UCO Strategic Planning Committee Report

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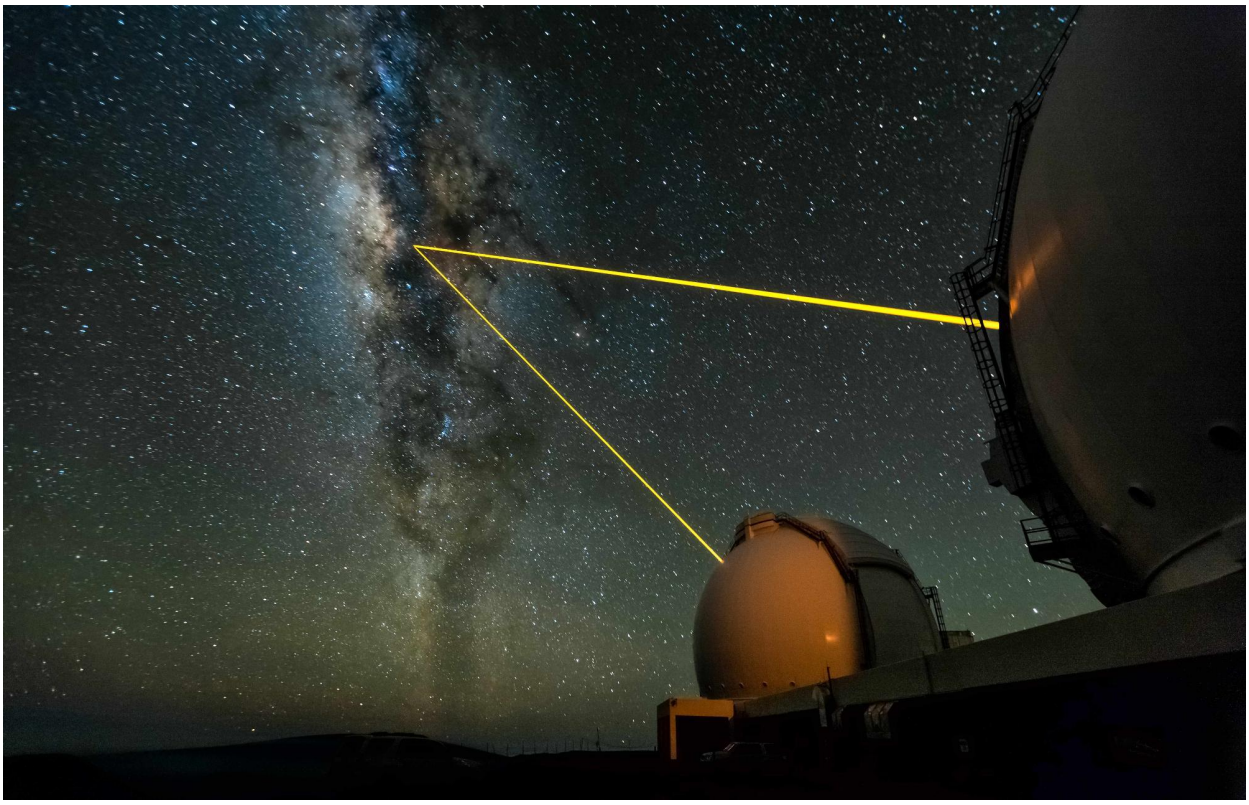
Preamble

The UCO External Review Committee recommended initiation of a strategic planning process “in which the needs of the Observatory in the post-2018 era are addressed, and a phased plan for achieving these objectives is formulated.” The following report summarizes the consensus of a committee convened by the UCO Advisory Committee (UCOAC) to address these questions. The committee, through membership drawn from eight campuses and the Livermore National Lab, represents a broad cross-section of UC optical and infrared astronomy.



The laser guide star system in operation at the Keck 1 and 2 telescopes, which are observing the center of the Milky Way galaxy. The lasers are tuned to the yellow 589 nm line of atomic sodium, which accumulates in the earth’s atmosphere at an altitude of 90 km producing a bright artificial star. The adaptive optics system on each telescope locks on to this “guide star” to correct for atmospheric blurring. The resultant images are sharper than those obtained from space by the Hubble Telescope. This technology was co-invented by LLNL and UC astronomers and was first developed into a scientifically productive system at Lick Observatory. Photo Credit: Andrea Ghez (UCLA)

1 Summary

1.1 Reinventing UCO

In 1874 James Lick placed $700,000 at the disposal of the University of California for “the construction of an observatory and the placing therein of a telescope to be more powerful than any other in existence.” This established the first, permanent, mountaintop astronomical observatory housing the world’s largest refracting telescope and propelling the fledgling university to the forefront of international science. For 125 years UC has dominated observational astronomy and astrophysics through a sustained program of investment in faculty, facilities, and technical and engineering staff culminating most recently with the W. M. Keck Observatory.

As we enter the 21st century, UC is embarking on another extraordinary program—the Thirty Meter Telescope—made possible by the unique strengths of UCO, remarkable philanthropy (this time from the Moore Foundation), and the legacy of James Lick’s vision.

This is a critical time for UC astronomy because a number of remarkable science goals—from first light in the Universe to the discovery and exploration of habitable terrestrial planets—are within grasp. If we cede our leadership, others will reap the rewards of decades of UC investment. For several reasons coherent action is more relevant than ever to achieving our goals: 1) the increasing technical, scientific, and political complexity of the TMT partnership; 2) the challenge of funding new instruments and advanced adaptive optics systems for Keck and subsequently TMT; 3) the transition to a joint operating cost model for the W. M. Keck Observatory; and 4) the challenge of funding the operation of medium size (3-5 meter) and robotic telescopes.

Historically, UC astronomy has drawn its strength from long-term investment in flagship facilities enabled and coordinated by leadership at UCO/Lick. Looking to 2018 and beyond we see significant challenges and opportunities for the UC astronomical community. The SPC envisions a vibrant UCO focused on its role as a multi-campus entity enabling over 100 system-wide faculty to achieve the priorities identified by the Astronomy Task Force in 2011.

The concentration of UC’s intellectual firepower, efficient and effective sharing of resources, and unity of vision allows our astronomy program to “punch above our weight” relative to our national and international peers and competitors. The External Review Committee noted that UCO enabled “the assembly of what arguably is the leading ground-based optical astronomical instrumentation group in the world”—we agree and propose here a strategic focus that will sustain this preeminence.

UCO should exist to enable activities that cannot be achieved by a single campus or an informal confederation of faculty alone. As our collaborations become ever more complex, we need dedicated scientists who can represent UC to funding agencies and to our national and international partners with reliable, authoritative, and sustained voices. We also need to foster and maintain a strategic core of engineering skills and technical excellence that can be drawn

on system-wide to conceive and build revolutionary new instruments and exploit radical new technologies. These technical resources are best deployed if they are allocated in a transparent, performance-based manner that amplifies the competitiveness of system-wide faculty PIs for external funding.

Physical permanence is necessary for UCO. Geographic concentration encourages coherence of purpose, which is essential to assemble effective leadership in our observatory partnerships. UCSC remains the optimal headquarters location. Key factors that support this conclusion include: a culture that understands, values, and fosters the development of astronomical instrumentation; substantial technical infrastructure and engineering heritage; commitment to Keck and TMT leadership and instrument building; existing and planned lab space; and an astronomy program that enjoys preeminence, promoting strong local administrative support.

