Response to

HCR 314, Regular Session of 2006

Report on long-term development of observatory sites on the summit of Mauna Kea

by

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Summary. **A report on the long-term future development of observatory sites on the Summit of Mauna Kea is given. A conceptual plan is presented that proposes a much smaller number of future projects than foreseen in the University of Hawaii Master Plan of 2000. The long-range goal is to have eventually fewer observatories than now, but still the very best in the world in this way securing continued world leadership in astronomical research and education in Hawaii for the next decades.**

1. Introduction.

This report is submitted in response to the request by the House of Representatives of the Twenty-third Legislature of the State of Hawaii, Regular Session of 2006, the Senate concurring, "that the University of Hawaii Institute for Astronomy prepares a report on the long-term development of observatory sites on the summit of Mauna Kea, including a conceptual plan that consolidates the number of observatory sites, to enhance the quality of astronomy research and limit the size of the geographical area on which to situate new observatories."

The report is structured as follows. We first describe the present situation of astronomical research and education in Hawaii and its important role for the State and the University. Then, we discuss the concept for long-term astronomical development, as it is described in the comprehensive and detailed "Mauna Kea Science Reserve Master Plan", which was approved by the Board of Regents in June 2000. Since the development of the Master Plan, the scientific priorities of astronomy for the new century have become much clearer, and a new more concise concept for future astronomical development has emerged that will guarantee Hawaii's continued world leadership in astronomical research and education, while at the same time being well balanced with the needs for cultural and environmental protection of Mauna Kea. This concept will be introduced in section three of this report.

1. The role of astronomy in Hawaii.

To appreciate the role of astronomy in our state, one first needs to understand the history of astronomy development in Hawaii; the basic philosophy behind that development; the essential role played by the Institute for Astronomy; and the educational, scientific and economic benefits that accrue from astronomy.

The Institute for Astronomy (IfA) is 38 years old and is by far the youngest among top-ranked astronomy programs in the U.S. In this short time, the Institute has grown to become one of the most visible of UH's scientific research programs and one of the most respected astronomy institutes in the world. The IfA plays in the same league as Caltech, Harvard, Princeton, Berkeley, and Cambridge. It attracts the best faculty and the best students from around the world. It has become a pillar of academic excellence and certainly an engine of economic growth in the State. Where once school kids in the world learned that the center of astronomy was Mount Palomar in California, now they learn it is in Hawaii. How has this story of scientific success been possible in such a short time?

The answer to this question is the superior quality of Mauna Kea and Haleakala as the world's best observatory sites and the concept developed by the IfA, the University and the State to build up the most capable observatory in the world. The astronomers of the IfA were the first in the world to dare to build a technologically very challenging and complex observatory with small, but very efficient, telescopes at the extreme elevation and thin air of 13,796 ft. With their exciting astronomical detections they were able to demonstrate to the world that Mauna Kea is unique as an astronomical site.

Scientifically, the logical consequence for UH would have been to use this enormous advantage to build the next generation of most powerful telescopes on its own, as the universities in California, Texas, Arizona and on the East Coast did before. However, UH was (and is) a medium size State University with a very limited budget, and Hawaii is a small state with limited resources. Thus, a different concept was developed—the concept of scientific partnerships.

Within this concept the national and international partners contribute the capital funding for the facility, carry most or all of the operational costs, and contribute to the infrastructure development. The University, through the IfA, provides the leadership and know-how to operate an observatory at extreme altitude, the management of the physical and operational infrastructure (roads, power, fiber-optics communications, food, lodging) and ongoing protection from adverse intrusions such as light pollution and radio frequency interference. The University also provides the land for the observatory site from its lease from the State, along with assistance in planning and permitting. The University and its partners collaborate in the scientific use of the telescopes including development of technologically advanced instrumentation. Most importantly, they share the scientific observing time on the facilities with no cost to the University.

