System-wide Review of the University of California Observatories

Executive Summary

1. By all criteria the performance of UCO as an organization that supports and advances observational astronomy within the entire UC system has been excellent. Objective evidence for this excellence includes:

    - UC leadership in astronomy through observations on the Keck and Lick telescopes has produced some of the most important astronomical discoveries of the past 15 years, including ground-breaking work in exoplanets, cosmology and black holes;

    - The assembly of what arguably is the leading ground-based optical astronomical instrumentation group in the world. This group provided much of the intellectual impetus for the Keck telescopes, world leadership in developing and implementing astronomical adaptive optics, and leadership of five instruments for the Keck telescopes, and five instruments for the Lick telescopes. They are now leading the design of two first-light instruments for the Thirty Meter Telescope (TMT);

    - Overall productivity in publications and impact of those publications which ranks in the top tier of major astronomical observatories worldwide;

    - The recruitment of outstanding junior and senior faculty to UC, and the expansion of astrophysics on several campuses, making astronomy one of the most visible and high-impact programs in UC.

2. UCO has been a very effective organization in managing the shared facilities and technical resources for the UC campuses. Access to telescope time is managed in a manner which involves all of the stakeholders and balances the principle of access for all with a strongly merit-based peer reviewed time allocation system. It has forged effective working relations with partner organizations for the Keck Observatory and the TMT project at the technical, scientific, and managerial levels.

3. This success in fulfilling its mission, the breadth of this mission (serving eight UC campuses), the large capital investments in its managed facilities, and its international leadership in astronomical instrumentation all strongly justify the continuation of UCO as a multi-campus research unit.

4. The committee broadly endorses the future vision for UC optical and infrared (OIR) astronomy presented by UCO and the UC Astronomy Task Force, which is built around participation in the Thirty-Meter Telescope (TMT) project with continued participation in the Keck Observatory, with operations costs of TMT largely covered by the 50% reduction in Keck obligations after 2018. In offering this endorsement we caution that it would be prudent for UCO and the University to consider carefully the long-term obligations that entry into the TMT project will entail, and the likely impacts that it will have on the infrastructure and staffing of UCO.

5. Fabrication of instruments for TMT will require significant upgrades to the Santa Cruz laboratory facilities, including a lab with a large interior volume, upgrades in optical measuring capabilities and possibly in the machine shops. Careful planning will be needed to reach the right mix of using outside vendors and internal expertise to make most effective use of limited funding, especially if TMT funds cannot be used for improvements to the laboratories. Given the expected need for IR technologies for TMT, the UCLA Infrared Laboratory also needs enhanced levels of support to ensure that the group keeps a core staff between large instrument and detector jobs.

6. UCO has made effective use of the facilities on Mt. Hamilton for a variety of purposes including major surveys of exoplanets, supernovae, and active galactic nuclei, instrument engineering, and education and public outreach. However the $1.8M currently spent annually on Lick is a significant sum in the face of other funding pressures. The committee would like to see Lick Observatory continue, but as a largely self-supported enterprise with a strong public function. We encourage the UCO Director, working with interested astronomers from the other campuses, to seek outside funding sources and implement streamlined operations at Lick if this historic observatory is to continue to contribute. The long-term future of Lick Observatory should be critically examined as part of a strategic planning exercise.

7. The committee is convinced that the presence of a core staff of UCO research faculty instrumentalists in stable appointments is a key element in UCO's success. Most of these faculty reside in UCSC for critical mass and the efficient use of technical resources. This proven model should not be dismantled. We did not fully examine the rationale for maintaining the current number (14) of "80/20" positions, but are concerned that eventually the cost of maintaining this level of staffing will compete with other UCO priorities. This issue should be addressed as part of our recommended strategic planning process, in the context of future needs in the TMT+Keck era.

8. Given the importance of UCO's role and the considerable resource it manages it is important to improve and strengthen its system of governance. We recommend the establishment of a board, largely composed of members external to UC, and including a representative of the UC Academic Senate, who would serve as trustees and advocates for the UCO program. The main roles of this UCO Board would be to give support and advice to the UCO Director on important policy and management matters; review and approve annual program plans and longer-range strategic plans; evaluate progress against those plans; periodically review the performance of UCO and its Director, and recommend the appointment of a new Director when a vacancy arises. It should report annually on its activities to the UCOP.

9. We recommend that the UCO Advisory Committee (UCOAC) be retained as the primary conduit for engaging the UC astronomical community in the management of the Observatories. The role of the committee, however, should be expanded to include discussions of policies, priorities, and plans, with a more formal structure of feedback and response between the UCOAC and the Director. We envisage that the UCOAC would report jointly to the Director and to the Board described above.

1. Introduction

From the establishment of Lick Observatory in 1888 the University of California has been an international leader in astronomy and astrophysics. Over the succeeding 125 years the formula for maintaining this leadership has been consistent: building world-class facilities which in turn attract outstanding faculty in astronomy and astrophysics to the UC campuses. Through the subsequent development of large telescopes on Mt. Hamilton, the construction of the Keck Observatory, and the establishment of major radio and millimeter-wave observatories the University stands at the cutting edge of astronomical facilities and instrumentation, and has helped build strong astronomy groups on eight UC campuses (as well as astronomers at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory). Through the Thirty Meter Telescope (TMT) project the University now aspires to extend and enhance its pre-eminent position in the coming decades.

A key element of this success has been the investment by the UC of nearly $20 million per year for the support of the Keck Observatory ($12M) and a Multi-campus Research Unit (MRU), the University of California Observatories (UCO; $8M). These funds flow centrally from UC through the UC Office of the President (UCOP). UCO manages access to the optical and infrared (OIR) astronomical facilities at the Lick and Keck Observatories, operates and maintains Lick Observatory, and designs, builds, and supports instrumentation for all of the OIR telescopes, including design work for TMT and its instruments.

Earlier this year the UCOP authorized "an external review of the structure, programs, and operations of the UC Observatories to assess the quality of its investment and to ensure that it will address the needs of the University in the future." Although various components of the telescopes and programs carried out in UC astronomy have been reviewed in recent years, this is the first comprehensive system-wide review of UC astronomy and UCO to be carried out since its founding in 1988. This external review was preceded by two in-depth internal studies, a Self Study from the UCO Director and a review of System-Wide Priorities for Astronomy in the University of California by a UC Astronomy Task Force (ATF) representing eight UC campuses plus Lawrence Berkeley National Laboratory. The ATF consulted broadly with the entire UC Ph.D. astronomy community. These two studies provided valuable starting points for the external review committee, and will be referred to repeatedly in this report.

The formal charge to the External Review Committee is included in this report as Appendix A. Our committee was asked to consider the full scope of activities being undertaken by UC in OIR astronomy, and to comment in particular on how priorities are set, planned, and implemented. The committee was keenly aware of the broader circumstances in place at the time of this review. On the one hand it is a time of potentially transformational change for UC astronomy, with the opportunity of the TMT and a reduction in the UC costs of operating the Keck Observatory coming in 2018. On the other hand the UC system is experiencing a period of severe fiscal austerity, resulting in a need to maximize the impact of every expenditure. As requested by our charge this report strives to advise UC "on how best to optimize the allocation of its resources to ensure that UC maintains its excellence in astronomy and astrophysics…"

2. Review Process

UCOP began organizing this review in late 2010, and as part of the process solicited nominations for committee members from the eight astronomy departments. The committee's members include leading researchers in their subjects, and most have directed observatories and institutes of their own, including national observatories (e.g., Space Telescope Science Institute, National Optical Astronomy Observatories, Smithsonian Astrophysical Observatory), and many of the leading peer-university observatories.

During the preparation of the UCO Self Study and the Task Force report the committee chair consulted with the Vice President for Research and Graduate Studies (VP-ORGS - Steven Beckwith), the UCO Director (Michael Bolte), and the Task Force Chair (Geoffrey Marcy) regarding the content of the Self Study and the progress of both reports. The committee met once by teleconference on 28 July 2011 to review its charge, the agenda for the main meeting, and identify additional information needed for the review. Throughout the review the committee coordinated its activities with Jenny Gautier and the UCOP staff and it is most grateful for the expert support that it received.