The SPC supports a Lick Observatory that enables unique and diverse faculty science while offering unequalled access to educational opportunities for graduate and undergraduate students and postdoctoral scholars. Lick also serves as a platform for development and demonstration of new astronomical technologies and a distinctive venue for public outreach. In the next 3-5 years Lick is the only viable venue to develop and demonstrate advanced sodium laser beacons for TMT, which have the potential to generate guide stars that are several times brighter—and therefore better—than currently available.

1.2 UCO functions & budget

Here we enumerate core UCO functions necessary to sustain an internationally competitive program that enables us to achieve our science goals and allows us to recruit and retain the best faculty, students, and postdocs.

Strong, continued leadership is needed in two critical areas. First, system-wide faculty must be able to act with strength and coherence as we transition to a shared operating-cost model for the W. M. Keck Observatory in 2018 with our principal partners at Caltech. Second, UC needs to maintain its strong role in TMT to ensure that we reap the full scientific rewards of our contributed intellectual property, leadership, and capital.

We focus on instrumentation and astronomical technology because telescopes are only as good as the instruments and auxiliary systems that they feed. Moore's law is just as applicable to detector technology, adaptive optics, and astronomical spectrographs as it is to computers—even the largest telescopes will lapse into obsolescence on a 5-10 year timescale without sustained development. Instruments define what science a telescope can do; hence, leadership in instrumentation translates to leadership in projects like Keck and TMT. Historically, the W. M. Keck Observatory and federal sources funded instrument development. The Keck Observatory now directs the majority of its resources to operations. Federal support for astronomical instrumentation has also seen recent declines, e.g., the termination of NSF's Telescope System Instrumentation Program (TSIP). Together these changes mandate that we reinvent how we keep our telescopes competitive. If we fail to maintain leadership in instrumentation we will imperil 25-years of investment in our premier facilities.

We summarize the core UCO functions as:

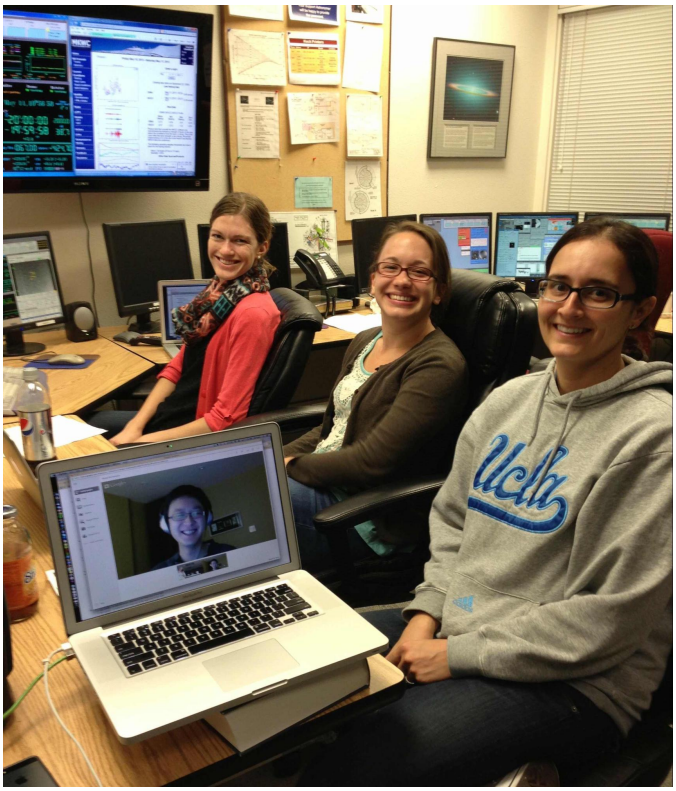
1. Coordination and leadership to represent UC strongly in our astronomy partnerships:
    a. A centralized office at UCSC, led by a strong director and including a managing director, chief technology officer, and core administrative functions.
    b. A distributed network of active UCO participants, enabled by faculty buyouts, that harnesses the entire UC astronomy faculty, including key partnership leads with Keck & TMT and instrument leads.
    c. A centralized development office to leverage the strong public outreach legacy of UCO and to strengthen fundraising.
2. Enable system-wide excellence in astronomical instrumentation and advanced technologies:
    a. Sustain a core of excellence engineering and technical superiority in astronomical instrumentation at UCLA and UCSC.
    b. System-wide initiatives for new instruments and advanced astronomical technologies with emphasis on advanced adaptive optics, novel detectors, and camera/spectrograph design.
    c. Vigorous instrument upgrade and innovation program for Keck, transitioning to TMT post 2020 (in exchange for negotiated fraction of telescope time.)
3. Facilities (Mt. Hamilton, Keck, and TMT):
    a. Continued operations of Keck through 2018; operation of Keck post 2018 in the shared operating cost model and transition to Keck + TMT in 2020.
    b. Sustain the educational, diverse science, technology, and outreach roles of Mt Hamilton with “Spartan-level” operations model through 2018.
    c. Investments required for Mt. Hamilton to transition to a substantially revenue-neutral model by 2018, including visitor facility and associated fundraising programs.

2 UC Astronomy & Astrophysics

The pace of advancement of optical telescope technology slowed following the deployment of the Palomar 200-inch and the Lick 120-inch in 1940s and 1950s. As a result, new instruments that opened up the previously unexplored regions of the electromagnetic spectrum (from radio to gamma-rays) dominated the major discoveries of astronomy and astrophysics from the 1960s to the late 1980s. This period led to the discovery of the Big Bang, the understanding of how elements from helium to uranium were forged in stars, and the discovery of neutron stars and black holes. But the mid-century slowdown in telescope technology meant that astronomy was poised for an explosion of discovery the W. M. Keck Observatory's 10-m telescopes saw first light in the early 1990s. The Keck Observatory, which was enabled through UC's partnership with Caltech and a generous gift from the W. M. Keck Foundation, hosts the largest and most scientifically productive telescopes in the world. The two Keck telescopes ushered in an era of exploration and discovery, which runs the gamut from dark energy to extra-solar planets. In the future, application of radical new technologies to our existing telescopes and the greater aperture of the Thirty Meter Telescope (TMT) will open new vistas that we can scarcely yet imaging of the universe, including habitable planets orbiting sun-like stars and glimpses of the very first galaxies.

For over 125 years University of California astronomers and astrophysicists have led the world, and through sustained strategic investments in facilities we are poised to continue this heritage. This success results from the synergy of access to world-class facilities, the cultivation and support of researchers that instrument these facilities with exciting new capabilities, and dedicated scientific and technical leadership within the system. State funding has been critical in supporting this model. UCO has played and will continue to play a central role in coordinating and enabling these activities, but it must change to meet new priorities while recognizing the stressed economic climate at UC.

