UNIVERSITY of CALIFORNIA OBSERVATORIES

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

OFFICE OF THE DIRECTOR
375 INTERDISCIPLINARY SCIENCES BUILDING
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
SANTA CRUZ, CALIFORNIA 95064

SANDRA M. FABER
831 459-2991
faber@ucolick.org

April 26, 2013

To: Aimée Dorr, Provost, University of California
From: Sandra M. Faber, Interim Director, University of California Observatories

RE: FY14 Budget Request for UC Observatories

Summary

We understand that UCOP is developing its FY14 budget at this time. Although you did not specifically solicit a budget from UCO, we proffer this update and budget request.

We very much appreciate the $250,000 one-time assistance from UCOP this year – it helped us get through a very difficult year. Added to our baseline budget of $7.548 M and revenue of $0.988 M this year, UCO will end FY13 with a balanced budget. We were able to do this only by implementing staff reductions in January 2013 and again in April 2013. More reductions, of both staff and faculty, are expected in FY14.

The requested budget for FY14 is given in Table 4. The total base budget minus expected revenue is $5.231 M. In addition to this, several augmentations are requested. The first three, totaling $0.521 M, are needed to fund mandates that have been imposed or urged by UCOP, including: 1) service buyouts for distributed UCO faculty around the system, 2) repayment of a portion of the UCO debt, and 3) funding for a study to plan the long-term future of Lick Observatory. An additional $1.139 M is requested for investments that are vitally needed to add new capabilities in both the short term and long term. These include: 4) a first year's work on the Keck 1 deployable tertiary mirror, 5) new project management/cost accounting software, 6) a Deputy Director, 7) a TMT travel fund, 8) a full-time communications/development professional, 9) two forward-funded TMT project managers, and 10) rebuilding the Observatory contingency fund. The total requested funding including all augmentations is $6.891 M.

1. Assumptions

In preparing this budget, we have made the following assumptions:

1) The Thirty-Meter Telescope project will proceed, with UC participation.
2) The UCO Astronomer faculty salary money will be separated from the UCO budget on July 1, 2013, and shifted to UCSC. These funds will no longer be at the discretion of the UCO Director to use for UCO operations.

3) The duties and responsibilities to UCO of all Astronomers who have not yet retired will remain unchanged. Thus, approximately 25% of the effort of these individuals will continue to be available to the Director to support UCO operations, as now.
4) This is a zero-base budget in which all activities need to be justified from first principles. However, there is no maximum total for the amount of funds that can be requested.

In preparing this budget, we have also paid high attention to the mandates given to UCO by the ORGS-sponsored Astronomy Task Force in 2011, the External Review of UCO commissioned by ORGS in 2011, and advance advice that is shortly anticipated from the UC O/IR Strategic Planning Committee report. These bodies have collectively advised UCO to give highest priority to developing new instrumentation and technologies for the Keck and TMT telescopes.

Finally, we conducted an analysis of Lick Observatory operations and identified further savings that could be achieved by adopting "spartan mode". This mode minimizes long-term investments at Lick while preserving current operating capabilities. I also determined that there are two cutting-edge projects at Lick – Shane adaptive optics on the 3-m telescope and the about-to-be-completed Automated Planet Finder Telescope – that will each require a further five years of operations to bear proper scientific fruit. On top of these are the many NSF and NASA grants that have been awarded to individual UC astronomers who observe with Lick and who also require Lick access.

As a result of these determinations, I have presented to the UCO Board, and repeat here, my recommendation that UC *commit to another five years of operations at Lick Observatory,* during which time a study should be made to develop a long term plan for the facility. Such a study has now commenced in collaboration between ORGS and UCO. I have therefore also assumed this vision for Lick Observatory and included funds for operation in spartan mode in FY14.

Finally, I note that UCO's report for the Portfolio Review Group presented eight ongoing Activities and five major new Initiatives for the Observatory. The budget priorities reflected in this FY14 request are maximally consistent with and supportive of the goals in the PRG report as well.

The following budget justification and description of activities are organized into sections that correspond to the five basic work groups of UCO. Section 2 gives a description of each work group's activities and its estimated operating cost for FY14. Section 3 describes anticipated external revenue from grants and gifts and uncertainties in these numbers. Section 4 describes ten requested budget augmentations and their justifications. Section 5 collects these results to compute a requested budget.

2. FY14 operating budgets by work group

2.1 UCSC technical group

Work of the technical group: The UCSC technical group, located at the UCSC Instrumentation Laboratories, is the heart of UCO. This is where the construction of most new instruments occurs and where new technologies are developed, under the direction of UCO faculty. In FY14,

the technical group will comprise 17 engineers and technicians and 4 research scientists. This group provides most of the manpower for the technical projects and instrument funding proposals, and most of the external funding raised through grants and gifts goes to support this group also.

The distribution of technical group manpower across projects is shown in Table 1. Yellow indicates that a project is externally funded from grants or gifts, grey that it is internally funded from UCOP funds. Not all external funding is secure; proposals have been submitted, but results are not yet known, and new sources of revenue are still being sought. Uncertainty in soft-money proposals is one of the biggest challenges in preparing UCO budgets, and this must be taken into account in preparing the requested budget from UCOP (see Section 5).

Altogether there are 23 project categories in Table 1; the notes give short descriptions. Three projects are connected with the Thirty-Meter Telescope (TMT), seven projects are connected with Keck, and the remainder are connected with Lick and UCO. The distribution of resources in this table follows the guidelines of the ATF, External Review, and SPC, which advise that UCO put highest priority on developing instrumentation and technology for TMT and Keck. We have endeavored to do this, consistent with continuing spartan operations at Lick.

We now describe these projects in more detail, sorted by observatory location:

TMT projects: The largest of the TMT projects is *MOBIE*, which would develop into a $50 M project to build a first-light optical spectrograph once TMT construction begins. In FY14, this project will advance to preliminary design phase. UCO is also designing the TMT motor-control software and developing the critical protected-silver reflective coating that is needed for the 492 primary-mirror segments.

Keck projects: The largest Keck project is a proposal to the NSF for $1.5 M over four years ($369 K in FY14) to design and build a rotating tertiary mirror for the Keck 1 telescope (*K1DM3*). The purpose of this mirror is to enable rapid beam-switching between instruments to allow short-duration, time-critical observations. Unfortunately, prospects for funding this proposal are poor, as we are told that NSF Astronomy may not award *any* new grant proposals this year owing to sequestration. A second large Keck project is the *Keck Cosmic Web Imager,* a large spectrograph intended to take spectra of very low surface brightness objects. KCWI is led by Caltech, but UCSC is designing and building the optically-critical spectrograph camera and writing the motor control software. This sort of subcontracting among the Caltech and UC instrument laboratories is typical.

