the various remotely controlled functions on our 4-m low-dispersion (R-C) spectrograph. This will require a fair amount of mechanical effort to replace the existing stepping motors and encoders with modern servo units. This project should let us retire the Camac crate from the 4-m Cassegrain cage. We are putting this effort into modernizing the R-C spectrograph because we do not imagine having the resources to replace it for at least another decade.

**Second-Generation Infrared Spectrometer**

This has been mentioned in previous program plans as an instrument for the CTIO 4-m telescope. It is now viewed as an instrument which will be shared between Gemini South and the 4-m.

This project will be carried out as a joint KPNO-CTIO effort. The CTIO contribution would be primarily at the scientific and design level. Fabrication will be carried out in Tucson.
C. National Solar Observatory

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NSO's primary instrumental goal continues to be the ongoing development of 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) the addition of 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.

NSO pursues a scientific program that 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 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 (AO) system at the NSO/Sacramento Peak Vacuum Tower Telescope (VTT/SP) continues into FY 1995 as NSO's highest priority project. Many of the fundamental physical processes on the Sun occur at angular scales of less than one arcsecond. For example, the interaction of surface convection and magnetic fields, the buildup and release of flare energy, and the emergence and decay of sunspots all involve processes at the subarcsecond scale. The addition of an effective AO system to the VTT promises to enhance significantly the ability to observe and measure such phenomena by providing diffraction-limited resolution for extended periods.

The success of AO for solar observations was demonstrated jointly by the Lockheed Palo Alto Research Laboratory (LPARL) and NSO/SP on a very successful run at the VTT/SP during July 1992. The quality of the image compensation over a significant field of view was much higher than expected. Disturbances to the wavefront that affect the performance of solar telescopes apparently can occur relatively close to the aperture.

The AO program closely follows the plan outlined in the LEST (Large Earth-based Solar Telescope) proposal, but at a reduced rate due to funding limitations. The plan calls for the Lockheed system to be integrated by NSO/SP into the NSO/SP adaptive optics system so that it can be used with the major focal plane instruments at the VTT/SP. Most of the integration involves a complete rebuild of the Lockheed wavefront sensor (WFS). This new system has 37 channels, allowing the Lockheed system to be upgraded from 19 to 37 channels. The LPARL system is expected to be running again in early 1995. While the Lockheed system has been successfully demonstrated, it has significant performance limitations. The permanent AO system development at NSO/SP differs in some major ways from the Lockheed design. Specifically, a) the SP design has a continuous face plate mirror; b) it eliminates the need for a large white-light Michelson interferometer to phase the segments; c) it replaces the analog wavefront reconstructor with a digital reconstructor; and d) it extends the wavefront sensing to granulation, not just sunspots as in the Lockheed WFS. Most of the hardware is under construction at this time.

Solar Image Tracker (Mark II Correlation Tracker)
During the 1980's, a correlation tracker system for removing solar image motion was built at NSO/SP for use at the Vacuum Tower Telescope. This device failed in 1992: the fact that it was custom built using now-obsolete components makes it hard to diagnose and virtually impossible to maintain. This failure represents a loss of capability at the VTT. During 1991, when the correlation tracker was available, 20-30% of the observing programs at the VTT used it. For 1992-93, it is estimated that about 90% of the observing programs at the NSO/SP VTT would have benefited from image tracking. In fact, almost 50% of the observing proposals received during 1992-93 explicitly requested the correlation tracker, despite its unavailability.

For the short term, it has been possible to return the original correlation tracker to service by using components borrowed from a duplicate system that the Kiepenheuer Institute is no longer using. For the long term, however, there is widespread agreement that the NSO needs to develop a new solar image tracking system. The advent of new technology during the past decade suggests that it should be possible to achieve significantly better performance and reliability than the original correlation tracker did.
Several approaches to the image tracking problem are currently being reviewed and evaluated. One option is to re-engineer with modern components the digital correlation approach used in the original NSO/SP system. Another is to exploit the rapidly advancing capabilities of liquid crystal technology to replace the digital processing with an optical correlator. A third is to adapt the new tracker based on the absolute difference algorithm currently being developed by the Instituto de Astrofisica de Canarias.

The schedule for this NSO project calls for the assessment activity to conclude around the beginning of FY 1995. We also plan to complete the design, procure hardware, and begin system assembly in FY 1995. Final assembly, testing, and delivery of the completed system is projected for FY 1996.

CCD Data Channel
The development of a CCD data channel is part of an ongoing effort by the observatory to provide state-of-the-art CCD detectors to the community. Many of the existing instruments that are now film-based need to have CCD capabilities added. New instruments using CCD technology must 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 a prototype generic CCD Data Channel, as well as enhance the current controllers. The requirements for solar astronomy are very different from those for nighttime astronomy, and so this development program is independent from the programs at CTIO and KPNO.

The generic CCD Data Channel is a computer system to handle acquisition, display, analysis, and storage from a single camera. It is a part of a system of parallel channels to handle maximum data throughput. The system will be camera independent and handle commercial and custom cameras. Part of the design effort is to choose a computer, display, and operating system. The storage requirement is a separate issue, but a SCSI system will be available for different storage media. Currently it is anticipated that exabyte will be suitable for a prototype system. When the prototype system is working, copies can be made for the cost of the hardware and OS license.

To improve readout speed and create the capability of handling multiple independent camera systems, a JPL-based, commercial controller, with widely configurable capabilities, is also being investigated.

2. Kitt Peak

Near Infrared Magnetograph-2
The major goal of the infrared program during FY 1995 will be the completion of the design phase and the beginning of fabrication of NIM-2, an imaging vector magnetograph based on a Fabry-Perot spectral isolator.

The existing Near Infrared Magnetograph (NIM) is a unique instrument developed to map the true magnetic field strength in the deep solar photosphere using the McMath-Pierce Telescope, the vertical spectrograph, a 256 x 256 InSb array camera from Amber Engineering, and the Zeeman-sensitive line Fe I 1.565 μm. Using the same infrared camera system, 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 continue to work with the McMath-Pierce upgrade project to measure seeing in the infrared.
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 proposed upgrade of the McMath-Pierce Telescope control and guiding systems. The existing limb guiders at the KPVT will be replaced with a CCD camera. The old limb-guider translation stage will be abandoned. Control of the Littrow spectrograph grating, shutters, lens focus, as well as telescope control console and handpaddles will be handled by a 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.

It is anticipated that the design phase will be finalized in FY 1994. Implementation funds are not available within the NSO budget, and it is hoped that the project will be funded by the NOAO Director from her (non-existent) reserve funds.

Kitt Peak Vacuum Telescope Image Motion and Polarization Compensators
Image "jitter" from wind vibration and mechanical sources degrades KPVT spectroheliograms and magnetograms beyond ordinary seeing. Recent magnetograph comparisons also indicate that spurious image motion is a serious problem for overall magnetic calibration and highlight the importance of accurate polarimetry.

The preliminary concept for the image motion compensator is to servo the number 3 mirror with the high-frequency error signal developed from the output of a two-dimensional CCD guider. The polarization compensator is envisioned as a low-frequency device using a stack of liquid crystal plates to zero polarization in a reference beam sent in reverse direction through the telescope. This project, partially supported by a grant from NASA, will be carefully coordinated with the KPVT TCS upgrade project.

Image Quality Improvement at the McMath-Pierce Telescope
This ongoing project seeks, first, to measure the distribution of seeing external to the telescope and to identify the amount and sources of internal image degradation. Then, steps will be taken to improve the quality of the images delivered at focus. The final image quality is the resultant of three main components: the seeing delivered by the site outside the telescope; internal seeing including thermal disturbance at mirror surfaces; and the quality of the telescope optics. The site seeing will be measured with an image-motion sensor (Brandt meter), a scintillation monitor (Seykora meter), and microthermal sensors at the top of the telescope. The internal seeing will be mapped with an array of microthermal sensors in the McMath-Pierce tunnel. The figure of the main optical elements will be determined from extrafocal images. The degradation due to mirror seeing will be determined from tests on a metal mirror and on the present McMath-Pierce mirrors. Baffling to reduce internal convection will be designed and tested.

The immediate goal is the scientific payoff from better imaging. The long-term goal is to form the objective basis for deciding whether to pursue high-resolution infrared imaging at the facility--e.g., through adaptive optics mated to a large (4-m class) aperture.

It is anticipated that the seeing meters, microthermal sensors, and data logging system will be installed and in operation by this summer. The system will run for several months to provide sufficient data for analysis in the fall of 1994.
D. Central Computer Services

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CCS is responsible for policy developments 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 office’s 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 also support the distribution of IRAF (Image Reduction and Analysis Facility) software to over 1000 community sites around the world.

NOAO-Tucson Computers
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 Ethernets, transmitted by wire in Tucson, optical fiber on Kitt Peak, and leased-line between Tucson and Kitt Peak.

In past years, we have undertaken an extensive and continuous program to improve our central computing facilities, replacing older high-maintenance systems with modern low maintenance ones, achieving concurrently a major upgrade of capabilities. In FY 1995 and subsequent years, we will continue our program of upgrades for increased performance with reduced maintenance and operating costs.

Thus, in FY 1995 we will upgrade one of the servers for the Science Workstation Network, Ursa, at a cost of $35 K. This upgrade will vastly increase the disk space available for visiting astronomers (and supplement the space available for staff), increase performance and increase reliability.

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 a decade ago, is now in heavy use within the NOAO observatories, at over one thousand sites in the world astronomical community, and within the
NASA astrophysics community. 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. In addition, IRAF is constantly evolving as the scientific reduction and analysis programs change to meet new needs and as the entire system becomes more graphical and easier to use.

During FY 1995, work will continue on IRAF systems software and scientific applications. Projects expected to be worked on during FY 1995 include further development and refinement of the new graphical user interface (GUI) software for IRAF, including xgterm and ximtool, and integrating GUIs into IRAF scientific applications. Also, support and refinement of a new major release of IRAF, version 2.11, will take place in FY 1995.

Kitt Peak Telescope and Instrument Control Systems
The Mountain Programming Group (that part of CCS that develops software for instrument and telescope control) will continue major projects that were begun during previous years. These projects include work on WIYN and the WIYN Multi Object Spectrograph, the new generation of HARCON CCD controllers, the 4-m Telescope Control System, adapting IRIM to the solar telescopes, and software system design for the Observatory Control System for the Gemini telescopes.

Funds for these activities, including salaries for the mountain programming group, are included in the budget for KPNO and NSO O&M.

VI. TELESCOPE OPERATIONS AND USER SUPPORT

A. Cerro Tololo Inter-American Observatory

During FY 1995 observers using the CTIO 4-m telescope will see the completion of our general program of optics improvements, the introduction of the new f/14 focus for the telescope, and significant progress with the implementation of a tip-tilt system at that focus. We expect this work to open up a new range of scientific investigations, along the lines of what has been achieved at the CFHT.

As part of the above effort, we will complete moving our observer support group from the 4-m building into a new observer support building located slightly below the summit on the East side, out of the prevailing northerly wind. The new building will also bring the whole observer support group together in one location for easier communication, along with an astronomer lounge, and will provide a funicular elevator for moving people and equipment to the summit. However, possibly the most important gain from this building is that we will also be able to move the machine shop out from under the 1.5-m telescope. This will help to solve a long-standing heat problem in that dome. Another improvement already made to the thermal environment at the 1.5-m telescope is to move the console room into a larger but better insulated location.

We intend to accelerate the retirement of obsolete computer and electronics hardware. This will free up significant amounts of manpower which will improve our ability to maintain the more essential pieces of equipment on the mountain. Over the years we have tended to add new equipment without making the additional investment necessary fully to retire what is supposedly being replaced. This has left us with many systems which do only a little, but require lots of maintenance.
The soon-to-be-retired systems most apparent to the observers are the VEB CCD controllers and the LSI-11 computers to which they and the IR array controllers have been connected. Observers are also sure to notice the replacement of the leaky-memory autoguiding systems in most locations, which will lead directly to improved image quality and throughput on long exposures.

We will also be retiring most of the Camac crates on Cerro Tololo, as well as the ancient Tolnet computer system (the latter at the cost of also retiring the IR photometer).

The Volkswagen fleet, however, will live on...some things are forever.

B. Kitt Peak National Observatory

Major priorities for KPNO in FY 1995 include commissioning and operations support for the WIYN telescope, operations support for the 4-m telescope, and maintenance of some level of support, albeit reduced, for smaller telescopes.

In FY 1995 KPNO will commence scientific operations of its first new facility in over two decades, the 3.5-m WIYN telescope and observatory. Observing time on the WIYN telescope will be distributed according to the financial contributions of the four partners. NOAO will receive a 40% share for use by the astronomical community. The scientific capabilities provided by the WIYN telescope will be multi-object, fiber-fed spectroscopy (moved from the 4-m to WIYN) and high spatial resolution CCD imaging. The NOAO portion of the observing time will be used to develop alternate modes of observing such as queue scheduling, remote observing, surveys, and service observing, both to provide access by the community to new scientific opportunities which are not supported on the traditionally scheduled KPNO telescopes and to prepare for the scientific operations of the Gemini 8-m telescopes.