A deep faculty commitment to graduate and undergraduate education is at the core of UC's astronomy enterprise. Twenty two percent of UC undergraduates, or almost 8000 freshmen per year, take a general education class in introductory astronomy. Astronomy is an accessible science with broad public appeal; it plays a key role in science education and raising science literacy in the population of California as a whole. The discoveries enabled by UCO-managed telescopes, including extrasolar planets, black holes, and the nature of dark matter and dark energy are frequently featured in the media and are a big component of the relevance of astronomy classes taught by UC faculty. Astronomy offers a high return on investment attracting students to science and engineering careers, and providing the kind of education needed to solve societal challenges involving science and technology.



UCLA students Kim Phifer and Anna Boehle and postdoctoral scholar Sylvana Yelda observing the Galactic Center at the Keck 1 telescope. Another UCLA student, Tuan Do, is participating remotely from California. Photo Credit: Andrea Ghez (UCLA)

3 Why we Need UCO & Why it Needs to Evolve

In 2011 the Astronomy Task Force reported that the UC astronomy and astrophysics community is essentially unanimous in identifying its ranked priorities. First, this survey shows unanimous support for UCO to focus on its current mission in ground-based optical and infrared astronomy. Tied for top ranking are TMT and the W. M. Keck Observatory, with 90% and 89% support, respectively, with the UC instrumentation labs at UCSC and UCLA a close third (70%). Lick Observatory with 40% support, was a notable but lower tier priority.

The Keck Observatory is the world's premier ground-based astronomical facility: it consistently ranks highest in scientific productivity and impact, outperforming other ground-based national and international facilities, including Kitt Peak National Observatory, Carnegie Observatories, Gemini Observatory, the National Optical Astronomical Observatory of Japan/Subaru, and the European VLT.

The preeminence of Keck—while being well beyond expectations relative to the direct operational costs borne by UC—is no accident. It is the direct consequence of the investment of hundreds of thousands of hours of coordinated, system-wide faculty labor over the last three decades. Likewise, UC is a global powerhouse in astronomy because we have created a unique

system-wide shared resource[1]. No single campus could have ever had the intellectual capital to conceive, construct, support, and use the Keck Observatories. This was the role of UCO, who drove the effort centrally and engaged key faculty throughout the system to realize this project.

The triumph of the W. M. Keck Observatory gives the UC community the unique expertise and credibility to lead the next major ground-based astronomical initiative—TMT. This success explains why Keck and TMT are tied for first place in the ATF survey; an endorsement that is unambiguous affirmation that TMT is the correct strategic choice for future of UC astronomy.

The support of advanced astronomical instrumentation labs at UCLA and UCSC is not a distinct activity, but a necessary consequence of the desire to be effective leaders in Keck and TMT. The development and application of radical new astronomical technologies (e.g., adaptive optics) continually enable revolutionary new capabilities, without which even the largest telescopes would be rendered obsolete over 5-10 years. This even applies to unique facilities in space, such as the Hubble Space Telescope, which has had four servicing missions to update instruments with state-of-the-art replacements. Thus, the top three priorities identified by the ATF are aspects of a unified strategic goal to maintain UC's international preeminence in astronomy.

What then is the future role of UCO in maintaining the premier status of Keck and delivering the promise of TMT? An observatory undertakes diverse tasks, some of which are best discharged locally; however, many tasks require the highest levels of faculty innovation, commitment, and leadership; they cannot be reduced to formulaic transactions subcontracted to a remote facility or accomplished by individual UC faculty working in isolation. The Keck operating budget is significantly smaller than that of rival observatories like Gemini and VLT, and yet its preeminence is confirmed by every possible metric. One of the secrets of Keck's success is the tight connection between the UC faculty, led and coordinated by UCO, and the observatory. The evidence shows that for UC to be an effective partner in Keck and TMT, a strong headquarters at UCO is necessary. The primary roles of UCO must be to enable coherent actions by and on behalf of system-wide astronomy and astrophysics faculty, and to act as a focus to maintain the technological and engineering excellence necessary to keep a major telescope at the forefront.

3.1 Observatory leadership

Running an observatory is scientifically, technologically, and politically complex, with tasks that run from the mundane to the esoteric. Regular operations of the W. M. Keck Observatory are delegated to a local director in Hawaii, who is responsible for coordinating logistics. The long-term success of the observatory is dependent on identifying, developing, and deploying new and strategically relevant technologies, which keep telescopes competitive. Even the most generously funded observatories must make strategic, science-driven choices regarding what opportunities to pursue. Keck focuses on multi-object and echelle spectroscopy and adaptive optics. The Gemini Observatory chose infrared-optimization, narrow field-of-view science, and queue-scheduled observing; the science grasp of the European Southern Observatory is very

[1] Access to UC telescopes is re-competed by peer review in a semiannually process coordinated by UCO. Telescope time is always oversubscribed—Keck observing time is often by oversubscribed by over 100%.

broad, including time domain and mid-infrared capabilities, and those choices are reflected in its budget. (The 2011 operating budgets—excluding instrumentation—of the Gemini Observatory and the European Southern Observatory/VLT are $30M and $48M, respectively, compared to $16M for Keck[2].) Gemini and ESO are international treaty organizations, with strong central leadership.

The W. M. Keck Observatory is a partnership led by UC and the California Institute of Technology, which, like UC, is internationally preeminent in astronomy. The economy of the Keck model relative to Gemini and ESO can be used as a measure of how well UC and Caltech have been able to make strategic choices that are mutually beneficial. In any partnership, both members must be strong, and it is evident that if we do not present a strong, coherent, and compelling voice that represents the UC faculty in making these decisions, then the observatory will fail to serve our research priorities. For example, without UC faculty leadership in diffraction-limited imaging, the Keck Observatory would not have deployed adaptive optics systems and laser guide stars.

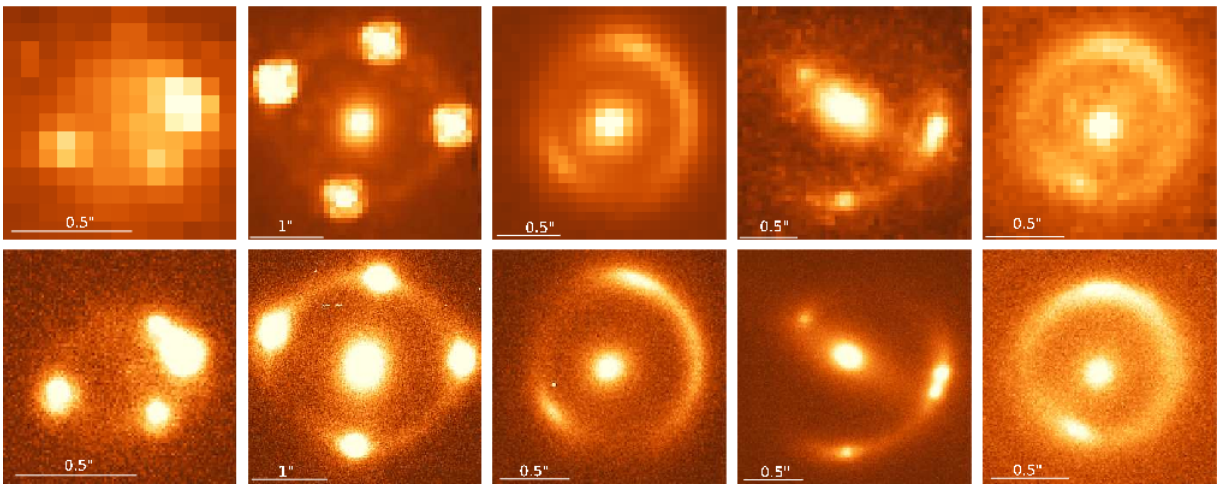
The dynamics of the TMT partnership are even more complex, with international participation from Canada, India, Japan, and China. Although UC owns much of the original intellectual property that makes TMT possible, we now are a minority partner. TMT is still at a stage where many fundamental decisions remain to be made, and UC can only expect to see its original vision fulfilled if we exercise strong, coherent leadership within the consortium. In contrast to many of our partners, UCO has the decades-long experience (both technical and political) in constructing and operating a world-class telescope in Hawaii. We also have the scientific depth and breadth required to properly prioritize TMT activities.

