The W. M . Keck Observatory

Vision

A vision statement is the difference in the world that we, as an observatory, are committed to making. Our vision is to create:

> ***A world in which all humankind is inspired and united by the pursuit of knowledge of the infinite variety and richness of the universe.***

Mission

What the W. M. Keck Observatory provides to make our vision a reality:

> ***We advance the frontiers of astronomy and share our discoveries to inspire the imagination of all.***

Values

CORE

Core values are crucial and essential for us to accomplish our mission – the things that we hold as a group to be fundamental to how we define ourselves as professionals associated with the W. M. Keck Observatory.

1) ***SAFETY*** - ***Safety is our primary core value. We hold as paramount the safety and health of Observatory personnel and equipment and that of our natural environment.***
2) ***INTEGRITY*** - ***We, as individuals and as an organization, hold to the highest ethical standards. We act with sincerity, honesty and fairness. We make promises carefully and keep them unequivocally.***
3) ***RESPECT*** - ***We respect all human beings and treat them with dignity. We respect the unique natural and cultural environment that is Hawai'i.***
4) ***DISCOVERY*** - ***We honor and nurture discovery – scientific, technical, and personal. Discovery lies at the very heart of our mission.***
5) ***SERVICE*** – ***We proudly serve each other, our community, and those who use the W. M. Keck telescopes, assuring that telescopes and instruments are fully operational for every night's observing.***

CULTURAL VALUES

Cultural values are highly desirable values that every Observatory staff member strives to exemplify.

- ***EDUCATION AND LEARNING:*** ***We encourage broad-based life-long learning and professional development for every member of The Observatory staff.***
- ***COMMUNICATION:*** ***We listen effectively and speak thoughtfully and honestly. True communication begins with careful listening.***
- ***TEAMWORK:*** ***We honor and encourage teamwork both within the Observatory and broad CARA community.***
- ***REWARDING WORK ENVIRONMENT:*** ***We strive that all who work here are enriched and inspired by what we have together accomplished. A challenged, educated and appreciated staff will maximize the chances for breakthrough scientific discoveries.***
- ***EXCELLENCE IN GENERAL:*** ***We carry out our mission with a commitment to excellence both in what we do and how we do it. We encourage and honor creativity, quality and initiative by all who work here.***
- ***COMMUNITY INVOLVEMENT:*** ***We involve ourselves in positive, meaningful and supportive interaction with our unique local community. We share the excitement of what we do and what we discover with all.***

EXECUTIVE SUMMARY

This Strategic Plan for the W.M. Keck Observatory identifies Observatory activities for the next 20 years to meet the strategic goals that the Observatory and its users have identified as essential to the Observatory's mission.

For the scientists who depend on the Keck Observatory for their research, four themes drive the priorities to which to apply our available resources: 1. Maximizing Observatory Efficiency; 2. Developing state-of-the-art instrumentation; 3. exploiting Keck unique high angular-resolution capabilities; and 4. exploiting the looming Keck/TMT synergistic activities.

In this document, we identify Observatory activities on the 5, 10 and 20-year timescale.

Astronomy Community Activities

Efficiency Improvements

In order to compete with the many state-of-the-art 8-m class telescopes now coming on line, the Observatory must be certain that it uses its larger light-grasp to maximum advantage. This means not only maximizing on-target integration time with every instrument, but also delivering the best possible image quality to the telescope and instrument focal planes. The Observatory will continue to develop efficiency metrics to evaluate end-to-end telescope/instrument performance, identify the sources of both overhead and downtime, and prioritize activities accordingly.

Scientific leadership through state-of-the-art instrumentation

Keck has established its enviable position as the world's leading Observatory by "getting there first" with a suite of "core" facility instruments that cover large areas of resolution/wavelength space. Our users have identified near-IR multi-object spectroscopy as the key missing core capability at the Observatory, and our near-term (5-year) instrument activities will concentrate on filling this gap. Other instrument activities will include upgrades to detectors on existing instruments and providing visitor instrument capability to exploit already-existing "niche" instruments that could be adapted for use at Keck.

High Angular Resolution Astronomy

The 10-m diameter of the Keck mirrors gives these telescopes an advantage over all current competitors in diffraction-limited imaging and spectroscopy, and many of our activities will be aimed at exploiting this advantage. The development of OSIRIS will provide Keck its first diffraction-limited, integral-field spectroscopic capability. The SSC has identified the development of laser guide star AO as one of the highest scientific priorities at the Observatory, and we identify many activities in this area. Keck Foundation funding has recently been received to upgrade the AO wavefront sensor/controller subsystems—the heart of the AO system—to assure it remains the state-of-the-art. Development of a next generation, higher precision, PSF-stable AO system will be the next major step we must undertake. Making the Keck interferometer a core and widely-exploited science capability of The Observatory is another key activity in the years ahead.

Keck/TMT Synergy

Within the 20-year timescale, the Keck telescopes will be eclipsed as the world's largest by the next generation, and our planning should clearly position Keck for the TMT era. We need to identify synergistic activities with the TMT project that will benefit both telescopes, and will assure the TMT is a success, and that Keck remains competitive.

Observatory Employee Activities

To maintain its world leadership, the Observatory must attract, retain and inspire the best and brightest scientists, engineers, technicians and non-technical staff. To this end, we identify herein strategies for achieving a high level of employee satisfaction and to develop full, appropriate and diverse staffing of the Observatory.

Community-at-Large Activities

The Observatory is uniquely positioned on a small island, the farthest point on the earth's surface from any major landmass. Yet Mauna Kea hosts the largest collection of world-class telescopes in the Northern Hemisphere. The number of astronomy-related jobs per capita in Hawaii is extremely high, and astronomy is a highly visible local activity—a source of pride to many, though not all, who live here. Thus inspiring non-astronomers by "the infinite variety and richness of the universe," as our vision states and "sharing our discoveries to inspire the imagination of all," has great significance to the Observatory staff. They are strongly encouraged to be active in our local community to bring the message of astronomy to this and future generations. This document identifies many of the outreach activities in which the Observatory expects to participate in the years ahead. In addition, it is important that Keck be recognized, as Hubble has been recognized, as a "national treasure," and we must work to make Keck a household word by publicizing the many discoveries that are made with the Keck telescopes.

1 Introduction

This document presents the Strategic Plan for the W.M. Keck Observatory hereafter referred to as the Observatory. It is a living document, meaning that all stakeholders must revisit it regularly and revise it as necessary in light of the changing worldwide landscape of astronomy. Nowhere is this more important than within the astronomical community in this era of rapid technological development and of the appearance of major new astronomical research facilities that challenge our leadership.

It is an incomplete document with many sections included by title only. These will be updated regularly, and the latest draft will be available to all via the Observatory web site.

This document grew out of discussions with the user community that began with a future instruments workshop in June 1997, and continued from that time onward through many discussions within the Science Steering Committee (SSC) and the Adaptive Optics Working Group (AOWG).

The impetus to codify the community's thinking about its future came through a 2-day Strategic Planning Workshop held in Waimea in December 2002 which included representatives from the Observatory staff employed by the California Association for Research in Astronomy (CARA), the Science Steering Committee (SSC), and other representatives of the Keck user community.

That workshop identified **vision, mission and values** statements for the Observatory as well as **long-term strategic goals** for each of three "stakeholder" groups—the astronomy community, the Observatory staff, and the community-at-large—recognizing explicitly that the Observatory's future must be considered in its broadest context.

The long-term horizon for strategic planning has been selected to be 20 years, in recognition of the fact that within that period, the Keck telescopes are likely to relinquish their place as the world's largest, and the Observatory must then consider itself in that era as well as its present one.

This document explores the implications of the long-term strategic goals of the three stakeholder groups. These goals provide the context for the activities of each of these groups in both the short term and long term.

The **astronomy community** long-term goals emphasize the need to maximally exploit the scientific capabilities of the Keck telescopes and to maintain the world leadership in astronomical research the Observatory has enjoyed for over a decade. We further recognize that the world-wide astronomy landscape has changed dramatically since the turn of the 21st century, and that the Observatory's leadership is being seriously challenged by many newly-operational 8-m class telescopes that are more modern and better funded that Keck. This new landscape forces us to prioritize those astronomical capabilities that are fundamental to meeting our long-term strategic goals—inevitably at the expense of other, highly desirable, but not essential capabilities.

The Observatory **employee** long-term goals emphasize the need to provide a work environment that attracts and retains the best and the brightest staff to work at the Observatory. Maintaining the highest quality staff is essential if we are to retain our position as the world's leader in astronomical research.

