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July 1, 2020

**THERESA MALDONADO, VICE PRESIDENT
RESEARCH AND INNOVATION**

Re: Five-Year Review of the UC Observatories (UCO)

Dear Theresa,

At its June 24, 2020 meeting, the Academic Council approved the attached Five-Year Review of the UC Observatories (UCO) Multicampus Research Unit (MRU). Following procedures outlined in the Compendium, the review was performed by a Joint Senate Review Committee, led by the University Committee on Research Policy (UCORP) with input from the University Committee on Planning and Budget (UCPB) and the Coordinating Committee on Graduate Affairs (CCGA).

The Review Committee recommends renewing the UCO as an MRU unit for five years, and also makes recommendations for strengthening the UCO in the areas of budget and administrative transparency, governance, student participation in research, and education and outreach. We request that that you forward the report to the UCO director.

The Academic Council appreciates the significant time and effort the Review Committee spent in preparing and writing this report. In particular, I want to recognize the substantial contributions and outstanding leadership of UCORP Chair Andrew Baird.

Please do not hesitate to contact me if you have additional questions.

Sincerely,

A handwritten signature in cursive script that reads "Kum-Kum Bhavnani".

Kum-Kum Bhavnani, Chair
Academic Council

cc: Academic Council
UCORP
Senate Directors

Review of University of California Observatories (UCO)

University Committee on Research Policy (UCORP)

(Lead Committee)

University Committee on Planning and Budget (UCPB)

Coordinating Committee on Graduate Affairs (CCGA)

May 19, 2020

I. EXECUTIVE SUMMARY

The University of California Observatory (UCO) provides UC faculty with a unique infrastructure and ability to show leadership in the deployment of world-class telescopes that would be otherwise far too expensive for any individual UC campus to acquire, manage or let alone maintain. In many ways, UCO is a jewel of the UC system and its stellar reputation has enabled UC to expand its impact in astronomy-sciences through the successful securement of the WM Keck Observatory (“Keck”) and astronomy’s next generation observatory, the Thirty Meter Telescope (“TMT”). Whereas UCB, UCSC and UCLA have historically dominated UCO, its resources are available and used system-wide and have enabled the development of Astronomy as a discipline across the UC system, and at the highest level of excellence. As cited during this review, *“UCO is absolutely essential to the ongoing success of astronomy in the UC system. Our investments in these observatories are what attracts faculty, postdocs, and students to come to UC to do astronomy, and it's what enables us to do much of the science that we do in astronomy. And, it is very true that UCO fosters systemwide collaboration: in many areas of astronomy much of the science that we do is based on strong multi-campus collaborations using the shared observatory facilities.”* That being said, the 5-year report, as originally submitted for review, was found sparse in important details regarding the descriptions of its accomplishments, obscure in presenting its administrative structure and its decision-making processes and superficial in descriptions of its budget. Fortunately, an in-person interview with the Director addressed these concerns so that UCORP, CCGA and UCPB enthusiastically support continuation of UCO, with certain caveats and recommendations, regarding transparency, governance and performance.

II. INTRODUCTION AND EVIDENCE FOR ACCOMPLISHMENT

- a) History The University of California Observatories (UCO) has provided UC's faculty, staff and students with ground-based observatories since Lick Observatory's opening in 1888. UCO leverages a central, system-wide investment in major astronomical facilities that enables scientists from across the UC system to collaborate on pioneering scientific projects, and to achieve system-wide economies of scale. To accomplish this, UCO provides stewardship and new instrumentation for the Lick and Keck Observatories, with very active design work underway for the planned Thirty Meter Telescope (TMT).
- b) Mission and scope UCO's mission is to provide UC students, faculty, and researchers with the leadership and management to access world-class optical and infrared astronomical observing facilities, and to build collaborations across UC on forefront scientific projects in the field of astronomy and astrophysics.

To this end, UCO designs and builds advanced equipment for the Lick and Keck Telescopes; maintains and operates Lick Observatory on Mount Hamilton, CA; provides the UC administrative interface and scientific support to the Keck Observatory in Hawaii; supports UC graduate and undergraduate teaching and the training of astronomy Ph.D.'s; runs workshops and meetings that bring together astronomy groups throughout the UC system; represents the interests of UC optical and infrared astronomers in major forums such as Keck Observatory, the Thirty Meter Telescope, on the national and international level. The resources that it provides ensures that UC astronomers have preferred access to world-leading facilities into the future. In addition, UCO runs a vigorous public outreach program at Lick Observatory on Mt. Hamilton, and helps to facilitate campus-based public outreach in astronomy across California.