It is vital that UCO harness the collective strength of UC for the success of the TMT project. While much of this leadership and intellectual innovation can come in the form of individual system-wide faculty contributions, UC must be represented by a core of sustained, reliable, and authoritative voices empowered within the institutional structure of UCO.

3.2 Preeminence in instrumentation

The first half of the 20th century saw steady progress in telescope aperture from 1.5-m (1908) to 5-m (1948). However, the pace of progress slowed until 1992 when the first Keck 10-m telescope saw first light. The reasons for the slowdown were twofold: first, no scalable technology existed to build larger mirrors; second, the application of photoelectric detectors improved the effective collecting area of existing telescopes by almost two orders of magnitude relative to those using conventional photographic processes. The segmented mirror technology of the Keck telescope means that apertures up to 100-m are now conceivable. Photoelectric detectors are now universal, but progress continues to be made in wavelength range, detector area, time resolution, and energy sensitivity.

[2] Includes non-UC contributions to Keck operations.



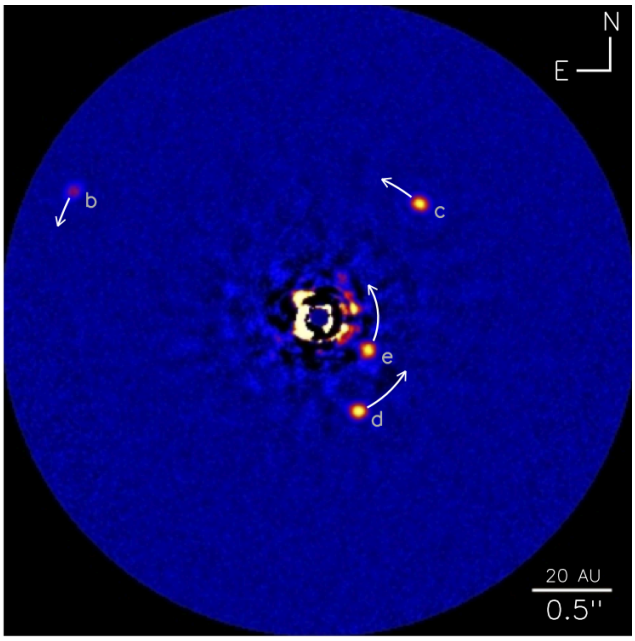
Images of five gravitational lenses. Top row: images from the Hubble Space Telescope; bottom row: the same systems image with Keck Adaptive Optics using laser guide stars. In each case, the object in the center of the image is the foreground lensing galaxy. The background object is lensed into arcs or a ring, and sometimes has multiple images of an active nucleus contained in the background galaxy. The superb resolution of Keck/AO is needed to tests key predictions of the standard cold, dark matter paradigm by enabling the detection of dark matter subhalos. Photo credit: C.D. Fassnacht (UCD)

A third revolution involves adaptive optics, which enables ground-based telescopes to achieve diffraction-limited imaging, and thereby equal or even exceed the performance of space facilities. Adaptive optics (AO) compounds the advantage of a big telescope, because performance scales as the fourth power of telescope diameter; with AO the TMT has a scientific reach that is two orders of magnitude greater than current facilities.

The pace of development is such that the lifetime of state-of-the-art instruments is typically no more than 5-10 years; this can be extended with a vigorous upgrade program that improves performance and extends capabilities[3]. Over the observatory lifetime, investment in instruments and auxiliary equipment can equal or exceed the original capital cost. Thus, a modern observatory cannot remain competitive without a state-of-the-art instrumentation program.

The current program has had multiple recent successes. The UCLA UCO lab has recently successfully delivered two major instruments—OSIRIS (2005) and MOSFIRE (2012) and is the lead for the TMT IRIS instrument. UCSC led DEIMOS (2002), raised funds for the Moore Laboratory for adaptive optics (2003), implemented mainland remote observing (2003), recruited two first-rate instrumentalists (2007) allowing UCO to lead MOBIE (the single most important instrument for TMT), led the LRIS and HIRES detector upgrades at Keck (2010), and led the optical design for MOSFIRE (2012) and KCWI (2012+). Currently, *all* of the future instrument projects under consideration for TMT are led by the UCO labs at UCSC and UCLA.

[3] Upgrade programs are also necessary because new instruments are frequently fielded with incomplete capabilities due to limited budgets.



The first image of an extrasolar planetary system. This adaptive optics image from the W. M. Keck Observatory shows four planets (b, c, d, and e) orbiting the young star HR8799A. Arrows indicate the direction and magnitude of the planets' orbital motions. This system was discovered by a UC-led team including LLNL astronomer Bruce Macintosh, UCLA astronomer Ben Zuckerman, and current or former UC postdocs Christian Marois, Quinn Konopacky, Inseok Song, and Travis Barman, using image processing techniques developed at the Center for Adaptive Optics (UCSC). Photo credit: Christian Marois, NRC & Keck Observatory.

While this represents significant progress, the pace has slowed and the current configuration of UCO is not suited to the contemporary federal funding climate. Part of the difficulty is that UC campuses, with the exception of UCLA and UCSC, have been hesitant to hire astronomers who can contribute to the design and construction of new instruments. Hiring an experimentalist is expensive and risky compared to hiring an observer, who can immediately generate high impact results using existing world-class UCO facilities. The contrast is stark, and evident to any UC faculty search committee. Yet such choices, although effective in the short term are ultimately unsustainable. We need to enhance the incentive structure so that system-wide UC faculty can contribute to instrumentation efforts.

When the original instrumentation budget for Keck was exhausted, development was funded by a patchwork of telescope time trades, federal funding, and private gifts. Notably, the NSF's Telescope System Instrumentation Program (TSIP) provided a $2M annual funding stream for upgrades and new instrumentation (e.g., OSIRIS, MOSFIRE, and KCWI) in exchange for telescope time for use by the U.S. community. TSIP is now defunct. Equally alarming is the lack of federal funding for adaptive optics systems, despite being ranked as one of the highest priorities in the National Academy of Sciences' 2010 Decadal Survey. Thus, despite an early lead in adaptive optics at Lick and Keck, our preeminence is being eroded, with others poised to take the lead.

