AURA

Association of Universities for Research in Astronomy

AURA's Role and Involvement in a Thirty Meter Telescope Project

----------Status and Prospects----------

October 11, 2005

In 2000, the Decadal Survey recommended as its highest ground-based astronomy recommendation 30-m class giant segmented mirror telescope (GSMT) that could complement the Next Generation Space Telescope. It recommended that:

- Technology development begin immediately;
- Construction start within the decade;
- Half the total cost should come from private and or international partners.

Appendix I provides a historical description of AURA's involvement in a 30-m class telescope.

On July 1, 2004, AURA submitted an unsolicited proposal to the National Science Foundation for the design and development of a GSMT (see Appendix IV for Proposal Summary). The total funding requested over a four-year period is $40 million. This proposal was intended to fulfill the goals outlined in the Decadal Survey for a GSMT carried out as a public-private partnership.

This document is intended to provide a background for AURA's actions, an update of activities, and a look to the future. It will be updated as necessary to provide the community timely information on ongoing activities and what we expect in the future. It is our intent that this information be broadly shared and that it represent the basis for a national dialogue.

Funding History for GSMT

Within the generic designation, GSMT, there are two major technology efforts now being carried out within the community. Private funding to begin design and development work on a 30-meter class telescope was first announced by the California Extremely Large Telescope Corporation (CELT) following the release of the Decadal Survey. Shortly thereafter fundraising efforts were announced by the Giant Magellan Telescope (GMT) project. To date, private funding for both projects well exceeds $35 Million.

Federal funding was first proposed in the FY05 President's Budget in February 2004. $1 million was identified within the NSF Astronomy Division budget for design studies and

technology development for a GSMT. Additional in house work within NOAO was also acknowledged in the budget request.

In December 2004, the Conference Report accompanying H.R. 4818 providing appropriations for the NSF stated… *"The conferees do not object to the allocation of not to exceed $5,000,000 for completion of a design and development study for the Giant Segmented Mirror Telescope if the Director of the Foundation determines such funding is warranted based upon private sector interest and commitment, other astronomical science needs, and subject to approval by the National Science Board"*.

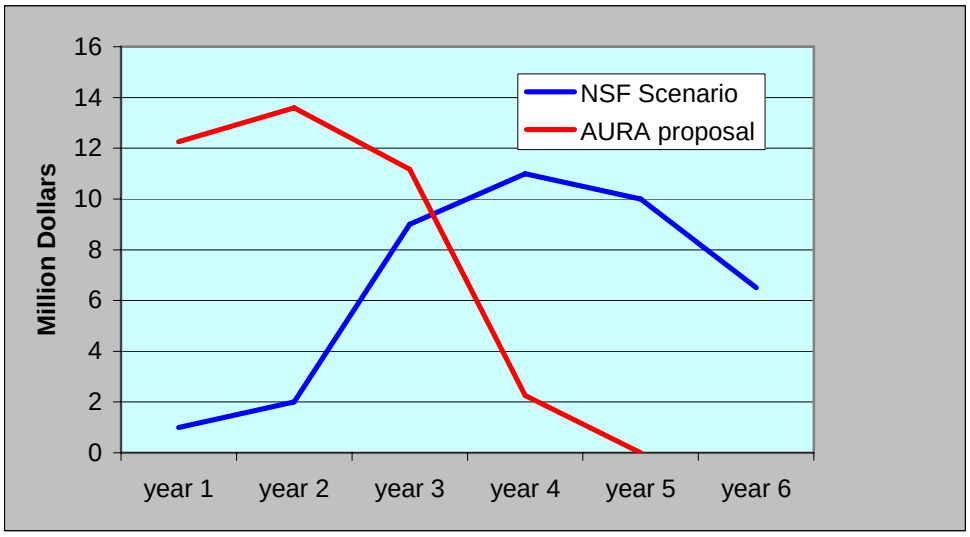
Thus, the Conferees recognized that additional funding beyond the $1 million identified may be needed and provided in advance the authority to the NSF to seek such funding in the operating plan for the NSF. The operating plan did not, however, request any additional funding.

Given the present limited outlook for the NSF astronomy division budget, it is unlikely that the AURA proposal can be funded on the schedule called for. However the NSF has indicated that funding could be made available on a more protracted schedule as follows:

- 2005-$1 M
- 2006-$2.5 M
- 2007-$9 M
- 2008-$11 M****partner chosen
- 2009-$10 M
- 2010-$6.5 M

Total ~$40M

A comparison of the NSF outlook for funding vs. the AURA proposal is shown below.