The goals for the **community-at-large** emphasize that the continued support for astronomical research, which is ultimately funded by non-astronomers, depends upon getting our message out to the public and, paraphrasing our mission statement, "sharing our discoveries to inspire the imagination of all." The goals also recognize the unique physical and cultural environment in which the Observatory finds itself, and the need to be good stewards of that environment.

In what follows, we define and explore the implications of our strategic goals, identifying important activities that we must pursue in the next decade and beyond to achieve those goals toward the accomplishment of our mission.

1.1 Vision, Mission and Values

All activities at the Observatory are guided by our **VISION, MISSION AND VALUES**. The **VISION** is defined as the difference the Observatory is committed to make in the world. Our **VISION** is to create:

> **A world in which all humankind is inspired and united by the pursuit of knowledge of the infinite variety and richness of the universe**

The **MISSION** is defined as what the Observatory provides to strive to make its **VISION** a reality:

> **We advance the frontiers of astronomy and share our discoveries to inspire the imagination of all.**

These are bold, broad, and nearly utopian statements, but astronomy is a field of human endeavor especially will-suited to be guided by such lofty ideals, and nowhere more appropriately than at the Observatory.

Key to accomplishing the Observatory's mission is fostering creativity among the scientists and engineers in our community, taking steps to ensure the resources are available to remain world-class, maintaining a vigorous public outreach program, and providing the incentives to attract and retain a first-rate, dedicated staff in Hawaii.

VALUES--critical or aspirational—are the things we hold as a group to be fundamental to how we define our relation to the Observatory to accomplish our mission. These will be discussed later in this document.

1.2 Purpose and Structure of this Document

The purpose of this document is: 1. to identify long-term **STRATEGIC GOALS** for the Observatory that must be reached to achieve its mission and 2. to translate those into a series of shorter-term **milestones** that will guide all activities at the Observatory. We have selected a 20-year planning horizon for setting our strategic goals—purposely beyond a horizon to which we can extrapolate from the present—thus, in the spirit of the 2002 Strategic Planning Workshop, "planning the future from the future."

This document is structured so as to identify goals and milestones for the major "stakeholders" or constituencies that the Observatory serves. We identify four such constituencies: 1. The **astronomy community** that uses the Keck telescopes and instruments for its research; 2. The Observatory **employees,** who assure the readiness and quality of the telescopes and instruments 365 nights a year; 3. The **community-at-large** in which the Observatory operates which is interested in its broad impact on that community. The state of Hawaii in general and the Big Island in particular make for a unique natural and cultural environment in which the Observatory operates; 4. The Observatory governing body, **the CARA Board of Directors**, who represent the University of California and the California Institute of Technology, the founding organizations of the Observatory.

In the major sections that follow, we identify goals and milestones for the first three of the constituencies above. Section 2 is devoted to the goals and milestones of the astronomical community; Section 3 to those for the Observatory employees; and Section 4 to those for the general community, with whom we interact through our various media and public outreach activities.

We find ourselves in a state of flux and ferment which necessitates that our astronomy community continue to review and debate future endeavors for the Observatory. It is important that we prioritize these future endeavors and define specific timelines for bringing on new capabilities as well as identifying potential sources for funding.

2 Astronomy Community: Goals and Milestones

2.1 Introduction

The Observatory's **MISSION** of "advancing the frontiers of astronomy" implies that it should enable the users of the Keck telescopes to tackle the most fundamental questions in astrophysics with stable, state-of-the-art instruments while being provided with reliable, efficient operations. Although the 2004 astronomical landscape is changing as the various 8-m telescopes are being commissioned and instrumented, the Keck telescopes remain, by virtue of larger collecting area and the attention paid to high throughput instruments, the most powerful optical/near-IR facilities in the world, particularly for very faint object spectroscopy and high angular resolution astronomy.

Our responsibility is to maintain, as a community, a leadership role in ground-based O/IR astronomy. The nature of our user community is such that long-term programs are uniquely possible (e.g. the Keck Planet Search, DEEP, Galactic Center proper motion program). We must also simultaneously maintain the flexibility for quick-response science programs and targets of opportunity. To do this requires setting our sights very high in selecting/soliciting new instruments, making upgrades to existing instruments, and maintaining the facility at the state-of-the-art. We must maintain our leadership in a continually and often rapidly evolving scientific and technological environment.

Twenty years is a natural timescale for strategic planning for the astronomy community. The CARA parent organizations, Caltech and the University of California, are engaged in the development of a 30-m telescope (TMT). There are a number of development activities for the TMT for which the Keck telescopes provide an excellent test bed. It is very important to structure any joint Keck/TMT activities to be synergistic and of direct benefit to the Observatory. When the TMT is in operation, the Keck telescopes will for the first time be eclipsed as the most powerful optical/IR telescopes in the world. We therefore have structured our future thinking into two eras. The period 2003-2014 will be the era of technical synergy with TMT development and the appropriate positioning of the Observatory in terms of the scientific capabilities; the following decade will be the era of scientific synergy with the TMT.

We start with a description of the **STRATEGIC GOALS** for the Observatory in 20 years. Next, specific programs for the next decade are identified on the road to achieving those goals. The efforts over the coming five years are described in even greater detail and Appendix 3 contains a resourced plan for activities through 2009.

2.2 Strategic Goals

The 2002 Strategic Planning Workshop identified the following 20-year **STRATEGIC GOALS** as paramount to the Observatory's **MISSION**:

- **Achieving highly efficient operations**
- **Maintaining scientific leadership through state-of-the-art instrumentation**
- **Maintaining world leadership in high angular resolution astronomy**
- **Achieving complementarity with Extremely Large Telescopes**

2.3 The Astronomical Landscape: 2004

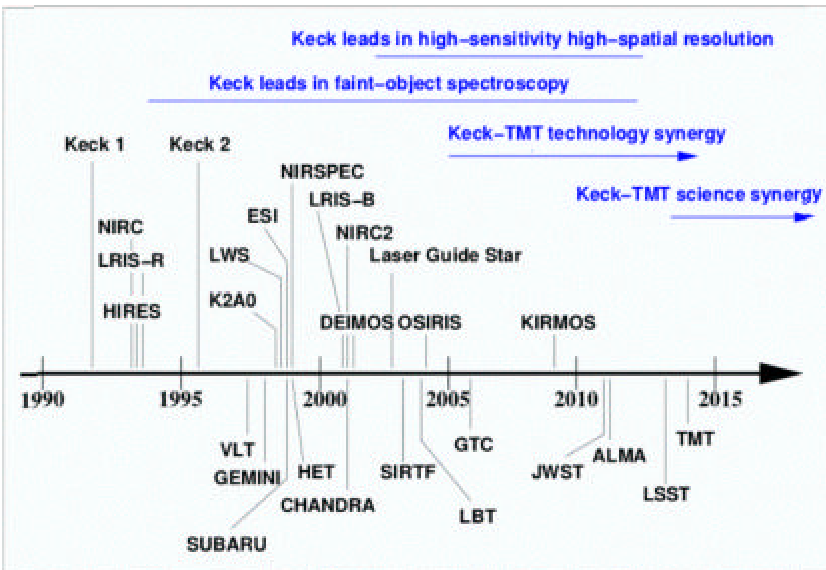

Figure 1. Timeline for important the Observatory new capabilities (top) and other significant new astronomical capabilities.

In order to achieve and maintain the optimal scientific performance, the Observatory must be considered in the context of a broad astronomical environment: the landscape of scientific ideas and trends, the capabilities of other major observatories and space missions (both present and forthcoming), and various enabling technologies. Some of the greatest successes of the Observatory have been based on leveraging of our spectroscopic capability with data obtained from space observatories (e.g., the HST, Gamma-ray burst missions, soon SIRTF, etc.). Other large telescopes are developing capabilities in which we are relatively weak (e.g., wide-field imaging, or MIR work), and we can find ways to exploit such complementarities and focus our resources in the areas where they matter most. Scientific interest in different areas changes in response to new discoveries, often in surprising directions, implying different instrumentation needs. As the astronomical environment evolves, so should the scientific roles and capabilities of the Observatory.

Probably the chief evolutionary factor is the advent of the TMT, and the Observatory should respond to it by a wise strategic deployment of resources, now through the TMT operations era. This is the key in achieving a lasting vitality and maximum scientific relevance of the Observatory in the years and decades to come. While the current challenge is to maintain and enhance the scientific supremacy of the Observatory over competing facilities, and to provide a broad spectrum of capabilities to the user community, this role will inevitably change when the TMT (and possibly other ELTs now under consideration) starts operations. Areas in which we excel now (e.g., the faint object spectroscopy) will be dominated by the next generation of ELTs, and the Observatory strengths and focus should then shift to other scientific niches or supporting roles for the TMT, analogous to the relation of the 3 to 5-m class telescopes to the Keck telescopes now. We must assure that we will be well positioned to the new set of demands at that time. For example, the desired set of scientific capabilities at the Kecks as we transition into the TMT era would depend (among other factors) on whether the TMT is built in the northern or the southern hemisphere, and on the status of the JWST and other major space missions.