The main review was held in San Francisco on 10-12 August 2011. An agenda for the review, which included an all-day site visit to UC Santa Cruz, is included in the report as Appendix B. The committee met in separate sessions with Dr. Beckwith, members of the ATF, the UCO Director, a group of UCO instrumentalist faculty, the UCO faculty as a whole, and members of the UCO Advisory Committee, the primary advisory committee to the UCO Director. For part of its visit to UCSC the committee divided itself into two groups, with one group touring the instrument laboratories and adaptive optics center, and the other meeting with the UCSC Chancellor (George Blumenthal). In addition the committee met informally over dinner with the Task Force members (10 August) and UC Santa Cruz faculty (11 August). Without exception the participants in these sessions were open and constructive in sharing their views. Apart from their own sessions with the committee Dr. Beckwith and Dr. Bolte were not present, in order to promote discussions that were as open as possible. However, the committee met with each at the conclusion of the review on August 12, to check facts and share preliminary findings.

Due to travel constraints the director of the UCLA Infrared Laboratory, Ian McLean, was unable to participate in the discussions on 10-12 August. Instead two committee members (Kennicutt, Sargent) interviewed him at UCLA on 17 August (Kennicutt via teleconference). Notes from that meeting were circulated to the rest of the Committee.

The remainder of this report is organized according to the four points in our charge (in modified order for clarity of presentation). We first assess the quality and performance of the UC Observatories, and the effectiveness of the organization in fulfilling its mission (charge points 1-2), and then address requirements and priorities for investments in the coming decade, and the process by which these priorities are set within the current UC system (charge points 3-4). Although not explicitly included in our charge, the question of the future of UCO as a MRU was raised repeatedly in our discussions with the VP-ORGS, so we address that point as well.

Before proceeding we add a general comment on the scope of this exercise. This report is primarily concerned with the organization and future of ground-based optical and infrared (OIR) astronomy within the UC. Although a large fraction of modern astronomy research is prosecuted within the OIR regime, one should bear in mind that these bands account for only five out of seventy accessible octaves of electromagnetic spectrum, with as much non-electromagnetic spectrum ripe for further exploration. Theory and computation are also areas of current opportunity. UC has wisely concentrated its appointments, effort and investment in the observational OIR band and has, arguably, become the most productive research effort in the world in this subfield. UC also has significant groups working in space astronomy, radio and ground-based gamma ray astronomy, although the combined effort is much smaller than that in OIR. Perhaps not surprisingly, a survey of astronomy faculty by the Astronomy Task Force (ATF) led to a clear conclusion not to change this emphasis. This Review accepts that conclusion without prejudice and only addresses issues raised by the organization of OIR within UC.

Charge Point 2: Assess Quality and Performance of UCO

3. UC Astronomy and UCO: Quality & Accomplishments

The review committee was asked to assess the collective performance of the UCO and its accomplishments. We carried out this assessment focussing on three main criteria:

(1) Evidence for major astronomical discoveries and breakthroughs enabled by the facilities supported by UCO;

(2) Metrics of scientific productivity and esteem measures of UC astronomers and UCO staff in particular;

(3) Evidence for unique scientific and technical capabilities within UCO on the national and international levels.

UCO itself has a core of 14 faculty on 80% research appointments ("80/20" positions), with the research time funded from the MRU. The user base for the facilities is approximately 100 faculty distributed over the 8 UC campuses. To fully evaluate the performance and accomplishments of UCO we assessed the research that has been enabled by the shared telescope facilities system-wide, while examining separately the accomplishments of the core UCO staff. We were not charged nor were we provided with sufficient information to assess individual staff, and instead evaluate statistical measures of performance and recognition.

3.1. Major Science Results

UCO's primary mission is to facilitate campus-wide astronomical research, by providing leadership for the support of the facilities and observing programs on Mauna Kea and Mt. Hamilton. An important indicator of UCO's success in this endeavor is the resulting science, and the number of notable results that have emerged from the facilities they support.

Keck Observatory:

The Keck Observatory supports a large number of very high profile, high impact research programs by UC astronomers. These in turn depend on a variety of instruments and software developed by the UCO. The Keck adaptive optics (AO) system developed by Claire Max (UCO) and colleagues, has been transformative for numerous Keck programs. We highlight below some of the major successes from the last decade. Names of UC faculty leads are listed in parentheses, with UCO faculty shown in boldface.

- **Exoplanets:** Precision radial velocity studies have led to discovery and characterization of a significant fraction of known planets around other stars (Marcy, **Vogt**). Direct imaging of stellar systems with dust disks using AO has also revealed some of the first potential protoplanets (McIntosh).

- **Milky Way Black Hole:** A decade-long study of the motions of individual stars orbiting the center of the Milky Way galaxy has revealed a supermassive black hole, and enabled an accurate determination of its mass (Ghez). The AO system (**Max**) has been essential for this work.

- **The Accelerating Universe:** Two large UC programs of spectroscopy to determine distances and properties of the host galaxies of supernovae have been crucial to demonstrating the accelerated expansion of the universe. The Keck telescopes have played a central role in studying the nature of Dark Energy, considered by many scientists to be one of the key discoveries in physics and astronomy of the past century (Filippenko, Perlmutter).

- **Galaxy Evolution**: Several surveys of galaxies have been undertaken with UCO's DEIMOS spectrograph to characterize the properties of galaxies over time. Much of what is now known about the build up of galaxies from the earliest structures that formed after the Big Bang has come from these programs (**Faber, Koo, Guhathakurta**, Davis, Shapley, Treu).

- **Dark Matter:** The detailed distribution of dark matter around galaxies has been mapped via gravitational lensing studies. Impossible to detect directly with telescopes, dark matter acts as a lens that produces minute distortions of objects that can be measured to map out the unseen dominant constituent of the universe (Treu, Fassnacht).

- **Buildup of the Elements:** By studying the absorption of light from galaxies of different distances and, by implication, of different ages, by intervening intergalactic gas, UC teams have succeeded in re-constructing the gradual buildup of the chemical elements from the initial hydrogen and helium produced by the Big Bang (**Prochaska**, Martin, Wolfe).

- **Stellar Populations:** The constituent stellar populations of the nearby Andromeda galaxy M31 have been pieced together through painstaking studies of many separate regions of the galaxy, and have enabled determinations of its basic structure, evolution, and merger history. . For the first time we are able to document for another galaxy the events that establish the mix of stars and gas that are present (**Guhathakurta**, Rich).

- **Gamma Ray Bursts:** Optical studies with the Keck telescopes of these most violent explosions in the universe since the Big Bang have allowed a determination of the nature of the distant galaxies that harbor the bursts, and provided important clues as to the environments which lead to bursters (Bloom, **Prochaska**).

Lick Observatory:
Lick Observatory stood as UC's major OIR facility until the commissioning of the Keck telescopes. It continues to enable internationally leading research, often through support of larger projects using Keck, Hubble, and other major facilities.

- **Extra-solar planets**: Since 1995 the most productive group in the world searching for extra-solar planets has been led by Geoff Marcy using the Hamilton spectrometer on the Lick 3m telescope. That spectrometer was designed by UCO scientist **Steve Vogt** and fabricated in the UCSC labs. A new Automated Planet Finder robotic telescope for extending this work is now nearing completion (**Vogt,** Marcy).

- **Nearby supernovae:** Observations with the dedicated KAIT telescope on Mt. Hamilton have produced the most reliable supernova rates as a function of galaxy morphology and luminosity, and have also led to the refinement of the Hubble Law for the expansion of the universe based on nearby Type Ia supernovae. The results from this project have also secured the low-redshift anchor for studies of the accelerating expansion of the Universe and dark energy (Filippenko).

- **Black holes and active nuclei of galaxies:** A multi-year campaign of monitoring accreting supermassive black holes in nearby galaxies has used reverberation mapping techniques to provide robust diagnostics for the masses of these black holes and important clues to the fuelling mechanisms for these activities (Barth).

- **Public Outreach Programs:** Lick Observatory's Visitor Center is visited by more than 30,000 people per year. Open year round the Center has programs for local organizations and has a number of exhibits and astronomical photographs on display. It is a popular destination for visitors to the San José area and has achieved a well-deserved high reputation as an outreach activity of the UC.

The scientific programs cited above are all at the forefront of the most important areas in modern astrophysics, and several have produced the most important discoveries and achievements in all of astronomy over the past 15 years. Nearly all of these advances have used telescopes, instruments, and/or a capability developed by a UCO staff member.