The third large Keck project is Next-Generation Adaptive Optics (NGAO). This is a major upgrade that will dramatically improve Keck AO performance. The total estimated cost is $50 M, and funding would start with a $20 M Mid-scale Instrumentation Grant from the NSF. Table 1 allocates manpower to prepare a major proposal in FY14, assuming that the NSF will inaugurate the Mid-scale program in FY15.

Lick projects: The largest Lick project is the *Shane adaptive optics (AO) camera*, a $2 M NSF Major Research Infrastructure project to build next second-generation AO for the Lick 3-m

telescope. Adaptive optics for Astronomy was pioneered at Lick, and technology developed there by UCO was transferred to Keck, where it has been used to weigh the black hole at the center of the Milky Way Galaxy and image planets around other stars for the first time, among other breakthroughs. This NSF grant funds a second-generation deformable mirror that will achieve more accurate wave front correction. All NSF funds will have been expended and further work in FY14 will be funded by UCOP funds. A matching grant from the Moore Foundation funds a new *AO laser* that will pump the sodium layer more efficiently and yield a brighter laser guide star. Together, these technologies will yield qualitatively sharper AO images. The goal is to have a working AO system with laser and camera by spring 2014.

While benefitting Lick initially, the new AO technologies developed by these projects are intended ultimately for use at Keck and TMT. They thus honor the advice given to us to give highest priority to Keck and TMT instrumentation. This strategy of technology development and transfer to Keck has been very successful in the past and illustrates the value of having our own close-at-hand Lick facilities as a test bed for new technology development.

The second large project at Lick is the *Automated Planet Finder* telescope (APF), which is a 2.4-m telescope that is designed to discover exoplanets using Doppler motions. This facility was started by a $6 M grant from the US Naval Observatory and was augmented by another $4 M of NASA and donor funds. The telescope and dome were bought from an outside vendor, while the Doppler spectrograph on the telescope was designed and built in the UCSC Instrument Labs. The telescope has had a very rocky start owing to vendor non-performance but is now coming on sky. The goal is to roboticize the telescope and commence science operations in fall 2013. Although the APF is not related to Keck or TMT instrumentation development, it is the intention that the money needed to operate the telescope in FY14 ($200 K) will come from the two telescope PIs, thus providing a welcome infusion of funds to support the technical group.

The third major Lick project is a new detector for the *Kast spectrograph*, which is the workhorse instrument on the Shane 3-m telescope. Mr. Kast has donated $51 K to help us install a new red CCD detector, which will greatly enhance sensitivity and photometric accuracy at red wavelengths on this heavily used instrument. This gift supports roughly a third of the total estimated cost. Smaller Lick/UCO projects include repairs and maintenance for Lick operations, improvements to the Lick CCD controller software, remote observing support, NSF-mandated Lick data archive, etc. Rounding out the table is manpower allocated to writing proposals in FY14 to support work in FY15. All of these latter projects are mostly or entirely internally funded from UCOP funds.

Structure and funding of the technical group: The manpower chart in Table 1 illustrates the basic challenge facing any astronomy technical group: many skills are needed to build astronomical instrumentation, and multiple skills are needed *in each instrument*. The analogy is a car, which needs an engine, wheels, tires, brakes, etc., to run. If you lose a single one of these experts, you don't build a car. The number of employees in the UCSC technical group declined from 31.5 FTE in 2004 to 23 FTE in FY13 and will be reduced to 20.5 FTE in FY14. The group is now so slim that it is impossible to trim further without losing essential skills. Doing so would mean cancelling projects, which would actually *worsen* the budget by reducing external revenue. The strategy in FY14 and going forward must therefore be to *adopt this minimum size* and use the

combined resources from UCOP and external funds to support it. Over time, the focus of projects being done by the group will move more and more to Keck and TMT, as recommended by the UCO advisory groups.

The question then arises, could the technical group become more self-supporting if additional outside revenue were raised? The answer here is mostly no. First, the US seems to be entering an era in which external grant funds are going to be harder to get, not easier. Beyond that, a minimum number of persons are needed in the technical group to perform repairs, maintenance, and renewal. The number in the manpower table devoted to this is 1.9 FTE, who can only be supported by internal UCOP funds. Some capacity also needs to be allocated to proposal writing, for which we have allocated 2.8 FTE next year (0.3 FTE for NGAO and 2.5 FTE for other proposals). Hence, nearly 5 out of 17 FTE are not eligible for external support, regardless of external funding, and enough proposals have been submitted to more than fund the remaining 11 FTE. Still, it would be good to have yet more proposals submitted in order to combat rejections, and a strategy to incentivize proposal writing by distributed UCO faculty is envisioned next year.

We close by noting that Table 1 contains a large number of small projects. This has been the trend in recent years as money for building major new Keck optical instruments has dried up, to be replaced by upgrades. Table 1 shows that we are competing effectively for those upgrades, but the new mode of funding means more paperwork per dollar and more work for the business office staff. This has increased our overall cost of doing business.

Technical group operating budget: The operating budget for the technical group is summarized in Table 2, which compares FY13 actuals to FY14 projections. (We will be happy to augment the information there with salary and benefit data for individual staff members upon request.) The estimated operating budget for the technical group in FY14 is $3.124 M. This is down from $3.264 M in FY13, despite salary and benefits increases, by virtue of a net reduction of 1.00 FTE.

2.2 Lick Observatory staff

Work of the Lick Observatory staff: The Lick Observatory staff operates four science telescopes at Mount Hamilton: the workhorse Shane 3-m reflector, the Nickel 1-m reflector, the Coudé Auxiliary Telescope on the 3-m, and the new Automated Planet Finder 2.4-m reflector. To this is added the historic 36-inch Great Refractor dating from 1888. Like the technical group, the Lick group needs to have a wide variety of skills, including knowledge of telescope operations and observing; telescope, instrument, and dome repairs; software expertise; training for new observers; maintenance of documentation and instruction manuals; facilities maintenance; monitoring the water system and other utilities; fire and public safety; and planning and staffing the numerous student, public, and fund-raising events, such as the Summer Visitors Program and the Music of the Spheres concerts that are put on 10 weekends each summer. Altogether 30,000 visitors visit Mount Hamilton annually, which are hosted by the Lick staff.