The development of the TMT and its enabling technologies cannot happen in a vacuum: it rests on the foundations and experiences gained in the development and operations of the Observatory. This calls for a genuine synergy of the facilities, with the Observatory acting as a partner in the development and testing of technologies and operating strategies relevant for the TMT, while benefiting from the same developments in improving its own scientific capabilities. At the same time, such partnership would assure that the Observatory retains and continues to attract capable and motivated staff, which is essential for its proper functioning in serving the user community.

We note that there is an additional consideration beyond strategic positioning of the Observatory in the broad astronomical landscape. The Observatory is the principal facility available to University of California and Caltech astronomers. For this (significant) component of the user community, maintaining a broad range of capabilities will continue to be a priority.

2.4 The Observatory in 2024

We begin with a description of how we see the Observatory in 20 years. The goals for two decades out primarily call for: 1. a suite of instrument capabilities that provides a complement to any ELTs that will be in operation by 2024; 2. much-improved high angular resolution capabilities—AO and interferometry ; and 3. much-improved efficiency at the Observatory.

Specific goals agreed upon at the 2002 Strategic Planning Workshop for 2024 are: 1. 90% efficiency for clear weather open-shutter time, 2. diffraction-limited capability from 10 microns to 400nm with Strehl>0.6 a significant fraction of the time on both telescopes, 3. faint-object capability for the Keck Interferometer, 4. pan-chromatic, hard mirror coatings on all optics, 5. data pipeline reduction codes for all instruments and 6. a complete archive.

Additionally, availability of alternative observing modes designed to make best use of conditions or real-time deployment of the telescopes for follow-up of time-dependent phenomena while maintaining the flexibility and hands-on nature of Keck will also be a part of the future Observatory.

A major challenge in twenty years will be to have steered the Observatory development in such a way that the Observatory complements the capabilities of the next generation of giant (20m - 50m) telescopes. There are a number of possibilities in this area. For example, the advances that will allow AO in the near-IR on 30m aperture telescopes will also lend themselves to AO at optical wavelengths with the Keck Telescopes. Wide-field imaging and multi-object spectroscopy will likely remain the domain of 10m-class telescopes into the next era and the selection of targets at the forefront of TMT astronomy will require the capabilities of 10m telescopes. It is not yet clear whether TMTs will have instrumentation and mirror coatings that allow observations to the atmospheric limit in the UV (310nm). Thus high- and moderate-resolution spectroscopy between 310nm and 380nm may be another area in which the Observatory will excel in the 30m era.

2.5 The Next Decade: 2004-2013

2.5.1 Themes

In keeping with our 20-year **strategic goals**, we identify themes in which to concentrate our activities in the next decade:

2.5.1.1 Highly Efficient Operations

Improving the efficiency of the telescopes, instruments, facility and observers to maximize the scientific output of the Observatory continues to be an activity crucial to the Observatory's mission and strategic goals.

2.5.1.2 World-leading Capabilities for Surveys and Faint-object Spectroscopy

The Keck telescopes have led and continue to lead the world in faint-object spectroscopy. The telescope primary mirrors are larger than those of the VLT, Gemini, and HET telescopes and the Keck instruments are among the most efficient ever built for astronomy. With the 2002 commissioning of DEIMOS, we now have excellent multi-object optical spectroscopic capability on both K1 and K2. The nature of telescope time allocation the institutions with primary Keck access is such that longer-term programs and surveys are possible.

2.5.1.3 High Angular Resolution Astronomy

The Observatory has enjoyed a lead in bringing high angular resolution astronomy to 8-10m class telescopes, with an adaptive optics system that has been in operation on K2 since 1999. The commissioning in 2001 of NIRC2, the first science instrument designed specifically to work behind the AO system, is a major step forward in capability. Closing the AO loop with a laser guide star for the first time in 2003 is another very significant event in the Observatory history. When the laser guide star facility is routinely operational, it will usher in a new and extremely exciting era for the Observatory and for astronomy. We stress here that successfully integrating the laser is crucial to keeping Keck at the forefront in AO-based astronomy.

In addition, we are just entering the era of Keck-Keck interferometry. Even without the outrigger telescopes, this will be a new, powerful capability, though we look forward to the era of full outrigger enabled science. The Keck interferometer (KI) was designed to meet the goals of a particular scientific niche. However, there are many possibilities in a broader arena. We anticipate that early science returns from the interferometry specialists will promote engaging the fuller CARA community. We will actively monitor the progress of this facility and be aware of opportunities as they arise to enhance the KI capabilities as appropriate.

2.5.2 Ten-year Goals and Programs

In our view, high-angular resolution imaging/spectroscopy, faint-object spectroscopy, and efficiency will continue to be areas in which the Observatory will lead the world for at least another decade until the next generation of 20 - 50 meter telescopes is built. Accordingly, these are the areas where we recommend placing high priority for resources in the next 10 years and where we anticipate Keck will set the standard of excellence in 2014.

The overall scientific capabilities of the Observatory are based on the dual foundation of enabling technologies (including AO, detectors, advances in computing, optics, etc.), and general improvements to the efficiency; for example, telescope and instrument throughput, detector efficiency, and image quality can be traded off directly with the telescope collecting area; the fraction of the on-the-target, open-shutter time is directly proportional to the amount of science generated; and so on.

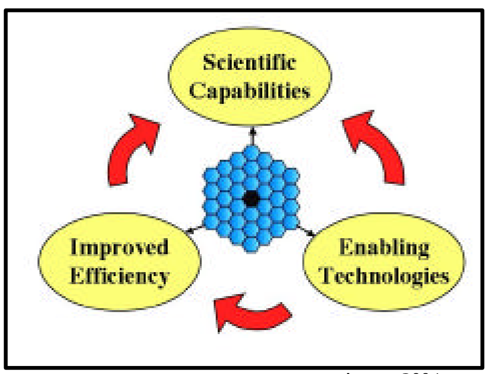

Figure 2. A schematic illustration of the relationship between the scientific capabilities and the output of the Observatory, the improvements in efficiency, and the enabling technologies which benefit both. The Observatory has to be the nexus of this creative synergy.

There are three major areas in which activities need to be concentrated at the Observatory: new instrumentation (i.e., new or improved scientific capabilities), improved efficiency and reliability, and improvements/extensions to the AO system.

2.5.2.1 OBSERVATORY EFFICIENCY AND RELIABILITY

In the second decade of the Observatory, there are now a number of 8m-class telescopes in operation. To take full advantage of the larger Keck aperture requires maintaining excellent throughput for the telescope and instruments and having a highly reliable facility. This is a multi-faceted area in which significant gains are possible.

The major areas in which improvements are needed are described in the following subsection.

2.5.2.1.1 Duty-cycle Metrics

Prioritization of efficiency improvement work requires quantitative identification of the principal sources of inefficiency impacting the scientific productivity of the Observatory.
In 2002/3 a ``metrics'' program was designed and implemented. Time spent on various aspects of night-time observing (e.g. slewing, acquisition, open shutter, detector readout, faults of different origin) are automatically tracked. This program has already been used to identify those areas in which efforts can best be directed to increase overall on-sky efficiency. Continued refinement and automation of the metrics program will be an ongoing activity.

2.5.2.1.2 Performance monitoring

Regular monitoring of instrument and telescope throughput and image quality are also necessary. We regard it as essential that monitoring of the natural seeing delivered at the Keck site begin as soon as possible so that we can quantify the degradation of the image quality at the focal plane of the instruments. Characterization and documentation of the total system throughput for each instrument is required to properly plan for observations. Regular monitoring of system throughput allows for early identification of problems. Procedures should be developed for each instrument that will allow a quick evaluation of total throughput as often as several times per year.

2.5.2.1.3 Software and Systems Engineering

Capable, reliable and user-friendly software is the key to maximizing the effectiveness of the telescopes, instruments and data handling software. In the past, the focus has too often been on functionality, with less regard paid to issues of reliability and simplicity of interaction. The result has been an uneven suite of software, with little thought to the impact of the overall system on the various users of the systems installed at the Observatory.

A further problem has been the lack of commonality among different instruments and telescope systems. While some of this is inevitable due to the rapid evolution of hardware and software, a clearer vision of standards and how to generate and apply them must be developed. Carefully developed and applied standards allow rapid development (and consequent lower cost) of large systems and a simpler and cheaper long-term maintenance effort.