3.2 Science Activity

An independent, albeit indirect, assessment of the success of the UCO is provided by standard metrics used to determine the impact of scientists and facilities. Below we reproduce two figures from the UCO Self Study which document this productivity and impact. Applied to the world's largest telescopes, Figure '1' below shows an index created for telescopes by D. Crabtree of Canada that combines the number of papers produced and the number of citations garnered by each facility in recent years. The results for the past five years show that the scientific research carried out at the Keck telescopes has produced the greatest impact of all large telescopes.

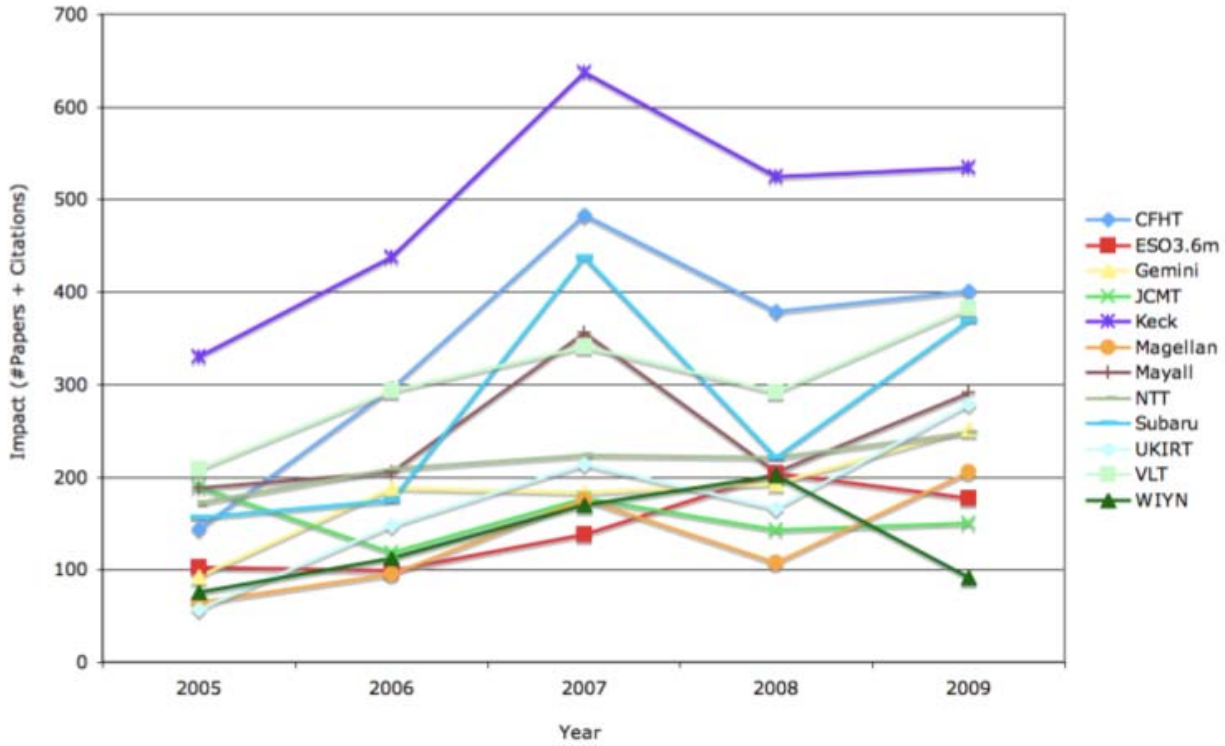

Figure 1: Publications plus normalized citations. Data: D Crabtree CADC

This graph demonstrates that the UC (and Caltech) observing facilities are without peer in astrophysics. While the statistics refer to observations carried out by all UC as well as Caltech scientists, the remarkable statistical success must be attributed in large part to the UCO effort. The UC administration can be pleased with the world class astronomy carried out by UC astronomers. A similar comparative study of telescope productivity applicable to the Lick Shane 3m telescope and based solely on numbers of published papers is shown below in Fig. '2' (again taken from the UCO Self Study).

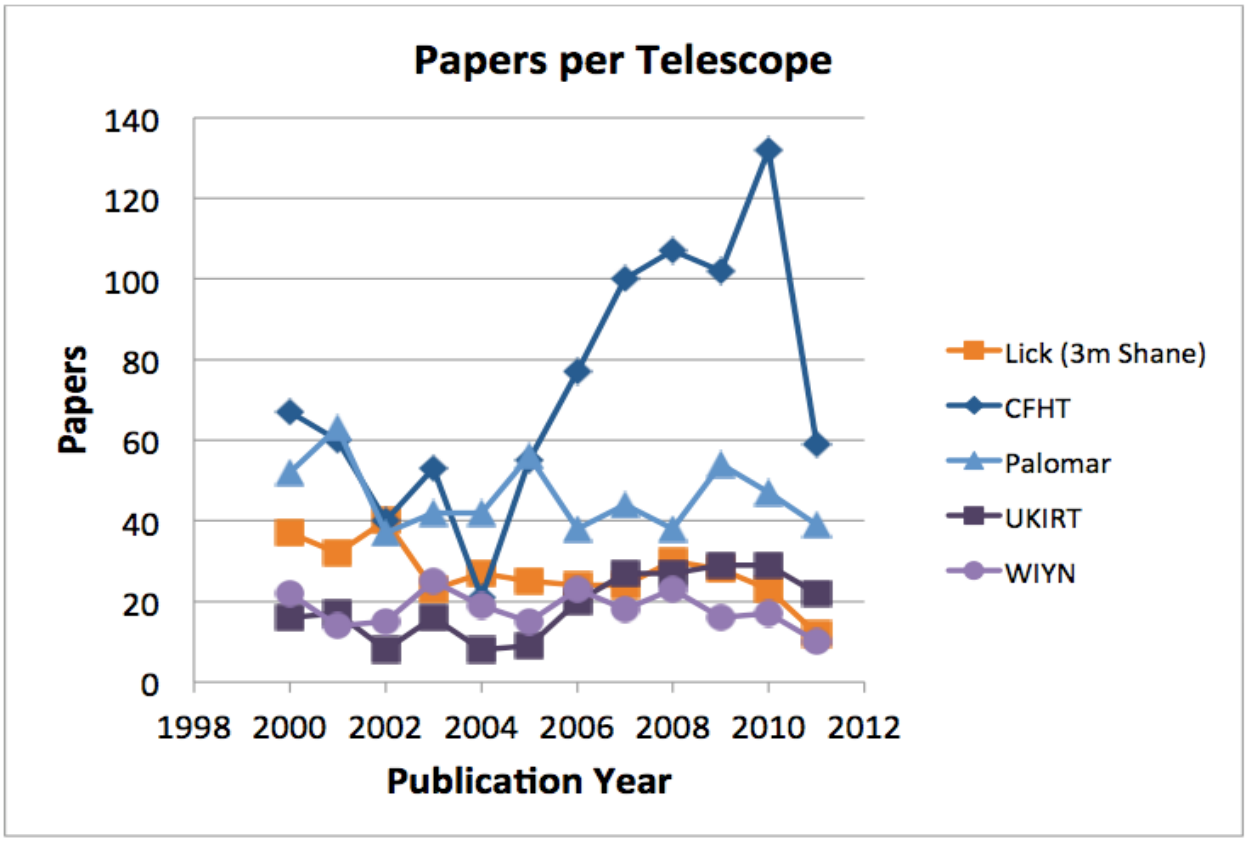

Figure 2: Papers per year using data from each observatory (per ADS). For comparison, in 2010 there were 278 papers published with data from the Keck telescopes, 500 papers published with data from the Sloan Digital Sky Survey, and 724 papers published with data from the Hubble Space Telescope

3.3 UC and UCO Faculty Recognition

The approximately 100 astronomy faculty at the UC campuses comprise one of the most distinguished groups of astronomers in the world. As but one measure, this currently includes 18 members of the National Academy of Sciences, representing more than 20% of the NAS members in the UC system overall and more than 20% of the Astronomy Section of the NAS.[1]

This level of excellence is well represented within the UCO (80/20) faculty. In addition to instrumentation development and Observatory support, all are actively involved in research programs. The research areas are broad ranging and in several cases the Santa Cruz based

[1] Astronomy Task Force Report, p.8

programs are world leading. Among the fourteen UCO faculty, three have been elected to the National Academy of Science (Faber, Nelson, Max). Nelson was awarded the 2010 Kavli Prize for his creation of the segmented mirror concept for telescopes and the 1995 AIP/AAS Dannie Heinemann Prize. Faber received the 2009 Bower Award, the 1985 AIP/AAS Heineman Prize, and the 2011 AAS Russell Prize Lectureship for her seminal career achievements in the area of extragalactic research. Vogt received the 2002 AAS Tinsley Prize for his design and development of spectrographs for large telescopes. In addition, Rockosi was awarded a Packard Fellowship in 2006, and Prochaska received a 2011 Humboldt Fellowship by the German government. Max received the DOE E.O. Lawrence Award in 2004 and the James Madison Medal from Princeton University in 2009.