KPNO has primary responsibility for operation of the WIYN facility. Under the WIYN Agreement, NOAO will provide 5.5 FTE, some capital expenditure, and facility support for the Observatory. These resources will come primarily from within the current level of resources available to KPNO, with some augmentation of capital from the WIYN universities. The WIYN telescope incorporates substantial new technology in its design, including an actively supported and temperature controlled primary mirror, a highly ventilated optical support structure and enclosure, and a state of the art control system and instrumentation. While the WIYN telescope is designed to be low-maintenance, the complexity of the observatory subsystems will require a high level of expertise to maintain optimal performance. The support of new observing modes on the WIYN telescope, which require a higher level of operational support, will further tax already limited resources.

To provide the appropriate level of technical support to WIYN, KPNO will necessarily reduce the level of resources dedicated to improvements and support of other telescopes. We will support fewer instruments on each telescope including the 4-m and 2.1-m telescopes. The length of observing runs will be increased on some telescopes to reduce the support load. Over the next several years we will evolve in the direction of increasing specialization on all telescopes, emphasizing those scientific capabilities which will be most relevant in the Gemini era. These include wide field optical and infrared imaging with good image quality, wide field, multi-object fiber spectroscopy, multi-object infrared spectroscopy, and survey and synoptic programs.
KPNO also expects to upgrade its CCD controllers and data acquisition systems to utilize the ARCON controllers developed at CTIO. KPNO will implement a hybrid array controller known as "HARCON" to preserve our substantial investment in low-noise analog electronics for reading out the CCD's. The new HARCON controllers offer substantial gains in reading out larger CCD arrays and mosaics. The HARCON controller hardware was installed at all telescopes late in FY 1993, but the software will not be available until FY 1995.

KPNO is actively seeking collaborations with the community to make the archived data more widely available over Internet. KPNO now archives all CCD and IR array data generated on the mountain, copies of all image frames are transparently and routinely routed to a central archive computer at the Administration Building and written to Exabyte tape. These data have proven useful already for monitoring telescope performance, for scientific programs requiring observations over several months by a variety of observers, and for recovering data lost through accidents.

During FY 1994, KPNO initiated a program whereby large observing projects or sets of projects with broad implications can be supported at Kitt Peak (i.e. key projects). The purpose of this program is not only to provide a wider variety of scientific opportunities to the community, but also to develop expertise within the Observatory to review, allocate, and support large programs. A key project is an observing program which seeks to answer a significant scientific question of general interest. We supported travel and subsistence for two groups of astronomers to come to Tucson to develop observing proposals for Key Projects. Several proposals for key projects were received for the fall observing semester. These proposals were reviewed by the Telescope Allocation Committee, and two relatively small programs were granted time. Criteria in addition to scientific merit for reviewing Key Projects will include: (a) Is access to significant amounts of telescope time necessary to make progress on the scientific problem? (b) Will KPNO telescope time comprise most of the observing for the project? (c) Will the projects selected be distributed among several KPNO telescopes, and not be concentrated on the 4-m? (d) How will the large body of data collected be made available to the community?

The KPNO electronic proposal submission experiment for telescope time in the fall semester of 1994 was quite successful. Over 70% of proposals were received via e-mail, including figures, and the procedures for receiving, printing, logging, and copying the proposals in-house went smoothly. We will continue to expand this program in FY 1995 to incorporate automatic logging of proposals, on-screen proposal viewing, and links to the data archive.

C. National Solar Observatory

Tests indicate residual instrumental aberration in the Vacuum Tower Telescope (VTT) due principally to the entrance window. As part of a program to improve the overall VTT performance, the present thin window will be remounted in the turret. Additional TJ 1024 x 1024 CCD arrays will be integrated into the observing program along with the new 256 x 256 HgCdTe IR array. The use of the IR array by visitors will be on a shared-risk basis. Renovation, calibration and testing of the Correlation Tracker will continue. A Mark II version of a Correlation Tracker will undergo further study. Operation and control of the grating on the Horizontal Spectrograph will be motorized and placed under computer control. Two new Exabyte 8500 double-density tape drives, writing at 200,000 pixels per second, double our present rate, will be installed. This will require an upgrade of the present MDA controller. A night-time guider will be developed further for use on objects of 4.5 magnitude or brighter.
At the Evans Solar Facility (ESF), new optical benches and associated stages, holders, and other mounting equipment, will be installed at the Littrow Spectrograph and the East Bench. This will greatly facilitate setting up and interchanging complex experiments. A new flat-field lamp will be permanently installed at the Universal Spectrograph. The new software will be refined and developed further and the servo drifts in the electronics reduced. A lunar guider has been developed and will be installed on the ESF coronagraph for specialized lunar observations.

Design work is underway toward a complete upgrade to the 20-year-old Telescope Control System (TCS) at the Kitt Peak Vacuum Telescope (KPVT). The current PDP 11/73 system will be replaced by distributed processors linked to a host Sun SPARCstation. This upgrade will allow the retirement of the PDP 11, FORTH environment, and CAMAC. It is anticipated that the KPVT TCS upgrade will be completed in late FY 1995 and that the McMath-Pierce TCS will be upgraded after completion of the work at the KPVT.

### VII. OPERATIONS AND FACILITIES MAINTENANCE

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#### A. Cerro Tololo

To maintain efficiency in observatory operations it is necessary to improve and replace some of the existing equipment. This kind of infrastructure renovation has been identified in the Bahcall panel report as its highest priority for ground-based astronomy. We have drawn up a 5-year plan of infrastructure improvements to CTIO, which we wish to have completed in time for the ramp-up to Gemini operations.

The most critical items of infrastructure needing attention are listed below in order of priority:
Summary

1. Water system Tololo (pipeline) 25,000
2. Water system La Serena (filter) 10,000
3. Vehicle fleet renovation 100,000
4. Telescope 4-m repainting 20,000
5. Power House 25,000
6. Main access road to Tololo 300,000
7. Stand-by power La Serena 55,000
Total funds requested $535,000
Funds requested in FY 1995 $135,000

The funds requested for FY 1995 improvements are not included in the base budget amount.

1) Cerro Tololo water supply line
The San Carlos water line--CTIO's only water supply--has been in continuous operation for over 20 years and is nearing the end of its normally-expected 25-year useful life. We must plan a gradual early replacement of those sections of pipe that are worn by use, pitting, or due to the problems caused by iron-eating bacteria (innocuous to human health) that badly affected the line during the first few years of its use. This problem has been dealt with so far by plugging the pipe or removing small stretches where soldering would not be possible because of the extent of the damage.

We have stocked pipe tubing from previous fiscal year funds and estimate that $25 K for manpower will be required to carry out this early replacement work.

2) La Serena water system
$10 K is necessary to purchase and install a new filtering system for the Compound well. We have detected impurities in excess of the 250 particles/cc guidelines set by the Chilean National Health authorities.

3) Vehicle fleet renovation schedule
Every time a fiscal budgetary crisis results in cuts, one of the first items to be reduced from our budget are funds for fleet renovation. As a result our fleet has been aging consistently over these past five years--where 2/3 of the vehicles average more than 6 years of use, and the rest are well over 15 years old. This is not a cost effective way to manage vehicle fleets, because of raising maintenance costs.

Day to day operations in Santiago require the use of a permanent passenger vehicle to run official errands. Present emission-control regulations in Santiago are making it a requisite to replace the current Chevrolet Celebrity for a vehicle equipped with a catalytic converter.

The policing of emission control measures in Santiago is expected to result in even greater restriction on the use of vehicles which are not equipped with the legally required control gear; current Chilean law already prevents such older vehicles from circulating in Santiago at least 20% of the working days.

As with the car, a light truck is a necessity for our Santiago Operations. The cost of owning and operating a small truck demands just a fraction of the cost that we would otherwise be required to spend if we depended solely on out-sourcing local transport services in Santiago. We estimate that the costs of the truck would be recovered in approximately four years, including operations and maintenance; moving cargo (one small truckload) from the airport to the Office in Santiago for example, is expensive when
using outside resources. At present we have a minimum of two weekly air cargo receiving operations, apart from the usual pick-up of supplies and materials from vendors, commissary orders, construction material, and incidental hauls of ocean cargo from Valparaiso. $30,000 is needed to cover these two items.

Plans proposed for the full renovation of passenger transportation vehicles (replacement with smaller, more fuel efficient models) and light duty and cargo hauling trucks would require total funding in the order of $ 100,000.

4) 4-m telescope
Weather conditions on Cerro Tololo deteriorate the exterior coating of our buildings and structures. This is specially true of the 4-m telescope building, where we must conduct repaint work every five years. We require $20 K for exterior repainting of the 4-m telescope. Delaying this kind of maintenance activity only leads to higher costs later.

5) Cerro Tololo Power house
During the past 3 years CTIO has been carrying out a plan to upgrade the Tololo Power House. At present $25 K are required to continue with this plan, specifically to replace obsolete switching and control gear which has been used for well over 25 years.

6) Cerro Tololo road improvement
The highly successful upgrade work performed on the road during the past five years has contributed to its excellent resistance to wintertime storms. However, there are still areas where necessary improvement work has been postponed because of lack of funds, as well as locations where it will be necessary to install additional culverts or replace the existing ones with larger-diameter units, clean clogged drains, etc.

The greatest safety hazard in our entire operation continues to be accidents on the access road to Tololo. We have, in recent years, installed 483 linear meters of guard rails in sectors of greatest potential danger. In order to continue offering greater protection to people using the road, we have estimated that a further 10,200 mts. of guard rail are needed, at a cost of US$ 27.50/linear meter, which ought to be installed over a 4 to 5 year period.

$ 44,155 per mile..................Total $ 300 K.

CTIO remains committed to steady improvement in overall operational safety through careful application of available funds to areas of greatest hazard.

7) Stand-by power generator for La Serena headquarters
Although the commercial power in La Serena is reliable, occasional power outages, infrequent though they are, call for the operation of a small stand-by generator of limited capacity rating (i.e. 50 Kw. 60 Hz. instead of the 50 Hz. frequency standard on the compound), which renders it scarcely sufficient to supply enough energy for essential service utilities, such as water and computer climate control (HVAC) systems. The present power consumption requirements in La Serena are in the range of 120 Kwh., greatly exceeding the maximum power capacity of this unit.

The purchase of a stand-by generator of larger output capacity with control gear would allow us to set up a fully automatic emergency power system, with ample capacity to supply electricity for the entire compound in the event of commercial power failures. The cost of this generator would be $ 55,000.
B. Kitt Peak

As the budget grows ever tighter, the burden of maintenance and the risk of deferred maintenance also grow. KPNO is attempting to meet these problems with a carefully planned program of scheduled and preventive maintenance and by eliminating equipment and instrumentation with high maintenance requirements. During FY 1993-1994 KPNO replaced the original control hardware and software on the 4-m telescope with a new, state-of-the-art control system. The new system is now working well and should reduce the level of ongoing support required to keep the 4-m telescope running efficiently, as well as improving scientific performance. KPNO has instituted a schedule of mirror aluminizations, optical alignment checks, and pointing maps to assure good telescope performance and to identify problems early, before they become more serious.

An especially critical long-term maintenance issue facing KPNO is the aging control systems on two small telescopes, the 1.3-m and 0.9-m telescopes. Similar problems exist on two NSO telescopes on Kitt Peak, the Vacuum Telescope and the McMath-Pierce Solar Telescope. The current 20-year-old control systems are increasingly difficult to maintain, resulting in increased downtime. The replacement of all of these systems with modern, lower maintenance hardware and software is a high priority. It is anticipated that the design phase of the NSO/Kitt Peak Vacuum Telescope’s Telescope Control System (TCS) upgrade will be undertaken in FY 1994, with installation in the summer of 1995. Design work on the McMath-Pierce TCS upgrade should follow in late 1995. The design of modern control systems for older telescopes is a common problem facing many observatories. KPNO will seek to build partnerships with industry and the university community to find solutions which may benefit not only NOAO but other observatories as well.

KPNO will continue to work to improve the quality of images delivered with its telescopes. Recent evidence compiled at the Michigan-Dartmouth-MIT facilities on Kitt Peak establish that the site can deliver substantially better seeing than KPNO telescopes normally achieve. A vigorous program to reduce dome seeing and telescope- and optics-induced seeing is underway. Work in FY 1994 included cooling the oil in the 4-m bearings and ventilating the 0.9-m dome. Equipment to measure the image quality delivered by KPNO telescopes has been installed in several domes. Effort to ventilate the 4-m enclosure has been postponed due to lack of resources, but will be a high priority in FY 1995. KPNO will also investigate, in FY 1995, ways to cool the 4-m primary mirror. Mirror seeing is known to be a significant component of image degradation in telescopes with massive (and usually warm) primaries. Also in FY 1995, KPNO will fabricate and install a new prime focus corrector to achieve a wider field for the new, large format, CCD mosaic detectors.

