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1. Introduction and Overview

The WIYN Observatory is owned and operated by the WIYN Consortium, which consists of the University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatories (NOAO). NOAO is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.

1.1 WIYN's Mission

The WIYN Mission is to learn about the Universe through forefront research programs in observational astronomy. The implications of this Mission are that we must:

1. Operate, maintain and enhance the WIYN Observatory, including the development of innovative operational modes and instruments to support diverse research and educational opportunities.
2. Communicate the excitement of scientific research and the exploration of the Universe to wider communities.
3. Develop new capabilities for astronomical research.

At the same time, the WIYN Telescope serves different functions for different partners. For example, at NOAO it is one of a large complement of telescopes maintained for competitive access by astronomers. For Universities it is a combination of an educational and research tool that looms large as a primary astronomical facility. All of the partners are united in their desire to see WIYN continue to perform at a world-class level.

1.2 What is the WIYN Observatory?

The WIYN Telescope, a 3.5-meter instrument employing many technological breakthroughs, is the newest and second largest telescope on Kitt Peak. The Universities provided most of the capital costs of the observatory, which amounted to $14 million, while NOAO provided the primary mirror, its support system, and the site for the telescope. Ongoing operations are provided mostly by NOAO, with additional cash contributions by the Universities. The yearly operating budget currently amounts to $1.3 million. This partnership between public and private Universities and NOAO is the first of its kind. The Universities benefit from access to a well-run observatory at an excellent site, and the larger astronomical community served by NOAO benefits from the addition of this moderate aperture, state-of-the-art telescope to Kitt Peak's array of telescopes. The innovations that have gone into the design, testing, and construction of the new 3.5-meter WIYN telescope make it one of the most powerful telescopes in its class. New moderate aperture telescopes such as WIYN will be valuable tools both as primary research facilities and in support of the much more expensive 8-10 meter telescopes now under construction around the world as well as space-based telescopes.

A comparison of the WIYN telescope, completed in 1994, with the 4-meter Mayall telescope, completed in 1973, demonstrates how innovative technology can be applied to telescope design. The WIYN telescope enclosure is a fraction of the size of the Mayall telescope dome, due both to the short focal length of the primary mirror, which results in a shorter telescope, and the Altitude-Azimuth mount, which requires less space. The moving weight of the Mayall telescope is 375 tons, while the WIYN telescope, with a primary mirror only slightly smaller in diameter, weighs only 46 tons. The smaller structure reduces the cost of the facility, and modern technology continually improves performance.

The mirrors in the WIYN telescope are capable of producing much sharper images than the larger 4-meter Mayall mirror. The WIYN mount, optics, thermal controls and enclosure are all designed to minimize degradation of the telescope image quality by the local environment. Other innovative features incorporated into the WIYN telescope design are active primary mirror supports, primary mirror thermal controls, and active ventilation of the telescope mount and enclosure. The support system for the primary mirror includes 66 actuators, which push or pull on the back face of the mirror to maintain the best optical figure. The primary mirror thermal control system can maintain the temperature of the surface of the mirror to within 0.2 C of the desired temperature, typically 0.5 C below ambient air temperature, eliminating mirror seeing, which is caused by turbulence in cool air over a warmer mirror surface. An open telescope chamber maintains the entire observatory at the nighttime air temperature. Optical tests indicate that all of these innovations in design have enabled the WIYN telescope to produce the highest quality images of any telescope in the continental United States.

During the past five years, WIYN has made the transition from a construction to an operations phase and the attention of the WIYN Consortium has turned in part to planning for the future, and especially for new generations of instruments. However, as we entered into this process it became clear that we needed a better understanding of what vision we, the Partners of WIYN, have for this facility. As a consortium, the WIYN partnership also faces challenges; for example, how best to achieve a consensus to start along any particular path towards providing new capabilities and how to raise the necessary funds. We decided therefore to develop a strategic plan to help guide our development and held two Strategic Retreats in 1997 to provide a forum for the discussion of WIYN planning issues and the drafting of a mission statement.

1.3 Current Successes of WIYN

Although the WIYN Telescope has not been in operation for very long, it has already achieved substantial successes - some highlights follow:

1.3.1 Telescope and Instrument Performance:

WIYN produces the best wide field images of any telescope in operation on the North American continent. The HYDRA multi-object spectrograph continues to be an effective instrument for a range of programs requiring spectra of multiple objects over a 1 degree patch of the sky. The DensePak fiber array provides an example of an instrument originally developed by two partners that is now a WIYN General Use instrument. It is opening a new era of imaging spectroscopy. University instruments such as HPOL (a spectrograph that measures the spectrum and polarization of astronomical objects—Wisconsin), a coronograph (to detect faint objects next to bright ones—Indiana), and a speckle interferometer (obtains diffraction-limited angular resolution for measuring binary star pairs—Yale) are adding specialized capabilities.

During the first years of WIYNs operation, we were plagued by poor pointing performance, an inability to maintain accurate focus and greater than acceptable down time. The WIYN Board of Directors responded to these problems by allocating a two-year increment in the operating budget and subsequently by approving the appointment of a Site Engineer. The combination of these additional resources has enabled us to solve the pointing problems, develop a sensor and computer algorithm to accurately track the telescope focus, damp undesirable oscillations in the secondary mirror and reduce the down time to a value that is competitive with the best telescopes. The WIYN Board then approved a permanent increase in the operating budget so that we would be able to maintain our high level of performance, continue to deal with existing problems and begin evolutionary upgrades to the instruments and the telescope.

Our Operations Manager has done an outstanding job of coordinating resources, managing personnel, solving problems and advocating improvement programs for the effective operation of the telescope.

1.3.2 Operational Modes:

WIYN has provided a platform for experimentation with new observing styles. NOAO has run an observing “queue” for its users. In this system astronomers request certain observations which are then carried out in an optimized way by NOAO staff; the Universities are also using informal queue observing for a part of their time. Remote observing is being used by the Universities as a means to make time-dependent observations, share nights, reduce travel costs and enable graduate students to experiment with small independent research projects. Finally, a Data-Archiving System has been developed to provide a central archive for all WIYN observations, as well as a means for distribution of the observations to the observers.

1.3.3 Collaborative Research:

The WIYN Open Cluster Study (WOCS) program has the goal of accurately determining the physical characteristics of a set of fundamental open clusters that span a range of ages and metallicities. Observations are currently being made to determine the membership in the clusters using the stellar proper motions; photometric investigations are defining the main-sequences of the clusters to very faint magnitudes; spectroscopic observations yield the metallicities of the stars;

radial velocities are being used to study the fraction of binaries in the clusters; and theoretical stellar isochrones are fit to the color-magnitude diagrams of cluster members to determine the ages of the clusters. Finally, the data are being consolidated into a database that will be available to the astronomical community. This Consortium-wide program has led to extensive collaborations between the astronomers and students at the different institutions and fostered more unity among the partners.

1.4 Current Problems at WIYN

1.4.1. Management Structure

From WIYNs inception, through its design, construction and first five years of operation, the Scientific Advisory Committee (SAC) has played the executive role for observatory management, with the SAC Chair evolving into the Chief Operating Officer of the Observatory. This approach has worked fairly well, in part due to the extraordinarily good relations that we have been able to maintain among our partners. In spite of this, we have identified serious inefficiencies and problems that arise from not having a full-time Observatory Director, since SAC members do not have time to adequately supervise and lead the many Observatory activities. Therefore, the WIYN Board allocated resources to hire a full-time WIYN Director and a search is in progress. Once the Director is in place the role of the SAC will be redefined so that it acts in an advisory capacity.

1.4.2. Operational Budget

WIYN was conceived as a minimum cost facility to meet the needs of its members for access to a moderate-aperture telescope. We have learned through experience that the initial concept has imposed serious constraints on our ability to place the telescope in operation, and operate it in an environment with minimal support. Through the combined efforts of the SAC and the Board, the staffing and operating budget have been increased to a level that is nearly commensurate with similar sized observatories. At the present time we operate at a lean, but satisfactory level. Our outstanding problem is dealt with in the following section, where we address the difficulties in obtaining new instrumentation for WIYN.

1.4.3. Instrumentation

WIYN was founded with neither an instrumentation budget nor an account that could be used to support cost sharing for instrumentation proposals to the NSF. During the last year, the Board established a fund that will help defray instrument proposal preparation costs, but for major-instrument development, including cost sharing for external proposals, it is necessary to ask the Institutions for an additional funding commitment each time. This is a serious barrier to moving ahead with initiatives.

A process for defining and assessing new general-purpose instruments for WIYN exists, and is centered on the SAC. The procedure involves a solicitation by the SAC to WIYN members for Letters of Intent to propose a WIYN instrument by a specified date. On receipt of the Letters, the proposers are advised of a date by which “pre-proposals” are due. That proposal must describe the science to be investigated, provide a general description of the instrument and its components and give cost estimates to build and place it into operation. Following receipt of the pre-proposals, a meeting of WIYN members is called where each proposer makes an oral presentation in support of the instrument. An organized discussion among the WIYN members attending the meeting follows with the goal of obtaining a consensus ranking of the instruments. The proposers of the highest ranked instruments are then requested to prepare a complete proposal and present it to the SAC for a thorough review at least one month in advance of submission to the prospective funding agency. Finally, the WIYN Board of Directors is asked to evaluate the SACs recommendation and must approve the proposals submission to the funding agency. In practice, WIYN Board approval has been sought before the proposal is complete in order to expedite its submission.

This procedure has worked reasonably well and has enabled us to build a consensus among WIYN members concerning the direction of instrumentation development for the WIYN telescope, however problems in its implementation have been identified and we are working to solve them. Specifically, we have found that it is crucial to actively encourage open communication between the proposers, the SAC and Consortium members with respect to the scientific justification and progress with the instrument design and costing. Based on our experience with this procedure, we feel that a WIYN Observatory Director would be able to be of considerable help here by providing guidance to the proposers and ensuring that full communication is maintained.

Two instrument proposals have been submitted to the NSF. The first was for a “Tip-Tilt Module” for image-motion compensation on the WIYN imaging port. The preparation of this proposal was a difficult learning experience for WIYN that we would not like to repeat. The principal problems encountered included: 1) writing a well-balanced scientific justification for the proposal that reflected the goals of the Consortium members, and 2) not having adequate resources to prepare an instrument design and an accurate cost model. As mentioned above, if we had had a Director, the writing process would have been better coordinated and the full-time oversight might have led to the identification of the inadequate nature of the cost model. Unfortunately, the proposal was rejected by the NSF MRI program. Since all parties in the WIYN Consortium were strongly in favor of the instrument, our existing resources were redistributed and NOAO increased their contributions to the instrument so that we could move ahead with its design and construction and we are anticipating first light with the Tip-Tilt system in 2001. A second proposal was prepared for a non-thermal Infrared detector system for the Hydra spectrograph and submitted to the NSF ATI program. The proposal preparation process ran into problems, again demonstrating the need for a Director, which we resolved by submitting the proposal through one of the Universities rather than as a Consortium. We expect to learn the results of the review of this proposal during the spring of 2000.

1.5 The Longer Term Vision for WIYN

In a decade we would wish for WIYN to be recognized as a world-class scientific facility having made outstanding contributions to specific areas of astronomy, and to have it operated with advanced technology instruments. We also need to have evolved into an organization with an effective and stable leadership and management structure.

1.6 Strategies to Meet the Future

A series of exercises have allowed us to define several key strategic priorities for WIYN and develop a strategic plan (included in the accompanying reference document):

1. Strengthen the administrative effectiveness of WIYN. We are establishing a clearly defined administrative system with the addition of an executive director position. The current organization is well suited for the operation of a stable organization, but not for one where there is a need to evolve in order to meet the challenges of competition and to take advantage of special funding opportunities.

2. Establish a well-defined process for WIYN instrument development:

   a. Build a wider understanding of the current process (instrument planning via the SAC) within the WIYN Consortium.
   b. Match people with interests in building instruments to projects.
   c. Clarify how WIYN obtains and commits resources to instruments.
   d. Implement a specific instrument development plan that will include new instruments for WIYN.

3. Seek to exploit targeted capabilities of the WIYN Observatory:

   a. Adopt the “doing what we do best” approach to defining areas of excellence for WIYN.
   b. Determine what our best capabilities really are.
   c. Continue optimizing the performance of the WIYN Telescope.
   d. Further perfect our innovative and flexible telescope-scheduling plan.
   e. Continue to enhance remote observing with WIYN.

4. Expand the horizons for WIYN to include new opportunities beyond the current telescope:

   a. Consider the potential for collaborative science programs.
   b. Examine benefits from joint efforts in education and public outreach.
   c. Evaluate trades of telescope time with Kitt Peak.

1.7 Conclusions

The WIYN Consortium members have successfully carried out the design and construction of a new high-technology telescope on schedule and to within 5% of the budget. During the first five years of its operation we dealt with the remaining technical problems and the telescope now meets all of its design goals. Furthermore, the operational performance of the observatory, both facilities and staff, is superb, and can be maintained with the recent augmentation of the operations budget. The partners have developed wide-ranging and exciting research programs. Several problems remain to be solved in the coming years. We must complete the hiring of a full-time director, establish workable procedures and funding sources to build state-of-the-art instruments and upgrades to the telescope, and find a productive and exciting role for the WIYN 3.5-meter telescope in the world of 8- and 10-meter giant telescopes. We look forward to an in-depth evaluation and suggestions from the Review Committee that will help us to solve these problems.

1.8 Resources

In the sections that follow, we elaborate with more specifics about the state of the observatory in different areas: the telescope and its control system, the instrumentation currently available, operational and management issues, the scientific and educational effectiveness of the observatory, future development and some sense of how we compare with other similar facilities. An accompanying collection of Wiyn Observatory Reference Documents (WORD). supplements our material in even more detail, and contains several technical reports and papers about the telescope, its instruments, and projects that have sought to augment its usefulness. Most citations to materials made in this document can be found in the WORD. In addition to this summing up of the state of the WIYN Observatory, we invite the Committee to use other documentation that is available from our Biannual Board meetings and the WIYN Web site at http://www.noao.edu/wiyn.

2. Telescope and Control System

2.1 Philosophy and Drivers

2.1.1 Goals

The WIYN consortium identified excellent image quality over a wide field of view as an important goal for the WIYN telescope. Wide field imaging , as well as multi-object spectroscopy (as achieved with HYDRA) were seen as areas in which the WIYN telescope could have the greatest impact.

While the main purpose of the WIYN project was to provide a state of the art facility for astronomical research, the telescope has served as a test bed for new technology being developed as part of NOAO's 8-m Telescopes Project. The WIYN primary mirror supports and ventilation system are prototypes for the larger telescopes, and the active optics and distributed control systems were developed to gain experience applicable to the 8-m effort.

The cost of operating a telescope over its lifetime greatly exceeds the initial capital cost. Because operating budgets are tight, two strong goals of the telescope and enclosure design were high reliability and low maintenance requirements to maximize the science return.

2.1.2 Basic Telescope Design

The telescope benefitted from experience gained from the Astronomical Research Corporation 3.5-m telescope, having a compact altitude-azimuth design with rolling element bearings and friction drives. For simplicity, cost and operational ease, it was designed to have a single secondary and all instruments will share a common back-focus (except for the Modified Cassegrain port). The two Nasmyth foci are the principal instrument positions. The telescope has a wide field of view to maximize advances in fiber fed instrumentation and was designed to take advantage of excellent intrinsic seeing at the site.

Two additional foci were included in the design for future expansion: a folded-cassegrain port on the top side of the optical support structure (OSS) and a modified-cassegrain focus immediately below the primary mirror. The beam is directed to the folded-cassegrain focus by rotating the tertiary 90° about the primary optical axis from the Nasmyth positions. The tertiary folds out of the way to allow the beam to reach the modified cassegrain focus. The initial design of the telescope did not include instrument rotators for these foci.

2.1.3 Operating modes

A number of observing modes are employed at WIYN. NOAO supports survey and synoptic spectroscopic and imaging observations with service observing of queued programs. The universities split their time between on-site and remote observing. Both groups require the ability to rapidly switch programs to adjust to changing seeing, transparency and moonlight. They require the telescope to acquire objects quickly and to track accurately. The telescope and control system were designed to be versatile enough to handle these requirements without undue demands on the skill level and learning curve for the operators and observers.

2.1.4 Basic Control System Design

The WIYN control system was developed at the University of Wisconsin to provide interfaces at all levels including high precision positioning and tracking of the telescope, secondary mirror control, engineering data streams for control of the primary mirror support, thermal monitoring, focus control, diagnostics, software safety limits, providing a platform to support remote observing and a standardized interface for instrumentation. The control system was designed to be inexpensive to build and maintain and emphasizes the use of standard tools, portable implementations, and network friendliness. Several aspects of the control system architecture underlie a powerful remote observing capability, including multi-user access, bandwidth conservation, interoperability, and portability (WODC 02-31).