In this way, the University and the State did not have to contribute the enormous capital costs to design and build the extremely powerful new telescopes, but were still able to provide researchers with access to these unique facilities and give them the opportunity to build up one of the best research and education programs in the world. The benefits, both economic and otherwise, are substantial as indicated below.

1. Astronomy facilities on Mauna Kea and Haleakala represent a capital investment of close to $1 billion. The economic impact of astronomy to the State amounts to $150 million per year. New projects for Haleakala and Mauna Kea have the potential to double these numbers.

2. The observatories and other astronomy-related activities on Mauna Kea and Haleakala provide 600 quality jobs in a clean high-tech industry on the neighbor islands. It is important to note that only a small fraction of these jobs are for astronomers. Most of them are for technical, administrative and logistic services. This number will increase if we continue to follow the sound policies that have been in place for nearly 30 years. Beyond the simple numbers, there is the fact that astronomy as a high-tech science diversifies the Hawaii economy and gives local young people with scientific and technical talents a wealth of opportunities to realize their potential without having to leave their family and friends in Hawaii to pursue employment elsewhere. Unlike some high-tech industries, astronomy is fundamentally rooted in Hawaii. Once established, an astronomy facility cannot be easily relocated to the mainland or overseas.

3. The IfA has developed into one of the world's preeminent centers for astronomical research. The Institute receives extramural awards totaling between $20 to $25 million annually for astronomical research, for development of new astronomical instrumentation, for improving its own old telescopes and for operating telescopes, such as the NASA Infrared Telescope Facility on Mauna Kea and the Mees Solar Observatory on Haleakala. Its graduate program belongs to the best in the world and about 1,000 undergraduate students per year participate in astronomy courses in Manoa. In addition, UH Hilo has recently developed a very successful astronomy undergraduate program. Astronomy is one of UH's most successful programs.

4. The Mauna Kea Observatories are the world's largest observatory complex, and will remain so for the foreseeable future. Hawaii and its State University are recognized around the world for this outstanding achievement—a source of tremendous prestige for the State. Approximately 1,500 scientists come to work at the Observatories each year; most add some vacation time to their trip. Hundreds of others come to Hawaii each year to participate in astronomy-related conferences. Several small companies make a business of providing quality tours to Mauna Kea. The observatories' base facilities in Hilo, Waimea and on Maui are a major addition to those communities and contribute in many ways.

5. Over the years, the observatories have made significant monetary contributions to the infrastructure, much of which is of benefit to the general community. This includes $2 million for road improvements on Mauna Kea and another $2 million to assist GTE Hawaiian Tel to install a fiber optics cable across the Saddle from Waimea to Hilo. This cable provides state-of-the-art service for both the Big Island telephone system and the observatories.

6. The observatories operate the Visitor Information Station at Hale Pohaku, which provides free public star gazing seven nights a week and welcomes about 100,000 visitors each year.

7. The observatories pay the entire cost of maintenance and snow removal for the road and they pay for emergency services. The public can use the road all the time. The costs for this service and the Visitor Station amount to $700,000 a year.

Although the economic benefits are substantial, it is important to keep in mind that the primary mission of astronomy is not to generate revenue. Astronomy is basic science and concentrates on the scientific exploration of the universe. Astronomy is the mother of all sciences and has changed our understanding of the world and our thinking as humans like no other science. The telescopes on Mauna Kea and Haleakala have contributed fundamentally to the advancement of modern astronomy. They are world-class research facilities, and the best window our planet provides on the strange and wonderful universe we live in.