Maintenance of the instrument rotator, guider, and instrument motor controller on the 4-m continues to draw substantially on limited technical resources. Scheduled maintenance of these systems will reduce down-time associated with failures, but the only way to reduce the maintenance burden is to replace the electronics with newer, more reliable designs. This has the added advantage of reducing heat generation below the primary mirror and may improve seeing. A new system should be designed in FY 1995 for possible implementation in FY 1996 if funding allows. The length of time to carry out this project is simply a result of the very limited resources available.

With several new telescopes coming into operation on Kitt Peak, including the WIYN telescope, the limited bandwidth of telecommunications between the mountain and Tucson is an increasing problem. Good telecommunications are a cost effective means to reduce support costs as well as observing costs. Remote engineering and diagnosis of equipment failures can help to reduce the burden of travel time
between Tucson and Kitt Peak. The availability of effective remote observing opportunities will reduce the number of visitors on the mountain, also reducing support costs. Improvements in telecommunications which also reduce ongoing costs will be pursued in FY 1995.

The observatory continues to make every effort to keep up with the maintenance of the Kitt Peak physical plant—painting, roof repair, water system, sewer, power, etc. The exterior paint of the McMath-Pierce telescope will be serviced during the summer of 1995. The required 110-foot crane needed to install air vents in the dome of the 4-m the Mayall Telescope will be available at this time. Inevitably, however, much maintenance work must be deferred for lack of funds. A sample of major work that will be deferred includes the replacement of a section of sewer line, implementation of a phased replacement program for the power line, and construction of a "clean area" for the 4-m aluminizing chamber.

C. NSO/Sacramento Peak

Continued level funding coupled with increased personnel costs has eroded our ability to maintain the facilities in a desirable manner. Instead we are forced to address critical safety and maintenance items from a reactive posture. During FY 1994, we were able to replumb our LPG tank farm, begin the final phase of the fire alarm installation, replace a maintenance vehicle and complete another leg of the water/gas main pipeline replacement. These were mostly a result of year-end surplus funds generated by NOAO.

Budget levels will determine which maintenance activities will be undertaken during FY 1995. Items which require consideration are furnace replacement in relocatable housing, power line replacement, painting of redwood housing, underground storage tank upgrades, completion of pavement replacement, continuing repair of water/gas pipelines, and Americans with Disability Act (ADA) upgrades. These are items which are safety issues, mandated by law, or serious maintenance problems. Additionally, we would like to consider lighting upgrades in all buildings and heater upgrades in the shop areas to take advantage of more energy efficient fixtures and continue our vehicle replacement program with a new staff vehicle. Unless additional funding becomes available, it is unlikely that many of the above items will be addressed this fiscal year.

During FY 1993 and FY 1994, additional funding was acquired for the Sunspot Education Center and Science Museum (originally called Visitor Center). The New Mexico State Legislature approved an additional $150,000, and we received a grant from the Intermodal Surface Transportation Enhancement Act (Federal Highway Administration) for $600,000. Our total budget for the project is now $1,025,000. It is expected that an architect/engineer will be hired and final plans completed during FY 1994 with groundbreaking late in FY 1994 or early FY 1995. Completion is expected during FY 1995.

D. NOAO Tucson Headquarters/Central Facilities Operations

CFO is responsible for providing all the basic facility support services required for the 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 supply distribution, telecommunications system management and research, 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, NSO Sacramento Peak, and Kitt Peak facilities.
The potential relocation of the NOAO headquarters is currently at a standstill. The University of Arizona is still keenly interested in acquiring our headquarters facilities, and has set aside space for a new NOAO facility in their campus planning. However, the University is not willing, or financially able to, at their expense, fully relocate NOAO; nor is NOAO in a position to fund the shortfall necessary to provide for the difference between sale of the property and new construction. Consequently, in FY 1994, a decision was made to proceed with several previously planned projects to improve the Tucson facilities. Emphasis will be placed on multi-year energy savings and telecommunications improvements. In addition, due to a severe shortage of office space, we will continue to modify and upgrade the building to adjust for changes in our programs.

Our goal in FY 1994 was to both reverse and substantially reduce the spiraling utility costs which continue to be a major cost of facility operations. Six months of financial data show that our preliminary goal has been reached. Combined utility savings in excess of 20% were quickly accomplished. Our new goal is to reduce costs further into the 30-40% range through expansion of our energy management system, and continued replacement of inefficient lighting. In view of the recent rate increases, these savings are considered major.

As a further cost cutting measure, we will review and consider upgrading our telephone equipment and installing our own microwave communications link between KPNO and the Tucson headquarters. The telecommunications link currently in use is projected to reach saturation in the near future. While it is possible to add capacity, through the local utility, the additional cost is considered to be prohibitive. The projected payback time is on the order of four years or less.

The savings generated from the utility cost cutting measures will be used to upgrade our shuttle vehicle fleet, complete the outside landscaping plan, provide new technology telephone capability, complete the last of the roof repairs needed for our older buildings, provide start-up funds for additional energy savings ideas and, hopefully, begin a study on measures to correct our unbalanced electrical problem.

One area of maintenance which must be deferred this year, due to a lack of funding, is the replacement of our antiquated fire alarm system.

VIII. PROGRAM SUPPORT

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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 Program, each headed by an Associate Director of NOAO. The former 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. He left NOAO in August 1993, to become chair of the astronomy department at the Ohio State University.

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.

External searches were conducted for new directors of CTIO and NSO and the US Gemini Project Scientist. These positions were filled by Malcolm Smith for CTIO, Jacques Beckers for NSO, and Todd Boroson for the USGP. For six months of 1993, KPNO was directed on an interim basis by T. Boroson, G. Jacoby, and C. Pilachowski. When T. Boroson was confirmed as US Gemini Project Scientist, C. Pilachowski became interim director of KPNO and G. Jacoby became IRAF Project Scientist. The issue of a long-term KPNO Director will be addressed after further discussions with the AURA Observatories’ Advisory Committee.

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.

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. 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. General services include the engineering manager’s office and those engineering specialists who are not assigned to a project group. Support for general services is budgeted initially in ETS but is subsequently billed to the NOAO divisions making use of the general services group. Costs related to the project groups are shown within the division where the projects actually occur. General services maintains basic equipment and facilities for use by people assigned to the project groups. This office also operates the NOAO coatings lab.

D. 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 school 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 supports educational outreach programs and special events.

The manager of PIO oversees the Kitt Peak Museum and Visitor Center. This year, the Museum will use private donations to complete construction of a dome addition. The former Kitt Peak No. 3 16-inch telescope will be installed in the dome. The Museum exhibits are being updated to emphasize Kitt Peak history and astronomy. The volunteer program continues successfully: on average 300-400 volunteer hours per month are logged. Volunteer docents act as tour guides, store workers, and help at special events such as public evenings and eclipse days. The Museum participates in 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.

IX. 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 1995 NOAO REU Site Program. The program award will cover salary and transportation expenses for the students.
The 1995 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.

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

- 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.

- 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 students 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 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 facilities at Kitt Peak, Sacramento Peak, Apache Point Observatory, the Very Large Array, and the University of Arizona's Steward Mirror Laboratory are planned for students. A Summer Student Research Presentation session is 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 and formal and informal get-togethers and recreational activities, such as scientific luncheons, barbecues, pool parties, and weekend hikes, are arranged for the REU students. To encourage students to present papers and posters, based on their REU experience, at scientific meetings and conferences, NOAO retains a portion of the REU award for travel assistance to such events after the close of the program.

While the 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.

The 1995 NOAO REU Site Program at Cerro Tololo Inter-American Observatory (CTIO) will provide an opportunity for up to four students to participate in independent research activities that are characteristic of the NOAO REU programs at Kitt Peak National Observatory (KPNO) and the National Solar Observatory (NSO), but with additional emphasis on observational techniques and direct observational experience. The program has been developed with Eileen Friel of the Maria Mitchell Observatory, and she will accompany the students.

X. BUDGET

The tables given in Appendix 5 show staffing and funding for observatory operations and for GONG. The US Gemini Program has been added as a fourth division. The instrumentation budget formerly assigned to KPNO exclusively has been shown as a separate line item that is now called KPNO/CTIO Instrumentation Program. At this time, there is no budget for instrumentation within KPNO, while CTIO does retain some site-specific engineering resources. By FY 1996, and possibly in later revisions of the FY 1995 plan, we will transfer some resources, with the amount yet to be determined, back to KPNO to retain the capability at both sites for a modest program of instrumentation. The joint KPNO/CTIO instrumentation funds will be reserved for major (approximately $1 M and over) instruments.

The budget figures have been derived by assuming 3 percent inflation on both payroll and non-payroll. We have not allowed for excess peso inflation in Chile. Note that funding at the level of the President's request of $28.8 M is required in order to maintain level of effort. The FY 1994 budget of NOAO did increase over that of FY 1993, but virtually all of the increase was earmarked for specific programs, including GONG, RISE, and the US Gemini Program. The budget for operations was level-dollar funded, with no correction for inflation.

The budget for salaries is now about 80 percent of the KPNO budget and two-thirds of the CTIO budget. It is our intention not to increase the fraction of the budget devoted to payroll. At the same time, it is AURA policy to provide competitive salaries. The scientific staff salaries lag behind those at AURA
member institutions, and salary surveys indicate that a 3 percent increase is required in order that we not fall further behind. Inflation in Tucson is currently running about 3 percent per year. Therefore, we do intend to adjust salaries upward by about 3 percent next year. As a result of these constraints—a salary increase combined with a limitation on the fraction of the total budget committed to payroll—failure to provide the full funding of $28.8 M requested by the President is likely to lead to a reduction in staffing, with the accompanying reduction in services to users.
APPENDIX 2

NOAO Management

S. Wolff  Director, NOAO
R. Green  Acting Deputy Director, NOAO
M. Smith  Associate Director, NOAO/Director CTIO
C. Pilachowski  (Interim) Associate Director, NOAO/Director KPNO
J. Beckers  Associate Director, NOAO/Director NSO
T. Boroson  Associate Director, NOAO/Director USGP
M. Phillips  Assistant Director, CTIO
J. Leibacher  Project Director, GONG
J. Kennedy  Manager, GONG Project
G. Blevins  Manager, Central Administrative Services
L. Daggert  Manager, Engineering & Technical Services
J. Dunlop  Manager, Central Facilities Operations
S. Grandi  Manager, Central Computer Services
I. Gatley  Manager, Public Information Office
R. Hunter  Administrative Manager, NSO/Sacramento Peak
Y. Estok  Assistant to the Director, NOAO
R. Barnes  Assistant to the Director, KPNO
J. Tracy  Controller, Central Administrative Services
APPENDIX 3

Cerro Tololo Inter-American Observatory

Scientific Staff: Primary fields of interest and 1993 publications (we have included those publications from 1992 that were not listed in the previous report).

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

In the coming year J. Baldwin plans to complete a detailed study of the Seyfert 2 galaxy NGC 3393. The HST observations necessary for this program were finally obtained just before the HST refurbishment. A post-doctoral fellow (A. Cooke, U. of Cambridge) will work with Baldwin to analyze the HST data plus an extensive set of ground-based data obtained over the past several years. Baldwin will continue to have a heavy involvement in service activities--principally the 4-m upgrades program and as the chairman of ACTR.


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

O. Eggen is preparing four-color, Hβ, DDO and R, I photometry of all Cape Zone Catalogue stars within
10 degrees of the SGP for publication. One of the most startling results is that equal density samples of old disk population objects at both poles reveal a 5/1 ratio of NGP/SGP blue stragglers. The mean dispersion, $\sigma_v$ for all old disk stars at the poles, averaged in 100 parsec levels of Z, is very well represented by $\sigma_v = 7.5 + 0.028|Z|_{\text{pc}}$. A study of the nearest blue stragglers is underway to test the apparent positional difference of those at the poles.

Also, some 350 four-color and Hβ observations of very short period cepheids (RR Lyrae) in the solar vicinity have been used to derive metallicity, reddening and luminosity for 34 variables.

A study of several indicators of surface gravity in unevolved GK stars shows a clear separation of gravity between the old disk (age $> 2 \times 10^9$ y) and the young disk objects. This result is being studied in two large samples of GK dwarfs—those in the Bright Star Catalogue and in the Gliese Catalogue of Nearby Stars.


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

The Magellanic Clouds are well-known as fundamental calibrators for extragalactic research. What is less generally realized is that they also can provide essential insights into objects in our own Galaxy as well. One such area is the comparative study of star-formation processes. This is an area where large-scale, sensitive surveys are critical; such studies will become possible as the latest generation of infrared arrays are implemented at CTIO. Jay Elias intends to use these new arrays to study the distribution of star formation (and related processes) in the Magellanic Clouds. Hitherto, most searches for star formation have been point observations at the location of "signposts"—e.g., H II regions, CO peaks, or IRAS sources—all of which can lead to bias of one form or another. This bias is potentially even worse when looking for interactions of star formation with the Galaxy—for example, buried supernova remnants or shocked molecular hydrogen. The new IR imager should be capable of surveying large portions of the LMC or SMC for molecular hydrogen emission, using one of the smaller CTIO telescopes. These data, combined with IRAS maps, IR images, and published CO data, provide a means of observing the shocks generated by star formation regions. The interaction of these shocks with the surrounding molecular material is thought in turn to trigger further star formation, and such interactions ought to be detectable as well.