The WIYN control system is a highly distributed system with a centralized message hub, called a router. All other processes are clients of the router that connect to the router via TCP sockets. The clients send subscription lists to the router requesting specific message trafffic to receive. A unique protocol was developed for the WIYN control system.

The control system was designed to support multiple users simultaneously. Scientists, engineers, programmers, and students can connect to and disconnect from the system at will as long as access control requirements are met.

The initial control system hardware design sought to improve reliability by minimzing interconnections and modularity. In practice this made serviceability difficult, and reduced maintenance efficiency. Improvements were made, and an acceptable compromise was found.

2.2 As-Built Telescope Characteristics/Attributes

The WIYN telescope is a 3.5 meter Ritchey-Chrétien design altitude-azimuth mounted instrument utilizing a light-weight primary mirror. The primary is a borosilicate glass honeycomb spun cast mirror from the University of Arizona Steward Observatory Mirror Lab with a focal ratio of F/1.75. The secondary is a light-weighted Zerodur mirror 1.2 meters in diameter with a magnification of 3.59 producing an F/6.29 focal ratio. An elliptical light-weighted Zerodur tertiary directs the light to one of two Nasmyth foci or to a folded Cassegrain port (the various foci are described in section 3.2.1). The final figure and polish of the optics exceeded the initial design specifications. The surface quality of the primary mirror corresponds to a 0.025 waves RMS with a peak to valley of 0.33 waves. The secondary and tertiary mirrors were finished to the same high quality and the combined optical error budget was better than specification by perhaps a factor of two.

The primary mirror is thermally controlled using a closed air cooling plenum within the mirror cell structure with blowers and heat exchangers[2]. This system has proved successful in maintaining the mirror temperature to within approximately 0.2ºC of the desired temperature setpoint (typically 0.5ºC below the ambient air) throughout the night. The heat extracted from the mirror cooling system is conducted to a radiator located far from the telescope on the prevailing downwind side of the ridge as is the heat generated by other instruments, electronics, motors etc. The mirror cell, fork and telescope structure are actively ventilated by forcing ambient air through the interior cavities of the mount and upper truss structure. Parts of the telescope with a direct view of the night sky are covered with low IR emissivity tape to reduce over-cooling.

The telescope enclosure is designed to provide protection for the telescope while not contributing significantly to image degradation during operation. The WIYN enclosure is a compact octagonal design similar to that developed for the Magellan 6.5-meter telescopes. Among the reasons for choosing this type of enclosure was the favorable air flow stream lines demonstrated for the octagonal design. The rotating portion of the enclosure approximates a hemispherical dome with flat surfaces. The panels are insulated and covered with aluminized mylar to reduce solar heating and nighttime radiative cooling. One face of the octagonal structure and the flat top provide the shutter opening. Each of the remaining seven lower vertical walls can be opened by garage door-like panels. When vented in this manner a complete air exchange will occur in less than one minute with a wind velocity of 2 meters per second. The interior volume below the observing floor level is force air vented to the ducts that carry the air downwind of the facility. The control room adjacent to the telescope enclosure is located on the downwind side and is thermally isolated from the enclosure. Adequate insulation and the outside radiative properties keep the exterior close to ambient temperature. All of these features of the optics, structure, enclosure and surrounding environment have been implemented to minimize the seeing disturbances due to the observatory itself.

Another requirement to achieve good imaging with a light-weight mirror is the maintenance of mirror figure and optical alignment independent of telescope pointing. WIYN depends upon an active optics system which provides real-time collimation of the telescope and optical figure control of the primary mirror. The primary mirror cell uses an electro-hydraulic support system to float the mirror. The system employs 66 axial supports and 24 lateral supports to provide this float against gravity. The lateral supports apply forces when the telescope moves from zenith and keeps the position of the mirror relative to the cell fixed by closing the loop on four LVDT readouts (three axial and one lateral LVDT). The axial support unit sums forces from three sources, a passive support piston, a smaller compensator piston which allows passive gravity vector tuning and an actively controlled spring force. These forces are monitored by load cells in the actuators. The active spring force is small relative to the passive force and acts as a delta force to optimize the shape of the mirror.

The optimum mirror figure is determined from wavefront curvature measurements. In practice the measurement is decomposed into Zernike polynomials and the coma and focus terms extracted for processing. The mirror figure is determined through a 12th order matrix and the necessary corrective forces are applied. Generally, this is a two-step process of first correcting the errors in focus and coma and then correcting for astigmatism in the primary mirror. Trefoil and other modes can be corrected, but are generally dealt with when building the active force look-up tables. Usually, astigmatism is the only aberration of significance besides focus and coma.

The secondary mirror cell is attached to the telescope structure so that it can be pistoned for focus control and tipped for collimation. A de-centering of the secondary results in coma. Tilting the secondary also results in coma. If the secondary is pivoted about the “neutral point” behind the secondary the two effects cancel. A small amount of coma detected in a wave-front measurement can be corrected by tilting the secondary and the resulting de-centering corrected by introducing a small offset in the control system pointing algorithm.

The routine mode of operation depends on open-loop corrections by means of a force look-up table. These tables have been constructed as a function of elevation based on the required delta forces indicated by wave-front measurements. It has been found that the system is stable enough so that usually it is only necessary to carry out real-time measurements at the start of the night and depend upon the look-up tables during the night. The tables contain secondary tip-tilt and piston position information and primary mirror delta force vectors for optimal performance relative to an elevation angle of 80º in 10º steps. Interpolation is used for intermediate angles.

2.3 Performance Measures and Acceptance

2.3.1 Operations Readiness Review (December 1996)

The WIYN Project convened an Operations Readiness Review (ORR) panel in February 1996. All major technical aspects of the WIYN Observatory were reviewed. The panel commended the reviewers for their presentations and the WIYN Project (and associated groups) on the success of the Observatory. A final report of the ORR is included in the accompanying WORD (WODC-00-06-01).

The WIYN Operations Readiness Review had three main goals:

- review original project technical and scientific specifications vs the as-built telescope
- develop a complete list of open items and assign them to the responsible groups

- identify the highest priority items

In particular, the ORR panel was charged with developing a list of unmet scientific and technical specifications and goals originally approved by the SAC. The baseline specifications reviewed were contained in the documents entitled "Scientific & Technical Requirements" (WODC 00-01-05) and "Control System Requirements Document" (WODC 01-20-11).

The following conclusions were reached:

- The panel recommended that the WIYN Observatory be accepted as complete in all areas except for the Instrument Adapter Subsystem (IAS).
- The panel recognized the remarkable progress that has been made by the Project team in commissioning the WIYN Observatory. Within six months of starting science operations, the entire facility, instruments included, is performing at a level which puts it at the forefront of its class, enabling the science programs envisioned for WIYN when the project was created.
- The panel developed a list of items originally considered to be Project deliverables that are either incomplete or have not met their original specification at this time. Except for the IAS, the panel recommended that these items be accepted "as-is". Completion or improvement of these items should become the responsibility of the Operations group. Prioritization relative to other Operations tasks should be the responsibility of the Site Manager and subject to review by the SAC.
- The WIYN Project should not be officially terminated until the IAS is completed, as certified by the SAC. A schedule and budget for the completion of the IAS was presented to the WIYN SAC at their March 1996 meeting.
- The ORR panel developed a second list of items that should be addressed to maximize the potential of the WIYN Observatory in the following areas: safety, operations efficiency, maintenance, and scientific & technical performance. The panel recommended that the following individual items be given highest priority:
    1. All safety issues should have the highest priority, especially telescope hardware limits & interlocks.
    2. IAS completion, especially the implementation of a more efficient wave-front measurement, active optics update process. The panel established 10 minutes as the upper limit for completing a wavefront analysis iteration.
    3. Correcting the maintenance problems that could lead to sudden and prolonged telescope downtime, especially the lack of spares for the custom built control system circuit boards.
    4. Improving the Hydra fiber positioning accuracy until it meets the original specification of 0.2 arcsec RMS. (At this time, NOAO continues to work towards this goal with no additional charge to the Consortium.)
    5. Improving the computer reliability, in particular implementing strategies to minimize downtime when computers hang or crash.
    6. Complete the implementation of the telescope temperature-focus feedback mechanism.
- The ORR panel recognized the desirability of upgrading the current Imager detector to a 4096 x 4096 pixel device with 15 micron pixels.
- The ORR panel also developed a list of topics that were deemed outside the scope of the review but nevertheless potentially critical to the success of the WIYN Observatory. These topics are listed in Section 3.2 of the ORR document WODC 00-06-01.
- Questions, concerns, and comments raised by panel members during the review are presented in Section 4 of the document along with short responses written by the WIYN Project.

The ORR covered the following sub-systems:

- Top-Level Science & Technical Requirements
- Telescope General
- Control System
- System Integration & Interfaces
- Control System Graphical User Interface
- Primary Mirror System (PMS)
- Instrument Adapter Subsystem (IAS)
- MOS/Hydra
- Imager

For each major sub-system, the following topics were covered:

- Operational Performance, including original specifications, results of performance testing, and operation limits & hazards.
- Documentation, including drawings and operations & maintenance procedures.
- Spares, including currently available and recommended additions.
- Training Requirements, including transportation, installation, operation, and maintenance.
- Remaining Open Action Items, of any nature.

The ORR panel developed the following list of items which were originally considered to be Project deliverables but were incomplete or did not met their original specification in some way as of 1 February 1996. The panel recommended that these items be accepted "as-is", with the exception of the IAS Completion, the Primary Mirror System, and the Hydra/MOS fiber positioning accuracy. In the case of the IAS, the ORR panel felt it was still the responsibility of the Project to complete the listed IAS items as Construction activities. In the PMS and Hydra/MOS matters, NOAO has stated that it intends to complete the PMS items as soon as possible and to improve the Hydra/MOS fiber positioning as much as possible. All other items became the responsibility of the Operations group, subject to prioritization by the WIYN Site Manager and WIYN SAC. Status updates since the time of the ORR are included in [] after each item.

I. IAS COMPLETION

- Comparison Illumination Assembly (CIA) installation/commissioning [done]
- Complete Image Processor Subsystem (IPS) Manager [done, but now being upgraded to a new system]
- Wave-front Sensing Camera (WFSCAM) commissioning [done, but also being upgraded to a new system]
- Verification/accomplishment of limiting magnitude specs [tested, but not improved]
- Implementation of more efficient wave-front measurement & active optics update pipeline (goal: 10 mins) [done with typical update of 12 minutes, now being upgraded to <4 minute update]
- Reduce time needed to set up probes for auto-focus and auto-guiding tasks. [improved positioning speed, but still don't meet spec in some instances]
- Implement auto-focus capability [newly completed]

II. PRIMARY MIRROR

- Fix hydraulic leaks [improved, but some slow leaks remain]
- Complete documentation/maintenance manuals [not complete]
- Reduce settling time [done]

III. HYDRA/MOS

- Fiber positioning accuracy (does not meet original specification). [done]
- Time of fiber positioning (does not meet original specification). [needs major upgrade to improve]

iv. Encoder/servo performance

- Pointing (does not meet original specification). [done, now at 3 arc-seconds all-sky RMS]
- Open-loop tracking (does not meet original specification). [improved with better pointing performance]
- Wind-shake/image jiggle (does not meet original specification). [improved disturbance rejection with added velocity feedback circuitry]
- Wind breakaway (does not meet original specification). [improved, but needs major hardware upgrade to eliminate]
- Blind spot radius (does not meet original specification). [no progress]
- Offsetting (may not meet original specification - requires further verification). [done]

V. OPERATIONS

- Complete and review mirror handling procedures/hardware. [done, but later efforts identified problems that are being addressed with new fixtures being built for summer 2000 aluminization]

- Improve spares inventory. [done]

VI. TERTIARY MIRROR

- Positioning repeatability (does not meet original specification). [evaluated, but not improved]

2.3.2 Safety Review

A safety review of the WIYN facility was conducted in December 1996, as requested by the WIYN SAC. A panel of NOAO and UW engineers and scientists was charged to:

a) evaluate the existing TCS to identify any potential hazards to personnel and/or equipment that might occur or be present during the use or possible misuse of the WIYN TCS, emphasizing the possible safety impact of changes that have been made to the TCS since delivery,

b) recommend a prioritized list of safety-related changes to the existing TCS, identifying any tasks as critical to safety at the observatory, and

c) prepare a written report to the WIYN SAC in a timely fashion and by a date to be specified.

The final report of the safety committee is included in the package of reference documents supplied along with this report. All safety actions identified with potential risk to personnel or high-risk for equipment damage have been addressed (see the email status reports also included in reference package). A few low priority items have not been addressed and are maintained in our list of improvement projects which are reviewed and prioritized each year.

2.3.3 Strategic Directions

The strategic plan that was created in 1998 (see reference materials) identifies directions, goals and actions that are related to the telescope and control system.

- Direction: Optimize the optical and mechanical performance of the WIYN telescope.
- Goal: Enhance resources
- Action: Carry out the series of evolutionary upgrades of the WIYN facilities and instruments to maintain a competitive and scientifically focused facility.

The above goal was implemented to enable the action to achieve the strategic direction. For FY's 97 and 98 the Board approved a "special assessment" of $400K to allow many needed evolutionary upgrades to be completed. The Board then approved an increment to the yearly operations cost starting in FY99 that provided additional funding for technical resources and equipment. As a result we have completed many of the high priority projects that have improved the performance of the telescope (see SPIE paper "Optimizing the Delivered Image Quality of the WIYN 3.5 meter Telescope", included in the reference materials) and the reliability of equipment (see section 4.3).

2.4 Future Directions

Since the upgrades identified for the WIYN facility that addressed system performance and personnel safety have been largely completed, the focus for evolutionary upgrades in the near-term will address needs related to maintenance and observing efficiency. The one exception is the first item listed below, new primary mirror handling equipment and procedures, which addresses several problems with the original equipment that were identified during the 1998 aluminization process. That item is the highest priority currently since we are planning to aluminize again this summer. Examples of the other planned improvements are listed below.

- Develop new equipment and procedures for primary mirror handling
- Rotational Guiding capability at WIYN port
- Implement the Cassegrain port instrument adapter
- Implement the information management system (INFORMS) at WIYN
- Move the power supplies for the mirror covers, tertiary rotator, and other optics support structure equipment to a location off the telescope itself.

In addition to planned improvements, we must keep in mind that failures due to component aging and wear will occur. We are learning that it is necessary to have an established preventive maintenance program which has been lacking due to resource limitations in the face of higher priority projects that had direct impact on safety issues and quality of science data.

3. Instrumentation

3.1 The Imaging Performance at WIYN

The design of the WIYN 3.5m alt-az telescope emphasized both a relatively large field of view and good image quality. It has a spun-cast boro-silicate mirror with an actuator-driven active support system, a primary mirror thermal control system, and a well vented dome. From the outset, it has delivered excellent images, with median seeing of 0.8 arcseconds.

Several further efforts have resulted in significant improvement in both the best images obtained, as well as the reliability with which we are able to take advantage of the best atmospheric conditions (Sawyer et al. "Optimizing the Delivered Image Quality", SPIE 2000).

Most notable among them are:

- Tuning the thermal control of the primary mirror
- Eliminating Structural resonances in the top end of the telescope
- Improving the thermal model for focus changes
- Improving the model (look-up tables) for active optics changes to maintain telescope collimation as a function of pointing position.

Focus jumps and drifts plagued observers on WIYN. The focus is very sensitive to thermal conditions. For instance turning on the active active heating/cooling blowers would induce quite large focus jumps. In addition to addressing the source of these drifts, a Shack-Hartmann sensor on the imaging port detects changes in focus from the guide-star, so that residual focus variations can be tracked and corrected even during an exposure.

With these improvements, the most probable seeing is now 0.7 arc-sec, and seeing better than 0.4 arc-sec is obtained approximately 5% of the time that the weather permits it to be open (Sawyer et al, SPIE 2000). It is notable that while many of these problems were known 3 years ago, the resources to fix them came only after the increased funding was made available, so that the site engineer could be employed. The single minded attention of an engineer savvy with the actual telescope operation has been the primary factor that unblocked the path to getting these problems solved.

