

Executive Summary

On September 13, 2007, University of California Observatories (UCO) Director Michael Bolte convened a committee consisting of a cross-section of the UC astronomical community to consider the future of UCO's Lick Observatory. The charge to the committee was:

"The Lick Observatory Strategic Planning Committee (LOSPC) will look at the short (five year) and longer term (twenty year) future of Lick Observatory on Mt. Hamilton, and make recommendations to the Director"

The major areas for consideration were research, time allocation, public outreach and education, and personnel and renewal. Questions the Director wanted addressed included:

What kinds of front line research are possible at Lick Observatory?

What kinds of instruments are needed?

Should UCO adopt policies to encourage increased proposal pressure?

Should UCO increase the public outreach program? How?

What resources should be put into infrastructure?

How do we continue the tradition of excellence in Lick Observatory staffing?

The committee concluded that Lick Observatory has played a vital and unique role in University of California astronomy and that over the next twenty years Lick will continue to play an important and integrated role in five areas:

- **Forefront research:** There are stand-alone programs carried out at Lick Observatory and important programs that support UC PI programs on the Keck Observatory Telescopes. Opportunities in this area that take advantage of the UC sole ownership of the facility include offering flexible scheduling modes to enable time-sensitive observations, encouraging programs that require large blocks of time and supporting high-risk, high-reward programs such as the early extra-solar planet searches. The implementation of remote observing capabilities has greatly facilitated making new scheduling modes a possibility. The instrumentation suite, with suitable regular upgrades and maintenance, is appropriate. Improvements could be made in the AO system and near-IR capabilities.
- **Graduate and undergraduate education:** Lick Observatory will remain the prime UC facility for training graduate students in observational optical astronomy. The committee recommends that Lick Observatory's telescopes remain open to graduate students, and that UCO increase its effort at graduate education, including offering on-site classes and making the remote facilities available for graduate instruction on the individual campuses. Lick Observatory has played a small role in undergraduate education through hosting visits by undergraduate college classes. UCO should expand the Lick Observatory role in undergraduate education by opening

the telescopes to use by advanced undergraduate classes throughout the UC system. This is another activity that can be enabled by remote observing.

- **Technology development for astronomical instrumentation:** Because of its proximity to the labs in Santa Cruz, Berkeley and to some extent UCLA, Lick Observatory is an excellent facility for astronomical instrumentation and technology testbed activities. This has proven to be very valuable in the development of AO and sodium lasers, detectors for use in astronomy, and the techniques for making very high precision radial velocity measurements of stars. This platform for developing in a very cost effective way the technologies to be used at the Keck Observatory and eventually the TMT should be continued.
- **Postdoctoral training:** There is an increasing number of postdoctoral scholars in astronomy at all the UC campuses. Lick Observatory remains the only optical observational facility in the UC system where postdocs can apply for time under their own name. To keep UC an attractive place for postdocs, the committee recommends that UCO keep policies in place that give a significant amount of telescope time to postdocs.
- **Public education and outreach:** Lick Observatory is a unique facility, in that it is a forefront research observatory close to a large population area. The committee recommends that UCO increase its commitment to public outreach. The exhibits should be modernized, with an emphasis on the ongoing research at Lick Observatory and other UCO facilities. UCO should offer more public access to its non-research telescopes, particularly the 36-inch refractor, and should consider reinstalling the 12-inch refractor in the 1-m Nickel dome if funds become available to move the Nickel. UCO should hire a full time director of Public Outreach and Education. UCO should consider using its unique resources to institute a summer training program for middle and high school science teachers. It is recommended that partnerships with other Bay area science centers be investigated.
- **Venue for fundraising:** The Observatory is an excellent venue for developing partnerships with Bay area philanthropists and philanthropic foundations. There is a long history in this area for generating friends of the Observatory. The committee encourages UCO to vigorously pursue philanthropic support for the Observatory activities.