2. Long-term astronomical development in the 2000 Master Plan.

The 2000 Master Plan is a comprehensive document, which was approved by the Board of Regents in June 2000 after an arduous, two-year process with input from all sectors of the community, and supervised by a community-based advisory committee chaired by two faculty members at UH Hilo's College of Hawaiian Language, Dr. Pila Wilson and Mr. Larry Kimura. It was accompanied by a State Environmental Impact Statement signed by the Governor of the State. The Master Plan has been submitted to the Legislature on many occasions and is available on the Institute for Astronomy's website. The scope of the Master Plan is much broader than future development of astronomy. It addresses the cultural and environmental aspects of the University's use and responsibility for the Mauna Kea Science Reserve and proposes a new organizational structure, which has been implemented by establishing the Office of Mauna Kea Management, based at the University of Hawaii at Hilo, and two important community-based advisory bodies, the Mauna Kea Management Board, and Kahu Ku Mauna, the Office's and Board's cultural advisory council. Within the new organizational structure the Institute for Astronomy's responsibility on Mauna Kea is limited to astronomical operation, research and education, whereas the Office has the responsibility for the cultural and environmental protection and all other aspects of land management. In this report we will not discuss these latter aspects. It is our understanding from the 2006 hearings that the objective of HCR 314 is to obtain information on the prospects and

plans for future astronomical development on Mauna Kea, and we have restricted the report accordingly.

The scientific progress in modern astronomy is intimately related to the development of new technologies, new instrumentation, and new and more powerful telescopes. Without such development it is impossible to stay at the forefront of astronomical research. It is therefore natural that the Master Plan also contains a section about very ambitious future astronomical development. However, this development together with all but one of the existing facilities is confined to the "Astronomy Precinct", a very small fraction of less than five percent (4.65% or 525 acres) of the existing Mauna Kea Science Reserve of 11,288 acres in order to maintain a close grouping of astronomy facilities, roads and support infrastructure. This approach minimizes the potential impact to the natural and cultural resources of the summit region. The criteria to be followed for new facilities proposed in the Astronomy Precinct include:

- Emphasize recycling of existing sites when possible so as not to disturb existing habitat areas, archeology and landforms;
- Limit visual impact and scattering of facilities by clustering within the existing development areas;
- Utilize the natural forms in the summit area to shield views of built facilities;
- Implement design measures to allow facilities to blend better with the existing landscape;
- Minimize infrastructure development by locating near the existing roadway and utility network;
- Minimal impact on existing facilities;
- Minimum impact of Wekiu bug habitat;
- Avoidance of archeological sites;
- Suitability for observations.

A vigorous UH approval process for new project has been introduced, which includes reviews by the Office of Mauna Kea Management, the Kahu Ku Mauna Council, the Mauna Kea Management Board, the Chancellor of UH Hilo, the UH President and finally the Board of Regents. In addition, new projects have to carry out an environmental analysis in the form of either an Environmental Assessment or an Environmental Impact Statement and they have to go through the State process with the Department of Land and Natural Resources to obtain a Conservation District Use Permit. In the whole process each new facility will be required to present a detailed justification addressing the following questions

(1) Why is the facility needed?
(2) Why is Mauna Kea the best site for the facility?
(3) What other location options are available?
(4) What are the expected benefits with regard to research and education, employment and economy
(5) What is the expected facility lifetime and term of sublease agreement?

There are currently 12 observatories on Mauna Kea. The Master Plan identifies five of those (the UH 0.6m, the UH 2.2m, the Canada-France-Hawaii Telescope, the United Kingdom Infrared Telescope, and the NASA Infrared Telescope Facility) as older facilities, several of which could be upgraded or replaced within the next 20 years. The expectation is that the new or upgraded telescopes would come in a range of sizes from 2 to 15 meter mirror sizes (note that the 10m-class mirrors of the existing Keck, Gemini and Subaru Telescopes represent the current state-of-the art observatory facilities), however there are clear restrictions in terms of the height and volume for these facility redevelopments. The Master Plan also assumes that the other seven existing facilities would remain as is over the next 20 years.

In addition, the Master Plan envisages the expansion of two existing facilities. For the Keck Observatory it proposes the addition of four to six 1.8m outrigger telescopes to create a very powerful infrared interferometer, which would study cosmic objects for spatially resolved fine details, for instance the motion of stars caused by the presence of Jupiter-like planets orbiting around them. For the existing Harvard-Smithsonian Submillimeter Array (SMA) – an array of 12 movable radio telescope antennas distributed over 24 fixed concrete pads – the plan foresees an extension by 12 more antennas and 24 additional pads to increase the sensitivity and efficiency.