Structure and funding of the Lick staff: Lick Observatory operations were the subject of intense budget scrutiny last year, and the current staffing plan for FY14 is the smallest possible plan that

will operate the Shane 3-m telescope seven nights a week. The biggest cut from FY13 is the reduction from four Shane telescope operators to three; fewer operators would mean closing the Shane two nights a week, which we have determined would disrupt time-critical observations and produce scheduling chaos. (Note: we anticipate rough waters in negotiating this change with the union regarding a dramatic change in work schedules for the telescope operators.) We also plan to close for a month over the Christmas holidays, when weather is poor, and make a number of smaller service reductions and funding shifts that in total will save $0.309 M on UCOP funds. The total mountain staff of 7.30 FTE on UCOP funds, 5.00 FTE on UCSC maintenance funds, and 1.30 FTE on gift funds is roughly half the size of the staff at Palomar, which operates the same number of telescopes.

Lick operations support systemwide UC astronomers and as such are funded mainly by UCOP with roughly $0.133 M coming from public programs. The possibility of charging a nominal fee for telescope time on NASA and NSF grants is being explored. We are also actively seeking outside revenue from telescope rentals, corporate sponsorships, gifts and donations, and other sources.

Lick Observatory operating budget: The operating budget for Lick Observatory is summarized in Table 2, which compares FY13 actuals to FY14 projections (salary and benefits data for individuals are available on request). The estimated operating budget for Lick in FY14 is $0.728 M. The above staffing cuts and other budget strategies have reduced UCOP funds by $0.309 M compared to FY13.

2.3 Business and administrative support staff:

Work of the business and administrative staff: The business and administrative staff of UCO handle many traditional tasks compared to other UCSC staff at both the departmental and divisional organizational levels. They also are responsible for complex tasks that are unique within the university setting. The Assistant Director for Administration and Business Services manages all administrative and business functions for UCO. She manages the budget (comprised of a broad range of complicated fund sources and activities), oversees business operations to ensure a high level of support and compliance, forecasts future expenditures, and supports the Director with special data analyses, planning activities, and solutions for unique, complex issues. The Director's Executive Assistant manages the Director's calendar, travel, and correspondence, is the gateway voice of the Observatory on phone and by email, manages the personnel process for academic employees (research scientists), manages the Observatory webpage and communications, schedules all student tours of Lick Observatory, and supports the *Friends of Lick* donor group.

The business operations staff of 2.00 FTE conduct procurement, direct payment processing, Lick lodging scheduling and billing, and equipment management. The human resources staff of 1.75 FTE are in charge of academic and staff personnel management, payroll and time reporting, staff recruiting, performance management, merit reviews, and labor relations. A single FTE in contracts and grants prepares budgets, coordinates with campus Contracts and Grants for submittals, manages the federal reporting system, and manages the grant closeout process. Four FTE in financial and facilities management manage all aspects of UCO operations accounts,

perform space planning and facilities coordination, prepare and manage special contracts with vendors and users of Lick land and facilities, perform contract analysis and compliance, prepare cost estimates and financial reporting for instrumentation projects, provide historical data on projects, liaise with the UC Real Estate office and Legal Counsel, etc.

FY14 will bring several changes to the workload of this group. Transfer of UCO faculty from UCOP to UCSC will mean that their science research grants, academic hiring on those grants, and their own academic personnel evaluations will be administered by UCSC, reducing the workload for UCO by approximately 1.00 FTE. Commensurate resources will be transferred from UCO to UCSC to cover this support. We will be eliminating the Business Operations Manager/Sr Buyer position when we adopt the campus purchasing system in July 2013. Moreover, an external review of business office operations in June 2013 is expected to recommend a major overhaul of database tools and project management/tracking software. New licenses, staff training, and possibly the services of a consultant will be needed. Thus, FY14 promises to be a very busy year for the business office staff, after which some streamlining is anticipated.

Structure and funding of the business and administrative staff: The total business and administrative staff numbers 11.6 FTE, reduced by 1.45 FTE from FY13. This being an infrastructure function, the group is supported mainly by UCOP funds though approximately $0.105 M, or 9% is raised from grants.

Business and administrative operating budget: The operating budget for the business and administrative staff is summarized in Table 2, which compares FY13 actuals to FY14 projections. The estimated operating budget for this group in FY14 is $1.158 M. Staffing cuts and other strategies have reduced funding by $0.101 M compared to FY13.

2.4 UCLA IR Lab

Work of the UCLA IR Lab: The prime work of the UCLA IR Lab has been designing and building infrared instruments for Keck Observatory. All operating IR instruments at Keck were led or had major components supplied by UCLA. Two Keck-related proposals have been submitted for FY14: a proposal to NASA to upgrade the NIRSPEC detector, and a proposal to NSF to upgrade the OSIRIS detector. In addition, if TMT goes ahead, the IR Lab will function as the lead institution for IRIS, which is a first-light infrared adaptive optics imager and spectrograph that will cost of order $30 M. Like MOBIE, IRIS enters the preliminary design phase in FY14.

Structure and funding of the UCLA IR Lab: The UCLA IR lab currently has three 9-month UCLA faculty and 8 technical engineers and technicians. This is their minimum sustainable roster; staff expands when work allows, as will happen when TMT takes off. The total operating budget in core mode is $900 K. Historically, UCO has provided $300-375 K, which pays three key permanent staff members: systems administrator, administrative assistant, and lab manager, summer salary to the faculty, and a stipend to the Director, Ian Mclean. Additional funds go for travel and operational support. The lab has typically relied on soft-money funding for the remainder of their budget, with a mixture of Keck-funded projects and outside projects for other

observatories. Since soft money is variable, having UCO funds for foundational infrastructure has been crucial to seeing them through lean times.

UCLA IR Lab operating budget: In FY14, the IR Lab faces another year of uncertain external funds. TMT/IRIS will bring $900 K, but not until spring quarter. The two detector projects may not be funded. The only secure source of funds at this time is an outside project called FLITECAM, which will bring in $300 K. The Director has submitted a well justified budget for $340 K, which we would like to fund. This increase of 13% over the FY13 amount is consistent with the priority stated in the ATF and PRG reports of ensuring a secure future for the IR Lab.