- c) Service to University and State UCO positions UC as a leader in observational astronomy. The research impact of these facilities is broad. Publication and citation statistics show that in most years, Keck Observatory has the highest impact per telescope of any ground-based observatory in the world. More than 950 peer-reviewed papers have been published in the past 5 years by UC PI's based on data from Lick and Keck. UC's leadership

is attested to by the impressively large number of awards and prizes received by its faculty, postdocs, and students.

UCO is working on projects to make Lick Observatory's exciting history, science, events and experiences more accessible to the people of California in the Bay Area and beyond. For example, it is in the process of bringing public WiFi to Mt. Hamilton. Once this is in place, UCO staff will be able to use social media features to stream lectures or behind-the-scenes tours. It will enable visitors to share their experiences with others and connect with the community. To provide a more informative experience for visitors to the mountain, it has installed a self-guided Walking Tour. Translations of signs in Spanish and other languages local to San Jose help the whole community to participate. It sponsors La Noche de las Estrellas (using private funds) and seeks grants to add a long-term mentoring program for Spanish-speaking high school students and their families.

The Lick Observatory continues to expand public events (Music of the Spheres, Evenings with the Stars, Photography evenings, and Walking Tours) so as to reach more people. UCO also pursues initiatives to “bring Lick down the mountain” to the Bay Area, starting with collaborations with Team San Jose and the California Academy of Sciences in San Francisco’s Golden Gate Park. UCO also works with UCSC’s Institute for Scientist and Engineer Education on several projects like an annual Future Leaders Workshop for graduate students from the Thirty Meter Telescope partners, the Akamai Workforce Initiative and the Astro Tech Workshop, aimed at students from groups under-represented in astronomical instrumentation.

d) Regional, National and International Visibility A key goal of UCO’s mission is to enable forefront Astronomy and Astrophysics research by UC faculty and students, and the communication of research through teaching and outreach to students and the community. In the last five years, UC-associated researchers published 951 peer-reviewed papers.

e) Internal interactions between Units There is strong participation of UC astronomy campuses and UCOP funds, gifts and endowments, and external grants enhance the

scientific capabilities and output of UC observers and its instrument-builders on campuses. To this end, UCO has equipped UC astronomy campuses with “Remote Observing Rooms,” providing the option of operating the Lick and Keck facilities without traveling to the telescopes. These resources are especially important for students since travel expense can be large, and it is hard for students to fit the travel into their class schedules. This UC investment in telescope time has been hugely productive with 43% of the 951 peer-reviewed papers that UC researchers published having co-authors from more than one UC campus. Accordingly UCO promotes a real culture of cross-campus collaboration.

- f) External interactions UC’s substantial investment in the Keck and Lick Observatories has resulted in significant new faculty hires throughout the UC system. In the past five years, 28 new astronomy and astrophysics faculty were hired at 8 UC campuses to help keep UC at the forefront of the global astronomy scene. In the rapidly growing field of extrasolar planets alone, UC campuses hired 12 new faculty. In FY15 through FY19, these UC astronomy faculty and UCO Affiliates secured \$85.5M/year in external contracts and grants. Other extramural resources include gift and endowment income, income from the Lick Observatory’s Visitor Program and sale of services such as cell tower space at Lick, and overhead return. In 2019, the new UCO Development Officer reportedly raised major and planned gifts from the existing annual donor base and reconfigured the UCO’s two Development Leadership Boards to focus on expanding the donor base and the annual giving program to create a pipeline for future major support.

FINDINGS:

The University of California Observatories are a jewel in the UC crown. The UCO has delivered exactly what UC should expect from any investment in a core infrastructure that allows its faculty to thrive in doing what they, in turn do best: teaching and research. Accordingly, it is this investment made by UC in its UCO that has made it a world leader in astronomy, established its standard for high quality multi-disciplinary work, shown it to be a paragon for research rigor and reliability, demonstrated the importance of outreach and education to the community and most importantly generated the next generation of educators, researchers and leaders in astronomy by attracting the same from around the world.