**R. Elston - Galactic evolution.**

R. Elston's main area of research interest continues to be the formation and evolution of galaxies and the history of star formation within galaxies. In particular the formation of early type galaxies, once thought to contain simple, old, stellar populations has been the focus of much of Elston's work. In collaboration with David Silva (KPNO), Elston has continued to study both near-IR color gradients and spectroscopic CO gradients in early type galaxies. They find no near-IR gradients, a result that implies that optical color gradients can not be simply driven by metallicity as is commonly assumed. During FY 1995, they will continue to study the resolved stellar populations of local-group galaxies by obtaining resolved photometry of stars in M31 globular clusters and searching for LPV variables among the luminous AGB stars they have found in M32.

Elston has also pursued another approach to the problem of galaxy formation and evolution by observing samples of faint field galaxies. To study early type galaxies out to redshifts of $z = 1$, Elston has continued his studies of field galaxies selected by their 2 $\mu$m emission. To follow up on his sample of $K < 18$ galaxies he has obtained spectra for nearly 200 objects. They extend to high redshift ($z = 0.8$), which indicates that early type galaxies were significantly brighter in the past. Also, the colors and depth of the 4000 $\AA$ break indicate little color evolution out to $z = 0.8$. But at the limit of the survey, galaxies may begin to show significant color evolution. To pursue this result, Elston has begun to compile a sample of $K$-band-selected galaxies reaching $K = 21$. This sample should provide galaxies with redshifts well beyond 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 $z > 1$. The first few fields where deep J and K images are in hand contain a large population of galaxies with very red J-K colors indicative of both old stellar populations and redshifts beyond 1.5.

The large excess of faint blue galaxies that is found in the field presents an interesting problem for our understanding of star formation in the universe. Elston is questioning whether the large number of blue objects appearing in deep surveys actually requires strong evolution in the star-formation rate of the universe or if selection biases are primarily responsible for the large number of galaxies. He has obtained a bright sample of nearby field galaxies selected by their ultraviolet flux. This local sample is the first to be selected in the same way as the faint blue-selected galaxies. He will now test if current galaxy models can reproduce the local universe.
Elston has also pursued the study of the most distant known galaxies with redshifts of 2 and beyond. With P. McCarthy (Carnegie Obs.) and P. Eisenhardt (Caltech) he has been observing Hα emission from distant radio galaxies using near-IR spectroscopy to assess the importance of reddening and of quasar-like nuclei. They have recently expanded this program to try to determine abundances in narrow-line regions of distant radio galaxies.

Elston, G. Hill (U. of Texas) and K. Thompson (Naval Research Lab.) will be continuing their work to study the near-IR spectra of luminous high redshift quasars. Perhaps most surprisingly, they find that very strong Fe II emission is very common even in quasars with z > 3. This strong Fe II emission seems to require a Fe abundance several times that of the Sun. In typical ISM enrichment models such high abundances can only be achieved by Type Ia SN, which require about 1 Gyr to produce Fe. Thus, star formation in the host galaxies of these quasars seems to have occurred at very high redshift z > 6.


B. Gregory - Low temperature physics and infrared instrumentation.

During the FY 1995 period, B. Gregory will continue to be active in the programs to improve image quality on the 4-m telescope. During this phase there will be work on active control of the primary figure, including the realization of a Shack-Hartmann wavefront sensor. Somewhat later a new f/14 secondary will be commissioned, which will employ piezo-electric actuators to permit it to be used as the active element in a tip-tilt fast guider. He also plans to be an active participant in refining the design of the next generation IR spectrometer.


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

S. Heathcote is a leading member of an international consortium that successfully applied for Cycle-4 HST time for the study of Herbig-Haro jets. The main emphasis of his work during the forthcoming year will be on the analysis and interpretation of images of HH 46/47 and HH111, which will result from this program. It is anticipated that these images will provide important insight into the physics of optical jets and in particular into the role that source variability and entrainment play in exciting the internal shocks within the jet.


T. Ingerson - Electronics, computers and optics.

Ingerson, T.E., ASP Conf. 37, ed. P.M. Gray, p.76, "Assessing the Performance of Argus -CTIO's Multiple Object Spectrometer"

Ingerson, T.E., Observing at a Distance World Scientific, ed. D. T. Emerson, R.G. Clowes, p.37, "Remote Observing at CTIO"

A. Layden - Stellar populations; structure and formation.

A. Layden will continue to work on four of his ongoing projects during 1994-1995. He has been granted CTIO 0.9-m and 4-m time for the Inner Halo rotation project, and KPNO 0.9-m and 4-m time for the High Halo rotation project. Layden, Morrison and Harding have been awarded CTIO Schmidt time to obtain V frames of their field, in order to work out star-by-star reddenings via the Blanco (1992) B-V(min) color method. They will propose for 4-m Argus time in August to obtain spectra of these stars. In addition, T. Beers (Michigan State U.) and Layden will obtain UBV photometry of stars in Beer's blue horizontal branch star catalog. These data will be used to obtain distances for stars which already have been observed spectroscopically. Layden and N. Suntzeff (CTIO) have begun a project to recalibrate the RR Lyrae abundance scale (for both ab- and c-type stars), using observations of stars in globular clusters of well-determined abundance. Spectra of stars in 5 clusters were obtained using Argus and will be reduced and published as a "pilot project" for this program.

Layden, A.C., ASP Conf. 48, ed. G.H. Smith, J.P. Brodie, p.326, "Comparing the Local Field RR Lyraes with the Globular Clusters"

M. Phillips - Supernovae; novae.

M. Phillips will continue to concentrate his research effort during FY 1995 on supernovae. 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 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 the theoretical understanding of these events. In a related project, Phillips, Hamuy, and J. Maza (U. de Chile) will complete an observational program to test the utility of supernovae (both types Ia and II) as cosmological standard candles.


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

R. Schommer will continue to analyze large scale peculiar motions. In collaboration with J. Mould (Caltech), G. Bothun (U. of Oregon), and T. Williams, a sample of galaxies for 13 clusters of galaxies in the redshift range of 5000-7500 km/s is being studied. The scale of peculiar motions still has not been determined (30 Mpc, 50 Mpc, 100 Mpc?), but published results and other recent cosmological observations require power on larger scale than the standard Cold Dark Matter simulations produce.

Because of the cluster age and metallicity gap it is necessary to study the properties of the LMC field to understand star formation within the LMC during the period 3-12 Gyr ago. Schommer, with N. Suntzeff (CTIO), W. Weller (Gemini), and E. Olszewski (Steward Obs.) has begun the study of field giants in the LMC. Photometric fields are being obtained with the Schmidt telescope and Thomson CCD in BVI color, and giants are being selected from color-magnitude diagrams. Spectra have been obtained using the ARGUS multi-fiber system, using the near infrared Ca II triplet lines to determine velocities and abundances. They intend to search for abundance-kinematic correlations, examine the metal abundance distribution, search for a metal poor halo, and map the age-abundance relation in the outer parts of the LMC.


M. Smith – Quasars.

During the coming year, M. Smith expects to conclude his preliminary experiments at the Curtis Schmidt with the 1024 × 1024 CCD on fields containing known QSOs with z > 4; he will then select a survey combination suitable for locating QSOs at even higher redshifts. Once the 2048 × 2048 chip is available on the Schmidt with suitable 4-inch filters, a survey with a field of 1 square degree per frame can be initiated, with a view to using a mosaic of CCDs on the 4-m for a deeper survey in a few years’ time. Follow-up work will use the 4-m and later Gemini.

N. Suntzeff - Stellar populations; stellar abundances; supernovae; Galactic structure.

N. Suntzeff plans to continue his research in four areas: the metal abundances and kinematics of the stellar populations in the Large Magellanic Cloud, fundamental observations of southern hemisphere supernovae, and a study of the metallicity and kinematics of the Galactic halo as revealed by RR Lyraes.

The LMC project is designed to study the overall kinematics and stellar evolutionary history of that galaxy. Suntzeff is collaborating with A. Klemola (U. of California, Santa Cruz), E. Olszewski (Steward Obs.), R. Schommer (CTIO), and E. Hardy (Laval U.) on various projects. With Hardy and Schommer, he has obtained data on virtually all known carbon stars in the LMC with the Argus multi-fiber echelle 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 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 distribution of dark matter. With the other collaborators, he is studying selected regions in the LMC to try 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 counter distinction 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 200 stars surveyed, about 100 are LMC members, and of those, about 30 are Population II stars. These 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.

Suntzeff will continue his work with M. Phillips and M. Hamuy (CTIO), and J. Maza (U. de Chile) on the evolution of supernovae. These projects involve the gathering of basic photometric and spectroscopic data on supernovae. The Calan/Tololo survey is a program to discover SN out to z = 0.15. Suntzeff has been concentrating on the photometric measurement of the local, bright supernovae to act as templates for the more distant supernovae discovered by the Calan/Tololo survey. These data are fundamental in understanding both the physics of the supernova explosions as well as the utility of SN as possible standard candles that can be used in distance scale measurements. This group, along with J. Elias (CTIO), will also continue to gather data on SN1987A.
With Kinman and Kraft, Suntzeff will continue their program of studying RR Lyraes in selected fields in the Galactic halo. He will observe RR Lyraes discovered by Plaut in a region at $b = 10^\circ$, to determine metal abundances and kinematics. This is an important transition region where the Galactic halo begins to merge into the metal-rich population at the Galactic Center. In collaboration with Olszewski, Suntzeff will begin a new search for RR Lyraes towards the south Galactic pole, to discover RR Lyraes to $V = 19$ with the CTIO Schmidt telescope.


**A. Walker - CCD photometry instrumentation; stellar evolution; distance scale.**

With H. Smith and N. Silberman (Michigan State U.), A. Walker will continue to study the Cepheid and RR Lyrae variables contained in a one-degree field in the Small Magellanic Cloud. This field contains many short-period Cepheids, and the program is aimed particularly at defining the structure of the faint end of the Cepheid Period-Luminosity relation in the HR diagram.

Work will continue on obtaining high precision B,V and I photometry for the RR Lyraes in particular, and the evolved stars in general, in a number of galactic globular clusters. 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, with positions of instability strip edges and mode boundaries, and with theoretical light curves obtained from hydrodynamic models.

Work on the Cepheid zero-point calibration will continue with B. Carney and A. Fry (U. of N. Carolina). Analysis of photometry and high dispersion abundance analyses will be carried out for several southern clusters which contain Cepheid variables in order to evaluate the sensitivity of the derived distances to abundances, which until now have been assumed to be solar.

A search will be made for RR Lyraes in some of the purportedly old clusters in the LMC bar, which if found would confirm the ages suggested from integrated photometry. Although the fields are extremely crowded, work on NGC 1835 has shown that variables can easily be found if present, whereas a CMD to the turn-off would be difficult even with the Hubble Space Telescope.


APPENDIX 3

Kitt Peak National Observatory

Scientific Staff: Primary fields of interest and 1993 publications.

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

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 be 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 – Stellar populations, globular clusters, dwarf spheroidal galaxies.

T. Armandroff will continue his work on the mass-to-light ratios of dwarf spheroidal galaxies. 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.). Armandroff et al. have used 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 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 30-year-old photographic star counts.


S. Barden – Spectroscopic instrumentation and binary stars.

S. Barden is instrument scientist for the Hydra multi-fiber positioner. This instrument is currently undergoing renovation for its permanent installation on the WIYN telescope. The move from the Mayall to the WIYN is taking place during FY 1994 with completion of the commissioning 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. Barden will also become involved in a FY 1995 design study effort to replace the 4-m R-C spectrograph with a new technology, high-throughput spectrograph. Barden is telescope/instrument scientist for the Coudé Feed telescope and spectrograph. He is also currently the scientist in charge of the KPNO filter collection. Scientifically, Barden will 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 that 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 – Planetary astronomy.

M. Belton will continue his work on the nuclear properties of comets. This includes a continuation of work already begun with N. Samarasinha on the interpretation of orbital non-gravitational forces in terms of jet reaction forces acting on nuclei with complex spin and on the interpretation of ground-based (KPNO) and HST images of the inner coma of Chiron, obtained with K. Meech, in terms of a proposed gravitationally-bound dust atmosphere. Belton will also continue his work with the Galileo project: the 243 Ida encounter was successfully accomplished, and the images are currently (May 1994) being returned
to Earth. He will focus his activities on the development of a shape model for the asteroid. He will also work with a small group headed by B. Zellner and use recently acquired HST images of Ida’s moon to determine its orbit. Other Galileo activities include the acquisition of data on the collision of comet Shoemaker-Levy 9 with Jupiter and preparations for the 1995 encounter with Jupiter. Belton will also pursue his SMACS (Small Missions to Asteroids and Comets) ”Discovery” program concept through the proposal process.