To achieve our goals for instrumentation, the UCO director should establish and administer a competitively awarded program to establish new Keck and TMT instrumentation programs. We recommend that this funding should be at a level comparable to the former TSIP program to be split between upgrades and new instruments. New instruments are likely to cost $20-60M, so UCO funds will be best used if devoted to conceptual development, design, and technology demonstration to aggressively leverage support from private donors, foundations, and funding agencies. Instrument upgrades, which are typically much smaller scope, may be partially or wholly funded, depending on priority. The upgrade program may also provide a mechanism to work with new, non-UC collaborators that bring special skills or resources. This program will benefit all astronomers pursuing research at Keck and TMT and consequently we must engage our partners in creative discussions regarding UC's share of operating costs and telescope time.

Historically, UCO focused on telescope and mirror technology (including mirror coatings), optical sensors, and spectrograph design. Current challenges emphasize infrared and adaptive optics. We envision that UCO will build on its investment at UCLA and jump-start the next generation adaptive optics initiative for the W. M. Keck Observatory. We endorse a strong instrumentation program for Keck and TMT and a clear path to upgrade existing instruments and enable the next generation of adaptive optics technologies. An important component of this activity will involve working to rebuild the Center for Adaptive Optics (CfAO) and re-engage with the national labs that are managed and operated by the University of California.

4 Faculty Functions

UCO needs a core of strong leadership with permanence and continuity at UCSC in order to lead effectively our partnerships with Keck and TMT. To complement these activities and to draw strength and energy from the broad intellectual resources of the astronomy faculty across the University of California, UCO should sponsor a program of faculty buyout by purchasing teaching release and summer salary.

Currently, many UC faculty donate their time to support UCO activities, for example to lead Keck instrument development or to chair and serve on UCO committees. Many of these activities are congruent with typical faculty service in related research fields and it is important to ask why UC should bring additional support to foster these activities. As the W. M. Keck Observatory matures and the TMT approaches realization, the scale and complexity of our activities has grown by more than an order of magnitude. Astronomical instruments become more capable, but they also have become more expensive: the next generation instruments for 8- and 10-m telescopes are $20-60M projects, e.g., the Gemini Planet Imager is a $28M project, HETDEX (Hobby-Eberly) costs $36.1M, and the Next Generation AO project for Keck is expected to cost upwards of $40M. Astronomy collaborations are no longer between two or three UC campuses, or even between UC and peer institutions in the US. The W. M. Keck Observatory has grown to include additional national (Yale) and international collaborators (Swinburne University, Australia). The TMT project includes our Keck partners at Caltech, but adds international participation from Canada (Association of Canadian Universities for Research in Astronomy), India (Department of Science and Technology of India), China (National Astronomical Observatories of the Chinese Academy of Sciences), and Japan (National

Astronomical Observatory of Japan). As articulated by the ATF, these projects offer enormous rewards to UC, but they potentially involve huge risk, which can only be mitigated by committed faculty attention.

The proposed faculty buyout program will provide a formal process through which UC faculty can bring to bear substantial time and effort to lead UCO-identified responsibilities, while ensuring broad, system-wide representation. By using teaching releases and summer salary (at an estimated cost of $15k per quarter and per month, respectively) substantial savings can be realized compared to the UCO faculty current model. The total number of buyouts represents a small fraction of the overall teaching carried out by UC astronomy and astrophysics faculty (nearly 100 throughout the system) but it greatly enhances the education mission of the university. The discoveries enabled by UCO telescopes are a key component of the popularity and effectiveness of general education astronomy classes throughout the system (22% of all UC freshmen take them), and a powerful tool to introduce undergraduates to scientific research.

4.1 Implementation

The UCO director in consultation with the UCOAC will identify and prioritize faculty tasks. While individual faculty volunteer to undertake the proposed duties through a competitive proposal process, the subsequent actions are not voluntary. These appointments are subject to regular review, annual performance evaluation, and termination at the discretion of the director. The principal features of the buyout program should be:

1. All UC faculty and research scientists are eligible to compete for these positions.
2. The appointee will be awarded up to one teaching release and two months of summer salary per year (estimated $45k p.a.) funded by UCO. The total support would be stipulated in a competitive proposal process and will depend on the nature of the task or assignment.
3. UCO support will be awarded competitively. The process, led by the UCO director, will be transparent and vigorous, and mediated by peer review with a clear emphasis on excellence and relevance to the UCO mission. To assuage fears that service to UCO may impede the career development of junior faculty, these awards will enable unique and substantial achievement by bringing a critical level of effort to bear on challenging problems.
4. Typically, these arrangements will be in force for 3-5 years, with the duration set by the scope of the task. UCO summer salary and teaching release can be renewed, with renewal of a second term contingent upon mandatory review, based on demonstrated scientific accomplishment, system-wide leadership, and overall benefit to UCO goals.
5. The total number of concurrent appointments will be defined and several categories of appointments will be established so that the interests of UCO are broadly served. These appointments will be constructed to be compliant with foundation and federal funding agency requirements for matching funds.

A full description of the faculty functions supported by the buyout program is described in the Appendix. An important aspect of implementation will include negotiation of favorable rates for teaching release with each campus.

5 Lick Observatory

For 125 years, facilities at Lick Observatory on Mt. Hamilton have uniquely served faculty research at the University of California. More recently, through UC's partnership in the twin 10-m Keck telescopes, scientific programs pursuing the faintest sources or requiring the highest spatial resolution have migrated to that world-class facility. The strategic plan for Mt. Hamilton must re-evaluate the primary functions of this facility, especially in the context of the Keck and TMT observatories. We identify five main activities:

1) Public outreach: Lick Observatory is conveniently located for over 7 million Californians in the San Francisco Bay Area. Lick hosts approximately 35,000 visitors per year. Guests are offered tours where they view exhibits showcasing UC's astronomy research. The observatory also hosts regular events, including the Summer Visitor and Music of the Spheres programs, which offer public viewing, lectures, and concerts.

2) Diverse, system-wide faculty research: Presently, the primary observing modes of the 3-m telescope are optical spectroscopy (low- and high-resolution) and observations with adaptive optics. These capabilities enable research on exoplanets, supernovae and other transient sources, AGN and distant quasars, and special classes of Galactic stars. Time domain and synoptic studies are a particular strength of the 3-m telescope.

3) Technology and instrument development: Lick Observatory is a unique test bed for innovative astronomical instrumentation that is ready to move from the lab to the telescope. Successes include the first scientifically productive astronomical laser-guide star adaptive optics (AO) systems and novel detectors systems.

4) Education: Undergraduate and graduate students access Lick Observatory for first-hand experiences in experimentation and to pursue their own research. Research helps undergraduates hone their skills, understand the nature and development of scientific knowledge, and clarify and refine students' choice of career directions. These are unique opportunities for hands-on work that cannot be had at the W. M. Keck Observatory.

5) PI facilities: The infrastructure at Lick has enabled UC PIs to execute dedicated research programs with their own facilities, notably robotic observatories. While supported by UCO, these programs are primarily funded by external sources. The Appendix also includes a white paper submitted to the SPC, which further describes the key current roles of UC's own observatory.