3.4 UCO Instrumentation

Over the last fifteen years, ten different UCO faculty members have served as Principal Investigator for a Keck or Lick Observatory instrument. Five of the major instruments at Keck Observatory have been designed and built in the UCO labs in Santa Cruz and UCLA, and many major subsystems of the remaining and in-progress instruments have been designed or fabricated in these labs. The concentration of technical expertise and infrastructure at UCSC has enabled the labs to assemble teams of skilled technical staff, and to build on the experience from previous projects to enable successive generations of more ambitious instruments. The expansion of activity to the UCLA Infrared Laboratory has enhanced the instrumental capabilities substantially and in a cost effective manner.

3.5 Service to the UC System

The UCO staff play a key role in maintaining and improving the performance of existing instruments and of the observatories, especially the Keck Observatory. As evidenced by the UC-wide ATF report the instrumentation work supported by the UCO and the UCLA Infrared Lab, which is not generally matched by a commensurate Caltech effort, is acknowledged to be vital to the success of the science that UC astronomers undertake at the Keck Observatory. The table below (extracted from the UCO Self Study) gives the UCO contribution to the functioning of the Keck Observatory in recent years.

WMKO Cost Contribution by UCO	FY2008	FY2009	FY2010	Total
Project Labor (reported)	$148,572	$363,993	$73,094	$585,659
Academic / Researcher Labor (est.)	$327,334	$336,575	$203,263	$867,172
Other Unfunded Costs	$8,693	$11,157	$14,631	$34,481
Remote Observing facilities at UC campuses	$43,723	$50,351	$21,395	$115,469
Total Unreimbursed WMKO support by UCO	$528,322	$762,076	$312,383	$1,602,781

As mentioned above UCO has provided support for research and technical development at other campuses. The largest recipient has been the UCLA Infrared Laboratory, which has received an annual contribution of $300K per year towards its funding from the UCO in recent years.

3.6 UCO Laboratory Facilities

A subset of the review committee toured the UCSC laboratory facilities, but we did not have the opportunity to visit the Mt. Hamilton compound of telescopes, labs, and dormitories. It was evident that much of the basic UCSC campus laboratory infrastructure, e.g., buildings and

support structure, is dated. The large machines are dated but adequate, e.g., there are CNC machines and various metal fabrication equipment that operate well. The 'clean rooms' consist of spaces of hanging plastic strips, which serve due to the ingenuity of the UCO staff. At the other extreme, the electronic and optical equipment is state of the art, and the technical staff was very knowledgeable. The UCO laboratory staff has done an excellent job of producing finished products that have helped to keep the UCO telescopes of Lick and Keck Observatories at the forefront of technical capabilities.

Charge Point 1: Review Management and Fulfillment of Mission

4. Fulfillment of Mission, Interactions with Stakeholders

This committee was provided with neither the time nor the detailed information needed to conduct a thorough audit of the performance and management of the UC Observatories. Instead we have concentrated on assessing whether UCO has fulfilled its mission by evaluating the primary end products of the effort (science, instruments, leadership), and assessing the effectiveness of the management through the experiences and information received from UCO's primary stakeholders. The first part of this assessment was already documented in the previous section; here we focus on the management side.

As a multi-campus entity UCO has a complex set of "customers" and stakeholders, ranging from its own staff and partner scientists at UCSC to astronomers and users on other campuses, partner organizations and facilities (e.g., Caltech, U. Hawaii, Keck/CARA, TMT), and the multi-faceted administration of the University. As detailed below most of these interactions are carried out with a high level of skill and success (commendable for such a complex organization), though a few are subject to clear tensions.

4.1 Partner Organizations (Keck, TMT, Caltech, Hawaii)

Since the Keck Observatory and TMT project are operated by independent multi-institutional organizations and not by UCO they technically fall outside of the boundaries of this review. Nevertheless the UCO organizes the time allocation process for UC access to Keck, and much of its instrumentation program is focused on Keck. We comment on these activities in other sections of our report, and address in particular the challenges of participating actively in both Keck and TMT later in this report.

Time limitations prevented the committee from interviewing representatives of the Keck and TMT projects, but based on the information received in the UCO and Task Force reports, interviews with UC faculty, and personal knowledge of the committee members these interactions have largely been productive and effective.

In the case of Keck UCO has been an excellent and generous partner, providing much of the intellectual impetus for the original project and the adaptive optics program, and frequently stepping in to repair instruments or provide hardware and expertise without charge to the observatory[2]. The practice of offering unreimbursed support, which amounted to a total of $1.6M in 2008-10, will not be feasible in the TMT era, and UCO should consider whether the terms of such *pro bono* work ought to be renegotiated with the Keck partners.

[2] Self Study Report, p. 33

The UCO Director and UCO scientists as members of the CARA (Keck) and TMT Boards and their science steering committees have made important contributions to the successful development of these projects. They also have an excellent track record in developing a productive and effective working relationship the Mauna Kea host institution, the University of Hawaii.

4.2 UC Santa Cruz

In our committee's meetings a strong sense of engagement of UCO and its staff with the larger UCSC community was clear, extending from the interactions with the other UCSC astronomers to the Chancellor. Astronomy is a flagship program for UCSC, and the campus has invested considerably of its own resources to build the program. The committee does encourage the UCO Director to tap for advice the considerable pool of expertise that resides in the UCO staff, and to delegate more responsibility to appropriate individuals. This would have the dual benefits of broadening the base of managerial experience for the future and reducing his considerable workload. As discussed below, more attention to the concerns of the other campuses may also be in order.

4.3 Other UC Campuses

The principal instrumentation center outside of the UCSC campus is the UCLA Infrared Laboratory (discussed separately later). Otherwise representatives from the other seven UC astronomy departments participate in UCO matters mainly through the UCO Advisory Committee (UCOAC), and through membership on other UCO, Keck, and TMT-related committees. Although the running of the UC Observatories is obviously concentrated in Santa Cruz, all of the documentation on allocation of telescope time suggests that time is allocated fairly, and that all of the campuses benefit from the availability of the shared facilities. Balancing the goals of access to all with the need for rigorously merit-based time allocation can be challenging, and those we spoke to were generally satisfied with the handling of telescope time allocation within UCO.

Relations between these departments and UCO were discussed in the committee's meetings with the Task Force and the UCOAC members. It was clear from these discussions that perspectives outside of Santa Cruz are quite different from those within UCO and UCSC, and this has led to considerable cross-campus tensions, as documented candidly in the ATF report. Many astronomers outside of UCSC feel detached from the information flow and decision making process. Underlying some of these tensions are real differences in objectives between the campuses, and some longstanding resentments, for example over the reduced teaching loads of the UCO faculty. Interestingly we found relatively little evidence for tension between the UCLA Infrared Lab and UCO. Indeed both parties spoke highly of their strong mutual respect and high level of cooperation.

Recently the UCO Director has taken steps to improve communications with the full UC astronomy community through publication of an on-line newsletter (minutes of the UCOAC meetings are also posted). The natural constraints of geography are such that some degree of detachment of the other campuses may be unavoidable, but more frequent face to face contact between the UCO Director and the other departments (for example through regional town hall meetings) could lead to considerable improvements in understanding and collegiality.

Apart from the general issue of communications the problem highlighted most clearly in the ATF report was the limited role currently played by UC astronomers outside of the UCO faculty in the priority setting, decision making, and management of the observatories. The ATF report proposes a solution in the form of an Astronomy and Astrophysics Council and an Astronomy and Astrophysics Strategic Planning Committee, each populated by representatives of the UC campuses, to oversee UCO and stand between the UCO Director and UCOP. We concur with the need for a governing board to advise and oversee UCO, but with a somewhat different structure and role than proposed by the ATF. This topic is addressed in Section 10 of this report.

4.4 UC Administration and Office of the President

Outside of the astronomy departments the UCO Director has established good relations with the Chancellors of most of the relevant campuses, some of whom (e.g., Henry Yang at UCSB) have become actively involved in UC astronomy activities within and outside of the UC system. As discussed earlier the UCO has also maintained strong and effective relations with the UCSC Chancellor.