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

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, is 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. In work now being written up for publication, an analysis with S.R. McCandliss (Johns Hopkins U.) of a long spectral-time series of two Wolf-Rayet stars concludes that these stars have non-periodic spectral line variations characteristic of the outflow of stellar material and that interpretations of periodic variability previously attributed to compact companions are a reflection of poor sampling of the time domain.


S. Charlot – Formation and evolution of galaxies.

During the coming year, S. Charlot plans to explore new constraints on the evolution of young galaxies from their spectrophotometric properties. The best candidates for ordinary galactic disks at high redshifts are the damped Lyα systems. These objects, discovered as strong HI absorption features in the spectra of background quasars, have a dust-to-gas ratio about a tenth of that of the Milky Way. He recently showed that because of this small but significant amount of dust, the null results of Lyα emission from the damped Lyα systems do not set tight constraints on their rates of star formation. Rough calculations, however, indicate that the new upper limits set by COBE on the infrared background radiation may constrain much more interestingly the dust thermal radiation (and hence the star formation rates) of the damped Lyα systems. He therefore plans to estimate this effect and determine the corresponding upper limit on the mean star formation per unit volume of the universe at high redshift using the statistical properties of the damped Lyα systems. In fact, the observed increase with redshift in the co-moving density of HI contributed by the damped Lyα systems already suggests that star formation must have been considerably less efficient at early epochs. Charlot also intends to include new stellar tracks and stellar absorption-line data in the population synthesis models developed recently to remove the age-metallicity degeneracy in the interpretation of galaxy spectra. This is crucial for extracting any valuable information about the evolution of galaxies from their observed spectra. Finally, in addition to initiating new collaborations with scientists at NOAO, he plans to complete projects underway about the interpretation of deep optical and infrared galaxy number counts based on new NTT and Keck observations, as well as the combination of his population synthesis models with a hydrodynamical simulation of structure formation.

S. Courteau – Large scale structure; properties of spiral galaxies.

S. Courteau has been working mainly on problems of large-scale distribution of galaxies in the universe and the study of physical properties and formation models of spiral galaxies. In recent work, he has shown that galaxies in both the Northern and Southern hemispheres are moving in a coherent streaming motion that extends as far as ~100 Mpc away from the Milky Way. More recent independent results by Lauer (NOAO) and Postman (STScI) support these findings and suggest that the amplitude and full extent of the flow may be even greater than that inferred by Courteau. These results put serious constraints on current cosmological models; the detection of streaming motions to larger depths would indeed cause us to revise all of the current cosmological models. In this coming year, Courteau and collaborators (Burstein, Dekel, Faber, Kolatt, Willlick, Yahil) will publish a series of five papers (all in progress) that will present potential field reconstructions (POTENT technique) from inferred galaxy distance maps and compare the results with independent density reconstructions from the IRAS redshift survey (collaboration with Davis, Strauss, Fisher, Yahil, Huchra) in the context of Cold Dark Matter cosmological scenarios. To address the questions raised in this series of papers, Courteau and a separate group of collaborators (Lauer, Postman, Geller, Vogeley, Hoessel, Huchra) have initiated a new project to measure bulk flows in a volume-limited survey out to 30,000 km/s (twice the distance of current surveys) using NOAO facilities. The data-taking phase should be completed by late 1995. Courteau is also involved in an observing program at NOAO to study the extinction of light and dust properties in spiral galaxies. One of the goals is to determine more
is to determine more accurate corrections for dust dimming at all visual spectral bands, which is crucial for the measurement of galactic distances. Courteau also works on mass modeling of spiral galaxies using the shape of the luminosity profiles and rotation curves to decompose the various mass components (gas, stars, non-baryonic), study the distribution of mass with radius and scaling relationships, and compare to models of galaxy formation with baryonic infall in a halo of dark matter. Systematics of Mass-to-Light ratios are also compared with predictions from synthetic models of stellar evolution. Courteau also plans a project to study the mass distribution and chemical abundances of distant galaxies using very large telescopes. This work must be preceded by a calibration phase of the diagnostic tools as they apply to both nearby galaxies and distant galaxies. Several selection effects need detailed investigation; these will be examined with Monte Carlo simulations and by conducting tests using the facilities of NOAO and Lick Observatory.

**D. Crawford – Stellar photometry and galactic structure.**

In the coming years, D. Crawford expects to be active in his continuing studies of open clusters. This work has applications to calibrations of the observed photometric indices in terms of intrinsic colors, absolute magnitudes, and other parameters, as well as to studies of stellar structure and evolution. In the coming year, analysis of the existing data on IC 1805, IC 1848, NGC 1502, and NGC 6611 should be finished and ready for publication. All of these contain 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 unfortunately often affected by systematic errors in the photometry and are hence far from conclusive. In addition, work continues on synthetic photometry studies relative to standard photometric systems, as well as on the impacts of light pollution on astronomy and on the general public.

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

In 1995, 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 superrubbles 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 is underway. Preliminary calculations have produced density condensations due to the thermal instability, which evolve into the nonlinear regime. However, it has become clear that the numerical scheme being used cannot accurately calculate the effects of both classical and saturated thermal conductivity, and a new numerical procedure is currently being developed. 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, very young stars and perhaps the lower luminosity extragalactic radio sources. A third and longer term project will also commence in 1995. Agreement has recently been reached between
De Young and the University of Chicago Press on the production of a book about the physics of extragalactic radio sources. Work on this project will begin at a significant level in FY 1995.


I. Gatley - Infrared emission lines of vibrationally excited molecular hydrogen.

Following the implementation of faster electronics for the 256 x 256 InSb array detector in the Cryogenic Optical Bench, I. Gatley is pursuing a program of 3 μm imaging in the daytime. Experiments have shown that the system performance during much of the day is equal to that achieved at night. This substantial increase in available hours of telescope time has made it possible to collect 3 μm images of a dozen large galactic H II regions, including Orion, M17 and the Galactic center. These high resolution images give unprecedented information on the spatial location of dust in the H II regions, crucial to the accurate positioning of the spectrometer slit in the next step of the study planned for the coming year. This spectroscopic experiment will probe conditions in the so-called "photodissociation regions" in the dense neutral envelopes surrounding the H II regions, through measurements of the excitation of both the gas and the dust.


Hillenbrand, L., Strom, S.E., Merrill, K.M., Gatley, I., ASP Conf. Series 35, Massive Stars: Their Lives in the ISM, ed. J.P. Cassinelli, p.141, "Identification of New Candidate Herbig Ae/Be Stars in Extremely Young Galactic Clusters: M8, M16, M17, M42, NGC2264"


Gatley, I., Merrill, K.M., SPIE, 1946, p.2, "The Impact of Two-Dimensional Infrared Arrays on Astronomy"

R. Green - Quasar energy distributions, emission and absorption lines; galaxy and quasar population evolution.

R. Green has acquired echelle data from the 4-m for studying metal-line and Lyman systems. Extraction is laborious at best, but has now been completed in collaboration with D. York, V. Kulkami, and J. Lauroesch (U. of Chicago), and K. Huang (Nanjing Normal U.). 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, 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 evolving population of star-forming and star-bursting systems.


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

As project scientist for the high resolution infrared spectrograph ‘Phoenix,’ K. Hinkle’s main activity in 1995 will be the assembly and testing of this instrument. Detailed design of this instrument was completed in FY 1994; fabrication was started in 1994 and will be continuing into 1995. System integration and testing will take place in FY 1995 with first light for this instrument in late 1995. FY 1995 will also see the conceptual design of the medium resolution spectrograph GRASP. Hinkle is a co-investigator on this instrument and will be involved in its design and construction. Hinkle is also the staff contact for the NICMASS array collaboration with the University of Massachusetts. In this collaboration a HgCdTe array will be placed at the Coudé Feed. Hinkle plans to use this instrument in 1995 to continue his collaboration with F. Fekel (NASA/ Marshall) on the orbits of symbiotic binaries. In preparation for the era of high resolution infrared spectroscopy with array detectors, Hinkle and L. Wallace will publish a high resolution (R = 100000) 1-5 μm spectral atlas of Arcturus in 1995. In collaboration with D. Lambert (U. of Texas), C. Pilachowski, C. Pulliam (U. of Texas), and L. Wallace, a detailed abundance analysis of Arcturus is also planned in 1995 using the spectra obtained for the atlas. Hinkle also plans to continue his collaboration 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. Hinkle is also continuing collaborations with Wallace, S. Edwards (Smith College), and M. Meyers (U. of Massachusetts) to produce a catalog of MK spectral standards in the infrared J, H, and K bands. Collaborations with R. Joyce and Lambert on medium resolution spectroscopy of carbon and S-type stars are also continuing.


in Circumstellar Shells"


Sada, P.V., Keady, J.J., Hinkle, K.H., BAAS, 25, 1320, "Structure of IRC+10216 Deduced from IR $1_{2}c_{16}$ and $1_{3}c_{16}$ Vibration-Rotation Spectral Line Shapes"


Wallace, L., Hinkle, K., Livingston, W., NOAO, NSO, "An Atlas of the Photospheric Spectrum from 8900 to 13600 cm$^{-1}$ (7350 to 112320 Angstroms)"

G. Jacoby – Planetary nebulae, the extragalactic distance scale, galaxy stellar dynamics and stellar populations.

During FY 1995, G. Jacoby will continue his work with Galactic and extragalactic planetary nebulae. Following on the successful modeling of the kinematical structure of the elliptical galaxy NGC 3379 based on planetary nebula velocities, he will be applying the "PN as test particle" technique to giant Virgo ellipticals to map their gravity fields. Other work will include a survey for PN in the Galactic center using IR and near-IR detectors to cut through the dust, and the completion of the long-term project to develop long period variables as standard candles.


R. Joyce – Evolved late-type stars, with emphasis on carbon stars.

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 is perhaps 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. 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 C$_2$H$_2$ and HCN, which are significantly enhanced over the bands of CH, CN, and C$_2$ found in relatively unobscured C stars. The extreme paucity of J and H band spectra of these, and most 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, McConnell 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. Joyce plans to obtain more definitive observations on a wider sample of stars using the enhanced capability of the upgraded IR spectrometer.


T. Kinman – Galactic structure and evolution.

T. 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) has shown that these stars can be discovered with good completeness among the Case AF stars (Burrell Schmidt Survey). It was found that previous surveys for BHB stars could be corrected for the presence of interlopers if they had been made at a sufficiently high galactic latitude. An analysis of this material and our own showed that the galactic halo beyond the solar circle has two components. One is the familiar spherical halo; this dominates at distances from the galactic plane that are greater than about 5 kpc. In addition, there is a flat component (scale height ~ 2 kpc) that makes up about 80% of the halo in the solar neighborhood. The metallicity distributions of the two components are quite similar and it is obviously of considerable interest to investigate what the (evidently rather subtle) distinctions are between the two halo populations. Besides extending the search program to obtain a larger sample of these BHB stars, Kinman (with various collaborators) is attempting to obtain a large photometric and spectroscopic database for the nearby BHB stars, which can be analyzed in a search for the physical differences between the two populations.

T. Lauer – Extragalactic observational astronomy.

T. Lauer's research plans for 1994 will be split into two major areas. The first area is continuing his program of Hubble Space Telescope research. In 1994, 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.


Lauer, T.R., Postman, M., Texas/PASCOS 92: Relativistic Astrophysics and Particle Cosmology, Ann. N.Y. Acad. Sci., 668, p.531, "The Motion of the Local Group With Respect to the 15,000 km/s Abell Cluster Frame"

R. Lynds – Cosmology.

In 1995, R. Lynds expects to continue being involved heavily in the reduction of data from the Hubble Space Telescope--data taken with the Wide-Field/Planetary Camera (the post-refurbishment mission WFPC-2).


During the coming year, P. Massey intends to complete work on IC 10, a galaxy nearby enough to probably be considered a Local Group member. Previous work (Massey, Armandroff 1992, AJ, 103, 1159) identified 21 Wolf-Rayet candidates, an astonishingly high number for a galaxy of this size, suggesting a very high star-formation rate for massive stars. Follow-up observations obtained with the 4-m and multi-object positioner Hydra have now provided spectroscopic confirmation of most of these candidates. UBV CCD photometry of the W-R stars will provide the first accurate assessment of the reddening of this galaxy, one of the great uncertainties in determining its distance. Massey is also completing studies of the massive star content of NGC 6822 and M33, two other Local Group galaxies. M33 has been the subject of a recent study with the Ultraviolet Imaging Telescope (UIT) on the ASTRO-1 mission, and in collaboration with L. Bianchi, Massey has now obtained spectra of the 50 brightest UV sources, finding a large proportion of previously unidentified Wolf-Rayet stars. In addition, Massey is working with Hillenbrand and Strom to determine the age and age spread of the Galactic cluster h and Chi Persei; previous studies of this well-known double cluster system suggested an age spread of 40 Myr, unlike that of other recently studied associations and clusters.