A very significant challenge for Lick Observatory is facility and infrastructure renewal. The recommendation of the committee is to prepare a detailed evaluation of needs in this area, prioritize them and seek resources, perhaps through partnerships, to begin the process of renewal.

Background

Lick Observatory (LO), founded in 1888, was the first permanently-occupied mountaintop observatory. From its founding, the primary purpose of LO has been to enable forefront research in astronomy and astrophysics by University of California astronomers. There is a long history of important contributions to science and of pioneering work in instruments and detectors for astronomy. For over 100 years, until the commissioning of the Keck Observatory in 1993, it was the primary research facility for all University of California optical astronomers. Until 1959, the main LO research telescopes were the 36-inch refractor and the 36-inch Crossley reflector. In 1959, the 3-m Shane reflector was put in operation, and UC astronomers had a telescope with a size competitive with other large telescopes. The Shane was the second largest telescope in the world for fifteen years after it was commissioned. Currently there are four (soon to be five) telescopes on the mountain that are used for research. The main research telescope, the Shane 3-m reflector, is used every clear night except Christmas Eve and Christmas night. The demand for time is high, and in semester 2008A astronomers requested 343 nights, while only 183 were available.

Initially, the LO astronomers and staff all lived on the mountain. In 1966, the astronomers and many of the staff moved to the newly-founded UC Santa Cruz campus and became the core of its astronomy department. Currently, the mountain staff is comprised of 24 people. In 1988 LO became part of the newly-created multi-campus research unit, the University of California Observatories (UCO). Lick Observatory on Mt. Hamilton is now part of this much larger organization. UC shares the management of the Keck Observatory with Caltech through UCO and participates in the Thirty-Meter Telescope (TMT) project through UCO. UCO runs an optical lab, electronic lab, machine shop, software group, engineering group, detector lab, and coating lab in Santa Cruz, and supports an infrared lab at UCLA, all of this in support of the Lick and Keck Observatories and the TMT project. UCO stands at the forefront of designing and building astronomical instrumentation.

The role of LO has changed significantly over the past 120 years. Initially, it served the research interests of a very small group of astronomers who mainly lived on the mountain. As astronomy programs were initiated and expanded at the growing number of UC campuses, LO began to operate more and more as a quasi-national observatory, particularly after the dedication of the Shane telescope. After operations began at the Keck Observatory, emphasis at LO moved to a more supporting role, e.g. as a test bed for new instrumentation and for Keck supporting observations.

There have been challenges over the last 120 years. In 1888, San Jose was little more than a village, electric streetlights were non-existent, and the skies over Mt. Hamilton were dark. Today, San Jose and the Santa Clara valley are one of the major metropolitan areas of California. San Jose has been cooperative in its street lighting, putting in low-pressure sodium lights during the 1980s, partly to aid the Observatory. Even so, Mt. Hamilton can no longer be considered a dark sky site. LO has adapted to the changing sky conditions by shifting more to high-resolution spectroscopy and adaptive optics.

Observing programs have changed to take advantage of our unique ability to provide large amounts of time to especially scientifically deserving programs.

Even though primary function of LO has been, is, and will continue to be to enable research, it has tried to fulfill a small role in public education and outreach and university education. When LO was completed in 1988, public viewing with the 36-inch refractor was offered every Friday night, a tradition that continues on a smaller scale with 12 nights of viewing now offered during the summer (six preceded by a concert). The Main Building has a gift shop and some exhibits. Guides give short tours of the 36-inch refractor. The Shane telescope has a visitor's gallery. Even with this limited effort, LO attracts 30,000 visitors a year. Tours, including nighttime viewing, are often arranged for undergraduate astronomy classes. Telescope time is made available to UC undergraduate students for their thesis projects. Several senior theses have been written based solely on data obtained at LO.

In the fall of 2007, the UCO Director convened a committee to review and evaluate the role of Lick Observatory for University of California astronomy. This committee was also charged with making recommendations regarding the role of Lick Observatory five and twenty years into the future. The committee met three times between Sep 2007 and July 2008. This report is the result of the committee deliberations.