III. BUDGET

A draft budget is prepared by UCO Associate Director for Business and Administration, after consultation with internal leadership, then refined by Director and Deputy Director and submitted to UCOP VP for Research and Innovation with 5-year projections and an expenditure report on previous year. A meeting is coordinated in spring with VP for Research to explain budget and respond to questions

UCO receives \$6.8M from UCOP, ~\$680K from UCSC, and with another ~\$3.5M extramural funds has a total ~\$11M expenses per year. As a rule, these funds serve in the maintenance and re-investment in the Lick observatory, which are entirely UC owned and UCO managed/operated. The Lick is a resource also used for research and education purposes in training graduate students as well as a test bed for testing advanced technologies for scale-up to operations of the Keck an/or Thirty Meter Telescope. The detector and instrument development work performed at (and with) Lick serves two purposes: (1) it advances the field for everyone and (2) increases capabilities at Lick, Keck and future TMT. ~\$1.2M of the 6.8M UCO budget is distributed to UC faculty, used for graduate student training workshops and has other benefits systemwide. These funds are also used to invest in skilled technical staff (about 40) whose expertise is then leveraged by UC faculty and campuses to compete for extramural grants to develop new instruments. In addition, support is also provided for 22 staff of the Lick observatory to help in overall maintenance and function of the facility.

UCO does not financially support operations at Keck through its own budget because UC's share of the Keck operating budget is allocated directly to Keck from UCOP's budget. That being said, UCO supports some administrative functions at the interface between UC researchers and the WM Keck Observatory (e.g. UC Telescope Time Allocation Committee, representation on Keck's CARA Board, Keck Science Steering Committee) and assists in instrument development for Keck by providing technical expertise in the upgrades, maintenance and troubleshooting of Keck facilities (software, hardware, infrastructure) by reimbursement directly to UCO. The UCOP funds supporting Keck are currently \$7M/year while only a small fraction of the UCO budget is used to manage the Keck advisory panel and to help coordinate time allocation to UC faculty. In addition, it is predicted that the next generation Thirty Meter Telescope will not use UCO funds and UCOP

will directly pay operating costs for 1/6 of the operating budget for 1/6 the user time. Access to the Keck is extremely valuable to UC astronomers as it is the best visible land-based telescope. Keck ranks as one of the top 3 of such telescopes (the top 2 are radio telescopes) with Keck being number 1 in visible/IR telescopes. UC astronomers compete for 5/12 of the total time and UC astronomy grants (measured by PI's who are UCO members) total \$85.5M/5 years including IDC=~17M/year.

UCO funds an IR detector lab at UCLA, and a similar technical collaborations are in the UC system, at UCSD for example. Significant budget stress track due to a lack of consistent support for increased salaries tied to union contracts, the new calculations of benefit rates and need for infrastructure has severely affected UCO. Even so however, the Lick Observatory has maintained largely self-supporting or NSF funded, outreach activities to include training of graduate students. As part of its expense profile, UCO is expected to pay for maintenance of its "Main Building" at Mount Hamilton, a multiple-use facility that houses the public-oriented 36" Great Refractor Telescope and as such the focus of our public outreach activities. The Main Building also houses one of the very active research telescopes (the Nickel Telescope), the working offices of Lick's Support Astronomers, the Lick archives, a video conference room used by Lick Observatory technical staff for communicating with UCO headquarters at UCSC, the Post Office that serves residents of Mt. Hamilton, and several utility rooms. The facility also includes a Gift Shop that is financially self-sufficient. Because of its multiple-use nature, it is difficult to assess what fraction of the maintenance costs of the Main Building are attributable to each function but significant effort is aimed at fund raising and philanthropy. The largest public events held in the Main Building include "Music of the Spheres" and "Evenings with the Stars" which generate significant income from ticket sales to help cover the cost of janitorial services, housekeeping and event planning. Because UCOP originating funds reportedly pay for a very small fraction of the outreach efforts, nearly all outreach efforts are supported by private gifts, endowments, or ticket sales.

FINDINGS:

Infrastructure is always under-funded and under-resourced, regardless of the success of the parties that benefit from its existence. UCO has had to turn to funding strategies that meet short term goals but will fail in the long run. UCO is no different and just as it has had to develop creative ways to fulfill its mandate, the complexity of its budget has made it difficult to assess.