2.5 UCO faculty

Work of the UCO faculty: The UCO faculty are currently located on two campuses, UCSC and UCLA. If the augmentation for distributed UC faculty is granted (Section 4), in FY14 there will also be UCO-affiliated faculty on other campuses. The responsibilities and duties of UCO faculty are as follows:

1) Setting overall goals and policies for UCO: Input from internal UCO groups, advisory committees such as the UCOAC, and external groups is synthesized by UCO faculty to develop overall directions and strategies for UCO.

2) Representing UC O/IR interests within UC and to external astronomical communities: This involves staffing and managing relations with external groups such as the Keck Science Steering Committee, the Keck CARA Board, the TMT Board and TMT Science Advisory Committee, the Office of Research and Graduate Studies at UCOP, UC Academic Senate committees such as UCORP, and the newly created UCO Board.

3) Providing policies, direction, and high-level oversight for the UCO work groups, including the UCO faculty themselves: This entails developing work plans that follow from high-level institutional priorities and providing oversight and high-level management through each work group staff leader. Faculty also confer with group leaders to resolve schedule and staffing issues, write staff performance evaluations, and advise the Director on salaries and promotions of staff.

4) Overseeing and managing policies and procedures for ensuring effective access to Keck and Lick by UC observers: This includes running the time-assignment process for UC nights at Keck and Lick, scheduling the telescopes, making sure (through oversight committees at Keck and direct management at Lick) that the instrumentation and operation of both observatories meets UC needs, and overseeing the creation of data archives and data-reduction pipelines.

5) Initiating and executing the construction of astronomical instrumentation for Keck, TMT, and Lick: This involves acting as Principle Investigator for projects, setting the performance requirements for each project, writing the necessary proposals, leading the conceptual design, assembling the necessary funding and other resources, interfacing with vendors, and leading staff in the detailed design, construction, and installation and commissioning at the telescope. Typical projects have budgets of $1-15 M and involve teams of 10-25 engineers, scientists, and

technicians (who may be located at Caltech and Keck as well as at UCSC and UCLA). Future TMT projects will be two-to-three times as large.

6) Developing the astronomical technologies of the future, through research, computation, and laboratory experimentation: This work in detail looks much like item (5) but is a separate activity that is crucial to the long-term strategy of keeping UC O/IR astronomy at the cutting edge.

7) Initiating, overseeing, preparing, and participating in education, outreach, and communication activities: This involves communicating the work and achievements of UCO to the public, to UC, and to the state of California. Communication channels include the UCO and Lick websites, the UCO annual report, *Lick Newsletter,* and UC reports such as the Portofolio Review Group report and presentations to the UCO Board. UCO faculty support visitor programs at Lick Observatory and partner with educational institutions to improve student learning, teacher training, and public understanding of science. Much of this can be done by staff, but faculty are needed to initiate programs, raise resources, and provide scientific oversight.

8) Initiating, overseeing, and participating in fund-raising and development programs for UC O/IR astronomy: This work is similar to the activities in item (7) above. As true there, much of this work can be done by staff, but faculty are needed to develop overall strategies, provide scientific guidance, and find and cultivate donors.

9) Supporting and promoting graduate, undergraduate, and postdoctoral teaching and training and carrying out forefront research. The teaching and training program is led by faculty but involves close collaboration with staff, particularly in instrumentation and technology.

10) Assisting the Director on special projects, such as the building committee for the design of a new Instrument Laboratories building at UCSC.

In FY14, UCO faculty will be carrying out all of the above tasks. Lack of space prevents details on all of them, but we highlight especially:

- Supervision of the UCSC technical programs in Table 1 and the instrument programs at UCLA.

- Leading major reviews and entry into the preliminary design phases of the two TMT first-light instruments, IRIS and MOBIE.

- Organizing the science team for Next-Generation Adaptive Optics at Keck ($50 M) and preparing proposals to donors and federal agencies.

- Implementing strategies and policies recommended by UCO's Strategic Planning Committee this spring, particularly the design and installation of distributed UCO faculty positions around the system.

- Initiating the study to prepare the long term plan for Lick Observatory.

- Chairing and supporting the work of the Building Committee to design the new UCO Instrument Laboratories facility at UCSC.

- Stepped-up participation to create the new TMT scientific community, which will involve extra outreach and travel to our partners in Canada, Japan, China, and India.

Structure and funding of the UCO faculty: This discussion of UCO faculty manpower does not include the Director, as this person works 100% on a wide variety of tasks and should be considered an administrative appointee going forward. Currently there are 10.6 UCO faculty FTE at UCSC, occupied by 13 individuals. If retirements take place as scheduled, four individuals will retire in FY14, leaving 9 individuals occupying 7.4 FTE. This 30% drop in a single year represents a serious loss of experience and expertise. To rebuild, we are requesting funds to hire a Deputy Director and to create the equivalent of three additional UCO faculty-affiliate positions distributed around the system (see Section 4).

Altogether, the 9 faculty left at UCSC, 3 at UCLA, and 3 newly created distributed faculty will amount to at total of *15 faculty engaged in the UCO mission* in FY14. Detailed assignments to individuals have not yet been made, but the aggregate workload for this group is shown in Table 3. The units are people (not FTE), where 1.0 person means one faculty member devoting 25% of his/her time in service to UCO. The assignments are rough and have not yet been vetted by the UCOAC but are illustrative. Instrumentation PIs are assumed to be in two stages, the initial phase and early construction, which counts as 0.5 person (except for TMT instruments, which are so big that they always need a whole faculty), and final construction and installation, which counts as 1.0 person. Staff management at UCSC includes the two Associate Directors for the Instrumentation Laboratories and Lick Observatory. The Miscellaneous/Unforeseen category provides flexible effort that can be distributed across a variety of smaller or unforeseen tasks that constantly come up, such as the UCSC building study did this year. The Director's effort is not indicated and is in addition to the faculty effort shown.

The number of estimated faculty-persons needed is 18.25 versus the total available number of 15. The agreement is encouraging considering the rough nature of the estimate. At the same time, the need for the three new distributed faculty across the system is extremely clear – without them, UCO would have only 12 faculty and would not be able to manage to serve all of its core roles for the system.