Research at Lick Observatory

In 1888, Lick's 36-inch refractor was the largest telescope in the world. That honor did not last long, as the Yerkes 40-inch refractor was completed soon thereafter, and technology advanced leading to the 60-inch and 100-inch Mt. Wilson reflectors. In spite of the relatively small sizes of its telescopes, Lick Observatory enabled the astronomers in the UC system to remain at the forefront of astronomical research. Shortly after operations began, E.E. Barnard discovered Jupiter's fifth moon, tiny Amalthea, and James Keeler took stunning photographs of galaxies.

Forefront research continues based on LO facilities. In many of the most exciting recent astronomical discoveries, LO has played a vital role. These include the discovery of planets around other stars, the acceleration of the expansion of the universe and dark energy, the knowledge that ordinary matter makes up only a small fraction of the gravitating mass of the universe, and the unified theory of active galactic nuclei.

Geoff Marcy (UC Berkeley) and his collaborators discovered a substantial fraction of the currently known sample of extra-solar planets (now over 250 objects) using the Lick 3-m and CAT telescopes coupled to the Hamilton spectrograph. They developed novel data processing and analysis techniques to detect minute, periodic shifts in the radial velocities of stars, indicating the presence of planets orbiting them. This set the stage for the subsequent discoveries with Keck and other telescopes. Such observations with the 3-m telescope continue, and will be expanded using the new Automatic Planet Finder (APF) telescope soon to go into operation on Mt. Hamilton.

The Lick Observatory Supernova Search (LOSS) utilizing the 0.76-m Katzman Automatic Imaging Telescope (KAIT) run by Alex Filippenko (UC Berkeley) and his colleagues has discovered about 700 nearby supernovae, by far the world's most

successful search. KAIT has also been used to obtain some of the earliest observations of the optical afterglows of gamma-ray bursts. Spectroscopic follow-up observations of KAIT/LOSS and other supernovae by Filippenko and his team have led to a much greater understanding of stellar explosions. For example, we now know that some hydrogen-deficient supernovae are not the thermonuclear explosions of white dwarfs, but instead occur in massive stars that have lost their outer envelopes. The studies of low-redshift Type Ia supernovae provide a database with which high-redshift SN Ia are compared and have led to the stunning discovery (and subsequent confirmation) of the accelerating expansion of the Universe, driven by repulsive "dark energy." The nature of dark energy is among the most important observationally motivated unsolved problems in physics.

David Tytler (UCSD) and his colleagues have used the Lick 3-m telescope to obtain spectra of a very large sample of quasars, in search of objects suitable for high-resolution Keck spectroscopy with the goal of determining the D/H ratio of primordial gas. Their measurements have shown definitively that normal matter (consisting of atoms) constitutes only a small fraction of the total gravitating matter in the Universe.

Joseph Miller and his graduate student Robert Antonucci (UCSC) sparked a revolution in studies of active galactic nuclei, showing that the appearance of at least some (and perhaps most) is highly influenced by viewing angle. They achieved this by obtaining spectropolarimetry of some bright, nearby Seyfert galaxies with the Lick 3-m telescope. The resulting "unified model" of active galactic nuclei is now the paradigm.

The development of laser guide star adaptive optics (LGSAO) on the Lick 3-m telescope is one of the great technological accomplishments in the past decade of astronomy. In the near infrared, the Lick 3-m resolution rivals that of the Hubble Space Telescope over narrow fields of view. The technology was transferred to the Keck telescope, leading to tremendous gains that would not otherwise have been possible. This is only one example of technology for astronomical research being developed at LO, then carried to the Keck Observatory.