For example, the original impression from the report that UCO pays ~\$1M to Keck from its UCOP operating funds seems to be a misunderstanding as UCO does not pay for any operations at Keck through its own budget. Instead, UC's share of the Keck's operating budget is allocated directly to Keck from UCOP, under a legally binding Memorandum of Understanding with Caltech. UCO uses a modest amount of its funds to administer the interface between UC researchers and the WM Keck Observatory by running the UC Telescope Time Allocation Committee, represent UC on Keck's CARA Board, and participating in the Keck Science Steering Committee but they are minor. Assistance in instrument development for Keck, technical expertise in upgrades, maintenance and troubleshooting of Keck facilities (software, hardware, infrastructure) is reimbursed directly to UCO by Keck. Yet much of the accomplishments claimed by UCO are from the work at Keck which is not a UCO funded activity. Ironically, the development and success of the Keck telescope and its suite of state-of-the-art instrumentation are tailored to the specific needs of UC's astronomers by keeping a significant amount of the development of cutting edge astronomical instrumentation within UCO. For example, it could be argued that maintenance of the Lick, small telescopes, etc. by UCO is no longer a good investment since Keck is so productive and no funded by UCO. Is spending any money on smaller telescopes money well spent? To this end, we heard that it is important to make a distinction between projects that could only be done on larger telescopes like Keck, and projects which could be done on either. In this way, less expensive facilities can address impactful science questions which don't require Keck capability. In addition, the smaller Lick telescopes can be used to develop target sets for future Keck surveys, identify the most promising targets and remove the false positives. Together they greatly increase the scientific productivity of Keck as exemplified by Exoplanet Searches, Supernova Surveys, and Reverberation Mapping of the supermassive black holes in Active Galactic Nuclei between 2013 and 2017 which have been cited 636 times. UCO is also looking to improve Lick which in recent years has developed significant capabilities to observe transient events such as supernovae and gamma-ray bursts. This capability has enabled a cross-UC group to lead in the identification of the first merger between two neutron stars, triggered by the gravitational waves emitted in the merger.

One of the hidden assets in supporting an infrastructure like UCO is in the testing of new instruments. This technical activity can potentially give UC the credibility to lead in initiatives like TMT and indeed in future leading edge telescopes (after TMT) and not calculated in the ROI

for UC's \$6.8M/year investment. While instruments are not physically moved from the Lick to the Keck telescopes, because of the large difference in size, technologies and expertise developed at Lick allow future high-performance instruments to subsequently be built at Keck like (1) The Gemini dual-channel infrared spectrograph on Shane 3m Telescope establishing that the technology and expertise of the UCLA Infrared Lab was scalable and then used to build three extremely capable infrared instruments for Keck: NIRSPEC, OSIRIS, and MOSFIRE. (2) The Adaptive Optics and Laser Guide Stars that were first deployed and tested at Lick's 1m telescope (the Nickel), then at Lick's Shane 3m telescope to lead directly to new adaptive optics and laser guide star facilities at Keck on their 10m telescopes. (3) The Iodine Cell use for Exoplanet Searches which was prototyped and deployed at Lick's Shane 3m Telescope, and used for the UC-built HIRES Spectrograph at Keck. (4) The Multi-Object Spectrograph used on Lick's Shane 3m Telescope eventually led to the very large and capable DEIMOS spectrograph on Keck and (5) a new project called PEAS that will directly shape the development and interpretation of results from a Keck (and possibly TMT) instrument called SCALES. As a major partner of Keck, UCO is validates and "debugs" untested technologies being installed on the flagship 10-meter telescopes.