Greater emphasis on software and its true costs must be reflected in development proposals. The approach of relegating software to a second order issue in the early development of such proposals has resulted in systems that are sub-optimal operationally, of uncertain reliability and unnecessarily hard to maintain.

2.5.2.1.4 Image quality/focus

At present, significant time is lost via night-time procedures for checking and correcting telescope focus. Possibly even more significant (but harder to quantify) are the efficiency losses incurred by observing with less than optimum image quality. Most modern 8m-class telescopes constantly monitor focus and primary mirror figure using wavefront sensors. At Keck, we make all of these adjustments "open loop". Retro-fitting all of the existing Keck instruments (with the exception of the A0 instrument instruments, for which focus control is essentially built-in) is one possible, but difficult, approach. Particularly for spectroscopic observations, automatic focus routines using guider images would take up no observing time and could monitor focus better than most observers. The guiders could also monitor photometric conditions and evaluate image quality as an aid to observers.

2.5.2.1.5 Mirror Coatings

This is an area in which there has been much discussion and little action due to the difficulty of the problems. Mirror coatings affect The Observatory adversely in three ways. (1) Segment exchanges for swapping in freshly aluminized mirrors remove 15 to 20 nights per year from the observing schedule. (2) The current schedule for segment exchanges is such that by the time a segment is exchanged, its reflectivity has often degraded by 15 to 25% (and even more in the near-UV). (3) Aluminum, even when fresh, has a 12% dip in the red part of the spectrum. This is a significant efficiency hit, e.g., for DEIMOS which loses this 12% at each of three surfaces (primary, secondary and tertiary) in a crucial part of the spectrum for many of the DEEP project observations.

In the long run, the application of a protected multi-layer coating along the lines of the LNLL silver/aluminum hybrid used for the LRIS collimator to all the mirrors at Keck would give improvements in throughput of up to 40% at some wavelengths and return several nights per year for science observations. Smaller steps that should be investigated in the shorter term are (1) protected silver for the K2 mirrors, (2) protected aluminum for K1 and cleaning procedures that can decrease the degradation of reflectivity between segment exchanges.

This is one of the areas in which there is significant potential for a joint Keck-TMT effort.

2.5.2.1.6 Detector upgrades
In addition to improved quantum efficiency, upgrades of CCDs and associated electronics dramatically reduce overhead associated with readout time. The opportunities in this area are discussed below in section 2.2.2.1.3.

2.5.2.1.7 Guiding/Acquisition
The guiders at Keck are old, difficult to support and limited in their capabilities. A path to replacing the existing guiders needs to be identified and the potential for decreasing acquisition time, monitoring focus and conditions and possibly assisting in calibration using the guiders needs to be considered.

2.5.2.1.8 Data Pipelines and Archiving

2.5.2.1.9 Novel Observing Modes

2.5.2.2 SCIENCE CAPABILITIES: INSTRUMENTATION

2.5.2.2.1 New instruments
The process by which new instrument needs are identified requires convolving the research interests of the Keck community with our collective prognosis of what observational capabilities will be required for the forefront research areas a decade from now. The Keck user community is relatively small, but quite diverse. As the core instrument complement for the telescopes has been developed, one primary goal was to have broad capabilities throughout the O/IR region of the spectrum. This remains a fundamental driver for instrument development.

Our current most significant missing capability is wide-field spectroscopy and imaging in the near-IR (to be addressed by KIRMOS). The other significant gap in our instrumentation is state-of-the-art imaging and spectroscopic capability in the mid-IR (where it is recognized that LWS is at best quite limited). This latter need may be addressed (at least in part) via time swaps with Gemini-N or Subaru to give the Keck community preferred access to MICHELLE or COMICS respectively and/or through addition of a visitor mid-IR instrument (see next section). In the absence of fiscal constraints, we would be aggressively developing new mid-IR instruments.

2.5.2.2.2 Visitor Instruments

As the second generation of instruments have been commissioned (NIRSPEC, ESI, NIRC2, DEIMOS), the additional support required has increased the fraction of the CARA yearly budget devoted to operations. Unless the base funding for the Observatory is increased, future major instruments will require significant outside funding. This may lead us to increasingly rely on visitor instruments for new capabilities. We also anticipate that expansions of the Observatory capabilities through visitor instruments will introduce more specialized programs (for example the XAOPI extreme AO system for direct detection of extra-solar planets) to the Observatory and considerably shorten the implementation time for new capabilities.

In order to effectively take advantage of the visitor ports, interface requirements documents need to be developed (this is being done) and a process put into place to evaluate and possibly solicit potential visitor instruments.

2.5.2.2.3 Major Upgrades of Existing Instruments

Upgrades to existing instruments are a very cost-effective means of improving capabilities. For most instruments, upgrading detectors to the current state of the art is the single most effective possibility. With detector upgrades we can usually achieve improved quantum efficiency at all wavelengths, larger spectral coverage per spectrometer setting, reduced detector readout noise, and large decreases in CCD readout time. The LRIS-B CCD upgrade was completed in June 2002, the HIRES upgrade is near completion and scheduled for commissioning in January 2004.

LRIS-R would benefit greatly from a CCD upgrade and improvement is also possible for ESI. Both NIRSPEC and NIRC2 could benefit from detector upgrades when significant detector performance improvements have been realized by either Rockwell or Raytheon. Such developments may occur very soon in response to NGST and other space missions.
Appendix 1 lists the current instrument complement at Keck along with possible upgrade paths.

2.5.2.3 HIGH-ANGULAR-RESOLUTION ASTRONOMY

2.5.2.3.1 Adaptive Optics

The third high priority area for the near and long term is to improve the AO system at K2 and to integrate the laser. Both are crucial to keeping Keck at the forefront of AO in astronomy. The larger Keck apertures (compared to Subaru, Gemini and the VLT) give the resolution edge to Keck in the diffraction-limited regime. For some science (point-source detection in the background-limited regime), sensitivity scales with the fourth power of primary diameter. New instrumentation (NIRC2, OSIRIS) and the implementation of the laser-beacon system are going to provide unprecedented capabilities in this area. It is crucial to have the baseline AO system working reliably and effectively and it is already time to be considering higher-performance systems for the future.
In 2002 the Adaptive Optics Working Group (AOWG) was formed to develop short- and long-term goals for The Observatory AO. In addition to making recommendations for improving the performance of the existing AO systems, the AOWG is developing plans for the next generation of AO for the Observatory. Based on a range of science goals, the group quickly converged on initial concepts for two systems.

2.5.2.3.1.1 Keck Precision Adaptive Optics (KPAO)

KPAO is a high Strehl system with a stable and well-characterized PSF that extends into the visible (with lower Strehl). In particular the stability and ability to have good knowledge of the PSF are crucial for improving the precision of quantitative AO-based science. The next step for KPAO is to develop requirements and to carry out a Phase A study to develop a conceptual design for the system.

2.5.2.3.1.2 Extreme AO

The second recommendation of the AOWG is to consider the Extreme AO Planet Imager (XAOPI), currently in conceptual design, as a visitor facility for Keck. This is a system optimized for very high-contrast imaging of bright stars for searching for planets and characterizing the circumstellar environment. On its current development schedule, XAOPI would be available in 2007 and would, in combination with Keck, be the premier instrument in the world for the direct detection of extra-solar planets.

2.5.2.3.1.3 K1 Laser guide star system

Also in the next decade, we believe that the demand for AO-based observing will make it very attractive to mount a laser on Keck 1. This may be made much easier by the rapid development in laser technologies. We currently have an imbalance in the demand on K2 and K1. When the K2 laser and OSIRIS are commissioned, this imbalance will be even greater. Deploying a laser on K1 will allow a transfer of one of the high-demand AO instruments (NIRC2 or OSIRIS) to K1 and give much better balanced capabilities between the two telescopes.

2.5.2.3.2 Interferometery

The Keck Interferometer (KI) has been and will continue for the next decade to be a mission-driven capability of the Observatory. This project has specific science goals and a well-defined path for adding capabilities. These are described below. A welcome challenge to the CARA community is to integrate the KI capabilities into the broader Observatory vision and planning.

The project has two phases: the first uses just the two 10-meter Keck telescopes, and is called the Keck-Keck Interferometer; the second phase operates several 1.8-meter Outrigger telescopes in conjunction with a Keck 10-meter telescope or other suitable large telescope, and is called the Outrigger Array.