A key question is the degree to which operations on Mt. Hamilton are needed to support the development of AO systems in the next 3-5 years. The AO technology development role is unique and there is an unambiguous need for the 3-m as the platform to develop and test laser guide star systems for TMT over the next five years. The physics of the terrestrial mesospheric

atomic sodium layer (a low density, turbulent, magnetized plasma) cannot be simulated with fidelity in the lab. If the 3-m were not available, then access to a different telescope would have to be procured. Other telescopes are of course available, including Keck. UC's Keck observing time is already oversubscribed, and the cost, including replication of the infrastructure already in place on the 3-m would be prohibitive. Other adaptive optics components like wave front sensors, deformable mirrors, and real-time control systems can be tested in the lab, so this project needs to maintain strong leadership to keep its focus razor sharp on the laser guide star problem.

An appendix details several operational models for Lick Observatory that consider the most valuable roles of this facility. The models range from a Spartan level of operation of all the current telescopes to a future without Lick Observatory. Following the system-wide priorities established by the ATF exercise and the recommendations of the ERC, the SPC recommends that UCO reduce its contributions to Lick Observatory as a general-purpose facility. This means transitioning to a substantially revenue-neutral model by 2018 that would allow UC to realize its investment in the Lick advanced adaptive optics technology program while increasingly focusing its support on Keck and TMT.

The loss of unique functionality at Lick Observatory should be mitigated using by alternative routes at modest cost. For example, instrument and technology development may be enabled using facilities at partner institutions (e.g. Caltech's Palomar). Time-domain follow-up capabilities may be preserved by properly upgrading the enabling Keck (and in the future TMT) instrumentations and operation modes and a greater partner share at Keck. We recommend that Mt. Hamilton maintain the capability to host PI facilities at no cost to UCO. We strongly advocate that Lick Observatory maintain and even enhance its education and outreach activities, ideally through a partnership with local Bay Area expertise.

6 The UCO Budget & Portfolio

6.1 Observing portfolio

The completion of the Thirty Meter Telescope at the end of this decade (first light is expected in 2021) will be a major milestone for UC astronomy. The ATF report identified TMT, Keck, and their instrumentation as the top priority for UC astronomy and astrophysics. Continuing support of Mt Hamilton was also identified as a priority although lower than TMT and Keck; it is clear that in the TMT era we have to focus on the ability of Keck to give UC astronomers a unique competitive advantage when using our limited access to the 30-m telescope.

Here we describe a balanced telescope portfolio for the UC system after 2018. The date is chosen to coincide with when the agreement that governs the W. M. Keck Observatory transitions to a shared operations cost model. At that time UC will have completed its contribution to the capital cost of the observatory. This will result in a substantial reduction in annual cost to UC, and provides an opportunity for rebalancing the portfolio in support of our priorities. Our core priorities, vital to execution of the long-term plan outlined by the ATF report are:

1. UCOP funds the UC share (12.5%) of TMT operating costs, starting at first light.
2. The W. M. Keck Observatory agreement continues beyond 2018, reaffirming UC's commitment to maintain its current share of the observatory.
3. UC commits to a strong instrumentation program for Keck and TMT. To achieve this goal UCO should establish competitively awarded seed and design money for Keck and TMT instrumentation. The seed and design money should be used to leverage support from private donors, foundations, and funding agencies. The TMT and the Keck agreement (after 2018) should reflect UC contributions to the instrumentation (in kind and in cash) and factor into shares of telescope time.
4. UCO maintains operations at Mt. Hamilton for 5 years to support development of TMT adaptive optics.

Additionally we recommend exploring increasing the share of Keck time available to the UC community. This could be achieved by increasing UC's capital share of Keck, by using the equivalent of TMT operation funds between 2018 and TMT first light to establish a one-time instrumentation fund for Keck. Also, if the Shane 3-m telescope at Mt Hamilton were closed for general observing we recommend investigating how to mitigate the loss of this research capability by increasing UC's share of Keck time by a small amount (2-3%) and gaining access to robotic 2-m class telescopes. Beyond 2018 the loss of the 3-m also means that we should seek a small share of time (5%) on 3–5-m telescope for technology development and small-telescope science. A natural way to accomplish these goals may be to include the Hale 5-m telescope at Palomar as part of the of the revised Keck operations model.

6.2 UCO budget sketch

The purpose of the UCO budget is primarily to fund the positions of the director, managing director, the faculty buyout program, instrument and technology development, the engineering and technical staff at UCLA and UCSC, observatory administration, and operations on Mt. Hamilton.

The key functions are

1. Support of a full-time UCO director
2. Teaching release and summer salary for faculty undertaking substantial UCO duties, distributed among various campuses, who execute key system-wide functions such as leading major Keck instruments, leading UC's effort in TMT, or leading the UCLA IR laboratory
3. A technology R&D fund to support initiatives at different campuses in key areas such as superconducting detector development or adaptive optics
4. Support for core engineering and software staff at UCLA and UCSC to work on conceptual design phases of proposed instruments, provide support to campuses (e.g. optical engineering)
5. Administrative and management functions including a managing director
6. Mount Hamilton operations transitioning to the "Spartan model" and ultimately to a revenue-neutral Mt. Hamilton, which includes a strong education and public outreach program.

7. A $2M increase in UC support for Keck observatory, provided primarily through work of UC-led next-generation Keck instruments and upgrades to existing Keck instruments, with terms to be negotiated with the observatory and partners.
8. A similar investment in TMT once it becomes fully operational.

Budget Sketch for 2016 & 2022 (in FY2014 $k)[4]

		2016			2022	
Item	**Buyout Faculty**	**Staff FTE**	**Cost**	**Buyout Faculty**	**Staff FTE**	**Cost**
Director			300			300
Systemwide initiative for new technologies	3		500	4		1,000
UCSC engineers	1	4	600		4	600
UCSC software		2	300		2	300
UCSC adaptive optics	1	3	450	1	3	450
UCLA engineering	1	3	450	1	3	450
UCO administration & management	2.5	10	800	2.5	10	800
Procurements & travel			500			500
Mt. Hamilton operations	1	4-6	1,000	0	-	0
UC faculty buyout			765			787
Sub Total			**5,665**			**5,187**
New investment in Keck & TMT						
Keck instrumentation and upgrades investment	3	4-6	2,000	2	2-3	1,500
TMT instrumentation investment	2	-		3	4-6	2,000
Shared observatory operations						
Keck operations	1			1		
TMT operations	1.5			2		
Total	**17**		**7,665**	**17.5**		**8,687**

In our budget sketch, quantities are expressed in 2014 dollars. The first column for each year shows the number of faculty associated with this responsibility (see §4). The second shows the non-faculty staff—engineering, technical, and administrative. The third shows the total cost including staff but not including faculty. The cost of the buyout faculty is shown on a separate row.

We do not include the operational budgets for Keck and TMT, as traditionally these funds have not been managed by UCO. However, we do assume a constant rate of UCOP support at $12.5M p.a. The transition to shared operations costs for Keck in 2018, when UC's contribution decreases by 50% or $6.25M p.a. At the same time, UC's share of TMT operations (12.5%; $5M p.a.) ramps up. In steady state, we assume that difference ($1.25M p.a.) is available for funding Keck and TMT instrumentation programs.

[4] Approximate FY2014 dollars. Budget breakdowns represent typical years before (2016) and after TMT (2022). The 2022 column reflects post-2018 shared operations costs at Keck ($6.25M p.a.) and approaching first light for TMT.