Part of the creative adaptation by UCO leadership is in the out-of-pocket costs for the students in the UC Graduate Student Workshop that are paid for by a private donation to Lick. The only cost to the UCOP-funded budget is the time spent on the effort by the Lick Supported Astronomers who run the workshop, and the "opportunity cost" of a few nights of Lick telescope time. Because all remote graduate, undergraduate, or faculty lead observers must train on site at Mt. Hamilton before they are allowed to use the remote observing rooms on the various campuses there is a gift fund which has been used to offset these training costs. Only a very small fraction of UCO's budget from UCOP is used for graduate student training activities many of the training functions that have been conducted over the years (e.g. Adaptive Optics Summer School) are taught at the Center for Adaptive Optics on the UCSC campus through self-funded through a workshop fee. *UC benefits immensely from this local no-cost activities that it could match.*

IV. UCO CONTRIBUTIONS TO GRADUATE EDUCATION

Information regarding the contribution of UCO to the graduate education mission of UC system wide is limited to a phrase in the report that they 'support UC graduate and undergraduate teaching and the training of PhD's. This appears to be accomplished through a UC-wide Graduate Student Workshop at Lick, an annual Future Leaders Workshop for graduate students from all the Thirty Meter Telescope partners, the Akamai Workforce Initiative and the AstroTech Workshop, the latter of which are aimed at students from groups under-represented in astronomical instrumentation. There was little detail provided but the Director teaches a UCSC graduate-level course in adaptive optics to UCSC students as well as to students from other UC and non-UC campuses, some from as far away as Brazil and Germany, using live video-teleconferencing and web-based materials. The contribution to undergraduate and graduate education was clarified by the in-person interview with the Director but the importance of this element to the UCO mission was viewed as underrepresented in the report.

V. ADMINISTRATIVE GOVERNANCE

Overview/Bylaws: The UCO 5-year review report provided a governance chart that unfortunately offered little clarity or explanation of decision-making processes within UCO. No bylaws were specified and links within the document do not appear to have been updated for a number of years. In one key case -- the Director's position and presumably other names specified on that chart -- the information dated from 2012-13. Specifically, the link lists Professor Sandra Faber (now emerita) as Director, while the document indicates that Professor Claire Max holds that position. In the course of interviews with the Director, discrepancies were tied to budget shortfalls in infrastructure support that delayed upkeep and maintenance of the UCO presence on the web.

Personnel: In addition to its director, Professor Claire Max (UCSC), the UCO has numerous faculty and staff that are located across several UC campuses at the Mount Hamilton facilities itself or associated facilities as compiled in the appendix of the report. In addition, teaching time buyout (100K) is provided to UCO faculty who currently provide administrative or advisory service to UCO including: Professors Aaron Barth (UC Irvine) UC Co-Chair of Keck Science Steering Committee, Tommaso Treu (UCLA) UC Co-Chair of TMT Science Advisory Committee, Shelley Wright (UCSD) Chair, UCO Advisory Committee, Michael Bolte (UCSC) UCOP Representative, TMT Board and Ian McLean (UCLA) as Associate Director of UCO for the Infrared Laboratory

Space and Resources: The UCO uses campus resources across UC including:

UC Santa Cruz campus: UCO occupies 7,154 ASF of office and conference rooms and 19,139 ASF of lab facilities. Equipment includes a CNC milling machine, manual lathes and milling machines, portable clean rooms and cold room, permanent clean room, 2 coating tanks, precision optical interferometers, adaptive optics systems, optical flatness measuring machine, Olympus STM6 microscope, Veeco optical profiler, vacuum pump stations, work benches, and videoconferencing stations.

Lick Observatory on Mt. Hamilton: There are 22,559 ASF of telescope domes, 49,041 ASF in employee residences, 8,312 ASF in the visitor center and 26,884 ASF of shop and other support facilities. Available at Lick Observatory are the 3-meter Shane telescope, the 2.4-meter Automated Planet Finder telescope, and numerous smaller telescopes.

UCLA Campus: Labs and office space occupy 5,300 ASF. Lab equipment includes two clean rooms, vacuum pumping stations, work benches, conference room, videoconferencing station, and access to the Astronomy Dep't Shop.

W. M. Keck Observatory: As a full partner, UC has rights to approximately 240 nights/year of observing time.

Although the report states that "UCO organizes the allocation of observing time to UC faculty, researchers, and students, and plays key roles in the governance and scientific direction of the Keck and Thirty Meter Telescope observatories for both non-profit corporations", little information was provided on how this is done, but the process was clarified during in-person interviews with the Director.