Research – Future Prospects

General Thoughts: The committee believes that forefront research must be the most important activity at LO. However, given the relatively small size of the largest LO telescope, and the brightening of the sky over Mt. Hamilton, it is fair to question what that role should be. LO is unique in several ways. It is reasonably accessible from all UC campuses. Since UCO directly manages LO, it has full control over the assignment of observing time. This means that time can be assigned in new and creative ways. It is the only well equipped optical facility open to UC graduate students, and the only one on which UC postdocs can apply for time as a PI. The LOSPC believes that it is vital to University of California astronomy that LO remains primarily a research institution providing opportunities not available now at Keck and which will not be available on the TMT. The committee believes that we need to move toward more creative scheduling modes, visible-light AO, and near-IR spectroscopy and imaging. LO should continue to be a test-bed for new instrumentation. The Kast and Hamilton spectrographs are currently the workhorse instruments, and it is likely they will continue to play that role, both in support of Keck and for stand alone-projects.

Giant Surveys and New Observing Modes: Rather than try to predict what science projects will be in vogue in 15 years, the committee looked at the changing ways in which science is being done, and what instrumentation and modes of observing will likely be most productive. In particular, it was thought that follow-up observations to upcoming large scale surveys will become of over-riding importance, and LO should be positioned to undertake such followup programs. This will mean moving toward more Target of Opportunity (ToO) observations and giving out large blocks of observing time to single projects. Large and ToO programs open ranges of scientific discovery space that may not be practical elsewhere, such as early-response spectroscopy of bright GRBs, or reverberation mapping to weigh black holes in AGN, or supernova science. To enable these projects, remote observing will become more and more important. LO is well positioned to both change its scheduling models and to increase remote observing, and has begun to do so. The committee supports these initiatives and believes they should continue.

Adaptive Optics: The committee believes that, given expertise within UCO, visible-light AO on the 3-m Shane Telescope is possible and should be pursued. Reaching the diffraction limit at $\sim 0.7\mu\text{m}$ will provide a capability that is not matched by any other telescope except the Hubble Telescope. With the wealth of discoveries anticipated by upcoming large surveys, and with the eventual demise of the Hubble Telescope, such high resolution imaging even over small fields will give the Shane a unique and scientifically critical capability.

Near-IR Spectroscopy: The committee also considered other instrumental improvements. Mt. Hamilton is a good site for near-IR spectroscopy: A cross-dispersed spectrograph that can reach $R\sim 3500$ at 0.9-2.4 μm would become a workhorse instrument. This would open up a wide range of scientific discovery space, where LO could compete at the forefront of the field.

Wide-Field Instruments: A prime-focus multi-object spectrograph covering a one degree field would be a valuable addition. Sufficiently long integrations could yield redshifts for thousands of galaxies down to 19th magnitude, competing very effectively with shallower surveys such as Sloan. Followup spectroscopy of interesting objects identified by the next generation of mega-surveys will be a crucial scientific bottleneck that LO can break.

Other instruments that the committee thought would be of value include:

- Wide-field IR multi-wavelength and multi-object imager.
- Wide-field Near-IR imager on the 1-m Nickel and/or the 3-m Shane Telescope
- Broad wave-length optical to Near-IR spectrograph with matching of exposure times and resolutions for optimal use of 3-meter observing time.

Metrics and Modernization: The committee believes there is a real need to keep the support instrumentation modernized. These items include guiders, interface monitors, data capture and archiving, and data links for remote observing. These technologies are constantly changing and are essential for successful observation, and, as the technology develops, we envision ever more efficiency and success. It is also worth investigating the use of AO technology to improve general seeing conditions and static aberrations (e.g.

specialized tip/tilt systems, active focus, etc). LO needs to explore high payoff, low impact means of achieving these goals. LO needs metrics, policy, and procedures for when to retire or upgrade or replace a given instrument. UCO needs to develop a strategy for optimizing the use of Observatory resources in the long-term planning of instruments and a strategy for attracting interested instrumentation builders to LO. Long-term Virtual Observatory (VO) compliance requires a modernization of the process of capturing metadata.