The primary relationship for UCO within the University of California system is that with the UCOP and in particular with the VP-ORGS. It was clear from discussions with both the Director Michael Bolte and the VP-ORGS Steven Beckwith that this key interaction is also strained, with some of this stress spilling over to the UC astronomy community as a whole so that this review in itself has raised considerable anxieties and suspicions within the UC departments.

The origins for some of these tensions are understandable. Prior to Dr. Beckwith's arrival strategic oversight of UCO from the UCOP (to be distinguished from routine oversight such as financial audits) was minimal, and virtually all important decisions on matters including strategic planning, prioritization, staffing, and allocation of resources were the sole prerogative of the UCO Director. Since this exceptional degree of independence dates back to previous Directors, the more active attention now coming from UCOP is a sharp change, although in line with current expectations for responsible reporting. Similarly, there is little doubt that the financial stresses currently being felt by UC and particularly by the VP-ORGS office, combined with the much tighter management of other MRUs by that office and reallocations of funding, have added to anxieties. For astronomers across the UC system, uncertainty over the future of TMT and the UC's role in the collaboration only adds to the concerns.

While it would be convenient to blame all of the tensions between UCO and the UC central administration on these circumstances and/or on the individuals involved, our committee believes that any dysfunction in this area is largely structural in nature, and we propose solutions in Section 10.

5. Summary Assessment of UCO as a MRU

By all criteria the performance of UCO as an organization that supports and advances observational astronomy within the entire UC system has been excellent. This excellence is evidenced in particular by:

- UC astronomers leading, through observations on the Keck and Lick telescopes, some of the most important astronomical discoveries of the past 15 years, including the discovery of large numbers of extrasolar planets, the discovery of dark energy, cosmic acceleration, and the expansion history of the Universe, and the precise measurement, using adaptive optics observations on Keck, of the mass of the supermassive black hole at the center of

the Milky Way. These Nobel-worthy flagship programs[3]. have been accompanied by a host of equally fundamental discoveries and surveys addressing the most fundamental aspects of dark energy, galaxy formation and evolution, the intergalactic medium, black holes in galaxies, stellar populations, supernovae, and gamma-ray bursts. The assembly of what arguably is the leading ground-based optical astronomical instrumentation group in the world. This group provided much of the intellectual impetus for the Keck telescopes, world leadership in developing and implementing astronomical adaptive optics, and leadership of ten instruments for the Keck and Lick telescopes and two of the three first-light instruments for the TMT

- Overall high productivity in publications and impact of those publications which rests in the top tier of major astronomical observatories worldwide.

- The continuing recruitment of outstanding junior and senior faculty to the UC faculty, and the expansion of astrophysics on several campuses (e.g., Santa Barbara, Davis, Riverside). Although numerous factors contribute to this expansion and growth of excellence within the UC astronomy departments it is clear that the lure of Keck and the outstanding instruments provided by UCO has played a major role in building this outstanding faculty. Overall, astronomy has grown to become one of the flagship programs in the UC system, as measured by NAS membership, major international prizes, and other esteem indicators.

- An effective distribution of observing time across the eight-campus user community, which balances access for all with a strongly merit-based peer reviewed time allocation system.

- Effective working relations with partner organizations for the Keck Observatory and the TMT project at the technical, scientific, and managerial levels. The metamorphosis of the Keck collaboration to form the TMT project and the assembly of additional partners and private donations for TMT testifies in itself to the success of UCO in helping to realize the hopes of the UC astronomy community.

In its discussions with the VP-ORGS our committee became aware of the unique scale and nature of UCO (and by implication the budget that supports the Keck Observatory) within the UC system. The total investment of $20M/yr in both activities dwarfs other UC MRUs by a considerable factor, and even the UCO budget by itself ($8M/yr) stands as an anomaly in the UC system. As with the other largest MRUs the UCO operating agreement has never been openly re-competed or subjected to a review of whether it should continue (though this current UCOP review fulfills much of this review function). As such, it is fair to ask whether UCO should continue to be treated differently than most of the other, smaller MRUs.

The view of this committee on this issue is clear and unequivocal. Subjecting the UCO (and by implication the Keck operating agreement) to frequent re-competitions and/or termination reviews is inadvisable, for several reasons.

First, the UCO is unique in that it exists primarily to support very large research facilities that are shared across eight UC campuses. The return on the capital costs and the full scientific capabilities of these instruments are only realized over operational timescales of decades, and it would be unwise to squander these considerable capital investments by terminating involvement while the facilities remain highly productive and cost-effective (clearly this argument does not apply indefinitely to aged facilities, as discussed later).

[3] As this report was finalized we were delighted to see our assessment validated by the Nobel Prize Committee itself, with the awarding of the 2011 Physics Prize to Perlmutter, Riess, and Schmidt.

Second, the UCO is unique in the breadth of the community it serves within the University. The shared telescopes constitute the primary University research facility for a large fraction of the astronomy faculty and staff within UC, and leverage a large body of observing time and external funding from national and international facilities. Although the absolute costs of these investments are large compared to other MRUs, when the number of departments, campuses, and astronomers served are taken into account, the investments are well in line with those of other leading astronomy departments in the U.S.

Third, the current UCO has assembled an exceptional level of expertise, arguably the world's leading group, in astronomical instrumentation. This expertise has provided the primary intellectual stimulation behind the construction of the two 10-meter Keck telescopes and now the 30-meter TMT, a world-leading adaptive optics group, and the PIs for two of the three first-light instruments on the TMT, an extraordinary achievement considering the size and multi-national composition of the TMT collaboration. Long-term stability in the UCO operating agreement is key to retaining and renewing this world-class expertise.

For these reasons our committee believes that the University's considerable past and future investment in astronomical facilities is best served by a multi-campus organization that exploits the economies of scale in a centralized group on the one hand and the strength of the University of California multi-campus system as a shared cross-campus organization as well. Whether this entity should be maintained formally as a UC MRU or some other form of organization that recognizes its unique mission and scale falls outside of the charge and expertise of this committee.

In making this recommendation, however, we also emphasize that a standing organization such as UCO should be subject to the same diligent levels of governance and oversight that one would expect for any multi-campus entity of its scale and role. If the University is to reaffirm its long-term commitment to UC astronomy and UCO as recommended in this report, much stronger high-level oversight than at present is needed to ensure that the UCO is responsive to the priorities for UC astronomy on a system-wide basis. We propose a mechanism for addressing this need in Section 10 .

Charge Point 4: Assess Future Requirements, Investments, and Advise on Priorities

A key recommendation of this report (Section 10) is the initiation of a strategic planning process for setting future priorities for OIR astronomy and astrophysics research, involving the UCO Director, a new UCO Board, and the UC astronomical community. At present, it seems most appropriate for this committee to offer its assessment of the broad vision of the coming decade that was presented in both the ATF report and in the UCO Self-Study. That vision is based on continued participation in Keck, with an approximately 50% reduction in contribution cost in 2018, and new investment in the TMT, supported by a large private donation and the operations costs savings for Keck after 2018. Other components of the UCO budget, including support for Lick Observatory, instrumentation laboratories, and faculty lines within UCO were envisaged as being maintained (or modestly increased) in aggregate over this period, possibly with modest redistribution of support among them.

Our committee strongly supports this vision in its broad outlines. We believe that a future strategy built around the two pillars of Keck and TMT will maintain UC's historic leadership in astronomy and astronomical instrumentation for decades ahead. Our singular concern is whether these

goals can be attained without restructuring or contracting other current components of the UCO enterprise. In normal economic times a plan predicated on essentially flat funding (at least in inflation-corrected dollars) would be considered conservative if not modest. However these are not normal times, and we have some concern that the UCO strategy makes insufficient allowance for unanticipated contingencies, either in the funding streams for UC, in the costs of TMT, or in the costs of building and managing the construction of TMT instruments. We take these concerns into account in our assessments of future priorities for the Observatories.

6. TMT and Keck

As described above, UC has a long and distinguished history in OIR astronomy. To its great credit, UC was very bold and ambitious when it supported Jerry Nelson and others to design a ten-meter telescope in the late 1970s. Initial funding was eventually secured from the Keck Foundation in 1985 through a partnership with Caltech. By 1996 this had expanded to a pair of ten-meter telescopes on Mauna Kea in Hawaii, which have since been linked as an interferometer. The Keck telescopes are internationally acknowledged as having pioneered ten meter class optical observation and with having contributed much of the tremendous progress in astronomy over the past twenty years. In countless investigations, Keck has supplied the spectroscopic follow up to Hubble imaging, leading to combined discoveries all the way from our solar system to the farthest reaches of the universe.