Contract and grant support: As described in the 5-year report, the overall budget of the UC Observatories groups at UC Santa Cruz and at Lick Observatory over the last 5 years (FY 15 through FY19) was slightly more than \$55MM (see Appendix I, Tab I of report). Of this amount, about \$31 MM (56%) originated UCOP systemwide funds, \$3.3M (6%) from UCSC campus funds, and \$20.7M (38%) from extramural sources that include contracts and grants to build optical and infrared instrumentation for the TMT, Keck, and Lick Observatories. With \$85MM in extramural funding to UC investigators, the financial return on UCOP investment is three-fold but arguably, immeasurable in terms of its reputation, international stature, educational mission and importance to astronomy research globally.

FINDINGS:

UCO governance and decision making can be separated into two parts: (1) Governance internal to UC andUCO and (2) Partnership governance of Keck andTMT Observatories. The functions of UCO Advisory Committee derive from the UCO Charter and include responsibilities like proposing and evaluating new initiatives, reviewing and allocating funds to mini-grants, keeping astronomers throughout UC system informed about new developments, gathering system-wide input on issues of importance to UCO-managed facilities, advising UCO Director on matters of policy and periodically undertaking Strategic Planning. The effectiveness of this committee in administrative governance is unclear.

Fluctuations in administrative costs from year to year appear high and are attributed to new costs like changes in UCSC Assessment Costs for HR (Compensated Benefit Rates) which should be addressed by UCOP mitigation funding. Some “administrative costs” were likely represent several types of activities categorized differently year to year like expenses for internship programs, overhead for Keck instrumentation projects that should be made consistent in future reports.

There is a need to formalize “customer satisfaction” surveys with a specific objective of establishing the value UCO provides (or not) to the UC system and to California. Current processes include assessing satisfaction with the “observing” experience, following “Trouble Tickets” generated by the users in a way that can generally be fixed within the day and through “Post-Observing Forms” generated at end of instrument use to identify items that need action and review in Director’s Office. While satisfaction with Keck instrumentation is assessed annually by the Keck Science Steering Committee when it hears reports from support astronomers on instrument status and satisfaction, there is no analogous system for UCO per se. General feedback appears to be given to UCO Advisory Committee and concerns from general public and/or UC faculty go to the Director’s Office. There is no formal systemwide survey of faculty that would be beneficial to the UCO to ensure adequate funding.

Key metric of success are publications, which are important (>950/5yrs), but the unique undergraduate and graduate student experiences (300/5yrs); the proven catalysis of collaboration (43% of publications use multiple UC campuses) and UCO national stature (20% of the astronomy section in the US Academy of Sciences are UC) is particularly impressive. *That being said the mechanisms of UCO performance review are inadequate and there are no processes for periodic evaluation of UCO leadership. Both of are easily corrected by expanded use of advisory committees and the inclusion of more comprehensive reviews of administrative governance.*

VI. ADVISORY COMMITTEE(S)

Internal: There is a UCO Advisory Committee that is described as advising the UCO Director's Office on matters related to UCO policies and operations. The UCO-AC also coordinates the functions of a mini grant program to support new initiatives. The group meets three times per year and includes representation from all UC Astronomy campuses. In addition, there are three Telescope Time Allocation Committees (TACs) with similarly broad system-wide representation whose function is to review proposals for UC time at Keck and Lick. It is somewhat unclear why three TACs are required for two observatories although interviews with the Director made it clear that they function well.

External: Although there is no external advisory committee for Lick, the Keck and TMT are observatories that are operated jointly by UC and other partners. In the case of Keck (Caltech) and TMT (international partners), the governing boards of these observatories have strong UC representation and are supported by science advisory committees. Interviews with the Director made it clear that UCO appears to enjoy and benefit from involvement and interactions across the UC system and from the international community.

VII. CONCLUSIONS

While it is clear that UCO is an academic powerhouse within the UC system, the report provided to UCOP is obscure and often uninformative regarding certain questions like how UCO is administered and how decision-making processes actually takes place. Some concerns were addressed by the Director's presentation to UCORP while others in follow up questions. The Governance chart offered little detail regarding structures of authority or decision making. (e.g. the lines leading in and out of the director's position are never fleshed out in terms of whether the individuals/groups are advisory or whether they have, e.g., voting privileges and so actual authority). Given the scope, complexity, and budget of the UCO it would be critical to understand what oversight capacities exist and with it, what might be improved.