3.2 Configuration of the Various Telescope Foci

3.2.1 The four foci

Finely sampled imaging over a relatively wide field and atmosphere limited image quality has been a priority for WIYN from the outset. Multi-object spectroscopic capability over a wide field has been another major goal. An important design consideration was to build in flexibility, in the sense that multiple instruments be held in readiness at different foci, and that it be easy to switch from one to another, depending on the observer's priorities, and the conditions presented by weather conditions. Emphasis was placed on the two Nasmyth foci at f/6.3. One of them, referred to as the WIYN port, has been used primarily for imaging, but also for some auxiliary instruments. The other, called the MOS port, has been used exclusively for the 1-degree field of view multi-fiber spectrograph feed called HYDRA. Provision was also made for 2 additional ports as ugrade paths: the straight through Cassegrain focus which goes through a re-imager, and produces an effective focal ratio of f/13.7 (referred to as the modified Cass, or MCASS), and a folded Cassegrain (FCASS) that is essentially similar to the Nasmyth foci, located in a direction perpendicular to the line joining the two Nasmyths. Switching between all four ports is done by moving the tertiary mirror. The MCASS port has been used for visitor instruments, and work is underway (described later) to make it easily accessible. It provides a focus that is symmetric around the line of sight to minimize instrumental polarization and flat field variations. Its re-imaging optics provides the additional attraction of a larger 'plate-scale' than the Nasmyths, but its physical proximity to the floor limits the size of any instrument that can be mounted there. The FCASS port has not been used to date.

Configuration of the four foci

	WIYN (Nasmyth)	MOS (Nasmyth)	Folded Cassegrain	Modified Cassegrain
Field of View	30 arc-min	1 degree	1 degree	8 arc-min
Focal ratio	f/6.4	f/6.4	f/6.4	f/13.7 (re-imaged)
Available now?	Yes	Yes	No	Yes
Rotator available?	Yes	Yes	No	Yes
Guider / Instr. adapter	Yes	Part of HYDRA	None	In development (CassIAS)
Instruments	Mini-Mosaic S2KB DensePak Speckle (Yale Instr.)	HYDRA	None	HPOL (UW Instr.) DensePak (future) USNO IR cam (future?)

3.2.2 The WIYN port

The WIYN port is the more versatile of the two Nasmyth foci in terms of access for different instruments. It is primarily used for imaging. In addition to the instrument rotator, it is equipped with the so called Instrument Adapter System (IAS), which serves as the mounting platform for instruments, and also provides auxiliary support such as guiding. It is worthwhile to describe its various components:

1) Two guide probes and the Image Processing System (IPS). The probes use ICCD detectors. Software to process the guider images to centroid on a star image and generate guide signals is part of this system. One of the probes has been fitted with a Shack-Hartmann sensor which uses the split image of the guide star to track focus drifts. The focus corrections can then be applied, even during an exposure. The device can detect focus changes of less than 10 μm (of secondary mirror motion), which is the least detectable change even in the best seeing. At the time that science observations began with WIYN, only one guide probe could be used at a time for guiding. This is still the situation today, which means of course that we operate without rotational guiding. The fact that it has not been a high priority to remedy this situation is at least partially due to the fact that even in the best seeing, open loop image rotation correction shows no noticeable problems as long as one is not within 10 degrees of the zenith. There were other factors that were degrading imaging performance and needed to be rectified first. An upgrade to the IPS hardware and software is in progress, which in turn will make it possible to enable two star guiding and close the loop on rotation correction as well as improve hold and centroiding performance.

2) The Wave-front Sensing camera (WFSCAM), which obtains images of a bright star taken out of focus that are analyzed separately to obtain corrections for the mirror figure. The WFSCAM is also undergoing a major upgrade. The original version took 6 minutes per iteration, and it took typically two iterations to obtain a mirror figure solution at the beginning of a night. Due to a hardware failure that was not curable, the WFSCAM has been unusable for the last several months. A major upgrade of hardware and software is now complete, and the new

system takes about 2.5 minutes per iteration. It is now faster to do a wave-front solution, which also provides a fiducial focus, than to obtain a focus sequence with the imager, which takes longer to read out.

3) The Comparison Illumination Assembly (CIA), which has an integrating sphere with various comparison lamps.

4) Atmospheric Dispersion Compensator (ADC) prisms, which also serve as a field corrector for a field of view of 0.5-degree diameter. This device is rarely if ever used, though it has been tested. The reason is partly that it absorbs about 26%, 17%, 14%, 14% and 16% of the light UBVRI respectively. It has also not been called upon to function in its capacity as a field flattener: the largest field-of-view for an imaging device mounted on WIYN has been only 14 arc-minutes (Mini-Mosaic corner to corner), and field distortions over this scale have been demonstrated to be insignificant.

In addition to the IAS, the Filter Shutter Assembly (FSA) designed and built at Indiana University, provides the filter and shutter mechanisms for an imaging camera at the WIYN port. The curved blade shutter design eliminates 'shutter-shading' effects, and the fast mechanism has been shown to behave linearly for exposures as short as 0.2 seconds. The filter bolt holds up to eight 4-inch square filters (adequate for a 10 arc-minute square field). This has sometimes been a shortcoming in the instances when observers have wanted to observe with a larger number of filters, but also has operational implications for university runs that have multiple observers and programs. There is a spare wheel that can be held in readiness but it is not easy to change wheels in the middle of the night due to difficult access to the FSA. The short back-focal distance effectively prevents implementation of two simultaneous filter wheels.

The initial imaging device was a 2048X2048 'STIS' CCD which covered a 6.6 arc-minute square field with 0.2 arc-sec per pixel sampling. The new imager, Mini-Mosaic, has 2 2048X4096 SITE CCDs with a 9.6 arc-minute square field and 0.14 arc-sec per pixel sampling. These instruments are elaborated upon in a later sub-section. Additionally, an integral field fiber feed to the bench spectrograph called DensePak has been used at the WIYN port. A visitor instrument for speckle imaging has also been accommodated at this port.

The IAS at the WIYN port will be modified in the coming year to accommodate a new tip-tilt camera which is due to see first light in the summer of 2001. The re-design will make it possible to have the tip-tilt camera on simultaneously with the regular imager (or other instrument) at the WIYN port, with the light path controlled by a feed mirror. The modifications to the IAS necessary to accomplish this include relocating the CIA. This work will take approximately 2 months, and the IAS will not be available at the WIYN port for a period of 2 months in early 2001. During this period, it will obviously not be possible to have an instrument at the WIYN port.

3.2.3 The MOS port

The MOS port at the other Nasmyth focus is equipped with an instrument rotator and a 1-degree field corrector. It has been used exclusively for HYDRA since the beginning of science operations. HYDRA, which is the multi-fiber feed for the bench spectrograph, utilizes the large field of view made possible by the corrector. Since HYDRA uses its own apparatus for guiding, no further development of this port has been has been necessary. There are some very early plates taken at this port during telescope commissioning. However there has been no quantitative or followup (HYDRA has never been off the port since it went on 5 years ago) study of image quality at the MOS port. However, the illumination pattern in the FOPS (detailed in description for HYDRA below) fiber bundles that are made up of 1.2 arc-sec fiber components, shows that in good seeing there is adequately good image quality at the MOS port.

3.2.4 The Modified Cassegrain (MCASS) Port

The MCASS port had occassionally been used for a visitor instrument named HPOL, which is a spectropolarimeter. As part of the HPOL installation, UW developed the reimaging optics needed to use this port, along with an instrument rotator. Both these components are available for use with other instruments. The field of view is 8 arc-minutes, and the focal surface is highly curved (radius of curvature is 19 cm). Due to the proximity to the floor, and impact on telescope balance, there are size and weight constraints for any instrument used at this port. It can accommodate an ADC, though there isn't one currently present. HPOL has its own guider.

A project to build an IAS for this port is underway at the University of Wisconsin. The Cass IAS will have a single guide probe, and a choice of feed mirrors with variously sized holes. A CIA (Comparison Illumination Assembly) will also be available. This port is targeted as an alternative home for DensePak, particularly since the f/13.7 focus provides a twice larger plate scale than at the f/6.3 Nasmyth.

It is possible that a pellicle assembly will also be put in to facilitate the use of DensePak. The desired timeline to implement the Cass IAS would put this adaptor on the telescope before the WIYN IAS has to come off for modifications in early 2001. There have been delays due to retirements/resignations of technical personnel at Wisconsin.

3.3 Facility Instruments

Instruments that may be used by all WIYN users, and which are supported using WIYN resources as regular user instruments are referred to as 'Facility Instruments'. These specifically include HYDRA with the bench spectrograph, DensePak with the bench spectrograph, the S2KB imager, and the new Mini-Mosaic imager.

3.3.1 The Bench Spectrograph

The Bench Spectrograph provides a thermally and mechanically stable environment and enormous flexibility in configuring resolving power and spectral range. It is fed by fibers, either from HYDRA, or from DensePak. HYDRA feeds either the blue or the red optimized set of fibers, and DensePak only has one bundle of red optimized fibers. The fibers terminate in a 'foot', where their ends are arranged in a row to look like a long slit. Filters can be placed in the feet after the fibers terminate, for blocking wavelengths in unwanted grating orders. There is a TV viewer tha can be inserted between the 'slit' and collimator to view the 'slit'. Extra fibers that can carry illumination from comparison sources enter the feet and are coaligned as part of the fiber 'slit'. If desired, these function as simultaneous comparison sources. A fiber back illuminator is also available, that illuminates the 'slit', and can be viewed from the HYDRA/DensePak end for alignment and other diagnostic work. The spectrograph has an f/6 collimator and a choice of 6 gratings, covering a wide range of resolution. There is a choice of 2 cameras, the Simmons Camera which is optimized in the blue, and the Bench Spectrograph Camera, which has better red transmission. The detector in both cases is a TEK 2048X2048 CCD designated as T2KC, operated with an ARCON controller.

Most of the tilt and focus adjustments in the bench spectrograph can be controlled remotely via computer GUI's. The important exceptions are the camera collimator angle and some alignment adjustments of the CCD dewar (needed only for major reconfigurations of the spectrograph). This degree of remote control means that human entry that would destabilize the Bench Spectrograph environment is minimized, to say nothing of the fact that the task of making optimal adjustments to the instrument is made extremely convenient and easy.

Some problems in the performance of the Bench Spectrograph have become evident. Most importantly there is focal ratio degradation through the fibers, and the output beam is f/4, in comparison to the f/6.3 input beam to HYDRA and DensePak. Thus a lot of the light is missed by the f/6 collimator, particularly from the fibers at the ends of the 'slit' (Conselice et al., "A Study of the Radiance of Fibers…", white paper 1998).

About 20\% of the light from the central fibers is missing the collimator, but for the end fibers as much as half the light is being lost. To rectify this drawback, a new collimator is needed, so it will match the f/4 emergent beam. In addition a field lens in the fiber foot is required to redirect the light from the end fibers so that it is not lost.

Matt Bershady of the University of Wisconsin is chairing an upgrade effort for the Bench Spectrograph. The first phase is to fix the illumination problem as above. A more ambitious second phase of the upgrade will be to use the more efficient volume-phase gratings, and also go to an all transmissive optics for higher throughput. The timescales for these changes has not been set. Additional funding is necessary for the second phase of the upgrade, and a proposal to do this is to be submitted to NSF later this year.

In yet another parallel effort, Steve Zepf of Yale has proposed to the NSF for grants to fund an infra-red detector for the bench spectrograph, which will extend the spectral range to 1.7 microns, which is the limit placed by the corrector on the MOS port.

3.3.2 HYDRA

Hydra is a multifiber feed to the Bench Spectrograph. It was a starting facility instrument at WIYN, and was modified from its previous incarnation at the Mayall 4m telescope. Sam Barden and Taft Armandroff led the efforts at NOAO to get this instrument constructed and commissioned.

HYDRA has two sets of 96 fibers: the blue optimized fibers that are 310 µm in diameter (3 arc-sec on the sky), and the red fibers that are 200 µm diameter (2 arc-sec on sky). Either the blue or the red set may be deployed (each has its own interchangeable 'foot' at the spectrograph). The fibers are terminated on 'buttons' which can be placed on the focal surface at the desired positions for objects in a field. The field of view is one degree in diameter. HYDRA is the exclusive instrument mounted at the MOS port.

In addition to the 2 sets of object fibers, there are 12 Field Orientation Probes (FOPS), each of which is a bundle of 7 fibers (arranged as a hexagon plus its center). Each component fiber is about 1.2 arc-sec in diameter on the sky. The FOPS are placed at the field locations of brighter stars in the field that can be used for guiding. The relative illumination in the 7 fibers in each bundle provides spatial centering information, as well as a handle for making focus adjustments. The centering information from several FOPS then provides the translational and rotational guiding signal. The guider operation is currently controlled by VME/VxWorks, but will be changed to use new guide code developed at CTIO for the southern HYDRA, which uses PC/Linux.

Fiber placement is controlled by a robotic arm called the 'gripper'. The gripper picks up and places buttons on desired locations. Its motion is governed by an X and Y stage. The gripper mechanism also carries a TV, and LEDs for illumination. A more detailed description of the mechanisms and capabilities see WODC 02-29-01 (Barden & Armandroff).

For all its complications, operating HYDRA is exceedingly simple, thanks is large measure to excellent software and astrometric detailing of its focal surface. The observer must provide good enough astrometry, and a ranked set of desired objects and sky positions, as well as positions of usable guide stars on which the FOPS can be placed. HYDRA software then advises fiber placement schemes, which in turn can be used to direct the configuration of all the required fibers. The software works exceedingly well, and hardware reliablity is also good. Button/fiber entanglements are rare (one in 5000 moves, or less than one in 50 field configurations). It takes 13 seconds on average for a single fiber to be moved from one location to another: a full field reconfiguration typically takes 20 to 30 minutes.

Demand for HYDRA and Bench Spectrograph use has remained high from all member institutions, and is projected to remain so for several years to come. There are maintenance issues: in particular that we are down to having only one set of spares for the X-Y stage hardware, which are no longer available or repairable. The CTIO HYDRA uses different hardware, which also provides fiber positioning speed that is about three times faster. An upgrade to such new hardware was estimated 2 years ago at about $125K, but not pursued. Another suggested upgrade is to furnish HYDRA with a set of fiber bundles, where each bundle delivers some spatial resolution, and several such bundles can be deployed within the 1-degree HYDRA field of view. No specific action to pursue this idea has been made.

3.3.3 DensePak

DensePak is a fiber bundle that operates as an Integral Field Unit (IFU) that feeds the Bench Spectrograph. It is a bundle of 91 fibers arranged in a 7X13 rectangle. The fibers are identical to the red fibers in HYDRA except that they are 310 µm in diameter, and each fiber projects to 3-arcseconds on the sky. Four additional fibers are placed at about 1 arc-min distance from the bundle, and are used as "sky" fibers. The displacement of the sky fibers from the array is smaller than optimal for many applications, but is constrained by the fiber feed head. The purpose of the device is obviously to obtain spatially resolved spectroscopy of a small patch of sky. DensePak is mounted in lieu of the imager at the WIYN port, using a fiber feed head originally made for the Indiana Fiber Optic Echelle Spectrograph (WIFOE). It includes a pellicle back viewer for verifying target placement on the DensePak array. The comparison lamp assembly in the WIYN IAS is used for calibration. Details can be obtained from (Barden et al. "Integral Field Spectroscopy on the WIYN Telescope Using a Fiber Array", SPIE 1998).

The Cassegrain IAS which is under development will provide DensePak with an alternate spatial sampling with 1 arc-second at f/13.7. If the Cass IAS is completed in a timely manner, it will also provide access to DensePak over the time period of 2 months when the WIYN IAS is being modified to accommodate the tip-tilt camera (described in section 3.3.6).

3.3.4 The S2KB Imager

The S2KB imager is essentially a 2Kx2K STIS CCD mounted at the WIYN port. The 21µm pixels project to 0.2 arc-sec on the sky, providing reasonable spatial sampling in most seeing conditions. The field of view is 6.6 arc-minutes, which is smaller than desired for WIYN. This device was on line at the beginning of science operations, and until December 1999 was the default imaging device on WIYN. It is run by a hybrid ARCON controller (HARCON). The imager was put on line without adequate testing, and a non-linearity in the electronics was detected while it was in use (and immediately fixed). In 1998, the device also developed a glowing amplifier, and one corner of the chip showed what was effectively a very high bias level. The problem was not repairable, but was well studied and documented. A small section near the offending corner of the device was made unusable, but the data from the remainder continued to be reliable.

3.3.5 The Mini-Mosaic Imager

The Mini-Mosaic is a CCD imaging camera consisting of two 2Kx4K SITE CCDs mounted side-by-side to provide a 4Kx4K pixel imaging surface. The device readout is performed simultaneously by 4 separate amplifiers, 2 for each CCD chip, which keeps the total readout time to 3 minutes. This camera is mounted on the WIYN port on the WIYN IAS, and employs the filters and shutter assembly (FSA) that is part of the installation for instruments at that port. The pixels in these CCD chips are 15µm, which, in this setup, project to 0.14 arc-seconds on the sky, and the device covers a field of 9.6 arc-minutes on a side, and so a diagonal extent of 14 arc-minutes. The pixel scale adequately samples the point-spread-function (PSF) when the delivered image quality (DIQ) is 0.4 arc-seconds, a situation not uncommon for WIYN.