The NASA/MSC KI science revolves primarily around the existence and origins of other planetary systems. Specific science objectives of the Keck-Keck Interferometer include detection and characterization of other planetary systems using several different techniques. Nulling interferometry in the mid-infrared will be used to characterize the amount of exozodiacal dust around other stars to provide information about planet formation, and to characterize potential targets for the Terrestrial Planet Finder. Differential-phase interferometry will be used to detect or confirm super-Jupiters or brown dwarfs around other stars. High sensitivity fringe visibility measurements will allow access to fainter astrophysical targets than is possible with other interferometers. These three techniques use just the two Keck telescopes.

The Outrigger Array will be used for narrow-angle astrometry to conduct an astrometric survey for exoplanets, complementing existing radial velocity detections. The objective of the astrometric capability will be to conduct a survey for exoplanets as small as Uranus-mass around solar-like stars out to a system distance of 20 pc. Finally, with the Outrigger Array linked to a suitably large telescope, synthetic aperture imaging will be used to provide resolved images of protoplanetary disks to detect evidence of planetary formation around nearby stars.

At the end of the Shared Risk science period, Keck-Keck interferometry will be open to “Key Project” science, and “General Observing”. There are two Key Projects associated with Keck-Keck interferometry: direct detection of hot Jupiters and detection of 10 um exozodiacal emission. It is envisioned that these two Key Projects would occupy 2/3 of the NASA Keck-Keck interferometry time for approximately two years until they are completed. The remaining time would be allocated to General Observing. Additionally, NASA will support use of the interferometer by other members of the NASA community (Caltech, UC, UH, NSF-funded, NASA single aperture) at a level up to 50% of the NASA interferometer allocation.

The final Key Project is Astrometry with the Outrigger Array. Because the Outriggers will be available 60% of the time for the NASA community, Astrometry and General Observing should be possible once the Outriggers pass their ORR.

Instrument modes and schedules:

The basic V^2 mode is the first mode to become available. The KI offers significantly higher sensitivity in V^2 mode over interferometers with smaller telescopes.

The second operational mode of KI will be Nulling. Nulling will be performed at 10 um. Nulling is designed to detect the faint emission of dust around nearby stars. Nulling is expected to be available for Shared Risk observations in FY2005.

The third operational mode will be Differential Phase (DP). This mode is expected to become available for Shared Risk observations in FY2005. DP is designed to detect the presence of very faint companions to nearby stars, eventually down to a contrast ratio of 10,000:1. Initially DP will be offered over the wavelength range of 1.6 to 2.4 um; later, DP will be offered from 1.6 to 5 um.

The addition of the Outrigger Array adds V2 with the outriggers (FY 2008) and astrometry (FY 2010). The imaging mode will utilize the Outrigger Array linked to a suitably large telescope (FY 2011).

2.5.3 Specific High-priority Programs

2.5.3.1 Five-year timeframe

- Development of a plan, and its initial implementation, for closed-loop control of the image quality delivered by the telescope to the instruments. The goal is to be limited only by the natural seeing at any time for non-AO instruments.

- Complete Detector/controller upgrade for HIRES.

- Implement procedures for evaluating and monitoring image quality, and instrument throughput.
- Integration of laser beacon for routine AO correction.
- Improvements to AO interface and performance
- Implement atmospheric dispersion compensation for LRIS.
- Start CCD upgrade for LRIS-R
- Development of an interface and ICD for visitor instruments that can be brought to Keck to take advantage of unique science opportunities.
- Near-IR wide-field imaging/multi-object spectroscopic capabilities.
- Improved guiders/acquisition systems.
- Instrumentation to further exploit AO capability.
- Near-IR detector upgrades (NIRC2/NIRSPEC)
- Overcoated silvering of K2 primary, secondary and tertiary.
- Mid-IR (5-25 micron) imaging and spectroscopic capability
- Adoption and development of a new detector electronics design that will be standardized and capable of serving our needs (at both optical and IR wavelengths) for the next decade.

2.5.3.2 Ten-year timeframe

- AO development: MCAO (Multi-conjugate adaptive optics, and associated instruments), extension to visible wavelengths, Extreme AO, K1 laser beacon
- Development of hybrid Ag-Al durable coatings for K1 and K2.
- Development of a comprehensive the Observatory data archive. Initial experiments with archiving will commence in FY2002 with funds provided by NASA.
- Next generation instrumentation (including those related to the Keck Interferometer).

2.5.4 Enabling Technologies

Any cutting-edge scientific facility – this Observatory included – is a venue which translates progress in technology into a set of scientific capabilities. Thus, the continued scientific vitality of The Observatory depends critically on our ability to recognize and adopt (and in some cases lead) new developments in a range of modern technologies:

- Large optics design and fabrication, including mirror coatings
- Control systems for telescope and optical systems
- Software engineering, including systems, architecture, interoperability, etc.
- Adaptive optics and lasers
- Detectors (optical and infrared)

Some of these technologies have stronger commercial or industrial applications (i.e., strategic value outside astronomy) than others. In such cases, we can benefit more cost-effectively from the outside developments. Software engineering and information technology in general are the obvious examples, with much faster development rates (e.g., the Moore's law) than, say, mechanical engineering or optics. Our strategic planning for new instruments and capabilities (including improvements to efficiency) should take these factors into account.

Not coincidentally, all of the technologies of interest here are also critically important for the TMT. Thus, there is a natural technological synergy between the Kecks – as the ideal test bed and a proving ground – and the TMT development. We have learned some costly lessons in the development of this Observatory, and we will likely learn some more; the TMT enterprise stands to benefit greatly from these experiences.

2.5.5 The Roles of the different players

The 2002 Observatory Visiting Committee report pointed out two areas in which we can make better use of CARA resources. Up to this point, the majority of the instrument projects were carried out at the mainland sites (Caltech, UCO/Lick and UCLA) and 'development' projects were carried out in Hawaii. As new instrument activity is slowing down, more emphasis is being placed on development projects and these make up a large number of the priority programs for the coming years. There is a tremendous talent and knowledge base at the mainland labs and campuses that can be brought to bear to assist the Observatory in accomplishing the development goals. Putting in place the procedures that make it easy to identify when and where collaborative (mainland-Hawaii) efforts can be implemented and making such collaborations easy to carry out logistically and financially is a very high priority.

The second area highlighted by the Visiting Committee is that we are not doing a good job of gathering and utilizing community input. In 2002 two new committees were established. The Adaptive Optics Working Group was established to assist in focusing the efforts to improve the AO capabilities and to help map out the Keck AO future. A general the Observatory Users Group was also established to improve the feedback from the community of users about the problems and possible improvements that would most effect the users. In addition to providing valuable feedback and advice to the Observatory, establishing these groups increases the base of regular users who interact directly Observatory personnel and have an informed understanding of the Observatory resource issues.

3 Observatory Employees: Goals

3.1 Introduction

In recognition of the fact that our human resources are our most important assets, the following guiding principles will apply to the management of our employees.

- *We treat employees with dignity and respect.*
- *We treat employees with consistency.*
- *We treat employees fairly and equitably.*
- *We keep our promises and do not make promises we cannot keep.*
- *We listen to employees and objectively consider ideas and suggestions.*
- *We believe employee input is crucial to efficiency in our operation.*
- *We address problems and issues constructively to find mutually acceptable and practical solutions.*
- *We share ideas in a constructive, positive manner.*
- *We strive for a barrier-free open culture of communication in which objectives are understood and accepted by all employees.*
- *We continually assess ourselves to identify areas of improvement and development essential for success.*

These principles are embodied in our corporate culture and are consistent with our core and cultural values. We strive to adhere to these principles in all our workplace activities.

3.2 Strategic Goals

To derive the best out of ourselves and fulfill the **mission** of the Observatory, we identify two strategic goals:

- **A high level of employee satisfaction**
- **Full, appropriate, and diverse staffing**

  These goals describe the employee environmental conditions we see in effect in twenty years. We do not want to be complacent and wait for the strategic goals to be accomplished by themselves. Rather, we wish to collectively put our minds and hearts together to actively work toward the achievement of these goals sooner than the twenty-year milestone. With commitment and proper direction, these goals can be accomplished earlier.

3.2.1 Strategies

To arrive at the two 20-year strategic goals, several strategies are identified.

For a **high level of employee satisfaction** –

- Create a work environment to attract and retain the highest caliber employees.
- Maintain a fair and equitable compensation package.
- Create an environment in which employees have a say.

For **full, appropriate, and diverse staffing** –

- Develop programs to achieve employee diversity.
- Ensure resources and needs are matched.

3.2.1.1 Create a work environment to attract and retain the highest caliber employees

A world-class observatory such as Keck requires the highest caliber employees, and a world-class observatory will not retain its prominence without such employees.