Oey, M.S., and Massey, P., Ibid, p.348, "O Star Giant Bubbles in M33"


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.

K. Michael Merrill’s current scientific research interests follow along two intimately intertwined threads: the stellar content within regions of star formation and the diffuse environment with which they interact. With Ian Gatley, he will be examining the circumstellar environment of stars, using the Cryogenic Optical Bench. COB is an excellent tool for isolating diffuse emission from the stellar "contaminant." Longslit and multislit grism spectroscopy, and spatial mapping with wide-field frequency switching on and off emission lines, are proving to be powerful discriminants. They have been employing 2 μm 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, including NGC 2024 (a young cluster embedded in a dense cloud) and the center of the galaxy, Sgr A. In NGC 2024, they intend to take
deep broadband JHK images to complement existing broadband L' and narrowband 3.4 μm and 4 μm images to enable unambiguous separation of the effects of reddening from excess emission in order to ascertain the luminosity and intrinsic color of the embedded stars. The scientific goal is to construct the H-R diagram and the luminosity function for this presumably young cluster and (through modeling) ascertain its likely age. They will then take K-band grism spectra of selected areas to pursue the issues of excitation, gas density and distribution using the observed molecular hydrogen line ratios and the He, Br gamma, and [Fe III] line strengths. When combined with existing Br alpha and 3.28 μm fluorescent dust images, these spectra will produce a multi-component (molecular gas, ionized gas and dust) map of the interaction of this nascent cluster with its parent/parental cloud, unprecedented in scope and detail. With P. Conti, M. Hanson and I. Gatley, Merrill will be classifying the very young, high-mass OB stars, which are usually found buried in their birth clouds of dust and gas. By combining near-IR spectra with JHK colors to estimate temperatures and absolute magnitudes, H-R diagrams for these shrouded H II regions can be constructed. From this, they can probe the masses, ages and evolutionary states of massive and intermediate mass stars in these young regions.


Hillenbrand, L., Strom, S.E., Merrill, K.M., Gatley, I., ASP Conf. Series 35, Massive Stars: Their Lives in the ISM, ed. J.P. Cassinelli, p.141, "Identification of New Candidate Herbig Ae/Be Stars in Extremely Young Galactic Clusters: M8, M16, M17, M42, NGC2264"


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

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. Spectra of nearly 300 stars in M15 and M13 have been obtained. The analysis will help to resolve whether sodium enrichment occurs during the process of stellar evolution and how the globular clusters self-pollute during the formation and early evolution of the cluster. Pilachowski will also initiate a program to look for magnetic fields in metal poor giant stars that show evidence of surface activity.


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

R. Probst’s primary interest is in the construction and commissioning of infrared array cameras, and their application to problems of star formation. The early part of FY 1995 will see the first operation of the Cryogenic Optical Bench as a fully commissioned facility instrument. Probst will continue as Instrument Scientist for this and for the IR imager IRIM, overseeing instrument maintenance, installation, and improvements, and providing support for visiting scientific users. He will take advantage of an interlude in which he will not be a project scientist for a new instrument to explore the technical and scientific aspects of IR imaging at very high resolution (0.1 arcsec per pixel) and very low resolution (10 arcsec per pixel). Scientific targets of interest are the Galactic Center and star forming regions, for which a substantial body of data has been collected by the infrared group.


S. Ridgway — Infrared astronomy.

S. Ridgway will work with the staff of the Center for High Angular Resolution Astronomy (CHARA), (Georgia State U.), in planning and building the CHARA array, an optical/infrared interferometer consisting of seven 1-m aperture telescopes. He will also work on several small projects supporting the implementation of adaptive optics by NOAO.


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

A. Sarajedini’s 1995 research plan is focused on three distinct areas of stellar populations. The foundation of a substantial fraction of stellar populations work is the existence of precise photometry for the open and globular clusters of the Galaxy. These data provide a great deal of useful information about these systems, including their distances, luminosity functions, metallicities, and reddenings. The latter two quantities are especially easy to derive using a method he developed, which takes advantage of the sensitivity to metal abundance of the cluster red giant branch as photometered in the V and I passbands. He plans to extend this method to the Washington photometric system, which is even more metallicity sensitive; then, he will apply it to the dwarf elliptical companions of M31 in order to study abundance differences between the globular clusters and the background field. The second area on which he plans to concentrate is the investigation of the ages of stellar systems in the Local Group. The data will answer such questions as: is there an age difference between the Galactic halo and thick disk? Can differences in age account for the observed differences in horizontal branch morphology at a given metallicity? How do the ages of the Population II clusters in the Large and Small Magellanic Clouds and the dwarf spheroidal galaxies in the Local Group compare with those of Galactic globular clusters? Can the mean color of the red horizontal branch be used as an age indicator to probe the formation of the outer Galactic halo? Finally, he also has an extensive program to study blue straggler stars in open and globular clusters. This involves the construction of the first photometrically complete luminosity functions for these populations in order to study their formation and evolution. In addition, since one of the theories of blue straggler formation involves mass transfer in a binary system, he has begun a search for photometric variables among the blue stragglers in a number of clusters.

Bailyn, C. D., Rubenstein, E., Sarajedini, A., Mendez, R., Structure and Dynamics of Globular Clusters, ASP Conf. Series 50, p.227, "Ground-Based Photometry of Nearby Cluster Cores"


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.
During FY 1995, D. Silva will be working on several projects. First, in collaboration with Richard Elston (NOAO/CTIO), Silva will be working on reducing and analyzing high quality radial color gradient data for the twelve brightest Virgo ellipticals. This project's goal is to establish the presence or absence of near-IR color gradients, to show how that correlates with the magnitude of optical color gradients, and to determine whether optical/near-IR color gradients can be attributed to a single astrophysical parameter, i.e. metallicity. Their initial study, published in the 20 June 1994 ApJ, suggests the answer is "no" but better data are needed. Their FY 1995 goal is to analyze and publish their Virgo data. Second, Elston and Silva will continue their effort to study the resolved stellar populations near and above the giant branch in nearby stellar systems. The chief goal of this project is to establish directly the presence or absence of intermediate-age AGB stars. During FY 1995, they hope to obtain JHK images with subarcsec resolution for several nearby ellipticals as well as a sample of M31 globulars. Third, Greg Bothun (U. of Oregon) and Silva will continue their JHK imaging survey of elliptical galaxies. Again, their main goal is to establish indirectly the presence or absence of intermediate-age AGB stars. In their initial sample of 30 ellipticals, almost a third show signs of such a population. Fourth, Silva and Mike Pierce (Indiana) will begin the spectroscopic followup to 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. During FY 1995, they will publish their imaging results for CL0939+4713 and C10024+1630 in parallel with the acquisition of medium resolution spectra with the Hydra Multi-fiber Spectrograph at the WIYN 3.5-m telescope.


S. Veilleux – Active galaxies.


Veilleux, S., PASP, 105, p.1038, "The Line-Emitting Gas in Active Galaxies: A Probe of the Nuclear Engine"


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.

L. Wallace's first research project is the identification of the features in the sunspot spectrum 8-21 μm as seen with the solar FTS. This project is being completed with the collaboration with P. Bernath (U. of Waterloo). The analysis of the silicon monoxide spectrum has been extended to include the majority of the features in the short wavelength band 8.0-9.5 μm plus additional features out to 11.1 μm. Except for a few OH lines, we have now determined by comparison with laboratory spectra that the long wavelength part of the spectrum 10-20 μm is mostly made up of water vapor rotational lines. These lines involve higher energy levels, which are not observed under ordinary conditions. A second program is the production, with K. Hinkle (KPNO), of an atlas of the spectrum of Arcturus 1-5 μm obtained with the 4-m FTS at extreme Doppler shifts (January/February and June/July). We are combining the observations with atmospheric absorption spectra obtained from the Solar FTS by W. Livingston (NSO) and from lunar spectra to produce a clean Arcturus spectrum corrected for atmospheric absorption. We have now completed the work on five sections of the spectrum 1.12-4.95 μm. The final two sections 0.90-1.12 μm and 4.95-5.35 μm should be completed in the summer of 1994.


Wallace, L., Hinkle, K., Livingston, W., NSO Tech. Report #93-001, "An Atlas of the Photospheric Spectrum from 8900 to 13600 cm⁻¹ (7350 to 11230 Angstroms)"

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.

In FY 1995, M. Wise will continue his study of the intracluster medium (ICM) in clusters of galaxies. Working in collaboration with C. Sarazin (U. of Virginia), Wise has developed detailed models for the X-ray spectra from these objects including the effects of radiative transfer due to cold material in the cooling cores. Wise and Sarazin will use these models to analyze and interpret X-ray spectra and images obtained with the ASCA and ROSAT missions in an attempt to determine the physical state of the ICM in clusters and the ultimate fate of the cooling material. In addition, Wise will continue an ongoing investigation of polarized optical 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. Tracing the cooling history of gas in the centers of clusters is also the focus of a planned program using the upcoming joint US-European ISO infrared mission. Wise, B. McNamara (Center for Astrophys.), D. Silva (KPNO), and R. Elston (CTIO) plan to obtain far-infrared images and spectra using ISO in order to search for signatures of cooling material in clusters such as coronal line emission and cold dust. A similar program with ISO is also anticipated to study the ISM in elliptical galaxies. This project will supplement an ongoing project with C. Sarazin (U. of Virginia) to investigate the nature of the interstellar medium (ISM) in nearby bright
ellipticals using ROSAT X-ray imaging data. Finally, Wise and D. Silva (KPNO) will continue to study
the effects of dust on the broad-band color properties in ellipticals. By quantifying the changes that dust
produces in the emergent color properties of ellipticals, Wise and Silva hope to provide observers with
a tool to aid in interpreting observations of these objects.

Emission from the Intracluster Medium"

Cooling Flows"

Optically Thin Models"

Wise, M.W., Sarazin, C.L., The Evolution of Galaxies and their Environment, ed. D. Hollenbach,
H. Thronson, J.M. Shull, p.271, "X-ray Opacity in Cluster Cooling Flows"
APPENDIX 3
National Solar Observatory

Scientific Staff: Primary fields of interest and 1993 publications.

R. Altrock – Studies of the long- and short-term variation of the solar corona.

R. Altrock will work on solar-cycle studies of the solar corona, using data from the Sac Peak 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 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 flux and their relationship to other global solar parameters will be performed. ELCP data will be searched for transients and correlations with chromospheric, upper-corona (from space-based instruments), and possibly solar-wind and geomagnetic data. Studies of coronal mass ejections will begin with data from the full-limb, "One-Shot" coronagraph after modifications to add a CCD camera are complete. Altrock 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). An investigation of the spatial and temporal variations of coronal temperature will be done. Correlations will be performed on East-limb ELCP Ca XV intensities and flare intensities of associated active regions during their disk passages.

Altrock, R.C., First SOHO Workshop, ed. Clare Mattock, (ESA), p.83, "Ground-Based Coronagraphic Observations of Solar Streamers"


K. Bachmann – Study of solar p-mode oscillations.

K. Bachmann is a member of the team that regularly collects and analyzes High-L Helioseismology (HLH) data (Bachmann, Duvall, Harvey, and Hill). He is working to finalize frequency results for 1 < 1200 from the 22-25 June 1993 images. They have proposed to collect 25 consecutive days of images in June 1994 and to perform frequency, splitting, amplitude, and linewidth analyses. They continue to operate the HLH instrument four days every four weeks in order to monitor high degree solar oscillation frequencies with time. Bachmann has begun working with C. Lindsey and D. Gezari (Goddard Space Flight Ctr.) on long-
wave IR imaging of the Sun with a segmented detector. They collected a several-hour sequence of 12.4 μm images of a sunspot region on 24 February 1994. Bachmann is currently analyzing these data to attempt to detect p-mode oscillations at long wavelengths and to learn more about sunspot structure. He continues to analyze HAO/NSO Fourier Tachometer data. He has transferred the complete 1984-1990 dataset onto four exabyte tapes in IRAF format. Bachmann intends to analyze these data using GRASP and to derive frequencies, splittings, and linewidths for comparison with Big Bear results. He is working with M. Brodsky and P. Stark (U. of California, Berkeley) to test their scheme of performing helioseismic inversions directly from oscillation time series without the necessity of first deriving frequency splittings. He intends to acquire recent data on daily solar activity in order to continue his studies on hysteresis among solar activity indicators. He awaits the availability of these indicators through the decline of solar cycle 23.


**K.S. Balasubramaniam – Solar activity evolution, Stokes polarimetry.**

K. Balasubramaniam will analyze data acquired during the past maximum observational data campaigns to seek velocity and magnetic field characteristics of active-region evolution in support of the solar activity modeling initiative. This includes data obtained with the Narrow Band Filter (UBF+FP) and the Advanced Stokes Polarimeter.