In order to fully capitalize on the good seeing over a relatively large field, a device such as the Mini-Mosaic, which combines fine sampling with moderately large area coverage, is highly desirable for the WIYN instrument complement. An imager that provided such a field of view was part of the plan for the initial instrument complement at WIYN. However the project to build a larger imaging device was delayed, mainly due to unavailability of suitable CCDs, and S2KB has been used as an interim instrument. The dewar and control electronics were built and held ready so that when the decision to go with the SITE 2Kx4K devices was made in late October 1998, the instrument was able to see first light in Decemberof the same year. A commissioning plan drawn up by a working group was followed. Commissioning activity took longer than anticipated, with much of the time spent in ensuring that the data interfaces that organize the data stream works rationally. The testing of device performance took comparatively less time at the telescope, but resources to process and test the voluminous data were scant. The instrument is now in regular use. Commissioning activities are not fully concluded, but a draft commissioning report is available in the document set.

The goal of deploying the Mini-mosaic was to reap the benefits of the natural seeing performance at WIYN: to get the best images possible over a substantial field of view, that are suitable for photometry (which high order adaptive optics does not allow). In keeping with this, the actual performance of the Mini-mosaic is superb, in that the image quality from corner to corner does not change perceptibly even in 0.4 arc-sec seeing. PSF fitting photometry with unvarying modelled PSFs works to 1 percent self-consistency over the entire field.

It was desired that the detector have higher blue response, and other CCDs, such as ORBIT chips were considered. However no satisfactory CCDs with high blue response have been available, and the decision to settle for the SITE chips appears to have been very timely.

3.3.6 The Tip-Tilt Project

In an effort to further enhance its imaging performance over a moderate field, a tip-tilt imager is being constructed for WIYN. The WIYN Tip-Tilt Module (WTTM) is an all reflecting modular VIS-NIR (400nm - 1.8um) re-imaging system that implements fast tip-tilt compensation and includes real-time focus sensing. The WTTM will become an integral part of the WIYN Instrument Adapter System and provide a "second" imaging port along side the 10x10 arc-minute FOV Mini-Mosaic 4Kx4K imager. A single pick-off mirror is used to rapidly select (< 5 minutes) between these two ports.

The WTTM optical design uses three off-axis diamond turned mirrors, first to re-image the telescope pupil on the tilt mirror and then to a 2 element "camera". Light from the camera is sent to the science detector off a front surface reflection of a beam-splitter, where the through path feeds the tilt/focus sensor. The field of view for the WTTM is 4x4 arc-minutes at a plate scale of 8.0 arc-seconds per millimeter and provides near diffraction limited images at 650nm. The WTTM uses a quadrant type error sensor feeding avalanche photo-diode photon counting modules for sensing tilt and focus. The speed of the error sensor and tilt platform will allow tilt corrections at rates up to 800Hz, while the focus signal will by necessity be a time average and correct the telescope focus at rates near 1Hz. With these tilt and focus corrections the image quality will be near 0.4 arc-seconds FWHM at 650nm more than 10 percent of the time, and will typically improve the most probable current seeing of 0.7 arc-sec to 0.6 arc-sec or better.

The first instrument to be mated to the WTTM is a CCD imager that uses the central 2Kx2K portion of a SITe 2Kx4K CCD. This imager will utilize the entire FOV of the WTTM, operate from 400nm to 1000nm, and have a resolution of 0.12 arc-seconds per pixel. Accompanying this instrument will be a suite of beam splitters that accommodate a wide range of science applications. These include: 1) 80/20 "grey" for use with moderately bright guide stars and where wide wavelength coverage is needed in the science beam. 2) 98/2 "grey" for use with very bright guide stars (e.g. in open clusters) and multi-color science. 3) A first surface mirror with a through hole to one side for very faint guide stars and multi-color science. 4) A custom designed dichroic coating that optimizes guide star sensitivity and efficiency for two color (broadband V and I) observations.

The modularity of the WTTM will allow future upgrades to other instruments and capability. The all-reflecting design gives the WTTM a wide range of wavelength where its optic performance is excellent. This will allow the WTTM to be mated with NIR instruments where the gains from tilt compensation are greatest. Further, the optical design of the WTTM allows the tilt mirror to be replaced with a deformable mirror for low order adaptive optics correction as a future upgrade. With this in mind, the error sensor has also been made modular so that it can be easily upgraded to facilitate more complex wave-front sensing in a low order AO system.

3.3.7 'Visitor' Instruments used at WIYN

Several "visitor" or "university" instruments have been used at WIYN. Several of them, such as HPOL (a spectropolarimater built by Ken Nordsieck at Wisconsin) and SPECKLE (a speckle camera by van Altena , Yale and collaborators) have been used on a regular basis for a variety of projects. Others have been oriented towards special ends, such as the coronagraphic adaptor for the imager used for the Saturn mutual ring events (circa 1996) by Honeycutt (Indiana), with which 0.6 arcsec images were obtained, and the "Barlow" adaptor (also Honeycutt) for use with DensePak to get 1 arcsec fibers for small nova shells. Honeycutt also experimented with an R=5000 fiber fed echelle with white pupil optics, but it had poor throughput, most probably due to the fibers. The fiber head from this instrument was later modified to be used with DensePak.

3.4 Future Instrumentation Plans and Efforts

The need to identify, develop and build the next generation of facility (for general use) instruments for WIYN is an obvious one. A working group was charged with devising a process by which new instrumentations are to be proposed, built and commissioned at WIYN. Such a process, that steps through conceptual planning, consortium review (via the SAC), development of a proposal for funding, and design and construction was outlined. Broad ideas for future instrumentation were discussed, in the context of both:

1. scientific interests and drivers

2. enhancing existing strengths of the telescope.

The working group identified the specific science areas that WIYN could address well that are also matched by consortium staff interests. These along with the instrumentation upgrade they drive, are listed below:

- Stars: Stellar abundances and variability—Hydra and bench spectrograph upgrades, high throughput spectrograph for abundances, retaining synoptic capability.
- Stellar Populations: resolved stars in nearby galaxies, including variable stars—wide-field imaging, imaging in the blue, low order Adaptive optics (AO).
- Galaxies: Structure and kinematics of galaxies, in particular their cores—AO, wide-field imaging,
- IFU spectroscopy.

- Cosmology: Morphology and colors of high-z galaxies, surveys—Wide field imaging for surveys, wide-field IR imaging, IFU spectroscopy with AO.

Proceeding with these guidelines, and with the tip-tilt module already in progress, the 3 instruments suggested most highly are, in order:

1) A high throughput spectrograph. Two designs have been presented to the SAC: one is from Yale (Jeff Snyder), that has low to medium dispersion using a compact, but conventional design that would be mounted at the MCASS port. The other design from Sam Barden at NOAO would utilize volume-phase (VPH) gratings with all transmissive optics to attain high efficiency, and would nominally be mounted at the WIYN Nasmyth port, but could be modified to go at MCASS. Both are dual beam optimized separately for blue and red, both are compact, seek full spectral coverage, high throughput, and designed to provide good sky subtraction capability. The Snyder design allows for inter-changeable gratings and and thus some choice in resolution. The Barden version, which has an echellette design with cross-dispersion to achieve full spectral coverage would be a proving ground for VPH gratings. The scientific driver for the Snyder team is well developed. There appear to be no science leads or resources at NOAO at this time to build the VPH design. The SAC has encouraged Snyder to proceed, and also to consult with Barden to see if elements of the VPH design which should provide better efficiency can be incorporated in the Yale instrument.

2) Developing a new port: Chris Anderson at Wisconsin is leading the effort to build the Cass IAS, as already described above.

3) Wide Field Optical Imager: no progress.

The opportunity to borrow a near infra-red camera from USNO has arisen, since USNO is offering it for a 3-year loan. Some retro-fitting will be required (pupil stops). If mounted at MCASS, the device will provide a 44 arc-second field at 0.17 arc-sec per pixel sampling. Efforts are underway to test out the IR performance of WIYN by borrowing this camera for a shorter period, with the intent of asking for the 3-year loan if WIYN IR performance (which has never been tested, and is an issue given its large secondary and the extent of possible scattering from the tertiary) is seen to be useful.

There are upgrade projects for the bench spectrograph as already described that are progressing slowly.

Despite these efforts to identify projects, as well as schemes to provide incentives to instrument Principle Investigators (PIs), there are no major instrument plans beyond the completion of the tip-tilt module. This is obviously a serious deficiency for the consortium.

With the exception of the imager front end built at Indiana, the facility instruments to date have all been built at NOAO, and the tip-tilt project is also being led by Claver with NOAO resources. The Cass IAS development at Wisconsin is a relatively small, but definite contribution from Wisconsin. The filter-shutter assembly at the WIYN port was built at Indiana. The bench upgrade to develop an IR camera is currently a proposal from Steve Zepf at Yale, but is not seen as a facility class project by the WIYN SAC.

The WIYN consortium did not at the outset set up a formal arrangement for re-investment in the telescope. It was the intent of the partners to find other sources of funding, and to contribute time and effort that would go in to keeping the telescope at the scientific fore-front. To this end, there is a ledger kept of such contributions, with the expectation that over a period of time the contributions from the various partners would even out. This projected balance has not been achieved during the first five years, and the ledger currently shows considerable imbalance. There has also not been a successful funding proposal for a facility class instrument for WIYN.

3.5 Strategic Planning for Future Instrument Development

Recognizing the imperatives regarding future instrument development, the process by which new facility instruments are proposed, built, and brought in to operation on the WIYN 3.5m telescope was devised by the Strategic Planning Working Group on Instrumentation that met in October 1997. That group identified two main drivers for developing new instrumentation at WIYN: interest in a particular science and/or interest in enhancing existing strengths of the telescope. Aside from these broadly worded drivers the group identified five options for initiating the process: an individual principal investigator (PI), the WIYN SAC, the strategic planning working group, operations, or an instrument program leader.

Development of Scientific Rationale

Regardless of the initiation, the next stage of instrument development requires that an individual (instrument leader - IL) take responsibility for detailing the motivation and justification of a particular instrument. This should also include a rough estimate of the cost and timescale for the instrument. The role of the IL is to develop the scientific rationale of the instrument and to justify the further development to the consortium as a whole.

Because several individuals may be developing instrumentation plans simultaneously, an overall Instrument Program Leader (IPL) will be given the responsibility to monitor the individual efforts. The role of the IPL is largely to to avoid duplication and foster collaboration between individual instrumentation development. An individual developing a preliminary instrumentation plan must inform the IPL of their activities. While it is the responsibility of the IPL to organize any necessary "road shows", it rests with the individual project leaders to present their plans to the consortium at large.

It is the responsibility of the SAC to give final approval that a particular instrumentation plan may proceed beyond this preliminary level. The SAC also has the responsibility to decide between instrumentation plans.

The following must emerge from this process for any instrumentation plan to move forward: 1) a well-defined instrument; 2) a well-defined team with a defined leader to build the instrument; and 3) a contact person at each WIYN institution. This group of people are to devise the specific plan to fund and build the instrument.

Science Drivers within WIYN (October 1997)

The working group identified four major scientific drivers for new instrumentation at WIYN.

Stars: stellar abundances and variability

Stellar Populations: resolving stars in nearby galaxies
Galaxies: studies of the structure and kinematics of galaxies, and, in particular, their cores.
Cosmology: morphology and colors of high-z galaxies, surveys

These science drivers led to the following broadly sketched ideas for future instrumentation.

Stars: Hydra upgrades, high-throughput spectrograph for abundances, retaining synoptic capability.

Stellar Pops: AO, concentration on imaging in the blue, wide-field imaging, and having access to more filters.

Galaxies: AO, wide-field imaging, IFU spectroscopy

Cosmology: Wide-field imaging for surveys, wide-field IR imaging, IFU spectroscopy with AO.

Future Instrumentation on the WIYN 3.5m Telescope

The working group examined some candidate instrument projects for consideration in the context of the process above. This list should not be considered definitive or representative; it simply reflects the opinions of those present. There was unanimous support for near-term development of a high throughput spectrograph and strong support for both a wide-field imager and the development of a new port.

The Working Group reconvened in October 1998 in conjunction with the WIYN Board meeting in New Haven. The purpose of this meeting was to gather members of the consortium interested in contributing to future instrumentation to discuss the next facility-class instrument for the 3.5m telescope. Five presentations were discussed: a wide-field camera to supercede the mini-mosaic; a near-IR Fabry-Perot; an IR upgrade for Hydra and the existing bench spectrograph, a UV upgrade for Hydra and the bench spectrograph; and a high efficiency slit spectrograph. The Working Group set a deadline of January 1999 for submissions of preproposals for these instruments. In the end only the Working Group received one a preproposal for the IR upgrade to Hydra and the bench spectrograph.

As per the process laid out by the Working Group the merits of the instrument were discussed at each institution, a team of interested individuals was identified to support the PI, and the SAC approved the motion that an IR upgrade to Hydra proceed as the next facility instrument. Ultimately, the process broke down and the instrument proposal was submitted to the NSF not as a facility class instrument for WIYN, but, rather, as a much smaller PI-based instrument.

The failure of this process to yield a consortium-supported and major WIYN proposal reflects both the lack of an executive whose responsibility it is to manage the overall future instrumentation effort and a dearth of resources, both in terms of money and expertise, that were made available to the PI by the Consortium as a whole. As discussed elsewhere in this document there are currently at least two instrument initiatives and the SAC has requested that the PI for each proceed with developing their plans and building support within the consortium.

4. Operations and Management

4.1 Management Structure

The WIYN management structure is presently going through a major transition, primarily centered around the introduction of a Director into the system. We begin this description with the present WIYN Management plan, and then return to a review of past successes and failures.

The essential components of WIYN management are as follows:

WIYN Board – The WIYN Board of Directors is comprised of three members from each institution, two astronomers and one administrative member. The Board leadership consists of a President, Treasurer and Secretary. The Board sets overall policy, is responsible for financial health, appoints and reviews the Director, reviews management effectiveness, and reviews and approves major proposals and projects.

WIYN Scientific Advisory Committee (SAC) – The WIYN SAC is comprised of one astronomer from each institution. The SAC reports to the Board on the scientific health of WIYN, and acts as the primary communication link between WIYN and the member institutions. Its role is to develop the scientific agenda for WIYN, and in the presence of a director, would regularly advise him/her.

WIYN Director – The WIYN Director is a newly created position. A search to fill this position beginning about August 99, turned up several good and viable external candidates. However, none of the three offers made were accepted.

The charge to the Director is to implement the policies of the WIYN Board, develop long range and annual program plans and budgets (in conjunction with SAC), foster major proposals for new instruments and facility upgrades, develop external funding, and supervise the Operations Manager and scientific staff to meet operational goals.

WIYN Operations Manager - The WIYN Operations Manager is presently David Sawyer. The Operations Manager is responsible for the operational readiness of the WIYN Observatory, which includes supervision of WIYN operations staff, coordination of on-site activities, implementing facility and instrument upgrades, and contributing to long-range planning.

WIYN Scientific Staff - From the beginning the partners have recognized that the funded operations personnel would not be sufficient to operate and develop the Observatory, and that each partner would need to contribute scientific staff to the cause. Roles of these scientists would include evaluation and maintenance of telescope performance, commissioning of new instruments and software, support of long-range planning, and support of other initiatives of the Director and the Observatory.

Specifically this scientific staff includes:

Telescope Scientist – Primarily responsible for telescope performance and community user support. Provided by NOAO; presently Abhijit Saha.

Observatory Scientist - Primarily responsible for instrument development, special initiatives, and long-range planning. This position was filled by Arthur Code (Wisconsin, Emeritus) during 1997-98. It is presently empty.

Instrument Scientists - Primarily responsible for instrument performance and support, with annual reports to the SAC. These positions were filled during 1998-99 by Paul Smith (NOAO; Hydra) and Michael Pierce (IU; Imager). Replacements are being established.

WIYN Post-doctoral Fellows and Graduate Students – Wisconsin created the McKinney Assistant Scientist position with a 50% commitment to support of WIYN. The first McKinney Scientist (1995-8), Dr. Ted von Hippel, was a major player in commissioning the S2KB imager and developing the DADS system. The present McKinney Scientist is Dr.

Sydney Barnes, with the charge of remote observing development. Additionally, in Summer 1998 a graduate student from each of Wisconsin and Yale spent a month in Tucson through the [KPNO Graduate Student Summer Program]. Their contributions were vital to be characterizing the Hydra fiber output beam and developing the INFORMS database.