What kind of environment attracts great employees? The answer depends in good measure on what an individual employee is seeking. Many look for an atmosphere that fosters scientific curiosity...or creativity...or social development...or a feeling of family.... Whatever the individual personal motivations of an employee, there are several environmental desires that are common to all CARA employees. They seek an organization:

- for which continuing educational and professional development of employees is important...the ability to grow in one's job.
- that cares about employee health and stress levels.
- that promotes a safe working environment and a well-maintained workplace.
- progressive enough to automate whenever possible to alleviate the boredom of repetition and minimize the possibility of error.
- that takes affirmative steps to become well organized and well managed.

3.2.1.2 Maintain a fair and equitable compensation package

Many research studies have shown that compensation is not the number one satisfier of employees. However, an organization that does not pay competitive wages/salaries, or administers the compensation structure in an unfair manner, will lose employees. Employee loss results in inefficiencies, is costly, and affects morale. A strong compensation package with well-thought out and designed benefits that is fairly administered will do much to strengthen the feeling of satisfaction among employees.

3.2.1.3 Create an environment in which employees have a say

Employees are happy when they have a say in their destiny—from daily work assignments to the long-term future of the organization. The development of a program promoting employee input and feedback is a way to achieve this goal. Employees desire to be knowledgeable about decision-making within the Observatory, to become part of the decision-making process through appropriate input mechanisms, and to feel confident that their input is considered.

3.2.1.4 Develop programs to achieve employee diversity

With respect to gender and racial diversity, a future organization representative of the cultural richness of Hawaii is highly desirable. To carry diversity efforts beyond the scope of what has been achieved already, we need to develop internship and partnership programs to attract a diverse work force. In particular programs to attract women and minorities to professional and engineering positions within the staff need to be pursued. In addition, there is great value in hiring culturally diverse individuals; the viewpoints and approaches of these individuals are important contributions to our scientific and engineering programs and enrich our perspectives.

3.2.1.5 Ensure resources and needs are matched

It is recognized that the operation funds available to CARA are fixed in current-year dollars through March 2018 when the Caltech/UC agreement establishing CARA expires. However, it is important to identify new or alternate sources of funding that will permit the organization to make progress toward the achievement of its mission and goals. Full staffing, which is funding dependent, is defined as a sufficient number of individual employees to achieve the mission. Appropriate staffing is defined as the right individuals for the right tasks. Appropriate staffing is not a state that can be accomplished overnight. Planning is required to identify those areas in which we are deficient in staffing so steps can be taken to remedy those deficiencies, whether through new hiring, retraining, reassignment, or attrition. In the event that additional funding does not become available, it is vital to assess our goals in light of our mission and to make appropriate changes.

4 Community-at-Large: Goals and Milestones

4.1 Introduction

> *"The public must understand astronomy—its basic science as well as the process of research—if we as a society are going to achieve our full potential. I strongly believe that astronomical institutions must make a concerted effort to communicate the fruits of their research to the public."*
> —Sir Arthur C. Clarke, March 28, 2003

The above quote is reflected in the second half of the Observatory's mission statement: "…We…share our discoveries to inspire the imagination of all." Pure science cannot be pursued in a vacuum. In a very real sense the Community is the ultimate beneficiary of our science product. NSF and NASA spend between 2% and 10% of all funding on public outreach because these organizations cannot exist without active community and taxpayer support. The scope of the Community Domain strategies is global, although we naturally have stronger influence locally. The choice of scope reflects the best application of our limited resources. We present both global and local strategies in the Community Domain.

A healthy Community Domain nurtures the Observatory with a better work environment, more satisfied employees, and a supportive external community. A supportive community in turn allows for expansion and funding of new projects. Community outreach is a powerful tool that, if used right, can greatly benefit the entire organization.

In addition to these reasons, which are common to other Observatories, we depend on the unique qualities of Mauna Kea. This implores us to be more culturally sensitive and proactive than would be the case in other locations. We will see these effects in the strategies outlined below.

One of the challenges in addressing the Community Domain strategies is the size of the Observatory's public information office: one. The other 100+ Observatory employees, and many hundreds of scientists that use The Observatory, provide a marked contrast. Although we have only one full-time staff member dedicated to PIO, the Observatory has made the commitment that every employee can be involved in public outreach.

The Community Domain strategy stresses three main themes: Engage, Educate, and Participate. The themes represent three levels of community interaction, each dependent on the one before. The milestones for each strategy represent meaningful behavior that can be measured over time, so they can be evaluated in their effectiveness in reaching the Community Domain's strategic goals. The first paragraph in each subsection describes that section's strategic goal. The 20-year strategic milestone in each subsection is described in the second paragraph.

4.2 Engage

Make science results, technology, and people widely accessible and exciting to the public.

The long-term goal in this theme is to spark worldwide public interest and participation in astronomy.

In order to "inspire the imagination of all" (part of the mission statement) we need to grab people's attention and pique their curiosity. Within this theme we identify both local engagement and regional and global engagement. Local engagement includes participating in career fairs, contributing articles to local media outlets, and providing material to other island outreach programs such as the VIS center. Regional and global engagement is provided initially by development of the Web site, and in later years by participation in museum events and media with more global mandates. Note that because "engage" is the first fundamental stepping stone to education and participation, most of the milestones occur early in the strategic plan.

4.2.1 2-year milestones

The short-term milestones are predominantly local in scope, with the exception of news articles and a new Internet site. The reason for this is that we can have more immediate and meaningful impact locally and can maximize our ability to make progress. The Onizuka Visitor's Center is seen as an excellent local contact site for members of the community that are already somewhat interested in astronomy.

- The Observatory sponsors quarterly astronomy events.
- The Observatory participates in high school career and science fairs.
- The Observatory actively supports the Onizuka Visitor's Center with new content and exhibits.
- The Observatory contributes news articles to local and worldwide publications.
- An updated Keck Internet site is launched.
- A quarterly newsletter, written for a non-technical audience, is in place.

4.2.2 5-year milestones

The 5-year milestones have the outreach programs diversifying and extending internationally. Public access (via the Web) to what the astronomers are doing each night has proven to be an exciting vehicle for engaging potentially millions of people. [McDonald Observatory's similar program (http://mcdonaldobservatory.org/research/) is a good example.]

- Four or more interactive hands-on events take place throughout the year.
- The Observatory science results are available to the public on the Web.
- The Observatory is featured in museum exhibits and events.

- Worldwide collaboration with other observatories on the 10-year milestones begins (Mauna Kea Observatories Outreach Committee, STARTEC).
- The public has access to a summary of what the astronomers are doing each night.
- The outreach program is diversified and meets regional outreach needs with education, media relations, and events.

4.2.3 10-year milestones

The 10-year milestone is basically a summary milestone that anticipates more astronomy coverage in worldwide media, and increased interest in astronomy and science amongst youth. It provides an important metric on how well our strategic goals are being addressed.

- Increased youth participation and curiosity about astronomy events and science.
- The Observatory outreach program expands internationally.

4.3 Educate

Provide programs for, and participate in, local and worldwide education.

The long-term goal in this theme is that the Observatory becomes a partner in worldwide and local education of astronomy and space science.

An educated public is more powerful than one that is simply interested. Education also performs a valuable function in integrating the Observatory into the local community, as well as forming the next generations of technicians, engineers, and scientists. Education improves public debate concerning matters of community interest, such as astronomy in Hawaii, and taxpayer support for future telescopes. The educational theme is the most far-reaching and powerful theme in the Community Domain strategy.

Most of the current outreach efforts are applied in this area, including hosting school trips, student mentorship programs, etc. CARA employees form a talented pool from which a modest amount of outreach help can be anticipated, to the benefit of both the community and the employees. Developing relationships with other organizations involved in outreach allows us to leverage both our resources and theirs.

4.3.1 2-year milestones

We are increasing the Observatory presence in local schools, and the initial milestones under this strategy indicate this. Preliminary steps in coordinating with other outreach programs are taken in the first couple of years. The first steps towards education via the Internet are also taken.

- Student mentorships in place, focusing on students at local high schools.
- Local schools have access to HQ and summit visits.
- Network and plan with other educational institutions.

- Working relationships in place with local public, private, and charter schools.
- The Observatory participates in educational workshops and programs with other astronomy and space science educators (e.g. MKAEC, MKOOC, other Mauna Kea observatories).