UCO faculty operating budget: Starting in FY14, the cost of the UCSC faculty to the UCO budget becomes zero, and the UCLA faculty cost (summer salary, Director's stipend) is contained within the UCLA allotment, which is at the UCLA Director's discretion. Thus, the only new item is funds needed to establish the distributed UCO faculty. Twenty-five percent service to UCO is the equivalent of two teaching buyouts plus one month of summer salary. The median salary of UC astronomy professors is $140 K. One ninth of this plus summer benefits (15%) is $18 K. We have argued that only $12 K should be charged for each teaching buyout on the grounds that UCO funds are internal UC funds and that UCO service benefits the entire system, like Academic Senate service. Three deans have agreed thus far. Assuming this, a UCO

faculty member at 25% service would cost \$18 K + \$24 K = \$42 K. We accordingly request 3 × \$42 K = \$126 K in new funds in FY14 to inaugurate the distributed faculty program.

3. Augmentations for mandates and new investments

The bottom line of Table 2 gives the amount needed to support the five UCO work groups, not counting any new funds or augmentations. This sum is referred to as the "base budget". Table 4 takes this base budget and adds a *prioritized list* of urgently needed new investments ("augmentations"), which we now describe. The cost of each of these is indicated in Table 4, together with a running total showing what the total outlay would be to that point. The first three augmentations are in a separate category since they stem from management decisions about how UCO should operate and reflect the budgetary implications that flow from them.

Mandated augmentations:

• *Service buyouts for systemwide Astronomy faculty (\$126 K):* This augmentation flows from the decision that UCO will move to a new 9-month model for securing faculty services to UCO. It is therefore necessary to add funds to the base budget to pay for these buyouts. We request to inaugurate the new program by adding the equivalent of *three full UCO faculty* (i.e., 25% of effort each from six quarters of teaching release and three months of summer salary) to be distributed to interested and qualified faculty around the system. The cost per faculty was computed in Section 2.5 and is \$42 K. The three distributed faculty created are critical for UCO to carry out is core mission in FY14. This augmentation was also given high priority in the PRG report.

• *UCO debt repayment (\$325 K):* UCOP has made clear that UCO should start to repay the debt of \$2.6 M. This item is a first step towards doing this. We propose this amount without admitting full responsibility or committing to a final repayment amount. The sum is half the amount stated by UCOP for FY14 (\$650 K). UCOP has also asked for a repayment schedule in future years. We do not know how to approach this since no future budget totals have been given, and without those we cannot plan future debt repayments.

• *Lick Observatory long-term use plan (\$70 K):* Per directive of the UCO Board and ORGS, UCO is now engaged in making a long-term use plan for Lick Observatory. A staffing plan and budget are still in progress, but it is already clear that additional effort is going to be needed from the UCO business office staff. This item would support 50% time for our senior analyst, who has an ideal background in project management, construction, financing, and real estate and extensive knowledge of past projects and activities at Mount Hamilton.

The above augmentations are increases in response to management decisions. The following requests represent new capabilities:

• *Keck 1 deployable tertiary (\$369 K):* An MRI request was submitted to the NSF to support this project, but its funding prospects look dim. This augmentation would allow work to start on this project anyway in FY14 from UCOP funds. There are several reasons for doing this. First, it would be consistent with the directives from the ATF, External Review, and SPC to give high

priority to Keck instrumentation. Second, the beam-switching capability enabled by the new mirror will open up whole new scientific vistas that many UC astronomers wish to use. This will thus enable stronger grant proposals by UC astronomers, and it will also make Keck more attractive for telescope rentals with partner institutions, which are already an important source of revenue and promise to remain so in future. Finally, this request is consistent with the PRG report, which requested an augmentation of $400 K annually to invest in Keck instrumentation. If the NSF grant is funded, this amount would be returned to UCOP. If the NSF grant is not funded, we will resubmit it, and this investment would greatly enhance competitiveness.

• *New project management/cost accounting software – licenses and training ($250 K):* An external study of UCO business operations will be conducted in June 2013 this year that is expected to result in recommendations to replace a variety of antiquated software and database tools used for telescope scheduling, project management/accounting, and annual database collection. These tools are urgently needed next year in order to manage the TMT instrument projects. The estimated sum is a one-time investment for licenses and training, after which operational savings are expected.

• *Deputy Director ($40 K):* Our study of faculty staffing responsibilities this year indicates that greater efficiencies can be achieved by hiring a full-time PhD astronomer as a Deputy Director. This person would manage many internal details and at the same time assist the Director with the complex web of external relationships that UCO needs to maintain with Keck, TMT, UCOP, the UC astronomical community, and the US and world astronomical communities. Now is an ideal time to hire such a person when many regular UCO faculty are nearing retirement and responsibilities need to be adjusted. The new position is also strongly recommended by the UCO Advisory Committee. The amount requested assumes that the new Deputy would be hired on Apr. 1, 2015, and join us in spring quarter.

• *TMT travel allocation ($20 K):* TMT scientific community-building activities will require more travel in FY19, starting with the inaugural *TMT Science Forum* in Hawaii on July 22-23; it is desirable to facilitate attendance at these events by having UCO reimburse astronomer travel from a fund dedicated to this purpose. We request a travel augmentation for partial support for ten trips to the Forum and other TMT science conferences at a cost of $2,000 per trip, or $20 K.

• *Full-time development and communications professional ($120 K):* UCO communication needs are intense. Formerly, much of this work was done by UCSC faculty, but this is not cost effective and the UCOAC has recommended hiring a dedicated staff person. A full-time professional would raise the quality of our media materials, strengthen community relations, identify and steward prospective donors, and partner with other UC units to advertise UC's importance to California. This position was noted in the PRG report as key to Initiative #5: exploit high public interest in astronomy for the benefit of UC and the state of California.

• *TMT project managers ($240 K):* UCLA and UCSC are poised to lead two of three first-light instruments for the Thirty-Meter Telescope. These are both large projects amounting to ~$80 M, a fair portion of which will be spent at UC, affording excellent opportunities to upgrade both UCO facilities and personnel. However, a major concern is risk from management errors or cost overruns. Hiring skilled project managers and/or systems engineers early will minimize this risk.

According to University rules, hiring can commence only when signed contracts are in hand. If this occurs in spring 2014, as anticipated, these skilled personnel will not be on board until a full year later, which will put the projects immediately a year behind schedule. It is therefore advisable to forward-fund one senior management position in each project in order to accelerate hiring by 7 months, from April 2015 to September 2014, which is the earliest that the TMT pace will allow. A sum of $240 K to be split between the two projects is requested. This is a one-time investment in order to get started and would no longer be needed once the projects have regular funding.