Not content to rest on their laurels, UC and Caltech scientists, again led by Nelson, quickly started designing a thirty-meter telescope known initially as the California Extremely Large Telescope (CELT). This project is now called the Thirty Meter Telescope (TMT) and has Caltech and Canada as partners, with Japan as a collaborating institution and China and India as observers - all preliminary roles to full partnership. Mauna Kea has again been selected as the observing site. TMT will utilize “Multi-Conjugate Adaptive Optics” to remove much of the blurring associated with the Earth’s atmosphere. The Gordon and Betty Moore Foundation has so far committed $240M to the project and Caltech and UC have each committed to raise $50M in matching funds from private sources. The estimated construction cost is $1.2B with completion expected early next decade and operations costs of around $25M per year. In addition, new instrumentation is expected to require an annual budget of $21M over a 20 year lifetime. In addition to providing much of the initiative for the TMT project itself, UC scientists in Santa Cruz and UCLA are leading the design of at least two of the TMT first light instruments. This is a remarkable statement of the confidence the TMT community has in UCO’s ability to develop state of the art instrumentation. As the financing currently stands, UC expects to have 15-18% of the observing time at its disposal. A recent GSMT Community Assessment Review (GCAR) of the project has commended the design, technical progress and management and declared that the telescope is ready to begin construction.

TMT is one of three telescopes in this class under development. A second Carnegie-led consortium plans to build the Giant Magellan Telescope in Chile with an equivalent primary mirror diameter of 22 meters. Chile will also serve as the site for the 39-meter European E-ELT telescope, which is planned to start construction next year and commence full science operations early in the next decade (pending approval by the member states). There is ample science to occupy all three telescopes for a very long time and they should collectively serve as the spectroscopic counterparts to the space-born James Webb Space Telescope and the ground-based Large Synoptic Survey Telescope.

The TMT telescope testifies to a remarkable level of vision and initiative by UC. It should revolutionize astronomy in much the same way as the Keck telescopes and their successors have done. The GSMT concept has received strong endorsement by the 2001 and 2010 US Astronomy and Astrophysics Decadal Surveys. Unfortunately, there seems little prospect of NSF funding

being made available for construction this decade given the economic climate. It is therefore intended that the international partners make up most of the remaining cost of construction. TMT is ready to start as soon as sufficient funding for construction, operations and instrumentation can be guaranteed. It is intended that the long term UC obligation to TMT operations and instrumentation, estimated as $8M per year, be met by the reduction in Keck obligations after 2018 when the agreement with Caltech expires. Participation in the TMT project would assure continued international leadership by the University of California in astronomy, and maintain its position at the forefront of astronomical instrumentation for decades to come. Our committee enthusiastically endorses this vision and the plan to use the savings in Keck obligations to maintain its active participation in both Keck and TMT.

In offering this endorsement we also believe it is prudent for UCO and the University to consider carefully the long-term obligations that entry into the TMT project will entail, and the likely impacts that it will have on the infrastructure and staffing of UCO. It is not part of this committee's charge to identify what guarantees should be sought by UC concerning future financial obligations to TMT. However, it is noted that the project is working with a new protocol where partners who take on construction obligations assume the associated risk. The scale of the instruments that are being contemplated for TMT – in the $50M price range – is larger than the cost of any completed instrument for a ground-based optical telescope. Building an instrument on this scale will require a level of management beyond that adopted for Keck instruments, in much the same way that the management of Keck instruments was more challenging than that needed to build instruments for Lick Observatory. In addition, attention will need to be focused on defining a clear sharing of administrative control between UCO and the TMT project. We note that there is much large project management experience in the three national laboratories that are associated with UC and some of this might be tapped to help with planning these projects, creating their management and assigning appropriate contingency. The committee also notes that the operational budget for TMT, which was informed by nearly two decades of experience of operating the Keck telescopes and which was endorsed by GCAR, is nonetheless significantly lower as a fraction of construction cost than is normal for projects of this scale. Accordingly, we urge UC to scrutinize the operations and instrumentation plans and costs for TMT at regular intervals.

In summary, we enthusiastically endorse the conclusion of the ATF report that continuing a leadership role in TMT should be UCO's top priority. However, it is also necessary to pay attention now to planning as carefully as possible for the many contingencies associated with this project and to be prepared to adapt as partnerships develop and evolve, technical risks are encountered and retired. Careful agreements made today, can save a lot of time and friction tomorrow.

The question will naturally be asked as to whether or not the Keck telescopes will be needed after TMT begins full operations. The answer is that just as 5-meter telescopes have an essential role in a world of 10-meter class telescopes, so it is to be expected that the Kecks will contribute a good fraction of the science when the TMT is fully operational. However, in order to fulfill their potential in the TMT era it will be necessary to continue to invest in their instrumentation. This has the additional benefit of providing a test-bed for new TMT instrumentation. For these reasons this review also agrees with the ATF that keeping the Keck telescopes at the "cutting edge" should be UCO's other top priority. The strategic planning that we advocated for TMT should also include a financial plan for ongoing operations and instrumentation for the Keck telescopes.

7. Lick Observatory

UCO has made effective use of the facilities on Mt. Hamilton for a variety of purposes including education and public outreach, exoplanet research, and instrument engineering. Unfortunately, the costs associated with running Lick appear relatively high, and must be considered in the context of other budget pressures. UCO also has a burden in the form of old facilities on Mt. Hamilton that would cost more to modernize than could be rationalized in terms of their usefulness. The use of the 120-inch telescope as a test-bed for adaptive optics may decline in the future as techniques become more oriented to multi-conjugate AO and TMT needs. The on-campus AO laboratory suggests that such changes are coming.

The UCO budget is straining to cover all of its pressing needs. The $1.8M currently spent annually on Lick is a significant sum in the face of declining funding for Keck instruments and development of TMT instruments. UCO should find alternate funding sources for Lick such as selling nights (offered purely as examples), possibly to future TMT partners, or perhaps by cross-charging within UC. Lick costs could also be reduced by reducing some services such as having longer delays in repairs (eg., no night or weekend repairs), requiring observers to do more (e.g. operating the telescopes), or using block scheduling of instruments even more than is currently being done. UCO staff consider Lick repairs and upgrades as a good use of the UCO technical staff between major activities such as building a Keck instrument. The committee suggests changing this mode into one where a Keck instrument could be built by taking part of the existing Lick budget and combining those funds with the UCO staff time. The reduced support for Keck instruments from the Keck Observatory and the difficulty in funding large instruments from the NSF highlights the need for changing course on how Lick is operated.

In summary, the review committee applauds the efforts made by UCO to adapt the usage of the facilities on Mt. Hamilton to changing needs, but it also suggests that further changes must be made in the face of higher priorities such as TMT and new instrumentation for the Keck telescopes. This suggestion is consistent with the low ranking of Lick in the ATF poll. We encourage the UCO Director, working with interested astronomers from the other campuses, to seek outside funding sources and implement streamlined operations at Lick if this historic observatory is to continue to contribute to UC astronomy.

8. Instrumentation

UCO has been very successful at building instruments for Keck, and they have been selected to build two instruments for TMT. The group at Santa Cruz has benefitted from a stable base of support and 80/20 faculty members who can devote substantial chunks of time to developing instruments. The UCO director has also provided support to the UCLA group in the form of a modest level of funding and teaching buy outs for faculty working on instruments. The UCLA group works almost exclusively on infrared detectors and instruments while the Santa Cruz group focuses on visible light instruments and detectors. Future success for UCO depends on keeping both of these groups active and with adequate access to technical and design resources which will enable them to maintain their competiveness.

The review committee did not visit the UCLA labs and shops, but did tour those at Santa Cruz. The Santa Cruz building for assembling and testing an instrument (only room for one at a time) is barely adequate for Keck-scale instruments, and will be wholly inadequate for TMT-scale instruments. A new instrument lab is sorely needed with a large interior volume to enable the construction and checkout of the TMT instruments that are likely to get built under the leadership of Santa Cruz faculty. Space will not be the only need when it comes time to proceed with actually building TMT instruments. The optics fabrication facilities at Santa Cruz will need upgrades in the measurement capabilities, and upgrades may also be needed in the machine

shops. Careful planning will be needed to reach the right mix of using outside vendors and internal expertise to make most effective use of limited funding, especially if TMT funds cannot be used for capital expenses. In our discussions with Chancellor Blumenthal, he indicated that if TMT moves ahead, funding for these facilities upgrades could be raised by UCSC.