**D. Braun – Helioseismology.**

D. Braun will continue his NSF- and NASA-sponsored research into the scattering of solar p-modes from sunspots and subsurface magnetic fields. Using observations obtained from the geographic south pole in 1988 and 1991 as well as the planned 1994 observing run of S. Jefferies, T. Duvall, and J. Harvey, Braun intends to measure the scattering properties (absorption, phase shifts and mode-mixing) from a wide variety of active regions. Of special interest is to verify a signature of p-mode scattering from sunspots prior to their emergence on the solar surface, which has recently been observed for one such evolving region in the 1988 dataset. In addition, Braun will continue to collaborate with D.Y. Chou (Tsing Hua U., Taiwan) on phenomenological modeling of the observed p-mode scattering from which they hope to deduce the subsurface morphology and scattering strength of sunspots.


S. D'Silva – Mhd studies of the structure and evolution of magnetic fields inside the solar convection zone.

The theory of the dynamics of magnetic flux tubes in the convection zone has been successful in describing most of the magnetic features we see on the solar surface, such as the tilts of sunspot pairs and their rotation velocities. However, the explanation of plages and ephemeral regions, which are also believed to emerge from the base of the convection zone, remains elusive. S. D'Silva's interest in this field will be in trying to understand the intriguing behavior exhibited by plages and generating a unified scheme of flux tube dynamics, which can explain the observed behavior of plages, sunspots and ephemeral regions, and which will (hopefully) cope with new observations. Understanding the subsurface structure of these magnetic features and the velocity fields in the convection zone will aid this pursuit, and in this direction, "time-distance helioseismology" seems to be a potential tool. D'Silva will be involved in exploiting this tool to aid our attempts to understand the subsurface structure and dynamics of magnetic fields.


R. Dunn – Image restoration, instrumentation.

R. Dunn plans to work on the adaptive optics program all of next year.


T. Duvall – The study of the interior of the Sun via helioseismology.

T. Duvall will be working on several projects: (1) An expedition to Antarctica to obtain helioseismology data, (2) extending our understanding of the time-distance diagram of helioseismology through analysis of data, (3) analyzing the data from the high-degree helioseismometer, and (4) analyzing data from the new Antarctic experiment.


Y. Fan - Solar MHD; dynamics and structure of active region flux tubes.

Y. Fan will continue her work on the theoretical modeling of the emergence and structure of subsurface active-region flux tubes. She carries out this work in collaboration with G. Fisher (Space Sciences Lab, U. of California, Berkeley) and A. McClymont (Inst. for Astronomy, U. of Hawaii). One focus of the research will be to improve upon the existing dynamic model, which assumes adiabatic evolution of the tube plasma, by introducing energy transport using the diffusion approximation to study the thermodynamic properties of the emerged tubes. This study will shed light on the cooling of active-region flux tubes after emergence and the subsequent evolution of the tubes beneath the surface. Fan will also continue her collaboration with R. Howard and G. Fisher in comparing the results of flux tube simulations with the observed data of active region and sunspot group properties.

M. Giampapa – Stellar dynamos and magnetic activity; asteroseismology.

M. Giampapa will implement a Ca II H and K survey of the solar-type stars in the open cluster M67 as a prelude to a larger program designed to investigate the nature of cycles in solar-type stars. The results of this broad, long-term program will yield a picture of the potential modes of the solar cycle as well as providing tests for theories of the solar dynamo. He plans to apply for time on the WIYN telescope and the Hydra/MOS (Multi-Object Spectrograph) in order to measure the levels of chromospheric Ca II H and K line emission in the solar-type stars in this cluster, which is similar in age and metallicity to our own Sun. In this way, we can learn the potential range of levels of chromospheric emission in solar-like stars. Following this project, he will explore ways to implement a long-term program at the WIYN telescope to measure cycles in the solar-type stars in this important cluster. Besides this program, Giampapa will initiate new programs at the McMath-Pierce solar-stellar spectrograph. In particular, he will acquire D_{3} spectra for a large number of F and G dwarfs for which he hopes to obtain 1083.0 nm spectra using the IRTF and cryogenic echelle at Mauna Kea. These data will be used to estimate active (plage-like) area coverages on F/G stars. Once the cross-dispersion project is completed, he will explore the feasibility of programs in stellar seismology. One key problem is to determine if solar oscillations can be seen with the system when the Sun is viewed as a star. This experiment will give insight into the advantages and problems of echelle spectroscopy for asteroseismology.


Y. Gu – Solar physics, computational physics, and numerical analysis.

Y. Gu’s research program for FY 1995 will concentrate on two subjects: one is stochastic radiative transfer in inhomogeneous media and the other is local helioseismology. He will also spend some time working on the general inverse problem of helioseismology.

J. Harvey – Solar magnetic and velocity fields; helioseismology; instrumentation.

J. Harvey will participate in a helioseismology observing run at the South Pole early in the fiscal year. This project, a collaboration between NSO, Bartol (S. Jefferies, A. Jones), and NASA (T. Duvall), is intended to obtain high-duty-cycle, long-duration observations of solar oscillations. These observations will complement those to be obtained with GONG and SOI by exploring high frequencies at two different heights in the solar atmosphere. Harvey will continue to work with his collaborators in reducing and analyzing the new data and previously obtained helioseismology data. He will also continue analysis of synoptic observations obtained at the Kitt Peak Vacuum Telescope. Emphasis will be on the times of the polar passages of Ulysses and on irradiance variation observations.


K. Harvey – *Emphemeral regions, active regions, coronal bright points, and magnetic fields.*

K. Harvey will continue her research in four areas: (1) Collaborative studies with the Soft X-ray Telescope on board Yohkoh. Of primary 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 based on the separation 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 and 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. (3) A project to estimate the contribution of ephemeral regions to the large-scale poloidal field and to determine more accurately the dependence of the tilt of the magnetic axis on latitude. (4) The study of the configurations and evolution of the large-scale magnetic field patterns that lead to the formation of filaments and filament channels.


Harvey, K.L., et al., in Adv. Space Res., 13, no. 9, p.27, "Lifetimes and Distribution of Coronal Bright Points Observed with Yohkoh"


F. Hill – *Helioseismology, the fluid dynamics of the solar convection zone, and the solar activity cycle.*

F. Hill plans to continue collecting data using the High-L Helioseismograph at the Kitt Peak VTT. In collaboration with researchers at the Astrophysical Institute of the Canaries, the University of Colorado, and the University of Cambridge, he will continue to develop methods 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 work with the SOI personnel to develop methods of measuring frequencies and splittings from high-degree power spectra. The SOI group will also continue to work on the effect of magnetic fields on observations of the solar oscillations.


**R. Howard** – *Observational study of surface magnetic and velocity fields as diagnostics of the sub-surface dynamo process in the Sun.*

R. Howard will continue his collaboration with 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 are now complete, and emphasis is shifting to analysis of the data. First studies will focus on the rotation and meridional motion of sunspots. Also Howard will continue his ONR-sponsored collaboration with R. Komm and J. Harvey in the analysis of Kitt Peak Vacuum Telescope data. Y. Fan has joined this group as a post-doctoral fellow and is participating in studies of surface dynamics of solar active regions. 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. Also the emphasis will shift somewhat to the subsurface dynamics of magnetic flux tubes. 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 S. D'Silva. Work next year will continue to emphasize the separation of magnetic polarities in regions and region tilt angles as parameters of activity and dynamic behavior.


Howard, R.F., IAU Colloquium, 141, eds. H. Zirin, Q. Ai, H. Wang, (Kluwer) "The Development of Sunspot Groups"


Howard, R.F., Solar Phys., 147, p.1, "Some Factors Affecting the Growth and Decay of Plages"


S. Jefferies – Helioseismology and image restoration.

S. Jefferies' main research in FY 1995 will be to reduce and analyze the helioseismic data that will be obtained during November 1994 – February 1995. These data will allow us to determine 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 subsurface structures of magnetic features. The iterative, blind deconvolution image restoration algorithm that he has developed has been very successful, both for helioseismic work and general astronomical imaging problems. He plans to extend the algorithm for use with non-isoplanatic point spread functions. This work will be
computationally expensive and will require the use of a parallel computer (e.g. the Paragon at SDSC).


A. Jones — Helio- and asteroseismology from the ground and space.

A. Jones, together with S. Jefferies, J. Harvey, and T. Duvall, is working on an instrument to measure both resolved intensity and velocity images of the Sun. This experiment will be taken to the South Pole for the Austral Summer 1994 – 1995. It is hoped that these measurements will resolve the issue of the nature of the oscillations seen by various groups above the solar acoustic cutoff, as well as providing observations of p-modes at another point in the solar activity cycle. In order to analyze the large amount of data from this and previous South Pole expeditions, we will further develop our restoration and fitting software. So that the data can be reduced in a reasonable amount of time, this code will be implemented in a parallel system comprising several workstations connected by ethernet. Jones also plans to explore the possibility of sharing a polar balloon flight to study solar-like oscillations on other bright stars, with α Cen being a prime candidate.

H. Jones — Structure, evolution, and measurement of solar magnetic fields.
H. Jones will apply new models of the formation of the He I triplet series resonance line at 1083.0 nm as developed with V. Andretta to interpreting spectromagnetograph and rocket EUV observations of the solar chromosphere and transition region. In collaboration with M. Wills, an REU summer student, Jones will investigate use of the multi-dimensional spectromagnetograph data to understand the origins of variations in bolometric solar irradiance. Jones will pursue development of joint NSO/KP and SOHO observational programs to model the chromosphere and transition region. Jones will also participate in the joint NASA/NSO instrumentation program for the NSO/KP Vacuum Telescope, which includes initial observations with a new 1083.0 nm video filtergraph and magnetograph and installation of a CCD-based guider and image-motion compensator.


Jones, H.P., IAU Colloquium, 141, eds. H. Zirin, Q. Ai, H. Wang, (Kluwer) "Spectrometer-Based Magnetographs"

Thompson, W.T., et al., Solar Phys., 147, p.29, "Correlation of He II Lyman Alpha with He I 10830 Å, and with Chromospheric and EUV Coronal Emission"


S. Keil is a co-investigator on the Flare Genesis experiment which is a joint APL/USAF program to fly an 80-cm telescope with a vector magnetograph on a balloon in Antarctica. The flight is currently scheduled for a 10 December 1994 launch. Keil and Wiborg (USAF staff at NSO/SP) are involved in writing an autonomous observing program that will run the scientific observing sequences, since the payload is out of contact with the ground during most of the flight. They are also implementing the data collection system. The goal of the experiment is to obtain measurements of the vector magnetic field uncontaminated by seeing. If successful, the mission will produce time sequences of the highest resolution magnetic images of the Sun ever obtained and could reveal the nature of magnetic flux tubes on the Sun. Keil, in collaboration with K. Balasubramaniam (NSO), Z. Mikic and D. Schnack (SAIC), and G. van Hoven (U. of California, Irvine), will use data on active-region evolution collected during the previous solar maximum to analyze and model pre-activity dynamics with a goal of developing predictive algorithms. Data consist of high-resolution magnetograms, vertical and horizontal velocities, and intensity fluctuations at several heights in the solar atmosphere.


C. Keller – The study of small-scale magnetic and non-magnetic phenomena in the solar atmosphere.

C. Keller will continue to use the McMath-Pierce telescope to record high spatial resolution images of the Sun by using speckle interferometric techniques. These observations should provide more information on bright points and shock waves in the solar granulation. In collaboration with J. Harvey, the Zürich Imaging Stokes Polarimeter I will be used to study the physical properties of non-network fields. These weak fields can only be studied with the large NSO telescopes and a very sensitive polarimeter. In collaboration with the Swiss Federal Institute of Technology in Zürich, the three-dimensional photon detector SHBD and the Zürich Imaging Stokes Polarimeter II will be developed.

R. Komm – Rotation, large-scale magnetic and velocity fields.


J. Kuhn – Helioseismology, infrared solar physics, instrumentation, astrophysics.

J. Kuhn expects to complete the breadboard RISE/PSPT instrument this year. The recently finished HgCdTe IR system will be used in an externally funded eclipse experiment designed to obtain the first coronal IR spectrum. IR experiments will be completed at the Evans Solar Facility to measure coronal magnetic fields. Instrumentation at NSO/SP should be completed during the next year that will allow narrow-band IR imaging. Models of irradiance changes, driven by entropy perturbations at the base of the solar convection zone, will be investigated. Further investigations of the diffuse light in galaxy clusters will be pursued with nighttime colleagues.


J. Leibacher – Helioseismology and atmospheric dynamics.

J. Leibacher will be devoting the majority of his efforts to assuring GONG’s technical and scientific
success. He will also continue work on techniques of time series analysis and--hopefully--return to work on chromospheric oscillations, as seen for example in Helium 10830. In addition, as time permits, ideas on the observational signature of the convective excitation of p-mode oscillations and the detection of gravity modes will be pursued.