The WIYN management plan as described is only now being implemented. During 1995-00 WIYN management did not include a Director. Effectively WIYN was directed by the SAC, with the Chair of the SAC acting as the Chief Operating Officer. From the perspective of operations this mode was quite effective. This can be attributed to 1) the superb performance of Dave Sawyer, who operationally (and then formally) redefined his original position of Site Manager into Operations Manager with enhanced executive duties, 2) highly committed SAC members and Chairs with very little turnover, 3) the ongoing contribution of Art Code in the early years (particularly to development of the WTTM project), 4) a Board committed to the success of WIYN, and 5) remarkably friendly and respectful relationships between all players.

A strategic emphasis of WIYN during the first five years was the development of superb and stable operations. This has been achieved within the initial management structure. However, it became evident that this same management structure could not take WIYN to a higher level of scientific performance in the future. Most critically, there was no scientist with a full-time career commitment to the WIYN Observatory and its future development. Consequently, in Spring 1998 the WIYN Board created the position of WIYN Director and initiated the search process.

In January 2000 Dave Sawyer informed WIYN that he would be leaving the position of Operations Manager as of October 31, 2000. Given that this critical change in WIYN personnel is contemporaneous with the start of the WIYN Director, the Board has decided to use this opportunity to revisit the WIYN operations personnel structure jointly with the future director.

One general weakness in the WIYN management and operations plan has been difficulty in getting University scientists integrally involved in supporting telescope operations. WIYN was fortunate to have Art Code take on the position of Observatory Scientist as part of his retirement to Tucson, but otherwise this full-time, short-term position has attracted no interest. Similarly, the part-time Instrument Scientist positions have attracted interest only from those already involved in WIYN Management in other ways. Practically speaking, the SAC and Board largely exhaust the pool of University scientists willing to commit substantial hours to WIYN. This in turn reflects the reality that each of the University partners has extended their operations (including and beyond WIYN) to the limits of their staffing.

4.2 Management of Telescope Operations

The WIYN organizational structure is arranged such that the resources provided for WIYN operations are employed by NOAO and drawn from the NOAO work force, with the exception of the Operations Manager who is an employee of the University of Wisconsin. The Operations Manager directly supervises the quality and effectiveness of work done by NOAO for WIYN, but the ultimate responsibility for supervision of personnel (e.g. annual performance evaluation, salary review, time cards, leave approval, general work assignments, etc.) remains with the individual's NOAO supervisor. The Operations Manager has overall management responsibility for the resources provided to WIYN by NOAO. The Operations Manager works closely with the KPNO Supervisor of Mountain Scientific Support and with the supervisors of the various groups to coordinate the use of NOAO resources

Figure 1 shows the organizational structure of WIYN. The blocks indicate specific functions and responsible individuals or groups. The diagram illustrates the lines of contact between WIYN operations management and KPNO resources and does not represent a management or authority structure. The solid lines represent the paths of communication and the dashed lines represent advisory links. The WIYN Operations Manager currently reports to the WIYN Scientific Advisory Committee (SAC), but it is expected that a WIYN Director will be hired during FY00. In that case, the Operations Manager will report to the Director as shown in the diagram. The Director will report to the WIYN Board and the SAC will be an advisory committee to the Board.

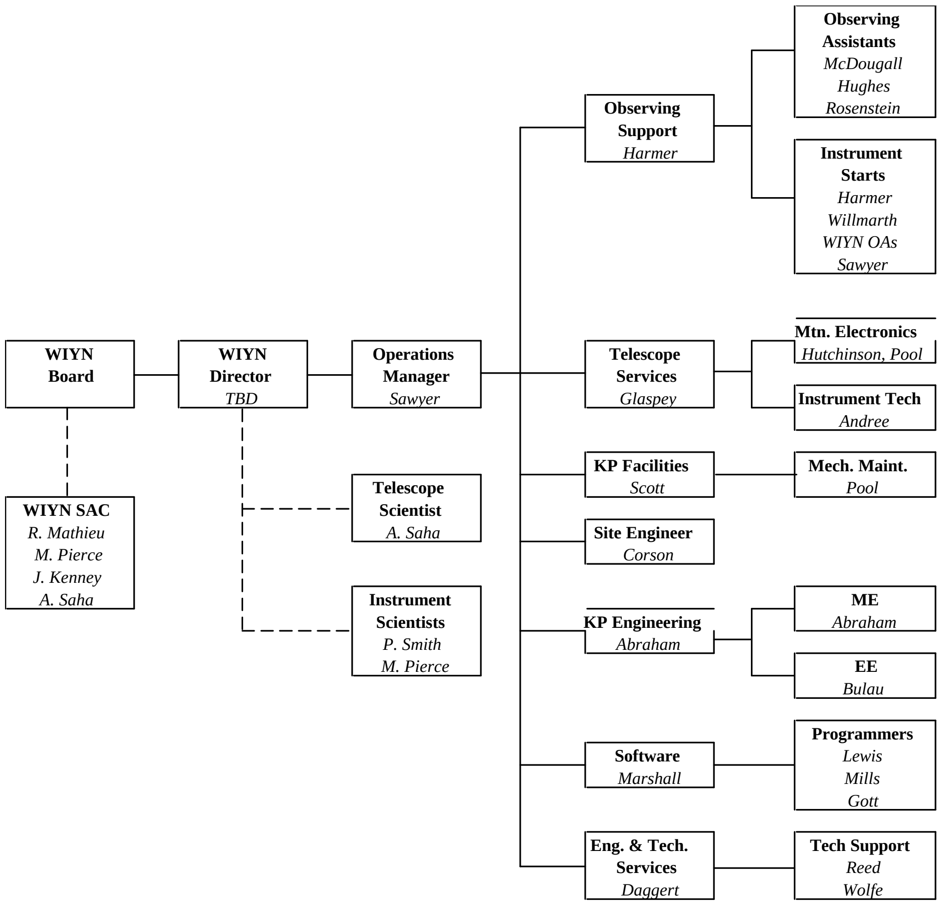


Figure 1: WIYN Organizational Structure. This diagram illustrates the lines of contact between WIYN operations management and KPNO resources. This diagram does not represent the internal NOAO management structure.

The original agreement between the partners in the WIYN consortium calls for an operations plan which includes a staffing level of 6.5 FTE and services provided by NOAO under a "footprint" calculation. The value of operations was set at $522K (1989 dollars). NOAO is obliged to provide operations related services as defined in the WIYN Agreement and MOU which have an agreed value of $363.2K (1989 dollars) annually, including 0.4 FTE of the Operations Manager and $50K in operating expenses. The University Members are to pay $158.8K (1989 dollars), including 0.6 FTE of the Operations Manager. The WIYN Operations Manager is currently an employee of the University of Wisconsin, with the salary paid as part of UW's contribution to operating expenses

During the 1999 fiscal year the Board passed a resolution (1999-9) that reset the operations assessments effective for FY99 to increase by a total of $385K, assessed according to the shares of telescope time. $175K of the increase is to fund the WIYN director. The remaining $210K will increase the operating budget to fund an increase in the staffing level by 1.1 FTE and provide cash for instrument upgrades.

The commitments of the universities and of NOAO as defined in the WIYN agreements are summarized below (the annual inflation rate of 5% has been applied as specified in the Agreement).

	'89$	'99$	'00$
TOTAL COST OF OPERATIONS	$522.0K	$850.3K+$385K	$1,297.1K
VALUE OF NOAO CONTRIBUTION	$363.2K	$591.6K+$154K	$782.9K
VALUE OF UNIV. CONTRIBUTION	$158.8K	$258.7K+$231K	$514.2K
OPERATIONS EXPENSE (Labor and Supplies)	$472.0K	$1053.9K	$1106.6K
CAPITAL EXPENSE (Operations Manager's Fund)	$ 50.0K	$ 81.4K	$ 85.5K
INSTRUMENT UPGRADE EXPENSE	$ 0.0K	$100.0K	$105.0K

At the time of the agreement, WIYN operations and technical support was defined to include 6.5 FTE, then estimated to include the mix of skills summarized in the table below.

	Agreement ('89)
Site Manager	1.00
Telescope Operators	2.00
Programmers	1.00
Mechanical Engineering	0.25
Electronics Engineering	0.25
Electronics Technical	1.00
Electro-mechanical Tech	1.00
Total FTE	6.5

Since that time, experience has shown that the 6.5 FTE level was marginally adequate to maintain status quo operations and did not provide means for evolutionary upgrades and improvements. As such, a Board resolution was passed that increased the base technical support level to 7.6 FTE. The staffing distribution for FY00 is expected to be as follows:

Operations Manager	1.0	
Site Engineer	1.0	
Observing Assistants	2.5	(includes instrument support*)
Technical Support	1.0	(includes ETS, MtnElec, Facilities, KP Eng.)
Programming Support	1.0	
Engineering Support	1.0	(improvement projects, WTTM, etc.)
Instrument Proposal Devel.	0.1	
Total FTE	7.6	

*Instrument Support includes instrument configuration and startup support.

The labor support needed for WIYN operations can be divided into two categories; the labor needed for "core" operations, and the labor needed for "evolutionary upgrades". The core operations group is the combination of staff that is required for maintaining status quo operations and are essential just to keep the telescope and facility operating at the current level of performance and efficiency. Evolutionary upgrades are any enhancements or improvements to the telescope, enclosure, or instruments that result from the natural evolution of the facility. For instance, replacement of obsolete equipment, or improvements that are identified as we gain experience with the facility and instruments.

The table below summarizes the actual labor support levels for the different skills categories for each complete fiscal year since the start of operations. The Operations Manager, Site Engineer (0.5 FTE), observing support staff, technical support staff, and the software support staff as shown in the table form the core operations group at WIYN and account for approximately 6.0 FTE. The labor support needed for evolutionary upgrades comes from resources over and above the 6.0 needed for core operations and consists of a diverse range of skills needed for engineering, design, fabrication, and test.

Resource	FY96	FY97	FY98	FY99	FY00 (thru 1-31-00)	Proposed (thru FY01)
Core Operations Group:						
Operations Manager	1.00	1.00	1.00	1.00	1.00	1.00
Observing Support	2.88	2.54	2.84	2.95	2.80	2.70
Instrument Support	0.33	0.34	0.20	0.12	0.13	0.30
Technical Support	0.76	0.90	1.09	1.28	1.07	1.00
Software Support	0.77	1.08	0.98	1.25	1.33	1.00
Core Operations Labor (FTE)	5.74	5.86	6.11	6.60	6.33	6.00
Evolutionary Upgrades:						
NOAO Pool, Site Engr.	1.40	0.56	0.79	0.87	0.86	1.00
Special Assessment	0.00	2.44	2.30	0.04	0.00	0.00
WTTM Commitment				1.00	1.00	1.00
Inst. Proposal Devel.						0.10
Evol. Upgrade Labor (FTE)	1.40	3.00	3.09	1.91	1.86	2.10
Total Labor (FTE)	7.14	8.86	9.20	8.51	8.19	8.10

The staff required to operate the WIYN observatory is provided from the “pool” of existing NOAO personnel as needed by WIYN. The advantage of the “pool” mode of support is that WIYN can call on specialized individuals for specialized tasks as needed. However, work is most efficiently done by trained personnel familiar with the WIYN facility since it is a complex telescope and thus we have attempted to designate “dedicated” staff to support WIYN for certain functions.

Telescope operation is provided by two “observing assistants” (OA) dedicated full-time to WIYN and a third dedicated half-time. We have found that OAs must operate at WIYN at least half-time in order to stay proficient with the telescope because of the complex nature of the distributed control system and alt-az type mount. In addition, our experience revealed a critical need for dedicated telescope engineering support. As such, the WIYN Board approved an increment the WIYN budget effective for FY99 to allow us to hire a Site Engineer with responsibility for performance maintenance and upgrades and enhancement of the telescope and instrumentation.

Soon after the start of operations and until very recently WIYN was assigned a dedicated full-time programmer and half-time electronics technician (ET). Circumstances resulting from staffing reductions within KPNO required us to move away from the "dedicated" personnel support model back to the "pool" support model for programming and ET support. At first we were concerned that this was counterproductive to our past efforts to identify dedicated WIYN personnel, however, changes in the support requirements due to the maturing of the telescope have changed our needs somewhat. The required level of certain skills, such as electronic technicians, has reduced significantly since many of the nascent problems with the telescope have been corrected. In addition, the “pool” mode of support provides important cross-training so that we aren’t relying on the support of one individual. And finally, we have more flexibility in the allocation of resources which allows us to address the tasks more efficiently.

One other factor that influences the pool vs. dedicated mode of support is the attitude of ownership. One of the issues we have been confronting is the level of “buy-in” that exists among the various groups at NOAO. When we have staff that are dedicated to WIYN it gives the impression to other non-dedicated staff that WIYN is not their concern. As a result, the NOAO support groups don’t necessarily feel the level of accountability that they do for other KPNO telescopes.

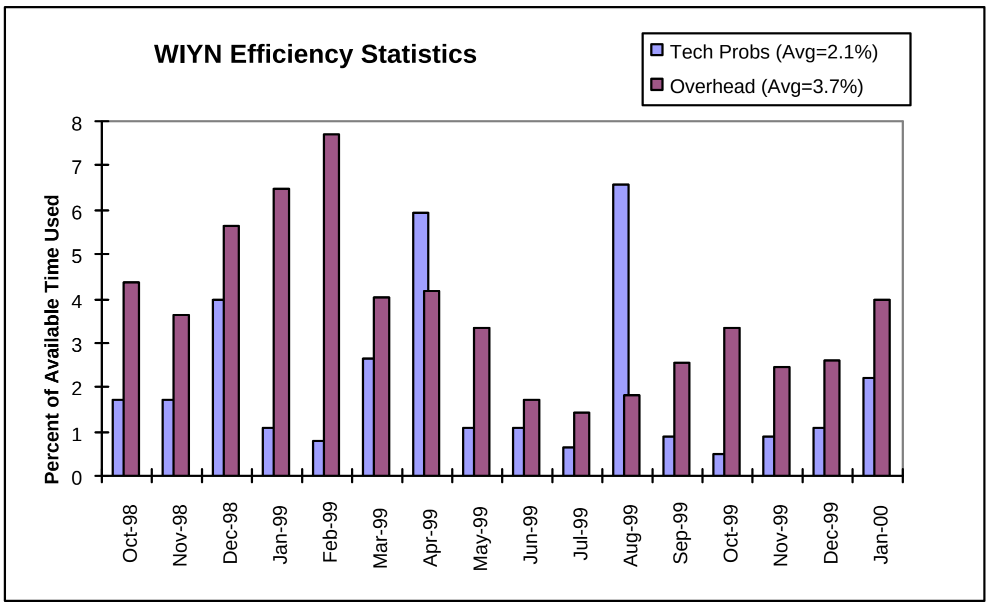
In general, the flexibility for adjusting the WIYN staffing to meet the demands has allowed the use of resources to be very efficient. Over the years we have adjusted the mix of skills allocated to WIYN to fit with planned improvement projects or to react to major technical failures. As mentioned above the type of support whether pool or dedicated is also adjusted to meet current needs. The role of the Operations Manager has been crucial to identify and plan for the anticipated resource needs. However, the maturity of the telescope and staff had mitigated the need for careful staffing oversight by the Operations Manager.

Due to the staffing cutbacks at KPNO and the limited resources available to WIYN it is very important to receive observing information well in advance of a run so that staff can be scheduled efficiently. We have developed procedures and Web-based information pages to improve the communication. However, we still experience many observing runs where information is not received in a timely and detailed enough manner causing scheduling difficulties. New policies are now being implemented to penalize those that fail to provide information as required.

4.3 Effectiveness of Operations

4.3.1 Lost Time Statistics

One measure of the effectiveness of operations is the observing efficiency. Efficiency statistics are logged nightly by the telescope operator and include the distribution of time as allocated to science, weather, overhead, and technical problems. A month-by-month summary of the time lost to technical problems and overhead are summarized for the period of October '98 through January '00 in the graph below.



The graph shows the statistics for the percentage of available observing time needed for overhead and time lost to technical problems. The overhead statistics have not been well accounted in the night-logs in the past and still require some improvement. For instance, in the past the night-logs only accounted for the time used to perform wave-front tuning of the telescope. Now they account for wave-fronts, imager focusing and instrument configurations, but do not account for time needed to acquire and setup on new fields. The statistics shown in the graph indicate that the average time used for overhead is 3.7% which is significantly lower than the values reported in the past (ranging from 6% to 10%), which were compiled from NOAO Queue observing logs that include all aspects of overhead, and thus may not be directly equivalent. However, the statistics shown here do show a clear improvement in the overhead when comparing the end of '98 to the end of '99. Some of this may be due to the fact that the WFSCAM has been off-line due to a failure, however, the wave-front overhead is usually low since they are done during twilight hours. Qualitatively the time needed for focusing the telescope was a dominant source of overhead. This will be significantly improved with the implementation of the Auto-Focus Sensor which is just now being released for routine use during science observing. Instrument configurations are also a significant source of overhead which are not likely to improve unless upgrades such as reducing the Hydra configuration time are implemented.