Appendix A: Faculty Functions

This appendix describes UCO functions including those enabled by the proposed buyout program that supplements 9-month salary of system-wide faculty with funds summer salary and teaching release. The planning horizon is 2013–2018.

1. Administration
    a. Director (1 full-time, 11-month faculty appointment) [Co-located with central administration.] This task includes supervision of personnel.
    b. Managing Director (1 full-time non-faculty appointment) [Co-located with central administration.] This task includes supervision of personnel, e.g., administration and business office. Needs perspective of a PhD with research experience, but faculty appointment is neither required nor especially desirable.
    c. Chair, UCOAC (1) [any campus]
2. Infrastructure Leads
    a. Facility Leads
        i. Instrumentation/Chief Technology Officer (1) [wherever the central shops are located]. Includes responsibility for new technology development, as well as for running and upgrading the instrument shops. This task includes supervision of personnel.
        ii. UCLA Infrared Lab (1) [UCLA]
        iii. Lick Observatory (1) [UCSC/Berkeley due to proximity]. Task includes personnel supervision. (Funding for this line will change during transition to revenue neutral model post 2018.)
    b. Technology Leads:
        i. Adaptive Optics (1) [UCSC]. Responsibilities include new AO systems for the Keck Observatory (e.g. NGAO), close liaison with TMT AO team, development and testing of new and innovative AO concepts, and Lick AO to provide on-sky or prototype tests of new AO concepts.
3. Observatories
    a. Keck
        i. Liaison, Keck Observatory (0.5) [any campus]
        ii. CARA Board member who represents UC. Currently this is the UCO Director.
        iii. Instrument PI (1 to 4 at any given time) [any campus]. PI for new or upgraded instrument or proposal, or for new AO system or subsystem. Can make use of local or central shops and engineers (or both).
        iv. Instrument scientist (2 at 0.3 effort) [any campus]. Science case and science optimization for a new or proposed instrument. Definition includes new AO systems/components
        v. SSC UC Co-Chair (0.5) [any campus]
    b. TMT
        i. Liaison, TMT (1) [any campus]. The member of the TMT Board who represents UC. Leave at (1) for next few years, to take account of large amounts of travel and meetings required.

        ii. Instrument PI (1 to 2 at any given time) [any campus, but likely UCLA or UCSC]. PI for a new or upgraded instrument or AO system. Can make use of local or central shops and engineers (or both).
        iii. Instrument scientist (1 to 2 at any given time; each at 0.5 effort) [any campus]. Science case and science optimization for new instrument or AO system
        iv. TMT SAC UC Co-Chair (0.5) [any campus]
    c. Advanced Technology Development PIs (1 to 3) [any campus]. Novel instrument concepts and detectors, photonic devices, AO systems, software, &c. Oversight responsibility will be under the Facility Lead for Instrumentation or the Technology Lead for AO, as appropriate.
4. Other Observatory Functions (under the responsibility of Managing Director)
    a. Telescope scheduling and TAC comments (0.5) [any campus]. Two Keck TACs, Lick TAC. An intense burst twice a year, in fall and again in spring. Faculty-level involvement is necessary, to: (a) understands science tradeoffs; and (b) been involved directly in the TAC deliberation process. Some administrative support is necessary.
    b. Education and Outreach Faculty Liaison (0.3) [Now focused at Mt Ham; hence best if UCSC or Berkeley location]. Experience of NSF STCs was that the best Education programs had the attention of faculty members, in addition to having EPO professionals as program leaders. Faculty member as liaison gives both perspective and added weight to EPO. Purview of Education and Outreach includes K-12 teachers and students, as well as undergraduate level programs.
    c. UCO Development and Private Fundraising (0.5) [any campus] Specific UCO fundraising efforts, plus liaison and close coordination with fundraising efforts at Keck, TMT, all UC astronomy campuses. This needs to be taken very seriously in the future, given the funding needs identified in the Business Plan. As long as Mt Hamilton remains open, should include the function of faculty liaison with the new Friends of Lick Observatory group.
    d. UCO Communications (0.3) [any campus] Annual Reports editor, Newsletter editor, glossy brochures when/if needed

Unless "Full Time" is specified, FTE numbers in parentheses refer to the number of regular campus faculty on 9-month appointments who also have either a month of summer salary or "equivalent" teaching release paid by UCO (UCOP) funds. (Addition support may be necessary in exceptional cases.) Notional locations for the activity are indicated in square brackets.

Among the responsibilities omitted are less onerous committee memberships (e.g. Keck SSC, TACs, TMT SAC, UCOAC, etc), internal UCSC functions (e.g. Computing Policy Management Committee, oversight of the UCO Scientific Programming Group), liaison with Academic Senate committees and functions, and membership on instrument science teams.

Total faculty involvement for which some UCO funding will be needed[5]

Role	No. of faculty[6]
UCOAC Chair	1
Associate Director, Instrumentation (CTO)	1
Associate Director, UCLA Infrared Lab	1
Associate Director, Lick Observatory	1
Associate Director for AO	1
Liaison, Keck Observatory	0.5
Keck SSC Co-Chair	0.5
Liaison, TMT	1
TMT SAC co-chair	0.5
Telescope scheduling & TAC duties	0.5
Education & Outreach Faculty Liaison	0.3
UCO Development & Private Fundraising	0.5
UCO Communications	0.3
Keck Instrument PIs	1-4
Keck Instrument Scientists	2x0.3
TMT Instrument PIs	1-2
TMT Instrument Scientists	1-2 x 0.5
Advanced Technology Development PIs	1–3
Total	**15-18**

Appendix B: Lick Observatory

We discuss several future visions for Lick Observatory, comparing their cost and the system-wide implications for the functions described above. For reference the current total operating costs of Mt Hamilton ranges from $2-3M including expenses on the mountain and at UC Santa Cruz. Following the ATF and ERC recommendations, the overall goal of these visions is to preserve vital functions while freeing up resources and personnel that can be used to strengthen UCO's effort in support of Keck and TMT and their instrumentation.

The Spartan model

This model would maintain—as nearly as possible—the current level of functionality at Lick Observatory but at the lowest feasible cost to state funds. In essence, this is the model currently proposed for FY 2014. The estimated annual costs are approximately $1.1M to the UCO budget,

[5] This does not include the director, which is a full time, 11-month faculty appointment.
[6] These are system-wide faculty (9-month appts) with 1 month of summer salary or a teaching release

approximately $500k to UCSC for mountain maintenance, and several $100k of work effort from UCO research staff and faculty. In this model, the research functionality at Lick would be maintained at nearly the current level (with a one month shut-down and reduced instrumentation) and each of the other functions (outreach, education, PI facilities) could be expanded without additional state funding. We further note, however, that this model would not generate sufficient funds for renewal of the facilities, e.g., dome repair or major building renovations.