• *Rebuilding the Observatory contingency fund ($100 K):* The Observatory contingency fund currently stands at $0.800 M. This is dangerously low for a unit that operates expensive equipment, where a failure could completely halt operations. The Keck Observatory contingency by comparison is $10 M, or roughly half of annual operations. UCO needs to start a practice of regular, annual contributions to build up this fund to $2.5 M, which is approximately half of our annual operations. This requested contribution is a start.

4. External revenue

Before analyzing the exact amounts of external revenue, some basic philosophy is in order. The externally raised grants and gifts that UCO raises contribute mainly to the technical group. The purpose of this group is *not* to run a job shop that builds astronomical instruments for competing observatories around the world! Rather, the purpose is to carry out work that benefits, and is prioritized by, UC O/IR astronomers. External contracts that are not directly related to our own work can be sought *provided*: a) there is spare capacity in our shops, and b) the job is of special value by seeding future capabilities of interest. These two criteria need to be applied very carefully, as every proposal soaks up faculty leadership, which is the commodity in shortest supply.

Two projects in Table 1 meet the above criteria. We accepted the subcontract to assemble GPI because of our long-term interest in adaptive optics and because the project was an excellent learning experience for our personnel. Likewise, we are seeking outside business for the Coatings Laboratory in order to assemble extra cash for capital improvements and to establish an international reputation as a coatings facility with unique capabilities. Astronomical coatings are a perennial soft spot in instrument construction, and our special expertise in durable, high-performance broad-band reflective and refractive coatings may have a strong external market.

The purpose of the above is to explain why there aren't more outside projects in Table 1 to bring in more revenue from the outside. Yes, these extra projects would allow us to employ more people, but they would in general *not* yield sufficient benefit to UCO to justify the cost incurred.

With that as background, the amount of revenue from outside grants and gifts is shown in Table 5. These are listed separately in FY13 and FY14 to indicate year-to-year volatility. Unconfirmed sources of external funds are shown in *italics*. The biggest item for FY14 is the NSF request for $369 K in FY14 (total request = $1.5 M over four years) to build the Keck 1 deployable tertiary mirror. This grant is uncertain since NSF Astronomy may not award *any* new grants this year

owing to sequestration. Also uncertain is the coatings contract for $90 K with the Advanced Technology Solar Telescope, as it is not clear whether we meet the requirements to bid.

The total of confirmed external grants in FY14 is $0.559 M, while the total of all potential external grants is $1.412 M.

5. Requested FY14 budget

The estimated base budget and augmentations for FY14 are shown in Table 4. To convert these into a budget request from UCOP requires adopting a best-guess value for external revenue. We have therefore taken a second look at the external revenue amounts in Table 5 and chosen those that appear *fairly likely* (starred values), which sum to an estimated external revenue of $0.853 M. Subtracting this from the base budget of $6.084 M gives the adjusted base budget of $5.231 M shown in the fourth line of Table 4.

This is the baseline to which augmentations should be added. These are shown in priority order in Table 4 with a running total to each point. The total budget including the three mandated UCOP augmentations is $5.752 M. The total including all augmentations is $6.891 M, which is our formal budget request. In the event that less than this total is granted, we would fund the augmentations in the listed order until available funds are expended.

The estimated external revenue is larger than secure revenue by $0.294 M, which creates some risk. However, if actual revenue falls short of estimated revenue, we would delay the lower-priority augmentations in Table 4 to serve as a cushion until the budgetary picture is clear. Also, several elements of our budget planning depend on the assumption that TMT will go forward. If that does not occur, the entire budget will have to be revisited in any case. Clear indications on the future of TMT are expected early in the fiscal year.

In conclusion, I would like to recall our conversation at the UCO budget meeting of October 30, 2012, where I committed to balance the UCO budget in FY14 at the previous year's value of $7.548 M, including faculty. According to instructions at that time, this was to be done by reducing non-faculty operations to approximately $5.0 M and finding offsets in the form of UCO faculty retirement savings for any amount over this.

Prompted by your urging at that meeting, we did approach faculty and succeeded in finding four individuals who have expressed strong interest in retiring in FY14, with consequent savings of nearly $1.0 M. At the same time, we have reduced the base budget minus external revenue to $5.231 M, down from $5.505 M in FY13. Thus, the basic UCO budget situation, computed according to this agreed-to metric, will improve by roughly $0.3 M next year, despite $0.1 M in staff salary increases. Furthermore, if the new faculty savings are added in, the total margin in the FY14 budget will be nearly +$0.8 M, which is sufficient by itself to fund many of the new augmentations requested in Table 4.

With this demonstrated fiscal responsibility, it is our hope that you will entrust UCO with the funds needed to realize the full potential of UC O/IR astronomy. UCO is now a very lean and efficient organization and will make excellent use of all resources provided.

Please let us know if additional information is needed or if other formats would be more helpful. UCO budget submissions have been criticized in the past for not being transparent, and this request tries out a new format. Feedback on how to adjust this would be most appreciated.

Cc: Nathan Brostrom, Donna Jones
George Blumenthal, Alison Galloway, Peggy Delaney
Aaron Barth
Karl Pister

Table 1. UCO TECHNICAL STAFF DISTRIBUTED ACROSS FY14 PROJECTS

(HOURS)