Three new projects at three new sites are proposed in the Master Plan. The first is the UH Hilo instructional telescope, a relatively small (1m mirror) telescope planned for a site adjacent to the existing UH 0.6m telescope. This facility is planned to be used for the education and training of undergraduate students in UH Hilo's Department of Physics and Astronomy program. The second is a new optical/infrared telescope comparable in size and capability to the existing Keck or Gemini telescopes. For environmental and cultural reasons a site below the summit ridge on the north shield is proposed.

The third new facility proposed is a revolutionary new telescope with a very large mirror of 25m to 50m diameter. This would be the largest telescope in the world. The site foreseen for this telescope is on the north-west lava plateau below the summit. This location minimizes visibility of the new facility from Hilo and Honokaa and would not affect Wekiu bug habitat.

The future astronomical development on Mauna Kea as foreseen in the University's Master Plan gives very high priority to the protection of natural and cultural resources, but at the same it also proposes a considerable expansion of future astronomical activity on Mauna Kea. If all facilities discussed in the Master Plan were built, the number of observatories would increase from 12 to 15 and two of the existing ones would be expanded.

In the next section we will introduce a modified plan, which proposes significantly less future development.

3. A modified plan for long-term astronomical development on Mauna Kea.

When future development for the next 20 years was discussed in the Master Plan of the year 2000, the goal was to be as comprehensive as possible in order not to exclude potentially important scientific options for the future. However, now six years later and after detailed scientific discussion within the Institute for Astronomy it has become clear that the number of future projects envisaged for the next 20 years is much smaller than anticipated in the Master Plan. The long-range goal is to have eventually fewer observatories than now, but certainly still the very best in the world.

After six years of successful operation under the Master Plan in coordination and collaboration with the Office of Mauna Kea Management and its community-based advisory boards it is well recognized that future plans for Mauna Kea require balanced management to preserve, protect and enhance the cultural and natural resources as well as providing a world-class center for education and research in astronomy. As laid out in the Master Plan and also described in the previous section, all major future development will be subject to stringent review by the Office of Mauna Kea Management, Mauna Kea Management Board, and Kahu Ku Mauna Council, as well as the community-based Hawaiian Culture and Environment committees, which report to the Board. In addition, as also already described in the section before, all major developments require a Conservation District Use Permit from the State Board of Land and Natural Resources. As the leaseholder for the Science Reserve, UH is responsible for submitting the use application. In conjunction with this process, UH must satisfy State and Federal environmental impact requirements (Chapter 343 and NEPA). The Institute for Astronomy is committed to sponsor only projects that are considered the best in the world, and not simply to add projects for the sake of adding another telescope to the mountain.

The goal of our new plan is to keep Hawaii's world leadership in ground-based astronomy. This achievement and recognition as a world leader will benefit not only UH as an educational and research institution but the entire state. The advancing and leading edge technologies associated with astronomy research and development will aid Hawaii's efforts to boost its technology industry, including software and instrument development.

In the following, we will discuss the new modified plan in detail. We will also compare it with the development as proposed in the Master Plan. We will start with the two observatories, for which significant expansion was proposed, the Keck Observatory and the Submillimeter Array (SMA). For the Keck Observatory the addition of six Outrigger telescopes was planned. In our new plan we do not foresee adding any more telescopes to the Keck Observatory.

For the SMA, the Master Plan proposed 12 more antennas and 24 new concrete pads for the array; however in our new plan, we consider only the very moderate expansion of two

more antennas and two pads. UH is also working on the relocation of two existing antenna pads located at the base of Pu'u Poliahu, a culturally significant site.