4.3.2 5-year milestones

Year 5 anticipates strengthening ties to local and regional schools, as well as the acceptance of astronomy into the formal educational standards for the state. Local scholarships will demonstrate to the community that the Observatory is serious about furthering scientific education as well as providing resources to local students who might otherwise not be able to pursue a technical career. By this time it is expected that CARA employees will have become more fully engaged with the outreach program, thus leveraging their extensive knowledge and enthusiasm for astronomy, science, and engineering. It is expected that external funding will be found for the scholarships.

- The Observatory has an ongoing program to support local schools with astronomy curriculum, computers, software, and materials and guest lectures for teachers.
- Educational partnership in place with Kamehameha schools.
- The Observatory actively supports Astronomy as a state standard for primary science.
- Local scholarships available to Hawaiian students.
- Regular presentations take place in K–12 schools; employees contribute a fraction of their time to public understanding of science.
- Breakthrough Internet educational materials are available to educators.

4.3.3 10-year milestones

The 10-year milestones feature initiatives with more global impact, as well as an increase in the scholarship program.

- Three full astronomy career-related scholarships routinely awarded to local and Hawaiian students.
- Partnerships in place with top ten astronomy and space science organizations (i.e. NASA, Smithsonian, NSF, planetariums, museums).
- The Observatory partners with universities, offers extended learning programs.

4.4 Participate

The Observatory engages in local community meetings and events and generates local community support. We also show responsible management of the summit environment and culture.

The long-term goal in this theme is that the Observatory becomes a fully integrated and welcomed member of the local community.

Clearly the scope of this theme is mainly local in nature. The advantages of being an accepted and respected community member range from greater employee pride in their place of work to more ready acceptance of input into community affairs.

The Community Domain strategies outline some possible methods for becoming a respected member of the island community. Three threads are addressed. The first calls for a CARA presence at community meetings and events: political and social participation. The second calls for CARA employees and visitors to have an understanding of Hawaiian culture: participation with the Hawaiian community. The third calls for CARA to participate in the responsible management of the summit environment.

All three threads encourage CARA's participation in various aspects of community affairs. Participation, and the dialog that follows, brings understanding to the entities that are working together, and encourages collaboration. With a collaborative approach there is more chance to discover resources that can be shared to everyone's advantage. A strong community base gives us a better opportunity to share our discoveries to inspire the imagination of all.

4.4.1 2-year milestones

Many of the early milestones are already underway, such as increased community visibility via a public lecture series. Integration of Hawaiian cultural topics into the lecture series will educate both CARA employees and the local community, and encourage cultural sensitivity.

A striking example of the last bullet point, encouraging other summit stakeholders to exceed the goals of the 2000 Master Plan, has already begun, as NASA has committed to a full Environmental Impact Statement rather than the lesser Environmental Assessment. This has improved relations between NASA, the Observatory, and the native Hawaiian community appreciably.

- CARA open house.
- Public lectures on Hawaiian cultural topics held in the Hualalai theater or elsewhere.
- The Observatory participates in state and local community meetings.
- Mechanisms in place for community input to and dialog with The Observatory;
- The Observatory accountable to the community.
- The Observatory has increased visibility and participation as a community member.
- CARA employees participate in community meetings.
- Summit cultural procedure defined and followed.
- Support Hawaiian cultural groups as stakeholders on the summit.
- The Observatory encourages protection of the Wekiu bug habitat.
- Office of the Director encourages other summit stakeholders to exceed the goals and objectives of the 2000 Master Plan.

4.4.2 5-year milestones

The 5-year milestones continue the trend of previous years, anticipating greater recognition at the state level.

- Establish participation in state and local politics for the advancement of astronomy in Hawaii.
- Astronomy is recognized as a vital part of Hawaii's economy.
- The Observatory has established relationships with Hawaiian cultural leaders.
- Majority of CARA employees are involved in community organizations.

4.4.3 10-year milestones

By year 10 we expect to have established excellent relationships with local and state communities, and hope to have good relationships with native Hawaiian groups. At this stage we move into partnerships with environmental and native Hawaiian groups.

- The Observatory staff earns respect and understanding from local community.
- The Observatory participates in local political activities.
- Summit lease extension plan in process, outlook favorable.
- Partnership is established with environmental groups to further environmental preservation.
- The Observatory, in consultation with Native Hawaiian groups, identifies projects that might be undertaken to mitigate any negative impact of The Observatory on Mauna Kea, a mountain held to be sacred by many of Hawaiian heritage.

5 Appendices

5.1 Resource strategies

5.2 Specific synergies with TMT

A strong technology synergy with the TMT development is a natural and mutually beneficial strategy for both enterprises. The Keck telescopes are *de facto* prototypes for the TMT, and offer unique and invaluable opportunities to develop, test, and perfect technologies essential for the success of the TMT.

A TMT investment into improvements of existing enabling technologies and development of new ones, all of which are essential for the success of the TMT, provides a potentially significant resource for The Observatory as well. The TMT project would gain essential, and in many cases unique, experiences and feedback for their own development, though extensive prototyping and real-life testing of the essential technologies. The Observatory would benefit directly from those technologies and their specific implementations that prove to be useful and successful in the operations of a large, segmented mirror telescope and the associated observatory systems.

Some of the specific areas for technological collaborative efforts include the following:

- Characterization and measurement of delivered image quality on a segmented mirror telescope and development of associated error budget.

- Development of the next generation of durable, wide-bandwith (UV to IR), efficient mirror coatings and optimal strategies for mirror maintenance. This is one of the key factors in achieving a high level of efficiency we strive for, and which would be just as essential for the TMT.

- Development, testing, and optimization of novel detectors, including large-format arrays in both optical and IR, both for focal plane instruments and wavefront sensors. While this is an astronomy-wide, general issue, a premier observatory cannot leave such developments to others, and must be an active participant or even a leader in this field.

- Development, testing, and optimization of the next generation of all mirror and telescope control systems, including the ACS, PCS, and DCS. The increased complexity of the TMT primary, and the advances in computing technology require a new generation of robust and reliable control systems and algorithms.

- A complete redesign and engineering of the Observatory software systems, standards and architectures, using modern software engineering practices. Software has been historically one of the key problem areas and sources of inefficiency at the Observatory. A significant overhaul of the existing software systems is essential – both the Observatory and the TMT must have a much more robust, reliable, and forward-looking software, which can take a full advantage of the rapidly advancing computing hardware and information technologies. Any major new software systems and approaches must be tested in a realistic setting – and in this the Keck telescopes provide a unique environment for the TMT software development needs.

- Advances in AO, at all levels, and including all AO subsystems, LGS, etc. The AO is correctly viewed as an integral part of the TMT design, with very ambitious requirements and goals well beyond the current state of the art. While some of the necessary developments can and should be done at smaller telescopes (e.g., at Lick or Palomar), for many of the crucial steps and milestones it will be necessary to demonstrate the feasibility at the Observatory, and then to optimize the AO implementations in a real scientific setting.

- Streamlining and improvements of the Observatory operations, instrument development, novel observing modes (including remote operations, near-real-time queue scheduling in response to the changing atmospheric conditions, etc.), and user support. Observing time at the Observatory, and in the future at the TMT, must be used for a maximum scientific return. We are still using the telescopes largely in the way they have been used decades ago.

- Data pipelines and archiving for the modern, complex, facility-class instruments, and effective archiving. Such developments are now widely recognized as essential in maximizing the scientific returns of any modern observatory. Fortunately, the rapid advances in computing and information technologies are now being increasingly harnessed in astronomy through the Virtual Observatory efforts and other approaches. Like any other novel technologies, they present us with a learning curve, which we can climb at the Observatory, providing a smooth transition for the TMT.

- Improvements to the mechanical design of the telescope and the dome, based on the Keck experiences. The example of the shutter design comes to mind: the TMT should not have to repeat such learning experiences.

Additional areas of fruitful collaboration may well develop in time, in what can only be a vigorous, stimulating partnership.

A strategic sharing of the staff and expertise between the TMT project and the Observatory can also benefit both enterprises, by developing a spirit and practice of collaboration, rather than competition for the best personnel, both existing and new.

5.3 Current and Looming Infrastructure Issues

- Dealing with original philosophy
  - Get there fast, fix later
- Known big problems (e.g. guiders, pointing, acs, pcs, shutters…)

5.4 Current Instruments and Upgrade Paths

ESI

- Detector upgrade to an MIT-LL high-resistivity, MBE process device, or LBL very-high-resistivity device. The spectrograph is designed for a 2k x 4k (15 micron) detector, so there is no upgrade path to larger field of view or larger spectral coverage.

- Filter-wheel Integral-field units (these are being developed).