The UCLA group also needs enhanced levels of support to ensure that the group keeps a core staff between large instrument and detector jobs. This need was also identified by the ATF. Virtually all of the infrared detector expertise for UCO lies in the UCLA group, so this group is very important for continuing work on Keck instruments as well as for TMT instruments in the future. In addition to more support of the core group at UCLA, it may also be effective to move one or two 80/20 faculty lines to UCLA to further bolster the infrared group. As the UCO model demonstrates, faculty-led instrumentation development yields state-of-the art instruments that other UC astronomers can use successfully, and support in terms of both annual budget and 80/20 faculty lines has contributed strongly to UCO's pre-eminence in developing instruments and observatories. Support for this style of instrument construction should be continued in the future, although modifications to ensure the correct balance between optical and infrared work should be made.

9. UCO Faculty

UCO funds 80% of 14 faculty positions[4] at UC Santa Cruz with funds provided from the UC Office of the President (UCOP). Approximately $3 million of the UCO budget funds salary and benefits for these positions. The funding arrangement permits UCO faculty to devote 80% of their time to research and instrumentation activities. The remaining 20% of funding is from the Santa Cruz campus and requires a teaching commitment of one quarter course per year plus committee work. The 80/20 faculty are contracted to fiscal year appointments.[5] They are members of the Astronomy and Astrophysics department at UCSC. While recruitments to UCO faculty positions are made to fulfill needs identified by UCO, appointment, merit, and promotion actions are reviewed both by UCO faculty as a group, and by the Astronomy and Astrophysics departmental faculty. While voting on these reviews is nominally conducted separately, all of the departmental faculty participate in the discussions of the reviews. Instrumentation work by UCO faculty is accepted in the review process as part of the scholarly contribution of UCO faculty. Input from UCO-user astronomers at other campuses is informal and appears to have relatively little weight.

There is no question that UCO faculty have made high-quality contributions as PI's for the development of instruments for Lick, Keck, and TMT, and that as a group they produce top-quality science with multiple high impact publications and national awards. UCO faculty are responsible for three of the most significant instruments at Keck, while two more have been produced by the smaller UCLA IR laboratory. In addition, appropriate UCO faculty and staff are available on a regular basis for troubleshooting, repair and upgrades of Keck and Lick instruments. Academic staff salaries are not charged to Keck projects[6]. The UCO director estimates UCO subsidies to Keck operations totaling around $312,000 for FY2010, of which approximately $200,000 represents academic/researcher time[7]

[4] The UCO Director's Self Study (6) gives the number as 14. The UCOP *Systemwide Research Review of the University of California Laboratories* (UCOP Review) (6) lists 13 80/20 faculty in UCO. The 14 number was most commonly referred to in presentations to the review committee. The discrepancy may be attributable to the fact that one UCO faculty member is currently 100% funded by the TMT board.

[5] Fiscal year faculty may also obtain 1/9 summer salary from grants.

[6] Director's Self Study, 32

[7] Director's Self Study, 33.

The Director and UCO faculty make a strong case for the aggregation at UCSC of a core of faculty with research expertise in designing instrumentation. In principle, this core could exist at any campus, but historical circumstances have resulted in UCSC being the location of choice. The committee sees many reasons to maintain that UCSC connection. The 80/20 arrangement provides the advantage of a less weighty teaching load and allows these faculty the freedom to spend time on research, particularly research and design work necessary to develop and maintain instrumentation that is important to the whole of the UC astronomy community. UCO faculty also note that the supportive atmosphere for instrumentation research within the UCSC Astronomy and Astrophysics department as an important element of their success. The stability of the funding arrangement avoids episodic staffing and turnover. UCO faculty also argued that the synergy among faculty, even with UCO faculty not directly engaged in the building of instruments, is necessary to the success of the program. As a result, UCO maintains a base of critical knowledge to undertake new projects and provide the technical expertise to support existing instruments at Keck. The collective experience of UCO faculty allows the group to build upon its institutional memory in the development of the next class of instruments. This core accumulation of knowledge will provide the base for UC's participation in the development of TMT as UCO faculty take the lead in developing instruments for that facility. UCSC Chancellor Blumenthal suggested that disbursal of the UCO faculty funds would be devastating to UCSC's strongest department and might result in the loss of the necessary research faculty for building instruments.

The committee also heard arguments that UCO faculty funds could be distributed in a different way within the University of California. The need for a central research and development group is acknowledged across the campuses, but there is some sense among the wider UC faculty that not all 80/20 faculty continuously contribute to the overall technical effort. Rather, these positions are perceived as on occasion giving a pure research advantage. Members of the ATF suggested to the Committee that only a fraction of the current 80/20 faculty are critical to current instrumentation work. There were also suggestions that some of this funding could be used to recognize and assist the UCLA IR lab.

A small portion of UCO funds (approximately $338,000) is directed to provide summer salary and/or teaching relief to faculty in the IR Lab at UCLA. UCLA IR lab faculty or staff are able to troubleshoot for Keck in special circumstances. On these occasions UCO supports travel expenses. Faculty salaries remain the responsibility of UCLA, who also must support their own technical staff. Again, academic salaries cannot be charged to Keck project funds.
The committee agrees with the argument for maintaining a dedicated base of research faculty in UCO for the support of instrumentation, and that most UCO faculty should reside in UCSC for critical mass and the availability of resources. The stability of appointments is important to maintain research competence in the design of instruments. The model has been successful, particularly in the development of instruments for Keck, and it should not be dismantled. However, we were not presented with a strong rationale for the current number (14) of 80/20 positions. Eventually the cost of maintaining this level of staffing will compete with other UCO priorities. On the other hand the major expansion of UCO activities to supporting TMT instrumentation in addition to its other instruments may place stronger demands on staffing in this area. It would be irresponsible of this committee to endorse the TMT+Keck vision on the one hand, while recommending cutbacks in the staffing and infrastructure which may be needed to capitalize on the TMT investment.

In Section 10 we recommend that UCO, together with a new Board and the UC astronomical community undertake a long-term strategic planning exercise, in which the needs and activities of the Observatory in the post-2018 era are assessed, and a phased plan for attaining these objectives is formulated. A key element of this exercise should be an evaluation of the staffing needs and priorities over the long term, both in numbers and deployment between 80/20 positions

and other mechanisms for engaging UC faculty, such as fixed-term positions, teaching buy-outs, and/or summer salary support.

Charge Point 3: Assess Process for Determining Statewide Priorities

10. Governance

The UCO currently reports to the UCOP administratively, from which it receives its budget. Personnel matters, however, especially for the UCO faculty fall under the purview of UCSC, leading to a division of responsibilities. These separate reporting lines have contributed to a lack of rigor and consistency in the oversight of the UCO. In addition, the sheer number of UC MRUs reporting to the UCOP is no doubt responsible for the fact that careful oversight of the UCO has not been carried out in recent years. For example, Director Bolte was not aware of any strategic or long-range plan that had been discussed or formulated with the UCO staff in recent decades, and he informed the committee that he had not had an annual performance evaluation in recent years.

The only board or committee with which the UCO interfaces on matters of policy is the UCO Advisory Committee, which reports to the Director. There is no other authority than the UCOP to which the UCO Director reports. There is no feedback loop apart from collegial persuasion by which the UC campuses, which the UCO serves, can officially influence UCO policy and priorities.

The environment within which UCO operates has changed dramatically since its founding more than 20 years ago. There are now strong astronomy programs at most of the UC campuses, not just at the traditional flagships of Berkeley, UCLA, and Santa Cruz. At the same time, telescopes and instruments are growing ever more expensive, and many of the traditional sources of funds for supporting astronomy - the state and federal governments - are facing growing claims on their resources. Those resources appear unlikely to increase at a rate commensurate with those claims. Thus, while we believe that concentration and continuity of engineering resources at UCO are essential in the era of Keck and TMT, we also believe that it is important to draw effectively on the scientific talent and diverse points of view throughout the UC system in formulating the UCO program.