The time lost to technical problems includes telescope and instrument problems as well as hardware and software problems. The lost time statistics only account for time where operations could not continue and do not account for reduced efficiency in cases where work-arounds were determined. The statistics for the period shown here indicate that the time lost to technical problems has been reduced to 2.1% on average which is a significant improvement over past night-log statistics where technical problems accounted for lost time of 8% in FY96, 5% in FY97 and 5% in FY98. As can be noted from the graph the time lost to technical problems is more typically closer to 1% with the exception of a few months where major technical failures occurred.

Inefficiencies in the telescope operation have been and are influenced by many factors. Many of the factors were one-time failures or had minor effect. However, some were significant and are listed below with a brief description of the status.

Focus instability - High power at the WIYN secondary makes the telescope very sensitive to defocus caused by changes in the primary-secondary spacing. Many factors influence the focus including thermo-mechanical changes in the truss structure, thermal conditioning of the primary mirror, and position control of the secondary mirror (SPIE paper on DIQ improvements, March 2000). Many improvements have been successful in mitigating focus instabilities and more are planned for the near-term. One such project will incorporate a sensor at the WIYN port to provide automatic closed-loop focus control.

TCS unreliability - During the first few years of operation it became apparent that the telescope control system (TCS) was subject to frequent hangs and crashes that resulted from both hardware and software problems. A major project to upgrade the TCS was completed in 1998 and the reliability is significantly improved. The software is now quite mature and system problems are very rare.

Secondary mirror control - The secondary mirror is moved in piston and tilt to maintain focus and collimation of the telescope. Several different subsystems (e.g. the PMS, truss temps, etc.) are sending commands to the secondary. Initially there was no arbitration or command queue for the motion commands sent to the secondary and frequently commands would arrive simultaneously and fail. This problem was aggravated by the fact that there was no command acknowledgement to inform the operator that commands succeeded or failed. The problem was resolved by developing a client to arbitrate motion commands and control the secondary positioning. Secondary control is now much more reliable and accurate, but further refinement is needed.

Guider software unreliability - The software used for closed-loop guiding at the WIYN imaging port as well as the Hydra port was susceptible to crashes and was cumbersome to switch from one port to the other. As a result we experienced unacceptable guider setup times when acquiring new objects. Many upgrades to the software and hardware have been implemented to improve the guider reliability. We are currently developing a new guider system that will be universal on Kitt Peak, using a system developed at CTIO.

Wave-front reduction process – Wave-front curvature sensing is the method employed at WIYN to tune the active optics on a night-by-night basis. At the start of operations we used the CCD imager to obtain the wave-front images (inside and outside focus) to be used for the analysis. This was an inefficient way to measure the wave-front because we were subject to the long readout times of the large format CCD. A typical wave-front measurement took about ten minutes per iteration and two iterations are usually needed for optimizing the wave-front. A dedicated wave-front camera was designed into the instrument adapter subsystem (IAS), but was not commissioned until January of '98. The camera reduced the time of a wave-front measurement to six minutes. The controller for the wave-front camera failed in May '98 and was not repairable because the model had been discontinued. This forced us to upgrade the system with new hardware and software (but the same camera). The new system is just coming on-line now and the wave-front measurement process has been reduced to just over two minutes per iteration. This will provide a very efficient system for wave-front analysis and will allow more frequent tuning (thus better imaging performance) during the night.

PMS failures - A major source of recent technical problems has been the primary mirror system. In April '99 we lost an entire night due to a major failure of the primary mirror support system where a software glitch caused the mirror to move to a position outside a valid range for the position feedback sensors. This caused the mirror to drive to motion limits on many actuators. The problem was aggravated by our insufficient understanding of the operation of the active support system, unavailability of the PMS engineers, and the lack of documentation. In November '99 the wave-front performance of the telescope suddenly degraded and the problem was traced to a failed lateral support unit. Very little observing time was lost because the failure did not prevent observing, although the quality of observing was diminished. The problem took a very long time to identify and correct due to the complexity of the PMS and also due to our inexperience with the system and lack of detailed documentation. In January '00 another problem with the PMS surfaced when the control loop failed to properly converge. Extensive testing and a significant level of resources was needed to trace the problem to a drift in load-cell zero-points which essentially changed the measured weight of the primary mirror and thus a critical servo parameter. These failures appear to be unrelated, but raises some concern because the PMS was trouble-free prior to this flurry of failures.

4.3.2 Documentation

The documentation for WIYN was provided from many different contractors and was thus provided in many different formats and levels of completeness. A complete set of documentation is maintained at the WIYN site as well as at NOAO. Version control for WIYN drawings is maintained through the NOAO system. However, some of the WIYN drawing formats are not compatible with the programs used at NOAO and require conversions. This is a process that we are addressing as drawings are used or updated. There is still a lot of work that is needed to get all WIYN drawings into NOAO version control (especially with the control system drawings) which will be done as a project-oriented effort once we have resources available for the task.

Following is a summary of the state of documentation for critical observatory components:

Telescope Structure - Mechanical drawings of the telescope structure components were supplied by L&F Industries, the manufacturer of the mount. These drawings have been adequate for maintaining and upgrading the telescope structure.

Building and Enclosure - Top-level drawings of the site, mechanical systems, electrical systems, and construction details were provided by the architectural firm, M3 Engineering. The contractor, Sundt Corporation, provided a maintenenace manual for all components of the building and enclosure. The combination of drawings and maintenance manual is sufficient to maintain the facility.

Control System - The control system was designed and installed by the Space Science and Engineering Center (SSEC) at the University of Wisconsin. A complete set of drawings was provided along with electronic versions. The electronic formats, though, are various and incompatible with the tools used at NOAO. We have not converted these drawings yet to a format we can use and thus many upgrades to the control system are still only marked up versions of drawings. It is estimated that a couple of man-months of effort is needed to get the control system drawings current. This has not been done because resources have been applied to higher priority tasks. UW also provided a Maintenance Manual for the control system which is very detailed and complete.

Primary Mirror System - The primary mirror system (PMS) was developed at NOAO. Documentation for the PMS is still incomplete, but we are working on improving it. A temporary designer was hired to generate mechanical drawings of the active support components, which was completed in 1998. We recently organized assembly notes and made copies while troubleshooting recent failures. And some procedure documents for preventative maintenance were developed as we addressed some mechanical issues, such as replacing a BelloFram in an actuator. However, we still don't have a maintenance manual or a description of the theory of operation which has significantly reduced our efficiency for reactive maintenance. We are developing expertise within WIYN on the PMS system, but we are still dependent on the original engineers since the documentation is inadequate. This is a concern as access to those specific people is continually diminishing.

INFORMS - Informs is a proposed information management system to implement at WIYN. It will be a database for tracking service requests and troubleshooting information, efficiency statistics and performance statistics. This system will allow us to better track and monitor our effectiveness, produce reports, as well as provide a history of all aspects of observatory performance. The design requirements for the system are complete and the database itself has been built. However, other project priorities have prevented us from completing the system.

4.4 Management of Science Programs

4.4.1 Flexible Observing Modes

A large class of scientific problems exist which cannot be effectively explored via the traditional approach of having a few dedicated observing nights assigned to various research groups each semester. For example, time-dependent processes may require brief observations over many nights, or a program may need small amounts of very rare weather conditions for its success. As such programs are central to the research of WIYN scientists at all three University partners as well as within the national community, the WIYN vision includes innovative observing modes.

Cooperation between the member institutions of the WIYN Consortium has enhanced the scientific output in that time can be traded and shared in such a way that time-critical programs such as synoptic, target of opportunity, and monitoring observations can be supported. In addition, the WIYN telescope was designed to provide a fast instrument change capability where a movable tertiary mirror is used to direct the light toward one of four possible instrument ports allowing observers to respond quickly to changing needs.

Queue Scheduling

For the last 3 years, most of NOAO's 40 percent observing share on the WIYN 3.5 m telescope has been used for queued observing, with the goal of facilitating highly ranked science proposals that require rare observing conditions and/or synoptic or `target of opportunity' observations. The ease of switching between imaging on one Nasmyth focus and multi-object fiber fed bench spectroscopy on the other Nasmyth port offers the choice of making the best use of the extant observing conditions, particularly periods of good seeing.

There were multiple goals for this experiment, some operational and others that are science enablers.

1) To see if Queue scheduling can in fact maximize the return for highly ranked projects, while making the `best effort' on lesser ranked ones. The answer is yes, as shown in Boroson et al. (1998, SPIE 3349, p41).

2) To make possible observations in the best imaging conditions for projects that demand exceptional seeing. Delivering these rare conditions to the projects that most need them (modulo their proposal ranking) is only efficient when a pool of diverse programs is assigned a sufficiently large total amount of time.

3) To enable synoptic observations, time monitoring, and Target of Opportunity (ToO) observations.

4) To learn how to run a ground based queue. The boundary conditions that govern ground based observing are vastly different from those relevant to HST, for instance. It turns out that designing a system for the ground from scratch is easier than retro-fitting HST scheduling software, as shown in the assessment of the WIYN queue experiment by Saha et al. (2000, SPIE in press).

The operational efficiency of the WIYN queue can be judged by its performance in the NOAO observing semester from August'99 to February'00, as summarized in the table below (from Saha et al. 2000). We assess this performance to be quite satisfactory, and the outcome was modulated essentially by the weather and total available time, with higher completion for high priority and synoptic programs.

Given the US commitment to run queued observing on the Gemini telescopes, the operation at WIYN has been an important fore-runner and learning experience.

Table: Breakdown of NOAO WIYN Queue time allocation in Semester 99B

Item Description	Total Nights	Dark	Bright	Completion
Nights Available to NOAO in 99B	63	40	23	
Nights available for Q observations	48	37	11	
Hi Priority Imaging:				
Non-synoptic & < 1.0 arcsec seeing	5	5	0	73%
Synoptic/ToO and ~1.0 arcsec seeing	5	5	0	79%
Hi Priority Spectroscopy (non-synoptic)	8	8	0	100%
Hi Priority spectroscopy (synoptic)	1	0	1	100%
Best Effort Imaging:				
Non-synoptic & < 1.0 arcsec seeing	1	1	0	50%
Non-synoptic & > 1.0 arcsec seeing OK	3	3	0	4%
Synoptic	6	5	1	60%
Best Effort Spectroscopy (non-synoptic)	17	12	5	25%
Best Effort Spectroscopy (synoptic)	3	0	3	100%
`Short' projects (~0.25 nights each)	1.25	0.5	0.75	100%

The science impact of the queue observations is assessed in a different section of this report. There is considerable debate about whether it has enhanced overall scientific productivity, and whether it has been cost effective for NOAO, in particular. Lack of resources has forced the queue to be reduced to a bare minimum in the 2nd 2000 semester, when less than 15 percent of the NOAO time will be used in this mode. This should keep alive some of the synoptic ability, but the pool of time is too small for ToO or `best seeing' programs to be supported reasonably. This makes the best that WIYN has to offer less accessible to the observing community.

Service Observing

Service observing is a mode where a classically scheduled observer (i.e. one that is on-site) is responsible for collecting data for colleagues. This improves observing efficiency in several ways. First, costs associated with an observing run are reduced because fewer individuals are traveling to the site. Second, observing programs that are short, only need a small amount of data to finish, or are testing a concept can be scheduled during larger programs that may have windows of time available. For instance, if a Hydra program requires several different fields to be observed on a given night, the observer can carry out short imaging programs during the Hydra instrument reconfigurations. These types of programs could also be carried out remotely, but having an observer from the home institution on-site helps to reduce the burden on the telescope operator. In some cases the quality of the observations is improved over fully remote programs because the service observer could be involved with the program preparation and it's objectives. In all cases, service observing coupled with remote observing allows scientists and students to carry out observations in a very efficient and optimized way.

Synoptic/Monitoring Programs

Time is block scheduled on WIYN so that the member institutions each receive a fair distribution of nights through all lunar phases and seasons. A repeating cycle of time allocation for each institution along with the flexibility of time trades within the WIYN Consortium make periodic observations possible. The permanent installation of the MOS/Hydra spectrograph and the semi-permanent installation of the CCD Imager make the facility instruments available a very high percentage of the time allowing synoptic and monitoring programs to be practical.

WIYN also has a F/13.7 modified Cassegrain port accessible by flipping the Nasmyth tertiary mirror out of the beam. This focus has been used for synoptic spectropolarimetric observations. Intrinsic polarization of stars is usually quite small, often less than a tenth of a percent, however, secular changes in this polarization are diagnostic of the process producing the polarization and of the related geometry. The modified Cassegrain port provides the necessary characteristics for this class of observation because the instrumental polarization is low and the instrumental stability is high. Furthermore, since the Cassegrain port is independent of the facility Nasmyth instruments, the instrument can remain on the telescope for extended periods of time allowing periodic measurements to be made.

Target of Opportunity Observations

The near 100% availability of the WIYN Imager, along with the quick change-over time between the Imager and multi-fiber spectroscopy ports, makes WIYN ideal for science requiring a quick and deep imaging response capability. In addition, cooperation between the consortium members gives WIYN the unique capability for responding to targets of opportunity (ToO). For example, members of the WIYN institutions were able to maximize observations of the comets Hyakutake and Hale-Bopp. Although, the time cycle allocation is fixed, flexibility and coordination between the institutions allowed time to be adjusted to support comet observations at optimum times. This cooperation also allows WIYN observers to respond to unanticipated targets of opportunity, such as supernovae and gamma ray burst events. There have been occasions when a ToO has been inserted during a University block of time by simply asking the observer. On occasion, Universities will use queue scheduling to insert a program on a short time scale. In some cases, ToO programs are planned and reviewed. For example, groups from the University of Wisconsin, NOAO, Yale University, and Marshall Space Flight Center (NASA) are currently using this WIYN capability to initiate rapid follow-up of Gamma Ray Burst (GRB) optical transients at WIYN. Initial proof of the use of WIYN for GRB optical transient searches was performed on GRB 970616. Following these tests, an important non-detection was made at WIYN on GRB 970828.

4.4.2 Remote Observing

Remote observing has always been an integral part of the University vision for WIYN, both for flexibility of science observations and to provide access for undergraduates as part of WIYN’s educational mission. University remote observing ranges from passive "over-the-shoulder" observing with an observer on site to "fully remote observing". NOAO has had little interest or participation in the development of remote observing. They have nonetheless been supportive at the Board level of the University efforts.

The foundation of WIYN remote observing development has been Dr. Jeffrey Percival of Wisconsin, who brings extensive space-based control system expertise to the problem. He was the architect of the WIYN control system software, which was designed to facilitate information transfer at modem data rates. He has chaired the remote observing committee since commissioning, and been employed at the 10% level by WIYN for remote observing software support.

In 1999 Wisconsin contributed 75% of Percival’s time to develop a sophisticated Java-based remote observing package. This effort had two main goals. The first goal was to integrate various remote observing programs into a single, "user friendly" package. The second was to solve the problem of distributing the remote observing program throughout the consortium, which represents a heterogeneous mixture of computers and operating systems. The resulting Java program was demonstrated successfully at a WIYN board meeting, and we are now in the process of commissioning the program for general use. Examples of some teething problems are that some vendors (e.g. Apple) have not yet caught up to the latest version of Java, and others (e.g. Silicon Graphics) are just now supporting the "Just In Time" compilers that speed up execution to acceptable levels. We are confident that this new remote observing tool will increase remote observing by lowering the learning curve and working on many different computers.

Despite this unique development capacity, incorporation of remote observing into the suite of WIYN capabilities has been slow, in part due to logistical difficulties. First, in the early days of WIYN the NOAO software team who took over the delivered control system , did not view the remote observing capabilities as a high priority and limited them in further developments of the control system. The underlying issue, as also mentioned in section 2, appears to have been the conflict between the capabilities of the original control system versus the need to make changes so it could be efficiently serviced. The situation was exacerbated by shortcomings in software management oversight. However, firewalls were built around parts of the control system that have preserved remote observing capability. Second, the software environment at WIYN is always changing, essentially completely independently of remote observing software. This lack of communication leads to frequent minor but distressing problems for a user. Again, this points to a system level approach to WIYN software that crosses institutional boundaries. Third, while the WIYN telescope control system was designed with remote observing as a central capability, the instrumentation - and especially the Harcon controller of the imager which was grandfathered into WIYN - are not friendly to remote observing. Fourth, the observing assistants have not been in the remote observing loop, which along with the changing software environment and infrequent use has led to "learning curve" difficulties. The OAs are now integral members of the remote observing development team.

Remote observing has been used on 10% of University nights. However, given that remote observing has never reached the level of standard operating procedure this is likely a lower limit on the eventual demand. Remote observing is most frequently used to 1) support synoptic programs and 2) to permit an institution to do detailed scheduling of small programs. Very few observers use remote observing in lieu of traveling to WIYN for a multi-night run.