In as much as UCO organizes the allocation of observing time to UC faculty, researchers, and students, and plays key roles in the governance and scientific direction of the Keck and Thirty Meter Telescope observatories, the report discusses how this allocation is determined nor any metrics or information regarding questions or problems for evaluating the process. Similarly, no information is provided about the decision-making processes-- whose input is solicited, how information is assessed, who makes the actual decisions—in matters relating to fostering collaborations and outreach activities across UC campuses, organizing and co-funding annual meetings and workshops. Whereas it invokes broadened UC-wide leadership and participation in UCO's activities and governance, it appears that governance is segmented to UC-wide participation in the UCO Advisory Committee, the Keck Science Steering Committee, and the TMT Science Advisory Committee. To this end, UCO developed two Mini-Grant programs to support early-stage innovation in instrumentation and provide time for UC faculty members to devote to key UCO activities and intends to organize and co-fund a series of annual meetings and workshops of which information is scant. The same applies to the lack of clarity regarding expenditures within UCO. Funding charts lack of substantive information it conveys, do not come with any corresponding percentages or dollar figures and rely on reviewer's "guesstimates". In addition to administrative expenses that cannot be discovered from the information provided, the lengthy appendices do contain the coding necessary to indicate that

individuals occupy multiple roles or ensuing time and cost allocations for the roles specified. Although the total administrative costs are indicated and appear to fluctuate significantly year over year, there was no explanation, discussion or projection of these costs going forward. recommendation, the UCO needs to be much more specific regarding its internal governance structure as it relates to decision making processes and resource allocation at all levels, from equipment access to outreach activities. In addition, and as importantly, more detail is owed regarding administrative costs, percentages of salaries/time that particular individuals receive for this, and what oversight mechanisms exist to evaluate administrative expenditures.

VIII. RECOMMENDATIONS

1. **Budget:**

- UCO should be fully funded and future funding increased, commensurate with its contribution to UC's status as a leading research university, UC's stature as an international institution of advanced learning and UC's standing reputation as a solver of societal problems.
- In the course of this review, it became clear that UCO has not recovered from severe losses that occurred in 2008-2010 budgets and it is now likely to be severely damaged by the ongoing pandemic of 2020, which began shortly after this review. In addition, UCO has had to bear the brunt of fiscal changes in policy from UCOP in regards to employee benefits. In view of the fact that UCOP is not paying the contractual \$7M/year for UC's share in the delayed Thirty Meter Telescope the unused fund should be used to help UCO fill its mission pending strategic planning in governance, research, education and outreach.

2. **Governance:**

- UCO needs to develop a comprehensive strategic plan for its administrative governance particularly in light of the ongoing pandemic so that it can be what it needs to become to continue thriving.
- UCO needs to be much more specific and accountable regarding its internal governance structure as it relates to administrative decision-making and resource allocation at all levels, from equipment access to outreach activities. This includes significantly more clarity regarding its administrative costs, the percentages of salaries/time that individuals receive on UC campuses, and the accounting oversight mechanisms that exist to evaluate expenditures.
- The Directorship of the UCO and other key positions in UCO governance should be subject to peer-reviewed performance evaluations by stakeholders. The process of selection, appointment and review needs clarification.

3. **Research:**

- UCO needs to develop a comprehensive strategic plan for its research particularly its relationship with merging observatories at Keck and TMT, its relationship to graduate students and its commitment to research education.

- With the requested increase in funding above, the UCO should look to increase graduate and undergraduate participation in its activities with an emphasis on developing and expanding programs for women and under-represented minorities to help fill the national pipeline of faculty needed to replace retiring personnel.
- With its proven ability to foster co-operation amongst different campuses, particularly in physical sciences and engineering, there is significant enthusiasm to integrate astronomy with emerging data science, artificial intelligence, the social sciences, the humanities, and in light of UC priorities, climate and emergency sciences.

4. **Education and Outreach:**

- UCO needs to develop a comprehensive strategic plan for outreach particularly in light of the effects of the ongoing pandemic the advent of remote learning and the need for social distancing.
- UCO is uniquely suited to execute a broad fund-raising campaign to increase awareness in, and understanding of astronomy and related fields. It should invest in this area
- UCO should (re)-invest in its web/virtual internet presence and look at social media tools to bring its activities, its research and its significance into the life of every Californian.