FY14	TMT MOBIE	NEW COATINGS CONTRACT	GPI	Keck KCWI CAMERA	Keck KCWI Detector	Keck Encoder	Keck Laser Launch	Keck Deploy Tertiary	Auto Planet Finder Tel	Shane AO Laser	LLNL Predictive AO	TMT Software	COATINGS RESEARCH	Remote Obs support	Keck Next Gen AO	Shane KAST upgrade	Lick Ops Support	Lick Data Archive	Lick CCD Camera S/W	Shane Aluminize	Shane AO System	Shane AO Camera	New Proposals	FY14 TOTAL
ME/Radovan	1462																							1462
ME/Cabak				400		100		730		160						220							450	2060
ME/Ratliff		300						1203	52				360		100								350	2365
Laser Eng/Dillon			363				360			900					100									1723
ENG TOTAL	1462	300	363	400	0	100	360	1933	52	1060	0		360		200	220	0	0	0	0	0	0	800	7610
EE/Peck																360					200	60	731	1351
EE/Sandford				41												140							731	912
*Optics Engr/Kupke										28	480				150						400			1058
EE Tech/Saylor								624	104							240								968
ELE TOTAL	0	0	0	41	0	0	0	624	104	28	480		0		150	740	0	0	0	0	600	60	1462	4289
*Master Optician/Hilyard				378				446								30	48			40				942
Optician Tech/DuPraw		845		0				75					960				112			40				2032
OPT TOTAL	0	845	0	378	0	0	0	521	0	0	0		960		0	30	160	0	0	80	0	0	0	2974
Machinist /Ward		100		496			52	946		80			120							200				1994
Machinist/Pfister		210		496			52	768		80			240			200	80			140		210		2476
FAB TOTAL	0	310	0	992	0	0	104	1714	0	160	0		360		0	200	80	0	0	340	0	210	0	4470
Programmer 5/Deich					32			183	200			731		91									350	1587
Programmer 4/Allen					150				200	80				91		124	350		192		146		350	1683
Programmer 3/Gates								102									790	80			147		350	1469
Programmer 4/Lanclos					150			180	200					171	100		500	80			147		350	1878
SPG TOTAL	0	0	0	0	332	0	0	465	600	80	0	731	0	353	100	124	1640	160	192	0	440	0	1400	6617
PROJECT TOTAL HRS	1462	1455	363	1811	332	100	464	5257	756	1328	480	731	1680	353	450	1314	1880	160	192	420	1040	270	3662	25960
PROJECT TOTAL FTE	1.00	1.00	0.25	1.24	0.23	0.07	0.32	3.60	0.52	0.91	0.33	0.50	1.15	0.24	0.31	0.90	1.29	0.11	0.13	0.29	0.71	0.18	2.50	17.76

** .75 FTE*

KEY
External Funds
UCO Funds

Total available FTE = 15.5 Total FTE programmed 115% Total FTE externally funded 61% Total FTE externally funded (secure) 21%

FTE REPRESENTS EFFECTIVE FTE (TOTAL HOURS / 1462=1.00 FTE)

This table describes the 16 engineers and technicians in the technical group at UCSC. In addition, there are four Research Scientists, whose efforts are also distributed across these projects. Yellow means the project is all or mostly funded from external funds. Gray means that the project is all or mostly funded from UCO funds.

Project descriptions:

* TMT MOBIE: Preliminary design study for the Thirty-Meter Telescope first-light optical spectrometer, a $50 M project if TMT goes forward. Headquartered at UCSC.
* New coatings contract: This is a possible $90 K contract to provide Solgel antireflective coatings for the polarimeter for the Advanced Technology Solar Telescope. Bidding requirements are complicated, and we may not have standing to bid.
* Gemini Planet Imager (GPI): This is a $24 M extreme AO camera for planet detection at the Gemini South telescope. It was designed and built by a team outside of UCO (Bruce Macintosh PI), but UCO Instrument Lab facilities and personnel were used for final assembly. The small project would provide an opto-mechanical engineer for the commissioning phase.
* Keck KCWI camera: This is the Keck Cosmic Web Imager, a high-performance spectrograph optimized to obtain spectra of very low-surface-brightness astronomical objects. KCWI is led by Caltech, and UCSC is providing the camera optical design, lens fabrication, lens coatings, lens mountings, and camera assembly.
* Keck KCWI detector: The UCO Scientific Programming Group is providing the CCD controller software for KCWI.
* Keck encoder mounts: This is a small amount of mechanical design for new encoder mounts on the azimuth drive of the Keck telescopes.
* Keck laser launch telescope: Keck recently won $4 M in grants from the Moore and Keck foundations to install a new center-launched laser on Keck 1. This project would provide mechanical design work and fabrication of parts.
* Keck 1 deployable tertiary mirror (KIDM3): A $1.5 M grant was submitted this year to the NSF Major Research Instrumentation program in collaboration with Keck Observatory to build a new rotatable tertiary mirror for the Keck 1 telescope. The mirror would rotate quickly to feed light to different instruments on the telescope, permitting rapid program changes and more flexible observing to follow time-critical phenomena. UCSC leads the mechanical design and fabrication of the mirror, which will be installed on Keck 1 in collaboration with Keck personnel.
* Automated Planet Finder telescope (APF): This is a new 2.4-m telescope at Lick Observatory that is dedicated to finding planets using the Doppler effect on their parent stars. The telescope was financed by $6 M from the US Naval Observatory plus grants from NASA and donors. The Doppler spectrograph was designed and built at UCSC. This project would commission APF and provide software to run the telescope in fully robotic mode from pre-loaded scripts.

* Shane AO laser: Part of the Shane AO project is a new high-tech laser that will greatly improve the pumping efficiency of the atmospheric sodium layer, and thereby increase the brightness of the laser guide star for AO. The laser project is funded by a $350 K grant from the Moore Foundation. FY14 work will design and build the laser control system and install on telescope.
* LLNL predictive AO: This is a small project to study our ability to better predict AO wavefront corrections by knowing the direction and speed of wind across the telescope light path. It is funded by the Lab Fees program at ORGS and is in collaboration with AO scientists LLNL.
* TMT software: Preliminary design study for standardized TMT motor-controller software; the goal is to obtain a substantial work package from TMT in future.
* Coatings research: The UCO Advanced Coatings Laboratory develops high-performance reflective and anti-reflection optical coatings for astronomical telescopes and instruments. We contract to provide coatings to Keck and other outside observatories as well as Lick. The protected silver coating that is under development at ACL is critical to coating the 492 segments in the Thirty-Meter Telescope, which require a durable, non-tarnishing coating with many-years lifetime. Work in 2014 will finish building a new coating chamber (NSF-funded) and initiate a collaboration with the Kobayashi group in the UCSC School of Engineering to develop precision atomic layer deposition.
* Remote observing support: UCO installed and continues to troubleshoot remote observing facilities on all eight UC astronomy campuses. These facilities permit UC astronomers to control instruments and analyze data taken at Keck and Lick remotely, thereby saving millions in travel costs. This project provides ongoing support and maintenance to the campuses.
* Keck Next Generation AO (NGAO): The UCOAC has adopted Next-Generation AO at Keck as its highest priority new technology program. A preliminary design exists for NGAO with a cost of about $50 M, and the funding plan starts with a $20 M request to the NSF. This project would provide work to support the proposal writing, which will occur in FY14 if the NSF initiates its Mid-scale grants program.
* Shane Kast upgrade: The Kast spectrograph is the workhorse optical spectrograph on the Shane telescope. Mr. Kast has donated $51 K to partially finance a new red CCD detector and dewar that will dramatically improve sensitivity and photometric accuracy at red wavelengths.
* Lick operations support: The technical group at UCSC provides backup technical support for the Lick mountain staff. This project provides repairs and general maintenance for existing instruments and telescopes at Lick Observatory.
* Lick data archive: NSF requires that all observatories receiving NSF funds operate public data archives that release their data to the astronomical community. This project is designing the database, storage architecture, and web interface for users to download Lick data. The goal is to transfer the design developed at Lick to Keck and other interested parties.
* Lick CCD camera software: This project would upgrade the UCAM software package that controls the readout of all optical CCD detectors at Lick.
* Shane aluminizing: This project would re-aluminize the Shane 3-m mirror. Master optician David Hilyard has historically led this process, but FY14 is his last year with us. We will take advantage of his last year to train the team that will take over the process going forward.
* Shane AO system: This is a $2 M NSF-funded project that is developing second-generation adaptive optics on the 3-m telescope. It operates in conjunction with the Shane AO laser project (above). Image sharpness will be dramatically improved at Lick, and the technology is transferable to Keck and TMT. The instrument is nearly built and is due to be installed and commissioned on the 3-m in FY14.
* Shane AO camera: This is a rebuild of the existing IRCAL infrared camera for use with the new Shane AO system.
* New proposals: This is reserve capacity to support the writing of new proposals submitted in FY14 for work in future years.