Technology Development and Pathfinder Activities: An important role for LO is to be a development pathfinder. Historically, LO has been a test bed for instrumental development. With its closeness to the major UC astronomy departments and the UCO labs, the committee believes that role should continue. New technologies for visible and IR detectors are developing all the time. LO can play a key role in testing and adapting these technologies for science usefulness in astronomy. Examples are the C3PO (multi-color CMOS) visible detectors, deep depletion CCDs, and high-speed, low-noise wave-front sensor detectors (CCID-56). Lick Observatory should have a rapid response capability, coordinated with the UCO detector lab, in testing and characterizing new chips and detectors on the sky. Another example is the ViLLaGES project on the Nickel telescope, which is pushing AO into visible wave-lengths by the use of MEMS devices.

Because Mt. Hamilton is a well-developed site, it is a perfect place for dedicated telescopes/experiments that do not require the darkest skies. Examples are the Kait robotic telescope used for supernova searches, the Vulcan telescope used as a concept demonstrator for the KEPLER space mission designed to find earth-like extra-solar planets, and the soon to be dedicated Automatic Planet Finder. The telescopes have done or will do front-line research in spite of their modest size, and these programs would have been more difficult or impossible without the support UCO offers. The committee believes that UCO should continue to encourage and seed such efforts.

Education and Training

Many undergraduate theses have been written using data obtained at LO, and UCO should continue to encourage and facilitate these activities. Students working under the guidance of a faculty member should have the opportunity to obtain their own data for original research projects that can be suitable for publication.

There is a terrific new opportunity to integrate astronomy research conducted at LO into undergraduate education. With the new remote observing capabilities, it is now possible to bring research directly into the classroom. This is an aspect of education that has until now remained unexploited and one that the committee sees growing in the next decades. LO should offer support for classroom labs for upper-division students, including providing remote time on the 40-inch Nickel telescope. Since the remote observing rooms include equipment for video conferencing, LO can foster a community of undergraduate researchers in the UC system where undergraduates can compare and discuss their research with students at other campuses.

UCO should continue to facilitate and enhance science visits, where undergraduate students from different campuses come to LO for a guided tour and to look through the

telescopes. Part of this experience can now be made available to students at campuses in southern California through the remote observing capabilities.

Finally, UCO should consider establishing a program for undergraduate summer interns at LO. Students would learn about instrumentation and other aspects of engineering and they would be able to carry out small development projects that would also be beneficial for the observatory.

One of the strongest roles that Lick Observatory has played and will continue to play into 2020 is in the education and training of graduate students. There continues to be a large number of science programs at LO that are led by UC doctoral candidates. These programs support and facilitate research at the Keck Observatory and are often forefront research in their own right. Lick Observatory is the proper class facility for students to become comfortable with observational techniques, a range of instrumentation, proposal writing, and data reduction/analysis. In an era where datasets on the largest facilities are frequently taken by support astronomers in lieu of the PI, it is ever more critical that students gain observational experience on smaller telescopes to properly learn how to design and execute observing programs.

Complementary to scientific research is graduate training in instrumentation. On 10-m class telescopes, the size and cost of instrumentation has grown to the point where a graduate student cannot possibly play a leading role, nor can such projects rely on graduate student participation within the critical path. The net effect is that there are fewer opportunities for students to be trained in the design and fabrication of modern instrumentation and we risk losing the crucial experience required to develop future, innovative instruments. The facilities at Lick Observatory afford PhD students the opportunity to become involved in small-scale, but leading-edge instrumentation.

There is an underexploited opportunity for Lick Observatory to be directly involved in the classroom education of PhD students. There are numerous UC Astronomy programs that teach observational techniques, all of which could and should be expanded to involve actual observing at Lick. Another area to explore would be to initiate a UC-wide class at Lick Observatory in the instruction of astronomical techniques. This is especially important for the campuses where astronomy is within a Physics department, i.e. where there may be few astronomically expert faculty.