The WIYN Board has consistently committed WIYN to full remote observing capability, and so we anticipated the continued commitment of resources to this effort.

4.4.3 Data Archiving and Distribution System (DADS)

WIYN is committed to developing an archiving system that at minimum provides centralized storage of all data [and optimally provides easy, distributed access to those data]. An integral part of this system is data delivery to each institution independent of observers.

At present the foundation of the DADS system is data storage on CD-ROMs. All S2KB and Bench Spectrograph FITS files (and eventually Mini-Mosaic data) are automatically written to each of a pair of CD-ROMs at the telescope. These are transported to NOAO – Tucson for verification and labeling. The archive set of CD-ROMs remains in a central archive in Tucson, while the distribution set is sent to the appropriate institution. (Note that NOAO does not make use of the data distribution set.) In addition, as part of the labeling process, the file headers only are input into a header database developed and resident at Wisconsin.

Due to sporadic support of the single NOAO software programmer familiar with the system, DADS has been very slow in coming on line. Initiated in [1997], standard operation began in early 2000, and this single-point limitation for maintenance and upgrade remains a concern. Evaluation of the astronomer usage of the DADS products is premature. At present access to the archived data is limited to the principle investigators. The Board has charged a subcommittee to rapidly develop a policy for access to both the file headers and the data themselves.

WIYN has just begun consideration of effective interfaces with the data archive. Indiana University has a terabyte data storage project (MASSTOR) which would be interested in using WIYN data as a showcase project; this is one of several options on the table for long-term data storage and access.

5. WIYN Scientific Productivity

Averaged over the past four years WIYN produces approximately 25 refereed papers per year, with 60% originating in the Universities. 58% of the University publications over the past four years deal with topics in extragalactic astronomy and a third of the University publications are studies of galaxy morphology and structure that take advantage of WIYN's excellent image quality. In fact imaging accounts for over 70% of WIYN's publications. The bench spectrograph, whether fed by Hydra or by DensePak, is responsible for 25% of WIYN publications. Hydra has been widely used by the broader NOAO community while the Universities have concentrated on Densepak observations.

The Strategic Plan identified three WIYN-specific characteristics that can and should lead to substantial scientific contributions: targets of opportunity (ToO); synoptic observations; and excellent image quality. The majority of WIYN publications take advantage of these unique capabilities and the most important WIYN papers are based on targets of opportunity, WIYN's excellent DIQ, and multi-object spectroscopy.

It is also apparent that WIYN is a young facility and that long term projects requiring 3 or more years of data acquisition are just now beginning to produce significant contributions. These include a number of Ph.D. dissertations, several programs dealing with the extragalactic distance scale, several programs using DensePak to investigate the kinematics of galaxies, programs focusing on the evolution of galaxies in clusters, at least two major investigations determining the extent to which the stellar halo is comprised of tidal streamers, and the WIYN Open Cluster Survey (WOCS). As these long term projects mature WIYN's productivity, as measured by the number of papers published, will increase.

WIYN's scientific impact has come in four areas: temporal phenomena; Galactic star clusters; stars and stellar populations in other galaxies; and galactic structure and morphology. We highlight each one of these below.

1. <u>Temporal Phenomena:</u> Flexible scheduling within the Universities and the NOAO Queue schedule facilitate science that can only be done as a target of opportunity or as part of a long term monitoring campaign. Statistics for the NOAO Queue schedule are elsewhere in this document. WIYN scientific contributions that could only be made with flexible scheduling include: measuring light curves of Type Ia supernovae at high redshift (Perlmutter et al.1998, Reiss et al. 1998, Perlmutter et al. 1999), the optical follow-up of gamma-ray bursts (Groot et al. 1998, Galama et al. 1998, 1999, Garcia et al. 1998), and trans-Neptunian objects (Millis et al. 1998). The search for the optical afterglow from GRB970828 also utilized the Wisconsin Graduate Student Queue. The ability to carry out monitoring programs with WIYN produced nearly 25% of the University refereed publications. Such observations are essential for the study of Galactic and extragalactic variable stars, binary systems, and QSO variability. WIYN has produced comprehensive studies of distances to nearby galaxies: Cepheid variables in Holmberg II (Hoessel et al. 1998) and red supergiants in NGC 2403, M101, and NGC 2366 (Jurcevic et al. 1999abc, Jurcevic 1999). These programs have also made use of WIYN's excellent image quality. Honeycutt and collaborators (Hillwig et al. 1998, 1999ab, Honeycutt et al. 1998abc) have used Hydra extensively to study the properties of cataclysmic variables. Bailyn and collaborators used both Yale institutional time and the NOAO Q in their study of X-ray transients. Ongoing programs include surveys for QSO variability (Bershady & Hoessel 2000) and variability studies of young massive stars (Massey and collaborators)

2. <u>Star Clusters:</u> One of the scientific highlights of the WIYN consortium is the <u>WIYN Open Cluster Survey (WOCS)</u>, a collaboration involving 13 current and former members of the consortium dedicated to a comprehensive and definitive photometric, spectroscopic, and astrometric study of Galactic open clusters. The body of investigations address critical astrophysical problems through the study of open clusters: detailed testing of core convective overshoot and implications for stellar lifetimes, photometric monitoring of periods

for study of surface angular momentum evolution, delineation of faint main sequences to test stellar evolution theory of very low mass stars, discovery of white dwarf sequences as independent dating mechanisms, detailed abundance analyses for studies of Galactic chemical evolution and primordial abundances, binary populations, stellar evolution in close binary environments, and initial and present-day mass functions.

The WIYN data includes deep UBVRI images of cluster cores, UBVRI wide-field surveys of cluster cores and halos, and photometric monitoring for variability. The WIYN spectroscopic contribution includes abundance determinations, precise radial velocities, projected rotational velocities, and spectroscopic monitoring for stellar activity. WOCS has yielded the deepest color magnitude diagram of the key old open cluster NGC 188 (Von Hippel & Sarajedini 1998).

Hydra is the longest serving instrument on WIYN and is a key component of the community's science programs and a workhorse for WIYN studies of clusters and associations. These programs include measuring the rotational period distribution of pre-main sequence stars (Stassun et al. 1999) and using the lithium abundance to identify young stars in the Orion complex. Hydra has also yielded a seminal study of the global kinematics of the globular cluster M15 (Drukier et al. 1998).

3. Stars and Stellar Populations in Galaxies: The most probable seeing at WIYN is 0."7 and the telescope yields 0."7 or better 40% of the time. Even in similar conditions WIYN yields a more centrally peaked image point spread function that other 4m-class telescopes. Thus, the WIYN 3.5m enables science that cannot be done at other sites in the continental U.S. On the other hand, WIYN's contribution in imaging science has been limited by: 1) non-linearity problems in the original S2KB imager between 1995 and 1996; and 2) lack of a wide-field imager before November 1999.

   WIYN's image quality facilitates deep optical photometry by concentrating the light in a smaller number of pixels and resolving crowded fields. This has been exploited the searches for extragalactic variable stars for measuring the distance scale (Hoessel et al. 1998, Jurcevic et al. 1999abc, etc). Published studies of the star formation histories of Local Group galaxies IC 1613 (Cole 1999, Cole et al. 2000) and Pegasus (Gallagher et al. 1998), and work in progress on IC 10 (Wilcots & Miller 2000, Gallagher et al.2000), depend on superb image quality. Similarly, the image quality makes possible detailed studies of individual supergiants in nearby galaxies (Massey et al. 1998).

   Studies of stellar populations in other galaxies are not solely the purview of imaging; Hydra has been used efficiently to carry out a census of red supergiants in nearby galaxies (Massey et al.)

4. Structure and Morphology of Galaxies: A third of University publications are in the structure and morphology of galaxies and the most significant of these rely heavily upon excellent image quality. These include a seminal study of extraplanar dust features in edge-on galaxies (Howk & Savage 1999), fine-scale substructure in clusters of galaxies (Conselice & Gallagher 1998ab), the impact of environment of galaxy morphology (Koopman & Kenney 1998, Koopman 1997, Koopman & Kenney 2000), triple bars and complex central structure in early type galaxies (Erwin & Sparke 1999, Erwin 1999), superthin galaxies (Matthews 1998, Matthews et al. 1999), starburst galaxies (Homeier & Gallagher 1999, Jogee et al. 1997, 1999), cores of galaxies (Jogee et al. 1997, 1999), structure of high redshift galaxies (Corbin et al. 1998), the distribution of ionized gas in irregular galaxies (Wilcots & Miller 1998), and the search for low surface brightness galaxies in the Local Group (Armandroff et al. 1999).

5. Galaxy Kinematics: The newest facility instrument, DensePak, is now a workhorse for investigating galaxy stellar and gas kinematics (Pierce & Berrington 2000, Homeier & Gallagher 1999, Wilcots & Thurow 2000). Because DensePak has been a facility class instrument for only 2 years, many of its science programs are just now reaching completion. Hydra has also been used in this regime to connect QSO absorption line systems with individual galaxies (Tripp 1997, Tripp et al. 1998, Tripp & Savage 2000, Rao & Turnshek 1999),

The scientific impact of the WIYN 3.5m is not limited to those strategic areas in which it is a unique facility. The partnership in WIYN provides a platform on which individual investigators can utilize University instrumentation to pursue particular scientific programs. These programs simply would not be feasible without guaranteed access to the telescope.

6. University Instrumentation: The University partners have contributed two instruments for WIYN: HPOL, a spectroscopic polarimeter built at Wisconsin (K. Nordseick, PI), and SPECKLE, fast speckle camera built at Yale (van Altena, PI). These are all described in more detail in 1.3.7. Guaranteed access to WIYN (HPOL, for example, is scheduled in blocks) insures that these instruments can carry out science programs that would have otherwise not been feasible. The University instruments have made possible one dissertation at each institution (J. Hoffman, Wisconsin and J.A. Orosz, Yale). Other HPOL publications include: Martin et al. (1999), Clayton et al. (1996), and Anderson et al. (1996).

It is clear that WIYN has been essential to the scientific productivity of individual investigators, particularly at the University partners. It is also evident that WIYN's scientific impact has come in those areas in which it is adept: time critical observations and programs requiring excellent image quality. Additionally, WIYN observers continue to take advantage of the multiplexing capabilities of Hydra. Recent efforts to push DensePak (e.g. using the Ca triplet to measure stellar velocities in spiral bulges and tracing the kinematics of ionized gas in star-forming galaxies using the [O III] line at 4363 A) should result in significant scientific contributions from that instrument in the near future. To date WIYN has been scientifically productive, but it has yet to define its signature scientific program(s).

Despite these positives, WIYN continues to trail similar, but more mature facilities, in terms of the number of papers published. The publication rate of the Canada-France-Hawaii-Telescope (CFHT) is three times that of WIYN. However, the operating budget of CFHT is n times that of WIYN, the support staff is n times larger, and there are twice as many instruments on CFHT as there are on WIYN. Compared to the Mayall 4-m, WIYN is quite competitive; since Semester B 1996 the 4m has produced 34 papers while WIYN has produced 28.

As we show below, WIYN has been invaluable for the graduate programs at the Universities and that its scientific productivity is underestimated at this stage because WIYN theses are only just now being completed. In only four years of operation WIYN is a critical component in at least 29 Ph.D. dissertations. Access to WIYN has been similarly valuable in facilitating successful grants; a number of individual investigators, including three associated with WOCS, are funded solely for their WIYN related science.

Ph.D. Dissertations

Andersen, D., "Kinematics of Spiral Disks: Ellipticity and the Tully-Fisher Relation", Pennsylvania State University, 2001 (anticipated), advisor: M. Bershady.

Berrington, R., "The Dynamical Evolution of Galaxy Clusters: Observations and Simulations", Indiana University, 2000, advisor: H. Cohn.

Cole, A., "Helium Burning Stars and the Star Formation Histories of Dwarf Galaxies", University of Wisconsin-Madison 1999, advisor: J. Gallagher.

Conselice, C., "Dwarf Elliptical Members of Rich Galaxy Clusters", University of Wisconsin-Madison, 2001 (anticipated), advisor: J. Gallagher.

Dolan, C., "An Observational Study of the Effect of Massive Stars on Low Mass Star-Formation" University of Wisconsin-Madison, 2000 (anticipated), advisor: R. Mathieu.

Erwin, P., "A WIYN Survey of Early-Type Barred Galaxies: Double Bars and Central Structures", University of Wisconsin-Madison, 1999, advisor: L. Sparke

Hillwig, T., "The Kinematic and Abundance Structure of Nova Shells", Indiana University, 2001 (anticipated), advisor: K. Honeycutt.

Hoffman, J."Mass Loss and the Geometrical Structure of Binary Accretion-Disk Systems", University of Wisconsin-Madison 2000 (anticipated), advisor: K. Nordseick.

Howk, J.C., "Extraplanar Dust in Nearby Edge-On Galaxies", University of Wisconsin, 1999, advisor: B. Savage.

Jain, R.K., "Multiwavelength Observations of Soft X-ray Transients", Yale University, 2001 (anticipated), advisor: C. Bailyn.

Jangren, A., "The Evolution of Blue, Nucleated Galaxies", Pennsylvania State University, 2000 (anticipated), advisor: M. Bershady.

Jogee, S., "Molecular Gas and Star Formation in the Inner Kiloparsec of Starbursts and Non-Starbursts", Yale University, 1999, advisor: J. Kenney.

Jurcevic, J.S., "Distances to Nearby Galaxies via Long Period Variables", Indiana University, 1999, advisor: K. Honeycutt.

King, N., "Luminous Blue Variable and Related High Mass Evolved Stars in M31 and Their Surprising Environments", New Mexico State University, 2000, advisor: R. Walterbos.

Koopman, R.A., "Environmental Effects on Morphology and Massive Star Formation in 93 Bright Virgo Cluster and Isolated Spiral Galaxies", Yale University, 1997, advisor: J. Kenney.,

Matthews, L.,"Galaxy Structure and Evolution at the End of the Spiral Sequence", SUNY-Stony Brook, 1999, advisor: J. Gallagher.

Meyer, R., in progess, Yale University, 2001 (anticipated), advisor: W. van Altena.

Morrison, G., "Butcher-Oemler Clusters", University of New Mexico, 1999, advisor: S. Gregory & F. Owen.

Orosz, J.A., "Optical Observations of Black Hole X-ray Novae", Yale University, 1996, advisor: C. Bailyn.

Otte, B., "Heating Mechanisms in Diffuse Ionized Gas Above the Midplane of Galactic Disks", University of Wisconsin-Madison, 2001 (anticipated), advisors: R. Reynolds & J. Gallagher.

Pisano, D.J., "Assessing the State of Galaxy Formation in Extremely Isolated Galaxies", University of Wisconsin-Madison, 2001 (anticipated), advisor: E. Wilcots.

Rengstorf, A., "High Galactic Latitude Variability: Survey, Detection, and Classification of Quasars and Other Variable Objects", Indiana University, in progress, advisor: S. Mufson.

Rhode, K., "Globular Cluster Systems in Spiral Galaxies and Galaxy Formatoin", Yale University, 2001 (anticipated), advisor: S. Zepf.

Robertson, J., "Two Examples of Mass Transfer Effects on the Long-Term Light Curves of Cataclysmic Variables", Indiana University, 1995, advisor: K. Honeycutt.

Slavin, S., "The Global Dynamical Evolution of Globular Clusters", Indiana University, in progress, advisor: H. Cohn

Stassun, K., "A Test of Star Formation Theory: The Connection Between Rotation, Accretion, and Circumstellar Disks", University of Wisconsin-Madison, 2000 (anticipated), advisor: R. Mathieu

Steinhauser, A., "The Evolution of the Surface Lithium Abundance of F Stars in Open Clusters", in progress, advisor: C. Deliyannis.

Tripp, T.M., "Nature of QSO Absorption Lines", University of Wisconsin-Madison, 1997, advisor: B. Savage.

Winnick, R., "Metallicity Distributions in 3 Local Group Dwarf Spheroidal Galaxies", Yale University, 2002 (anticipated), advisor: R. Zinn.

Undergraduate Theses

Greene, J. "Optical/IR Observations of Black Hole Binaries in Quiescence", Yale University, 2000, advisor: C. Bailyn.

Winnick, R. "The Pre-CV NN Serpentus", Indiana University, 1995, advisor: K. Honeycutt.

Key WIYN Related Grants

"Survey for Pre-Main-Sequence, Short-Period Binary Stars and Associated Disks", National Science Foundation, PI: Robert D. Mathieu (Wisconsin), $234,000.

"High Precision Radial Velocity Study of Open Clusters", National Science Foundation, PI: Robert D. Mathieu (Wisconsin), $250,000.

"The History and Initial Mass Function of the Lambda Orionis Star-Forming Region", NASA, PI: Robert D. Mathieu (Wisconsin), $56,000.