- Second, higher-R grating.August 10, 2004

HIRES

- Detector/controller upgrade. This project to upgrade the 2048 x 2048 Tektronics CCD to a 3-CCD mosaic of MIT-LL chips. This will give improved quantum efficiency at all wavelengths (particularly in the blue and UV), larger wavelength coverage per exposure, reduced readout noise by at least a factor of 2, improved sampling for narrow slits and reduced readout time from 120s to <40s.

LRIS:

- Red camera CCD upgrade. The red side would would benefit by going to a dewar with a two-CCD mosaic of 2k x 4k, 15µm-pixel devices (or a single 4k x 4k device) with fast readout electronics, better QE, and reduced fringing. The result would be a (slightly) longer slit, better sampling, improved throughput, reduced readout noise, vastly reduced fringing amplitude (the main systematic limiting faint object observations) in the red and reduced readout time.

- A deployable integral-field unit.

- A flexure compensation system for the red side CCD. A system was designed and built (but not implemented) for the blue side; a similar approach could be used for a red side system.

- Additional grisms, and spectrum-shifting wedges (allows more control over the wavelength range seen by the detector) for LRIS-B.

LWS:
No upgrade path specifically identified. What is needed here is an instrument with a significantly larger FOV and also a high-spectral-resolution (R~50000) capability. These might have to be separate instruments.

NIRC:
No upgrade path identified, but KIRMOS will replace most NIRC capabilities (exceptions: speckle imaging, 3-5 micron capability) on a timescale of five years. The gain in field of view for IR imaging programs will be approximately a factor of 64. The forward-cass module could be de-commissioned once KIRMOS and a replacement for LWS are completed.

NIRC-2 :
The NIRC-2 detector should be upgraded when InSb arrays with significantly better noise properties become available.

NIRSPEC:
NIRSPEC will benefit similarly from a detector upgrade; currently most high-dispersion observations are detector—limited. There would also be significant scientific benefit from a higher-spectral-resolution mode (resolution of ~100,000). Currently NIRSPEC achieves spectral resolution of ~25,000 in its highest dispersion mode. If NIRSPEC continues to be used behind the adaptive optics system for thermal-IR observations, it would benefit significantly from a colder AO bench.

DEIMOS:
- Adding the second side would double the instrument capabilities for some survey projects; this second side could be added for a fraction of the cost of the initial DEIMOS.
- The CCDs could be significantly upgraded.

5.5 The History of This Document

The genesis of the Observatory Strategic Plan came in early 2000 when funding projections for the Observatory revealed clearly that significant additional resources would be needed if the Observatory were to maintain its position as the world's leading ground-based astronomy research facility. In light of this, in January 2001 the Keck Director proposed to the CARA Board that a major endowment campaign be initiated to assure that the Observatory could remain competitive for the remainder of its life.

The Board demurred at this proposal, and recommended that a management review of the Observatory be carried out and that a Visiting Committee be convened to evaluate the Observatory's productivity and future potential.

The Management Review occurred in October 2001, and the Visiting Committee met in early December. Many insightful and helpful recommendations resulted from those reviews that helped change the course of the Observatory. One of the most important was the strong recommendation by both reviews that a Strategic Plan be formulated for the Observatory to guide its future.

5.5.1 Strategic Planning Workshop, December 2002

In response to these recommendations a strategic planning workshop held in Waimea on December 9, 10, 2002. Thirty-three members of the Observatory staff and 12 members of the broader CARA community—mostly scientific users of the Keck telescopes--participated in person. The workshop was facilitated by Ivan Rosenberg of Frontier Associates, Inc. of Valley Village, CA.

Through a series of intense sub-group and full-group interactions, the participants collectively created vision, mission and values statements for the Observatory. They also identified long-term (32-year), mission-driven strategic goals for "stakeholders" in each three "domains"—the astronomical community, the community-at-large, and the employees of the Observatory.

Finally, based on an existing Science Steering Committee draft long-term instrumentation plan, intermediate-year goals were identified for the astronomical community consistent with the long-term strategic goals.

5.5.2 First Observatory 5-year Plan—April-July 2003

Based on the intermediate-year astronomical community goals identified at the strategic planning workshop, the Observatory Executive worked closely with the Observatory Council and the co-chairs of the Science Steering Committee to develop the first-ever 5-year plan for activities at the Observatory, commensurate with the known UC/NASA revenue stream. This draft FY04-08 plan revealed unequivocally the need to obtain long-term additional funding to support an adequate instrument development program for the Observatory. The Observatory had already received funds from the Telescope Systems Instrumentation Program (TSIP) of the National Science Foundation in which instrumentation funding is provided in exchange for telescope access to the National community, and the 5-year plan revealed the continued need for long-term access to such funding.

A draft FY04-08 plan was presented to the full Science Steering Committee and the CARA Board in April 2003, showing three possible TSIP funding assumptions—full TSIP funding, ½ TSIP funding and no TSIP funding for major new Keck instrumentation. Full TSIP funding was found to be the only viable option, and an FY04-08 Observatory plan, based on the availability of such funding, was approved by the CARA Board in July 2003.

5.5.3 Establishment of Intermediate-term Goals for Observatory Employees and the Community-at-Large: Follow-up Strategic Planning Group meetings, August 2003 beyond.

On August 15, 2003, Ivan Rosenberg returned to facilitate a strategic planning follow-up meeting with representatives of the employee and community-at-large "domains" to identify intermediate-year goals in those domains, consistent with their long-term strategic goals identified in the December 2002 workshop.

This precipitated a series of meetings of representatives of these domains that produced the intermediate goals and activities contained in the present document.

5.5.4 Updating the Astronomy Community goals—December 2003

On December 9, 10, 2003, The Observatory Executive (Chaffee, Beletic, Lewis) held a 2-day retreat with incoming SSC co-chair, George Djorgovski (Caltech) and outgoing SSC co-chair, Mike Bolte (UC), to review and update the strategic plan, concentrating on the intermediate-term astronomy community goals.

A significant new ingredient affecting the Observatory strategic planning was identified during this retreat--the emergence of the Thirty-Meter-Telescope (TMT) project. With $17.5M "seed" money from the Moore Foundation having been granted in 2003 to both Caltech and UC, this project has suddenly gone from being a chimera on the far horizon to something quite likely to be completed well within the 32-year the Observatory planning horizon adopted at the December 2002 workshop.

This dramatic change in the astronomical landscape led the group to change the long-term strategic timeline from 32 to 20 years--a period divided roughly equally between the pre- and post- TMT operations era—and to begin to address specifically what the consequences of a 30-m telescope would be to Keck. In the short run, it offers the promise of synergistic Keck/TMT development projects to the benefit of both.

For the first time, the TMT was incorporated specifically into the strategic planning process, and some synergistic Keck/TMT projects have been identified in this draft.

5.5.5 Updating The Observatory Strategic Plan—Jan.-April 2004

At the January 2004 SSC meeting, Mike Bolte rotated off as UC co-chair and was replaced by Ian McLean (UCLA). Although Ian had participated in the original December 2002 strategic planning workshop, he had not been involved in many of the subsequent discussions.

The current draft The Observatory Strategic Plan incorporates all of the input and planning that has taken place since December 2002, laying out for the first time the long-term plans for all domains associated with the Observatory.

It was presented to the CARA Board at their April 2004 meeting.

Participants in the December 2002 Observatory Strategic Planning Workshop:

The Observatory:

Sean Adkins	Pat Crivello	Dennis McBride
Sarah Anderson	Don Esmeralda	Bob Moskitis
Joel Aycock	Bob Goodrich	Chris Neyman
Jim Beletic	Erik Johansson	Tom Nordin
Jim Bell	Kyle Kinoshita	Hector Rodriguez
Dennis Callan	Laura Kraft	Barbara Schaefer
Randy Campbell	David LeMignant	Paul Stomski
Fred Chaffee	Hilton Lewis	Sheila Sumaylo
Jason Chin	Gloria Martin	Doug Summers
Jon Chock	Bill Mason	Kevin Tsubota
Al Conrad	Rich Matsuda	Peter Wizinowich

SSC, Adaptive Optics Working Group (AOWG), Keck Users' Group:

Jacques Beckers	Lynne Hillenbrand	Jerry Nelson
Mike Bolte	Dave Koerner	Chuck Steidel
Mike Brown	Ian McLean	Alan Stockton
James Graham	Claire Max	Keith Taylor

The 2003 Keck Science Steering Committee:

co-chairs: Mike Bolte (UCSC), George Djorgovski (Caltech)

Jacques Beckers (NASA)	David Koerner (NASA)	Jerry Nelson (UCSC)
Marc Davis (UCB)	Ian McLean (UCLA)	Alan Stockton (UH)
Richard Ellis (Caltech)	Joe Miller (UCSC)	Keith Taylor (Caltech)