Public Education and Outreach

LO has always been a magnet for visitors. Its domes can be seen from throughout the Bay area, and its rich history is intertwined with that of the SF Bay region. Moreover, it is directly accessible to the citizens of the state of California. On a clear day the view from the summit includes the high peaks of the Sierra Nevada 120 miles to the east, downtown San Francisco to the northwest, and the Monterey Peninsula and the Santa Lucia Mountains to the southwest. As discussed above, LO has a modest public outreach program, consisting of some viewing during the summer, a few (outdated) exhibits, gift shop, and guided tours of the 36-inch refractor. Even so, nearly 30,000 people visit Lick each year. After decades of avoiding anything beyond a minimal commitment to

outreach, there is now a real groundswell of interest from within the UC astronomy community to expand and modernize these programs.

The Bay Area has a wealth of outstanding institutions interpreting science and technology to the public. They include the Exploratorium, the Lawrence Hall of Science, Chabot Space and Science Center, the Tech Museum, and the California Academy of Science (Morrison Planetarium). Each does well at what they do, focusing on science education, and are far more accessible than Lick Observatory. However, LO is unique in being a forefront research observatory and in having a long and interesting history. We should take advantage of and capitalize on this uniqueness in its approach to public outreach and education. Rather than trying to duplicate broad scope science education, LO should concentrate on what it is, where it has been, and where it is going.

The committee believes that Lick Observatory needs to significantly expand and improve its public outreach and education program. There should be increased public access to non-research telescopes and expansion of the evening visitor program, development of new exhibits effectively demonstrating cutting edge science and the rich history of the observatory, and expanded programs for science teacher training. To meet these needs, UCO needs to hire a full-time Director of Public Outreach, at a fairly high level, and should pursue outside funds to do so. This position could also be partly a fundraising position and could become self-supporting.

The committee believes that LO can have the largest impact on public education by concentrating on K-12 science teachers. In the last decade, the Observatory has run four very successful and well-received science teacher workshops. The science teachers were resident on the mountain, observed and obtained data with the Nickel telescope, and reduced the data. This gave them a real appreciation as to how science research is conducted. These workshops required a major effort and Lick did not have the resources to sustain an ongoing program. The committee believes UCO should reinstitute these workshops, and should look for outside resources to do so. UCO should look to partner with other organizations, such as the SETI Institute and the Astronomical Society of the Pacific, and involve, if possible, faculty from local UC campuses such as UCSC and UCB.

Lick Observatory as a Fund-raising Venue

With its rich history, prominent location overlooking the Bay area, grand architecture and high profile as a science center, Lick Observatory is a wonderful venue for fundraising and developing partnerships with philanthropists and philanthropic foundations. There is a long history of support from prominent Bay area families and the committee supports increasing the efforts to hold events and pursue philanthropic support for the Lick Observatory activities.

Infrastructure

The facilities on Mt. Hamilton include 57 buildings. Ninety-three per cent were constructed prior to 1960. Most show the effects of age, a hostile environment, and lack of funding for proper maintenance. Some abandoned buildings are eyesores and potential fire hazards. Much of the infrastructure, such as the water system and

telecommunications, is inadequate. The historic main building, housing the 120-year-old Great Refractor, is in desperate need of a fire suppression sprinkler system and of improvements to allow increased visitor usage. Most of the staff housing requires major repair and remodeling. If, as the committee believes, LO will continue to play an important role in UC astronomy for at least the next twenty years, these infrastructure problems need to be addressed. Even with the advent of remote observing, the committee does not see significant staff reduction on the mountain through 2020.

The committee recognizes that maintenance is a problem throughout the University of California system, although these problems are exacerbated at LO because of the age of the facilities and their exposure to the elements. The committee believes there will not be internal resources to address the infrastructure problems on Mt. Hamilton. UCO needs to prepare a long-range facilities renewal and renovation plan and seek outside funding to implement it.

Conclusion

The committee believes Lick Observatory plays a vital, integrated, and cost effective role within UC astronomy. As noted above, it fulfills functions that neither Keck nor the TMT can provide, and does it at a modest cost. The committee foresees LO continuing to play an important role in research, education, and public outreach for the next twenty years.

Appendix A-Committee Members

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Professor Michael Bolte, UCSC, Director UCO

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