"Study of Galaxies in Clusters", National Science Foundation, PI: John S. Gallagher (Wisconsin), $100,000.

"Relationship Between Lyman Alpha Clouds and Galaxies at $z<0.3$", HST, PI: Blair D. Savage (Wisconsin), $71,000.

"WFPC2 Imaging of Dust Structures and Star Formation in the Disk-Halo Interface in Spiral Galaxies", HST, PI: Blair D. Savage (Wisconsin), $95,000.

"Pervasive Hot Gas in Galaxy Groups: A Substantial Baryon Reservoir", HST, PI: Todd M. Tripp & Blair D. Savage (Wisconsin), $35,000.

"Nature and Distribution of OVI Absorbers in the Vicinity of Galaxies", HST, PI: Todd M. Tripp, Edward B. Jenkins, Blair D. Savage (Wisconsin), $40,000.

"Extended HI Envelopes Around Irregular Galaxies", National Science Foundation, PI: Eric M. Wilcots (Wisconsin), $167,000.

"Accretion, Asymmetry, and Outreach", National Science Foundation CAREER, PI: Eric M. Wilcots (Wisconsin), $499,000.

"Spatially Resolved Kinematics of Distant Galaxies", National Science Foundation, PI: Matthew A. Bershady (Wisconsin), $200,000.

"Io", NASA, PI: Christopher M. Anderson (Wisconsin), $90,000.

"Torus", NASA, PI: Christopher M. Anderson (Wisconsin), $60,329

"Hale-Bopp", National Science Foundation, PI: Christopher M. Anderson (Wisconsin), $173,000

"Optical Observations of Black Hole Binaries and Related Systems", National Science Foundation, PI: Charles Bailyn (Yale), $228,000

"Dwarf Spheroidals", National Science Foundation, PI: Robert Zinn (Yale),

"Abundance Studies of Open Clusters: Implications for Stellar and Galactic Astrophysics", National Science Foundation, PI: Con Deliyannis (Indiana), $195,112

"Deep Astrometry and Photometry of Key Open Clusters: A New Foundation for Stellar Astrophysics", National Science Foundation, PI: I. Platais (Yale), $185,00

"Collaborative Project: Deep Astrometry and Photometry of Key Open Clusters: A New Foundation for Stellar Astrophysics", PI: A. Sarajedini (Wesleyan), $165,000

WIYN Related Graduate Fellowships

National Academy of Sciences Minority Dissertation Fellowship, 1999-00,K. Stassun (Wisconsin)
Wisconsin Space Grant Consortium Fellowship, 1997-98, K. Stassun (Wisconsin)
Sigma Xi Grant In Aid of Research, 1998-99, K. Stassun (Wisconsin)
Wisconsin Space Grant Consortium Fellowship, 1998-99, K. Stassun (Wisconsin)
Wisconsin Space Grant Consortium Fellowship, 1999-00, D.J. Pisano (Wisconsin)
Wisconsin Space Grant Consortium Fellowship, 1998-99, C. Conselice (Wisconsin)
Danish National Fellowship, 1999-, S. Meibom (Wisconsin)

The 6-pak project facilitated access to NSF/ATI funds via Bershady from Penn State. This instrumentation project also provides training in instrumentation for graduate students (currently, D. Andersen).

Educational Mission

Graduate training at the University partners is the key component of the educational mission of the WIYN consortium. Primarily, this is measured in terms of access to the telescope for thesis students, though there are other benchmarks. WIYN has been an integral component of 14 PhD theses at Wisconsin (7 in progress), 7 at Yale (4 in progress), and 7 at Indiana (6 in progress). It is fair to say that half of the dissertations at Wisconsin.

WIYN has been incorporated in a number of classes at Yale (7) and Wisconsin (2). Indiana has yet to incorporate WIYN in any courses. The Wisconsin courses include a graduate WIYN seminar taught by J. Gallagher in 1998. To date the partners have used three main modes for this: class participation in the remote observing activity (largely at the introductory level), development and implementation of an observing program (at the undergraduate major level), and integration of WIYN science in the curriculum. WIYN science has been a critical component of a number of upper level undergraduate and graduate courses at Wisconsin, including: "The Interstellar Medium" (graduate and undergraduate; Prof. B. Savage), "Galaxies & Cosmology" (undergraduate; Prof. E. Wilcots), "Galaxies" (graduate; Prof. E. Wilcots).

With the exception of courses at Wisconsin and Yale, WIYN has yet to be fully integrated into the undergraduate educational mission of the Universities. A number of undergraduates have observed at WIYN and have worked with WIYN data as part of their research experience.

Impact on Graduate Program

WIYN is an important component of the recruitment of graduate students at the individual institutions: at least half of the graduate students who arrived in Madison in the last four years would have gone elsewhere for graduate school had there been no WIYN.

WIYN has been important in training students at Wisconsin to devise and execute observational program via the WIYN Graduate Queue. That this has thus far not produced formal papers is perhaps not too critical as it has led our graduate students to learn how to develop observing programs and to get into the details of data processing. WIYN has indirectly boosted our program by making it easier to attract highly motivated students, and to develop collaborations involving graduate students. It has enhanced the ability of our observational students to carry out pre-thesis independent projects.

Wisconsin provides access to WIYN for all graduate students through the "graduate student queue". The graduate students are collectively given 2-3 nights per semester to pursue science programs of their own design. Experimentation is encouraged. "Queue" data has led to a number of poster papers.

6. Future Development

6.1. Finding WIYN's niche

In order for WIYN to make a significant scientific impact, we must do some things better than anyone else. This is a challenge for a telescope which is medium-sized by today’s standards. Finding a niche for WIYN is recognized by the consortium members as very important, and we are not satisfied with our efforts to date.

WIYN can make a unique contribution in two ways. One is by undertaking scientific projects of significance and broad scope. The WIYN Open Cluster Survey is the premier example, where scientific interests in several of the partner institutions overlapped. The Consortium recognizes the potential and importance of such major efforts, but no further projects have coalesced to date.

The other path to uniqueness is provision of instrumentation that is cutting edge and captures a performance niche not otherwise strongly occupied.

The strength of the WIYN Telescope is very good image quality over a wide field of view. Instrumentation that exploits that wide field would provide capabilities that complement the narrow-fields typically provided by 8-meter class telescopes. The choice of instrumentation must specifically complement the wide-field facilities being provided on the upgraded MMT and recognize the impact of instruments such as CFHT Megacam in order to provide a competitive niche.

6.2 Future Instrumentation Development

Directions for the future which have been identified include:

i) Excellent imaging over a wide field. While the fully corrected 0.5-deg field at the WIYN port is no longer forefront, it nonetheless represents a competitive strength of the telescope. We consider it critical to develop an imager which can make full use of this capability. A more ambitious realization is to replace the Hydra positioner at the one-degree port with a next-generation CCD Mosaic, filling the field, and consisting of orthogonal transfer devices, each of which zonally provides a tip-tilt correction.

ii) Corrected imaging over a narrow field. Two steps are possible to build on the WIYN Tip/Tilt Module implementation. One is to provide a near-infrared camera to be fed by the tip/tilt system. Since 10% of the time now shows image quality better than 0.4 arcsecond in the visible, the gains for tip/tilt correction in J and H band would be substantial. The Calypso telescope on Kitt Peak has already delivered 0.25" images in I with just tip/tilt correction, and the improvement should be greater at longer wavelengths. Science drivers include systematic detection of sources in obscured regions found in X-ray, gamma-ray, and other space-accessible wavelengths; narrow-band emission-line imaging of structure in distant galaxies; and synoptic follow-up of variability in strong gravitationally lensed quasars, obscured proto-stars, and heavily reddened AGN.

The second step is to replace the tip/tilt mirror with a deformable mirror for low-order adaptive correction. For the near-IR, such correction would give moderately high Strehl ratio images while continuing to concentrate and reduce the broader core and wings of the seeing-delivered profile. The high spatial frequency information provides reconnaissance information for HST and large telescope follow-up in crowded star fields, galaxy centers, and regions of star formation.

ii) "The blues": With most of the new large optical-IR telescopes emphasizing the near infrared, we recognize there may be a niche for WIYN at blue-near UV wavelengths. Admittedly this photon-starved domain is a difficult direction for a 4m-class telescope, but optimized high spectrograph throughput at these wavelengths promotes abundance and interstellar science that is a forte at the Universities. A permanently mounted narrow field spectrograph at a bent-Cassegrain port would provide unique synoptic monitoring and target of opportunity capability. WIYN has made major contributions in the optical detection of gamma ray burst sources and supernova light curves, both through synoptic imaging. Synoptic spectroscopy is powerful for suddenly active cataclysmic variable X-ray sources and symbiotic stars, AGN emission-line profile variability, and redshift determination for GRB and other targets of opportunity.

iii) High-spatial resolution multi-object and IFU spectroscopy. Given a set of optimized IFU cables and the Hydra, the high-resolution capability of the Bench Spectrograph provides a niche, especially for star cluster work and studies of the structure and kinematics of nearby galaxies. To optimize this capability, we consider it imperative to substantially improve the throughput of the Bench Spectrograph. That project will start with a collimator and field lenses that compensate for the beam spreading due to fiber focal ratio degradation. A more major improvement is to create a transmissive system that exploits Sam Barden's developments in volume-phase holographic gratings. Additional performance gains could be found in upgrading the positioner stages and servos to the much faster system deployed on the version of Hydra at CTIO.

A nearly unique major project would be to replace the single Hydra fibers with a group of deployable IFU's. Such a combination would enable systematic studies of the dynamics and abundance gradients of galaxy cluster members, HH objects in star-forming regions, and seeing-limited spectroscopy of dense stellar regions.

iv) Near-infrared multi-object high-resolution spectroscopy. A plan for multi-object spectroscopy in the non-thermal near-infrared has been developed by Steve Zepf (Yale) in consultation with WIYN consortium members, particularly NOAO staff Dick Joyce and Ken Hinkle. By using an infrared array as the detector for the current Hydra multi-fiber instrument Bench spectrograph, a unique capability for multi-object spectroscopy in the non-thermal infrared over a wide field is possible. This can be achieved rather straightforwardly although a fairly large IR array is required (1024^2 minimum, 2048^2 preferred). This project was the focus of a Packard Fellowship proposal by Zepf and Yale that was not funded. An ATI proposal for a "Hawaii-2" 2048^2 HgCdTe array, dewar, and electronics is currently pending. The high cost of the required array is the main stumbling block for such an instrument. Examples of science programs that could be carried out with such an instrument are a survey for H-alpha in galaxies at z ~ 0.8 and spectroscopic classification of embedded young stellar objects.

These ideas were developed as part of the strategic planning process described in Section 3.5. The implementation plan and outcome were also as described there. There was reluctance on the part of the consortium to prioritize these major directions internally, consistent with the desire to encourage PI's to develop their own programs, sometimes in parallel, toward proposal and funding. The key to a successful observatory five years hence will be success in at least one of the major initiatives above.

6.3. Funding development

Since the beginning a critical barrier for WIYN has been that major funding for new instrumentation was not built into the base budget. The intention of the early Boards was that such funding would be developed externally. In practice this has been difficult to achieve, both in terms of internal leadership and organization and external success. Consequently we have a superbly operating telescope that is vulnerable to serving outdated instruments. Arguably solving this problem is the key issue for the future of WIYN.

6.3.1 Role of Director—

The primary goal in creating the WIYN Director position was to have an individual fully committed to the future development of WIYN. Thus the primary charge to the Director is to promote the scientific impact of the observatory, with an emphasis on the development of a vigorous instrumentation program. The latter includes establishing commitment to an instrumentation direction for the consortium, developing funding, engaging leadership at the partners, and ultimately oversight. As such the Director must be engaged in fundraising initiatives in both the Federal and the University domains.

6.3.2 Funding sources

6.3.2.1 National Science Foundation—

To date we have submitted proposals to both the Major Research Instrumentation and the Advanced Technology Initiative? programs. These experiences made it clear that major WIYN instrumentation proposals for General Use instruments (i.e., 1+ M$ projects) require leadership and management from a Director. The ideas – adaptive optics and near-infrared multi-object spectroscopy - were competitive, but the diffuse nature of the WIYN organization led to proposals that were not fully developed. In addition, there was little preparatory work done with the cognizant NSF program officers. Our future depends on learning from these experiences and integrating the WIYN Director in the process.

We note that the MRI proposals require matching funds at the 33% level, which we were able to develop.

6.3.2.2 Universities and Foundations—

We have worked with the University development offices to promote adopting astronomy programs generally and WIYN specifically as high priorities for targeting prospective donors. The widespread interest in astronomy makes this a potentially rewarding endeavor. While some universities, and Yale in particular, are protective of their development people, the universities have allowed us to talk to people in the development offices, and one development person from each of the universities did attend a recent WIYN board meeting. However, to date these efforts have not borne fruit. We recognize that this is a long-term endeavor, and will continue a steady pressure.

There has been ongoing discussion of developing a Board of Visitors to assist in WIYN development. A set of well-connected alumni with a passion for astronomy would provide both potential direct resources for small projects and links to more major donors.

6.4 Expansion of the consortium beyond the 3.5m?

The success of the 3.5m telescope has vividly demonstrated that each of the partners is able to accomplish far more as a consortium than as individual institutions. While this is most evident in the observatory itself, it is equally evident in scientific initiatives such as the WIYN Open Cluster Study. It is also important that the relationships between the partners have been very cordial and enjoyable, making the prospect of expanding horizons very welcome.

As a first step in a broader vision of WIYN, we are giving serious consideration to proposing to assume the operation of the KPNO 0.9m telescope, located on the same ridge as the 3.5m telescope.

6.4.1 KPNO 0.9m

Due to budgetary limitations, NOAO is making the KPNO 0.9m available for operation by other institutions through a proposal process described in the March 2000 NOAO newsletter. The prospect of including this telescope within WIYN facilities is very attractive, since this telescope would permit:

i) Wide field-of-view imaging – the 1-deg field of the MOSAIC imager is well matched to the Hydra field, while the 23 arcmin square field provided by a 2Kx2K imager remains a useful wide-field imaging instrument.

ii) Synoptic and monitoring capabilities for the many time-dependent research programs within the WIYN consortium.

iii) Photometric calibrations supporting WIYN observations.

iv) A significant education arm to WIYN. The WIYN consortium was conceived with a major educational mission for undergraduates for the University partners. In reality, the pressure on time at the 3.5m has made significant observing experiences infrequent. The 0.9m represents a very real means of accomplishing WIYN's educational mission. Equally important, the 0.9m will provide the opportunity for long observing runs for graduate students, providing more significant hands-on observing experiences.

Explorations are underway in preparation for submission of a proposal. Since NOAO is directing its attention away from 1m class telescopes, the proposal will be led by the University partners. In support of the educational mission, each of the partners has themselves developed partnerships with smaller colleges in their states, including Wesleyan University, the University of Wisconsin campuses at Oshkosh, Stevens Point, and Whitewater, Butler University and Indiana University – South Bend. NOAO has offered to provide the MOSAIC imager when it is off the 4m in return for 40% access to the 0.9m/MOSAIC for the national community. A fundamental premise in this effort is that it must be accomplished without diverting funds and time from the 3.5m. Hence the budget ($500K over 4 years) has been set to permit renovation of the telescope control system, development of a 2Kx2K imager, a full maintenance contract and a full-time "friend of the telescope" so that the 0.9m should represent little burden on WIYN personnel and faculties. Furthermore, funding is entirely from educational sources that could not otherwise be tapped for the 3.5m.

If we are successful with our proposal, operation would begin in August 2001 and the initial lease would extend through 2003.

6.5 Potentialities

The success of WIYN has shown that a partership of public and private universities and the National Observatory could produce a high performance telescope on time and on budget. The Board interactions have been a model of collegiality and shared purpose. The performance of the telescope verified the limiting performance of borosilicate honeycomb mirrors and reawakened the community to the outstanding delivered image quality on Kitt Peak. High-reliability operations have been achieved on a lean operating budget.

What further successes could be realized in the next five-year period?

- A focused and successful instrument development program, tapping sources of public and private funding, and utilizing the best talents of the Consortium across institutional boundaries. Such projects are critical vehicles for the training of instrumentalists by the Consortium partners.

- Allocation of telescope time resources in a way that maximizes unique science from WIYN. Those allocations must span a range from synoptic monitoring and quick response on targets of opportunity to major, cross-institutional projects with long-term significance.
- A demonstration by example that wide-field 4-meter class telescopes with excellent imaging produce major scientific advances in an era of large apertures.
- A major impetus to education and outreach activities at the partner institutions and in their communities. Provision of WIYN data as the basis for undergraduate training and public appreciation of astronomical science can make an incalculable impact on long-term support.

We are optimistic that, with commitment and change, these successes can be achieved.

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