Table 2. OPERATING BUDGETS FOR UCO WORK GROUPS

Category	FY13 (actual)		FY14 (requested)		Δ(FY14-FY13)		Comments
	FTE	$(M)	FTE	$(M)	FTE	$(M)	
Faculty	10.60	2.508	7.40	1.540	3.20	0.968	Thirteen Astronomers in FY13. Assume 4 retirements for FY14. Budget excluded from totals.
Faculty stipends		0.033		0.025		0.008	Two associate directors.
TECHNICAL GROUP:							
Research scientists	4.50	0.823	4.00	0.732	-0.50	-0.091	FY13: Mid-year layoff.
Engineers & technicians	17.00	2.441	16.50	2.392	-0.50	-0.049	FY13: 3rd quarter retirement and mid-year layoff. FY14: Some project-funded work ends part way through.
Business & support staff	13.05	1.259	11.60	1.158	-1.45	-0.101	FY13: Mid-year layoff and mid-year retirement. FY14: One separation.
Lick Observatory staff	10.01	1.037	7.30	0.728	-2.71	-0.309	FY13: Mid-year reduction in one FTE. FY14: Further reduction for second FTE. Retire one teleops. Shift one SA to endowment funds. Shift part of Deputy Director to public program revenue.
Staff salary & benefit increases	N/A	0.000	N/A	0.109	N/A	0.109	
Non-salary expenditures	N/A	0.600	N/A	0.600	N/A	0.000	Travel, purchases, computer support charges, etc.
UCLA IR Lab	N/A	0.300	N/A	0.340	N/A	0.040	
TOTAL EXPENDITURES:	44.56	6.493	39.40	6.084	-5.16	-0.409	

Table 3. UCO FACULTY TASKS FY14

Task	Number of Faculty
Instrument PIs:	
TMT IRIS	1.00
TMT MOBIE	1.00
Keck KCWI camera + software	0.50
Keck NGAO + Shane AO	1.50
Keck deployable tertiary	0.50
Keck OSIRIS detector	0.50
Keck NIRSPEC detector	0.50
Lick Kast spectrograph detector	0.50
Lick Automated Planet Finder	1.00
Total instrument Pis	**7.00**
TMT community management	1.00
TMT Science Steering chair	0.50
Keck Science Steering chair	0.50
UCOAC chair	0.50
UC O/IR development chair	1.00
Staff management at UCSC*	2.50
Staff management at UCLA	0.25
TAC process and scheduling	0.25
New proposals incentive program	1.50
Lick Observatory long term plan	1.00
UCSC Labs Building Committee chair	0.25
Miscellaneous and unforeseen^	2.00
Total faculty required	**18.25**

Note: A unit is one UC faculty giving 25% of annual effort to UCO.
The Director's time is distributed over many tasks and is not explicitly shown.
* Includes Assoc. Dir. For Instrument Laboratories and Assoc. Dir. For Lick Observatory
^ Small projects and contingency

Table 4. FY 14 REQUESTED BASE BUDGET & PRIORITIZED AUGMENTATIONS

Expenditure	Amount ($M)	Running Total ($M)
Base budget	6.084	---
External revenue range	0.559 - 1.412	---
Adopted external revenue	0.853	---
Base budget minus adopted external revenue *	5.231	5.231
Prioritized augmentations:		
Service buyouts for distributed systemwide UCO faculty	0.126	5.357
Debt repayment	0.325	5.682
Lick Observatory long-term use plan	0.070	5.752
Keck deployable tertiary	0.369	6.121
New project management/accounting software	0.250	6.371
Deputy director (spring quarter only)	0.040	6.411
TMT travel allocation	0.020	6.431
Development/communications professional	0.120	6.551
TMT project managers	0.240	6.791
Contingency fund	0.100	6.891

**Adopted external from starred projects in Table 5*

Table 5. EXTERNAL FUNDS

FY13 ($M)		FY14 ($M)	
REVENUE:		**POTENTIAL REVENUE:**	
GPI high res AO camera	0.274	*Italics means not yet secure*	
NSF MRI Shane AO	0.325	* means likely	
SAO BINOSPEC lens	0.024		
DEIMOS detector (Keck)	0.030		
MOBIE spectrograph (TMT)	0.098	*MOBIE spectrograph (TMT)**	*0.294*
KCWI camera barrel (Keck)	0.054	APF operations*	0.200
KCWI camera optics (Keck)	0.148	*Coatings contract*	*0.090*
TMT software	0.025	Grad training gift*	0.020
Coatings	0.010	KAST red upgrade*	0.036
		KCWI camera barrel (Keck)*	0.105
		KCWI camera optics (Keck)*	0.023
		KCWI detector s/w (Keck)*	0.030
		Keck 1 deployable tertiary	*0.369*
		Keck AO laser launch tel.	*0.050*
		Keck encoder mount	*0.050*
		LLNL predictive AO*	0.030
		Moore laser for Shane AO*	0.100
		Software contract*	0.015
Total	0.988	Total	1.412
		Total secure	0.559
		Total likely (*)	0.853