C. Lindsey – Local heliosismology, infrared solar physics.

C. Lindsey, S. Jefferies and D. Braun are working on a project to explore the prospect of using p-modes to detect subsurface magnetic structure. The general concept is called 'local helioseismology.' The particular goal of this project is to develop techniques in computational holography that will allow us to extrapolate the acoustic field observed at the solar surface into the interior. They are using the NSO-Bartol-NASA South Pole Observations of 1987, 1988 and 1990 as their main database. They have made a detailed survey of acoustic power maps of the 1987 and 1988 data in selected acoustic passbands and have seen surface features that suggest the occurrence of magnetic flux tubes crossing the equator to connect active regions in the southern and northern active-region bands. They also see strong acoustic signatures from emerging plages long before a strong manifestation is seen in the K-line. They are preparing a preliminary program of holographic computations to determine whether some of the features they are seeing are caused by subsurface interactions.


D. Neidig – Solar activity (especially flares), flare optical spectral analysis, flare high-energy emissions, instrument development, and the development of solar flare prediction methods and algorithms.

D. Neidig is co-investigator on the USAF Space Weather And Terrestrial Hazards (SWATH) mission and, if the mission proceeds, will be heavily involved in mission planning and in assembly of the SWATH coronagraph. This 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 – Solar polarimetry, polarization optics and solar convection.

L. November is in the process of writing up and publishing a number of projects from several fields of interest which he has developed over the past five years. His goals for 1994-1995 are to submit the following: (1) "Depth of the Supergranular Horizontal Flow," (2) "Five-Minute Oscillation Spatial Diagnostics" reports power and phase spatial distributions made in velocity and intensity in a number of lines that span the range of heights from the deep photosphere to the middle chromosphere. The work reports a wealth of new observational results on the height variation of the wave amplitude in velocity and temperature, phase differences between temperature and velocity at one height, and phase differences between two heights, (3) "Multi-element Resonators" reports polarization properties in multi-element resonators, such as cavities for light states. These systems exhibit geometric properties naturally and exhibit analogies to general quantum mechanical systems, (4) "Polarization Inverse Problems" provides a powerful formalism for defining general conditions for recovery of intermediate elements in serial optical systems, and (5) "Solid-state Magnetic-field Measurements with Liquid Cystals" has as its goal the development of an imaging magnetograph based upon a liquid-crystal polarimeter.


M. Penn – The study of the corona and sunspot oscillations.

M. Penn is working with J. Kuhn on a study of the IR spectrum of the solar corona. Studies include the line ratios of two Fe XIII emission lines at 1080 nm, a study of the polarization of one of these Fe XIII lines, and a search for new emission lines from 1000 to 2400 nm. Along these lines, Penn and Kuhn are planning an experiment to be run during the total eclipse on 3 Nov 1994 in Chile. Penn is planning to observe the Jupiter/SL9 comet encounter in July, with J. Luu and J. Kuhn as collaborators, to look for intensity and velocity oscillations caused by the comet impact. Also, with J. Arnaud, he will investigate the weak magnetic fields of the Sun during the annular eclipse of 10 May 1994 from Sac Peak. Finally, Kuhn and Penn are looking at the coronal magnetic field in prominences and will search for oscillations in the magnetic fields in sunspots.

**D. Rabin – Magnetic fields and infrared solar physics.**

D. Rabin will continue to study the structure of the magnetic field in the deep photosphere using the Near Infrared Magnetograph (NIM). The scientific goals of this project include characterizing the spatial and statistical properties of flux tubes and measuring the vector magnetic field in and around sunspots. Specific experiments will include simultaneous 1.6 μm and 12 μm magnetometry (in collaboration with D. Deming) and an attempt to measure inter-network fields using a beamsplitter in the NIM optical path (with C. Keller). During 1995, initial data are also expected from NIM-2, an imaging magnetograph based on a Fabry-Perot filter. With several collaborators, Rabin will study thermal inhomogeneity and oscillations in the temperature minimum region using vibration-rotation lines of carbon monoxide near 4.7 μm.


**R. Radick – High-resolution solar imaging and interferometry; solar and stellar variability.**

R. Radick will be involved in the development of a second generation solar image tracker ("tip-tilt corrector") for use at NSO telescopes. Options to be evaluated include re-engineering the current digital correlator using modern components, purchasing a copy of a solar image tracking system currently being developed by IAC/KIS, and adapting optical correlation technology for solar applications. He will continue his studies of solar and stellar variability, focusing on the long (greater than 10-year) time series observations of variability among solar analog stars now available, and evaluating the impact of these stellar observations on our understanding of solar variability and its role in driving global change.


**G. Simon – Magnetic fields, convection, and oscillations.**

AFOSR Window-on-Europe funding will support G. Simon in new observations of long-lived solar convection flows at one US and two European observatories. This study will employ a revolutionary new image tracking and selection system being built with funds provided by the Spanish and German governments. This instrument is designed to compensate for solar image motions four times faster than current trackers, and will determine by real-time analysis of image quality the optimal moments to trigger exposures. Preliminary tests indicate that such an instrument can dramatically increase the number of high-quality images during an observing run. Vortex motions have been observed at the solar surface. Such twisting flows can build up stresses in magnetic field configurations, so that they become unstable, leading to sudden energy release in active regions. Simon will measure the geometric structure of such vortices and compare it with a potential field model that predicts the form of the vortex flows. Observations of the Sun's surface magnetic field indicate that it is completely replaced every two or three days. This occurs despite the absence of any marked change in the large-scale appearance of the field over many days or even weeks. How the Sun can have a quasi-static appearance while actually undergoing a complete and rapid transformation of its magnetic structure will be investigated by Simon, using kinematical modeling. Kinematic modeling will also be used to explain the diffusion of magnetic flux elements across the solar surface. This process affects both the decay and build-up of solar activity. On the one hand, the flow fields...
of supergranulation and mesogranulation convection cells concentrate small, isolated flux tubes into large, strong bundles (pores and sunspots). At the same time, these convective flows contribute to the breakup and decay of existing active regions. Simon will carry out an analysis of several unusually long time series of solar convection obtained in FY 1993 to determine the evolution of long-lived mesogranulation and supergranulation flow cells. Because of their length, these are the first data sets ever obtained that hold hope of determining the birth and death processes, the velocity structure, and the advection of these cells.


**R. Smartt** – *Studies in observational solar physics, primarily coronal physics; development of optical instrumentation, especially new-technology coronagraphs.*

R. Smartt will continue with the analysis of coronal loop interactions. Specifically, the relationship of the morphology of post-flare loops as observed in coronal line emission and in Hα will be investigated to provide more insight into details of the complex plasma processes involved in loop interactions. Comparison of these optical data with similar phenomena observed in soft X-rays will be attempted if joint data common to the same event can be obtained. Instrumentation will be developed and observations carried out at the 3 November 1994 total solar eclipse. Work will continue on the development of mirror-objective coronagraphs and, in particular, on the construction of the third, mirror-advanced coronagraph (MAC III) instrument. Work will also continue, if funds are available, on development of an engineering version of the SWATH coronagraph. With full funding, a flight instrument will be constructed and tested.

Smartt, R.N., Zhang, Z., ESA SP-348, First SOHO Workshop, ed. Clare Mattock, p.185, "Morphology of Coronal Loop Interactions"


Smartt, R.N., Koutchmy, S., in Segundo Congreso de Astronomia Solar, ed. J. Farah, p.152, "Recent Developments in Coronagraph Instrumentation"


**C. Toner** – *Global and local helioseismology, and image restoration.*

During FY 1995 the GONG network will become operational. C. Toner plans to work on testing the GONG data reduction pipeline to quantify any errors resulting from the data processing. He will use GONG data to develop local analysis techniques to investigate the interaction of p-modes with both
surface and sub-surface magnetic fields. Toner will use similar techniques to look for evidence for acoustic power deficits at the antipodes of solar active regions. In collaboration with the South Pole group, Toner will continue working on image restoration techniques, which can be used to correct solar images for both atmospheric and instrumental degradation.


**J. Zirker — Physics of the corona.**

J. Zirker plans to continue collaborating with S. Martin (Caltech) and her consortium on the formation, structure and dynamics of filaments. They intend to investigate the interesting global patterns she has found for the direction of the magnetic field in filaments. He also plans to continue collaboration with D. Neidig on observations of magnetic shear in active regions. They hope to supervise a summer student in 1994 to analyze some of the data sets they have in hand from the Vacuum Tower Telescope. An experiment at the November 1994 eclipse is designed to yield data on Doppler velocities as a function of temperature in the corona, which will be analyzed in FY 1995.


APPENDIX 4
NATIONAL OPTICAL ASTRONOMY OBSERVATORIES
USER STATISTICS\(^1\)
FY 1993

VISITOR TELESCOPE USAGE

<table>
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<tr>
<th></th>
<th>CTIO(^2)</th>
<th>KPNO(^3)</th>
<th>NSO(^4)</th>
<th>NOAO Totals</th>
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\(^1\) 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 1993, a total of 235 observing programs were carried out by visitors and the NOAO staff at Cerro Tololo. Visiting astronomers were assigned 83% of the scheduled telescope time and the remaining 17% was assigned to the staff.

\(^3\) During fiscal year 1993, a total of 296 observing programs were carried out by visitors and the NOAO staff at Kitt Peak. Visiting astronomers were assigned 81% of the scheduled telescope time and the remaining 19% was assigned to the staff.

\(^4\) During fiscal year 1993, a total of 141 observing programs were carried out by visitors and the NOAO staff at the National Solar Observatory. Visiting astronomers were assigned 48% of the scheduled telescope time and the remaining 52% was assigned to the staff.

VISITOR REDUCTION FACILITIES USAGE
FY 1993
NOAO Tucson*

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<tr>
<th>Number of Institutions</th>
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* 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 4
NATIONAL OPTICAL ASTRONOMY OBSERVATORIES
USER STATISTICS\(^1\)
FY 1993

VISITOR TELESCOPE USAGE

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VISITOR REDUCTION FACILITIES USAGE
FY 1993
NOAO Tucson*  

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### NSF FUNDING

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(In Full Time Equivalents)

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(1) FY-1994 Program Plan, Revision I
(2) Includes NSF Astronomy Division support of RISE
(3) Includes cost of early retirement incentives: $88k KPNO, $302k NSO
(4) Beginning in FY94, indirect costs recovered by the observatories are subsumed in observatory budgets.
### SUMMARY OF NSF FUNDING BY COST CATEGORY

(Amounts in Thousands)

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(In Full Time Equivalents)

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### NOAO FY-1995 Provisional Program Plan

**TABLE III**

**SCIENTIFIC STAFF & SUPPORT**

(Amounts in Thousands)

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**STAFFING SCHEDULE**

(In Full Time Equivalents)

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### INSTRUMENTATION
(Amounts in Thousands)

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(In Full Time Equivalents)

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### NOAO FY-1995 Provisional Program Plan

#### TABLE V

**OPERATIONS & MAINTENANCE BY COST CATEGORY**

(Amounts in Thousands)

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<th>Total FY-1994</th>
<th>Total FY-1993</th>
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#### STAFFING SCHEDULE

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TABLE VI

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(Amounts in Thousands)

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<th>Total FY-1994</th>
<th>Total FY-1993</th>
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</thead>
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<tr>
<td>Engineering &amp; Technical Services</td>
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<td>1,041</td>
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<td>(32)</td>
<td></td>
<td></td>
<td>(562)</td>
<td>(562)</td>
<td>(631)</td>
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STAFFING SCHEDULE
(In Full Time Equivalents)

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<th></th>
<th>CTIO</th>
<th>KPNO</th>
<th>Sunspot</th>
<th>Tucson</th>
<th>Central Offices</th>
<th>Total FY-1995</th>
<th>Total FY-1994</th>
<th>Total FY-1993</th>
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<td>Engineering &amp; Technical Services</td>
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<td>302.48</td>
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1 Includes support for all Directors' offices (NOAO, KPNO, CTIO, NSO), all non-payroll funds held by Directors and not yet allocated to specific programs; recruitment and relocation, insurance, central administrative services, freight to Chile, committee and observer travel support. Budget in 1993 unusually low because of recovery of Gemini salaries charged originally to NOAO. Remaining increases result from change in policy to return overhead to divisions rather than using it to offset administrative costs.
### TABLE VII

**NON-NSF FUNDING**
(Amounts in Thousands)

<table>
<thead>
<tr>
<th></th>
<th>CTIO</th>
<th>KPNO</th>
<th>Sunspot</th>
<th>Tucson</th>
<th>Central Offices</th>
<th>Total FY-1995</th>
<th>Total FY-1994</th>
<th>Total FY-1993</th>
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<tbody>
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<td>Personnel Costs</td>
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### STAFFING SCHEDULE
(In Full Time Equivalents)

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</tr>
</thead>
<tbody>
<tr>
<td>Scientists</td>
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