In the Master Plan a new observatory site on the summit ridge was proposed for the UH Hilo instructional telescope. In order not to increase the number of observatory sites on the summit ridge, the Institute for Astronomy has agreed to give its UH 0.6m telescope and the site to UH Hilo so that the instructional telescope can be built there with only little if any modification of the existing site. This minimizes cultural and environmental impact for this important educational project, which was described in the previous section. An Environmental Assessment of the project by UH Hilo has been completed.

Another redevelopment of an existing site in our new plan is the use of the UH 2.2m site for the Institute for Astronomy's new Pan-STARRS observatory. Pan-STARRS uses completely new technology being developed by the Institute to detect killer asteroids which threaten to impact the Earth. It will detect the majority of the most dangerous objects about 30 years before their potential impact giving some time to develop protection for mankind in case of a serious threat. This project is federally funded. The Institute for Astronomy is preparing a federal EIS in collaboration with the federal funding agency. In addition, UH will submit a comprehensive Mauna Kea management plan to the State Board of Land and Natural Resources for review and approval, before applying for a Conservation District Use Permit for this project.

In addition to the UH Hilo instructional telescope the Master Plan proposes two new telescopes at two new sites, as described in the previous section. One of them, the optical/infrared telescope of Keck or Gemini size, is not pursued any further in our new plan. With the enormously increased efficiencies of Keck, Gemini, and Subaru we do not believe that there is a scientific need anymore for another telescope of this size. It is worth mentioning at this point that the observatories on Mauna Kea are experimenting with the use of new fiber optics technology to combine the light from the already existing telescopes, the so-called Ohana Project. This is a challenging project, which will probably take decades to be successful, but it will greatly expand the capability and utility of the existing observatories.

The only project at a new site proposed in our new plan is the Thirty Meter Telescope (TMT). With its mirror of 30m diameter it will be the largest telescope in the world, and will be ten times more powerful than the Keck telescopes. It will be able to image planets orbiting around other stars and to analyze the light coming from these planets and, thus, to ascertain whether the conditions exist for the formation of life in planetary systems around other stars. It will also be able to detect the most distant galaxies in the universe and will see them in stage when the universe was still very young after its birth in the Big Bang.

As described in the previous section a site is foreseen for this observatory on the northern plateau below the summit ridge. This new site is preferable to a replacement of one of the existing telescopes, because the facility would be less visible and the environmental

and cultural impact would be smaller. The Institute for Astronomy is currently carrying out site testing and atmospheric characterization measurements at this site.

The TMT is a $1 billion project and the most ambitious project of modern astronomy. It is the dedicated goal of the Institute for Astronomy and UH to attract this unique project to Hawaii. It will have an enormous scientific, educational and economic impact and it will secure leadership of Hawaii in astronomical science for the next decades. This is the key project for the future of astronomy in Hawaii.

In summary, our new plan does not propose any further extension of the Keck Observatory with Outrigger telescopes and only a very small expansion of the SMA. It proposes two new projects, the UH Hilo instructional telescope and Pan-STARRS, which will use existing sites and will stay within the footprints of the existing facilities. As the most important project it proposes the TMT on a new site on the northern plateau below the summit ridge.

While the Master Plan of the year 2000 assumed that all existing facilities, which would not be replaced by new ones would continue to exist for the next 20 years, we do not make this assumption for the new plan. It is clear that newer facilities such as Keck, Gemini, Subaru, Pan-STARRS, the UH Hilo telescope and the SMA will certainly continue to operate over the next 20 years. However, some of the others will not continue with their operation, because other aspects of astronomical observations will become more important. In such cases our plan is not to refurbish all of them but only a few and only in cases where an extremely important scientific case can be made. Otherwise, our new plan is to demolish the old facility, to clean the site and to recreate the site in a stage as it was, before the facility had been built. (It is important to note that Operating and Site Development Agreements – the contracts between UH and the telescope partners on Mauna Kea – require that the costs for such reestablishment of the site in its original status have to be paid by the telescope partners.) We are confident that in this way the number of observatories on Mauna Kea in 20 years from now will be smaller than now. But with all the new facilities, in particular the TMT, Hawaii will still have the very best in the world.