In this environment, the UC astronomy program, with its access to Keck and its plans for TMT, stands poised to play an even more important role in national and indeed in international astronomy. According to the information provided us, it appears that much of UC's obligation for TMT can be met by reprogramming resources from Keck operations when the current operating agreement expires and from UCO's lower priority existing programs. This reprogramming will, however, require very difficult decisions and will undoubtedly generate opposition from the groups affected.

For all of these reasons, we think it is important to strengthen the system of governance for UCO and to engage not only the astronomy community within UC but also outside experts in the formulation of policies, priorities, and plans for the future.

10.1 Establish a New UCO Board

Effective planning for, and management of, the changes that will be required in the TMT era would benefit from the review and advice of a Board, whose members would serve as trustees and advocates for the UCO program. This Board would be advisory to the designated person within the Office of the President of the University of California. The President's Office should determine the charter for this Board. Based on our review we suggest that the Board should consist of 8-10 members, most of whom should come from outside the UC system. This has the advantage of avoiding the conflicts of interest that would inevitably arise if the allocation of scarce resources were managed entirely internally. It also provides the opportunity to bring into the strategic planning process external expertise in areas such as the management of large instrumentation projects, the infrastructure required to support telescope operations, fund-raising, and so on. Although we envision a Board comprised mainly of astronomers, members might also be drawn from scientists in other fields and/or individuals with high-level experience in administration or management. In addition, we believe it would be helpful to include as a Board member, a representative from the UC Academic Senate.

The Board would be responsibile for oversight of the UCO program but would not direct the program. Line authority for UCO would continue to reside with UCOP. Tasks undertaken by the Board, which should meet once or twice each year, would include the following:

1. Give support and guidance to the UCO Director on important policy and management matters.
2. If the position of UCO Director becomes vacant, work with the UCOP to establish a search committee and develop the charge to the search committee. The Board would then receive the recommendations of the search committee and make a recommendation to UCOP.
3. At a suitable interval - perhaps every five years - establish a committee to review the performance of the Director of UCO and based on the recommendations of that committee recommend to UCOP either reappointment or termination.
4. Review and approve annual program plans and longer-range (5 years) strategic plans. Evaluate progress against those plans.
5. Meet annually with the UC leadership to report on Board activities and discuss UCO.

10.2 UCO Advisory Committee (UCOAC)

The UCO Advisory Committee currently reports to the UCO Director. We believe that such an advisory committee is important and should continue. However, some restructuring is required tomake it more effective. At the present time, most committee members feel that information flow is largely from UCO to the committee, with little opportunity for the committee to provide meaningful input or feedback. We recommend that the members of the committee should be more strongly engaged in debating the isues and priorities of UCO and should have an opportunity to discuss and contribute to annual program plans and strategic plans while they are still being formulated. They should also be conscious of their important role as liaisons to the various campuses.

We recommend that the UCOAC report jointly to the Director and to the Board described in the previous section.

10.3 External Reviews

External reviews are an additional source of important input on the quality and directions of the UCO program, but they should not happen too frequently. The reviews could follow a fixed schedule, but there are some important milestones for the UCO program that might be appropriate triggers for reviews. The first major milestone is likely to be the decision to begin TMT construction, and the determination of the scope of the project and the collaboration at that stage. At that point UCO will need a strategic plan for how to reallocate existing resources to best support this initiative and also to identify what additional resources (e.g. instrument fabrication facilities) may be required in order for UCO to continue to provide intellectual leadership for TMT. A second milestone might be tied to the expiration of the current Keck operating agreement and/or to the start of TMT commissioning.

11. Final Remarks

In the course of examining UCO, the committee was reminded repeatedly of the manner in which the organization has seized opportunities to keep the University of California at the international forefront of OIR astronomy, and how it now finds itself in this position once again with the advent of the TMT. The members of this review committee are confident that UC has the capacity to meet the associated challenges and the wisdom to make the best choices, and we wish it well in this exciting and historic endeavor.

Robert C. Kennicutt	University of Cambridge (Chair)
Charles Alcock	Harvard Smithsonian Center for Astrophysics
Roger Blandford	Stanford University
John E. Carlstrom	University of Chicago
Rolf Kudritzki	University of Hawaii
Marcia Rieke	University of Arizona
Anneila Sargent	California Institute of Technology
Daniel Simmons	University of California, Davis
Robert Williams	Space Telescope Science Institute
Sidney Wolff	Large Synoptic Survey Telescope Project

31 October 2011

APPENDIX A

Charge for Systemwide Review of the UC Observatories

Background

Starting with the construction of Lick Observatory in 1888 and continuing with the support of major facilities in radio and millimeter-wave astronomy and the Keck Observatory, the University of California (UC) has made substantial investments in research infrastructure for astronomy and astrophysics. Access to these facilities has been a major factor in creating excellent departments in astronomy and astrophysics across the UC system.

In order to maintain this research excellence, the University of California currently invests almost $20 million dollars of its systemwide budget annually to support a combination of infrastructure and research in astronomy and astrophysics. Approximately $8 million dollars fund the operations of the UC Observatories (UCO) Multicampus Research Unit (MRU) and Lick Observatory, with the remaining $12 million dollars going to the operations of the Keck telescope. These facilities generally provide access to UC astronomers working in optical and infrared astronomy.

The UC Office of the President has requested an external review of the structure, programs and operations of the UC Observatories to assess the quality of its investment and to ensure that it will address the needs of the University in the future. Specifically, the Review Committee is charged to examine UC's process for setting priorities, allocating resources, implementing the resulting plans, and assessing the results. UC seeks advice on how best to optimize the allocation of its resources to ensure that UC maintains its excellence in astronomy and astrophysics during times of fiscal austerity.

Charge to Review Committee

Charge Point 1: Review the management of the UC Observatories and advise on how effectively UCO fulfills its stated mission, meets its goals, manages its operations, and responds to or helps set systemwide priorities in astronomy and astrophysics research.

Charge Point 2: Assess the quality and performance of the UC Observatories, its current programs, collaborations, facilities and accomplishments.

Charge point 3: Assess the process by which the UC astronomy and astrophysics research community determines systemwide priorities. Evaluate how UC invests systemwide funding to address these priorities, and how well this current investment addresses UCs needs.

Review and recommend an optimal way for UC to determine systemwide priorities for astronomy and astrophysics research across the multicampus system, how it may invest systemwide funding to address these priorities, and how well the current investment addresses UCs needs.

Charge Point 4: Assess the likely future requirements for UC investment in astronomy and astrophysics in the next decade and advise on what combination of resources, facilities, and funding structures will be needed to meet these requirements.

APPENDIX B

WEDNESDAY, AUGUST 10
Hyatt Regency San Francisco Airport
Boardroom IV

10:00 Boardroom IV available with wifi internet access
14:00 Executive Session: Getting Organized
15:00 Welcome and Introductions (Beckwith)
- Background of review
- Discussion

16:00 Task Force Report and Discussion (Marcy, et al)
17:30 Executive Session
18:30 Reception – Scalini Room
19:00 Dinner (Committee, UC Admin, Task Force Members) – Scalini Room

THURSDAY, AUGUST 11
UC Santa Cruz
Alumni Room, University Center

06:30 Boxed breakfast available in lobby until departure (can be taken on van)
07:00 Depart Hyatt Regency San Francisco Airport for UCSC via chartered van
09:00 Executive Session
09:30 UCO Self Study and Discussion (Bolte)
11:30 Panel: UCO/Keck/TMT Instrumentation Leads
(Bernstein, Max, Rockosi, Nelson, Larkin, Macintosh, and McLean-via Skype)
12:30 Lunch
13:30 Break into Two Groups
- Group 1: Tour of UCO Labs
  - Meet Informally with Technical Staff (during tours)
- Group 2: Meet with Chancellor Blumenthal

15:00 UCO Faculty Group
16:00 Executive Session
16:30 UCO Advisory Committee (Filippenko, et al. – most non-UCSC members by phone)
17:30 Executive Session
18:00 Reception and dinner (Committee, UCSC faculty)
20:00 Depart UCSC for Hyatt Regency San Francisco Airport

FRIDAY, AUGUST 12
Hyatt Regency San Francisco Airport
Boardroom IV

08:00 Breakfast Executive Session
11:00 Follow up session with UCO Director (Bolte)
12:00 Lunch Executive Session
Executive Session: Organize Report Writing, etc.
13:00 Briefing/Presentation of Preliminary Findings (Beckwith, Gautier)
14:30 Adjourn
Note: Complimentary shuttle to SFO departs every 10-15 minutes.