Alternate Revenue streams: It may be difficult to justify the level of state support detailed above to (primarily) maintain the research capabilities at Lick. As such, one would actively pursue additional revenue to support the activities on Mt. Hamilton and thereby reduce state funding. There are several paths that have been proposed:

1. Partnerships: Other observatories (e.g. Palomar) have successfully integrated new partners, trading observing time for funds. The UC community is open to this model, but the present demand for 3-m class facilities is low, and there are several other telescopes of the 4-m class where time is becoming available. Members of UCO have explored interest in the US and international communities without success to date.
2. Grant funded, longer-term projects: Efforts on other 3-m class telescopes (e.g. CFHT) have demonstrated both operational and scientific success in pursuing long-term, dedicated programs. One could encourage PI's from within UC (or even outside) to propose, pursue, and fund such activities.
3. Fee-for-service: It has been proposed and thus far dismissed that one could charge UC astronomers for usage of the 3-m telescope. To generate significant revenue, the fee would need to exceed $1000 per night.
4. Philanthropy: Despite its proximity to the great wealth of the Bay Area, Lick Observatory has not aggressively cultivated financial support from foundations or individuals for its operation. To address this issue, UCO established a Friends of Lick group in 2012 which is developing a donor base and network of members that may offer significant financial assistance. This has the potential to significantly defray state funding, but realistically only on the time-scale of 5+ years.

Summary of the Spartan model

The observatory would maintain the core functions that have driven its success over the past 100+ years. Every effort would be taken to generate new revenue streams, in particular to support science operations. Activities related to outreach and education would very likely be enhanced over time while research capability may continue to be reduced. Funds would likely not be available for major facility repairs and renewal.

The public-PI model

In this model, Lick Observatory would become a major public outreach center, and the main point of contact between UC astronomy and astrophysics and the California citizens. We envision Mt. Hamilton becoming a Northern California Griffiths Observatory/Griffith Park where families from California would go to enjoy the wonderful nature and historic buildings as well as learn about the wonders of the cosmos. Permanent exhibits as well as temporary exhibits would

describe and highlight the discoveries of UC astronomers, showing new results from the Keck and TMT telescopes and the historic impact of Lick. Ticket sales at the visitor facilities and concessions would help support this model. Realistically, a successful business plan would require partnerships with corporate and/or existing museums (e.g. the San Jose Tech Museum, with which Lick has a nascent partnership) within the Bay Area or elsewhere (for example Griffiths Observatory itself). The overall goal would be for the center to generate sufficient funding to cover maintenance and staffing costs for the public outreach center. UC astronomers, meanwhile, would be engaged to provide content for the exhibits and overall scientific direction.

A portion of the rest of the mountain would still be available for PI experiments such as KAIT and APF. The PIs for these activities would be required to cover the additional operations and maintenance costs as well as providing the necessary personnel to support their experiments. The 1-m Nickel telescope would be converted to public outreach or closed. The Shane 3-m would stay open only if a PI or group of PIs took over its funding.

Systemwide research

Research would be heavily impacted, eliminating all general observer capabilities at Mt Hamilton. Closing the Shane would severely reduce the capability of UC astronomers to conduct extensive time-domain optical spectroscopy, long-term monitoring, and large survey programs. To mitigate the loss the vision calls for an expanded UC fraction of Keck time after 2018. We would propose redirecting a significant fraction of the state funds currently spent at Lick Observatory to enhance UC's partnership at Keck. This should include support for the deployable tertiary mirror which would enhance time domain activities, enabling most of the science in that area currently pursued at Lick. Furthermore, in 2018 UC would have the opportunity to modestly increase its partnership share (e.g. augment by 10-15 nights). By both improving the Keck facility and expanding UC's role, this would effectively balance the loss in science capability at Lick. An additional way to partially mitigate the loss of access to small telescopes could be to purchase time on small telescopes elsewhere, e.g., Palomar ($TBD/night), Las Cumbres Observatory Global Telescope Network ($200/hour on 1–2-m telescopes, or commercial observatory sites such as New Mexico Skies $2000/month rental to host a 1-m robotic telescope.) In this model, postdocs and students will lose the ability to be principal investigators of telescope proposals within the UC system.

Technology test bed

This function would be lost. It could be mitigated by opening up the 3-m for short technology campaigns or by reaching an agreement with one of our Keck/TMT partners (e.g Caltech and Palomar) for finite-duration technology projects (e.g., a 5% partnership in a medium aperture facility). One might consider collaborating with the San Pedro Martir Observatory.

Education of students and postdocs

The opportunity for first-hand observing experience would likely be lost. Keck and TMT will have to provide training opportunities. Setting up a small fund could mitigate this loss for graduate students and postdocs to travel to Hawaii at least once during their studies at UC to visit the summit and conduct observations. Undergraduate students would have to limit their experiences to remote observing.

Estimated cost

We estimate that five on-site FTEs are required to keep the mountain and the main buildings open and provide basic technical support. These costs would need to be covered by the public outreach center and any ongoing PI projects, resulting in no state-funded support. We propose that a portion of the savings realized be devoted to additional Keck share and instrumentation development ($0.5M p.a.), a minimal telescope share at a partner institution for technical development (about 5%, $50k p.a.), and student/postdoc travel funds ($100k p.a.): Total cost to UC of $650k p.a. Providing more small telescope access would require additional funds. The costs to decommission the parts of the mountain that would no longer be in use are currently under study, and are probably large due to the need for lead and asbestos mitigation.

Summary

The mountain would preserve two functions that take unique advantage of the location in California, i.e. public outreach and hosting PI instruments. The research and graduate education functions would be transferred to Keck and TMT, concentrating all the system wide research and graduate education activity on Mauna Kea. Reducing the cost and range of activities at Mt Hamilton would increase UCO's capabilities to support our top priorities Keck, TMT, and their instrumentations. The main disadvantage of this model is that the system-wide capacity for technology development and undergraduate education would be reduced.

The no-Mt. Hamilton model

Closing Mt Hamilton will mean giving up all the functions listed in the introduction. The loss of research, graduate education, and technology test bed functions could be mitigated as discussed in the public-PI model, but this would eliminate the successful model of public outreach and PI experiments within California for UC astronomy and astrophysics. Considering that the savings would be minimal over the proposed public-PI model, this vision seems unequivocally inferior. In addition, the costs to entirely close the site may be truly prohibitive such that realizing true savings would take 10+ years to achieve.

The no-Mt Hamilton model with mitigation

In this model, Mt Hamilton would close but some of the functions would be preserved as in the public-PI model by increasing the UC Keck share, and getting access to small telescopes for technology testbed/science. The downside about closing costs and loss of public outreach and PI capabilities is the same as the no Mt Hamilton model.

Roboticize the 3-m telescope.

An alternative to reduce operating costs at Mt. Hamilton while preserving some of the observing capabilities is to make the 3-m robotic. This would require an initial investment followed by substantial operational savings. If this option is of interest, a detailed study must be carried out to figure out the initial costs and see if the resources can be found, perhaps through private fundraising efforts.

Summary Synoptic Table

	Spartan	Public-PI	No MH	No MH with mitigation
Public outreach	In house	Partner	NO	NO
PI exp (e.g., KAIT APF)	YES	YES	NO	NO
Systemwide research	3-m	At Keck, with increased share	NO	At Keck, with increased share
Technology	YES	Elsewhere (Palomar?)	NO	Elsewhere (Palomar?)
Education	YES	Reduced, at Keck	NO	Reduced, at Keck
UCO running costs	$1.5M/yr	$0.7M/yr or more	0	0.7M$/yr or more
UCO one time costs	$	$	$$$	$$$