While the AURA proposal seeks to match federal funding with private funding to provide an efficient design phase, the NSF profile envisions only a minor investment in the first two years but a relatively greater level of funding at the point the program must transition to the construction phase. The integral under the two curves is the same. AURA was

asked to revise its cost proposal to reflect the NSF outlook for FY05 and FY06. AURA received its first $1 million increment of funding for FY05 in September, 2005.

The difficulty in providing the requested funding for GSMT is part of the overall set of problems that have been identified in the NSF's approach to funding major facilities. The "Brinkman report" makes the case that (1) there is a backlog in construction new starts (2) the process NSF uses is opaque, (3) there is no effective way of funding pre-construction concept development.

Absent an agency wide fix, in April, 2005, the Astronomy Division announced that it would conduct a Senior Review to examine the options for freeing up funding within the existing Astronomy Division budget in order to fund the design studies for future initiatives such as GSMT and provide for operating budgets for projects in the post construction phase such as ALMA.

In effect, the projected increase in funding beginning in FY07 shown above is contingent upon achieving these goals. The NSF anticipates having the results in hand in March or April 2006 in order to affect the FY07 budget. A full summary of the Senior Review process and progress to date can be found at http://www.aura-astronomy.org/nv/nuresult.asp?nuid=97.

Recognizing the difficulty of funding major pre-construction projects within a flat base budget (even with any funding freed up by a Senior Review), AURA has recommended a modification of the process for funding major facilities and research equipment (MFREC) within the NSF. AURA's recommendation can be found at http://www.aura-astronomy.org/nv/nuresult.asp?nuid=92.

Essentially, AURA has recommended that the MFREC budget account be expanded to accommodate some pre-construction design for projects envisioned to move into construction. This would ensure that the design and development phase is adequately funded, and that the transition to construction can be achieved on a timely basis.

Schedule for GSMT

There exist important differences in the schedules envisioned by the TMT and GMT projects and that envisioned by the NSF. The Decadal Survey expressed a strong desire for a complementary overlap with the James Webb Space Telescope (JWST), now envisioned for launch in 2013. The NSF schedule, on the other hand, is primarily driven by the procedures in place for approving new construction projects, and the funding wedge that should become available when ALMA construction is complete.

In trying to develop a clear view of the plausible schedules for GSMT, the NSF asked AURA to convene an Optical/IR Long Range planning Committee. That report can be found at http://www.noao.edu/dir/lrplan/lrp-committee.html.

A comparison of the ideal GSMT schedule from the OIR Plan with that envisioned by the NSF is as follows:

		NSF Schedule	O/IR Plan	
	1Q			
2005	2Q			
	3Q			
	4Q			
	1Q			
2006	2Q			
	3Q			
	4Q			
	1Q			
2007	2Q		Funding Req.	LSST Proposals submitted, community decision TBD
	3Q		Defined	
	4Q			
2008	2Q			
	3Q	Down select	Proposals	
	4Q		submitted	"Flagship facility" selected for further funding
	1Q		Approval	
2009	2Q	Readiness	Phase	Abbreviated approval phase in OIR Plan
	3Q			
	4Q			
	1Q	Approval	Construction	
2010	2Q	Phase		
	3Q	(NSB)		
	4Q	(OMB)		Extended approval phase in NSF outlook
	1Q	(NSF)		
2011	2Q			
	3Q			
	4Q	(Congress)		
	1Q	Construction		
2012	2Q			
	3Q			
	4Q			
	1Q			
2013	2Q			
	3Q			
	4Q			
	1Q			
2014	2Q		Completion	

Several features of this comparison are:

- In 2007, the OIR Panel recommends that a community decision be made as to whether to continue funding for LSST or, if budgetary or scientific conditions argue otherwise, to fund only GSMT.
- The NSF envisions public funding for design studies for only one GSMT variant after 2008.

- The OIR plan envisions only one year for the approval phase compared to two years envisioned by the NSF.
- Construction initiation earlier than 2012, as envisioned by the OIR plan, can only be accomplished with private funding.

From both a funding and schedule standpoint, early private funding is the pacing and most important factor in achieving a working facility during the JWST era.

AURA's Proposal Effort

A summary of AURA's current proposal is included as Appendix II. In order to achieve an operational capability early in the JWST program, the NIO study, as well as others, suggests that a near-term, aggressive, and focused technology development effort is necessary. Therefore, AURA submitted a proposal to NSF that would:

- Move beyond the preliminary concepts identified by AURA's New Initiatives Office, the California Extremely Large Telescope project, and the Canadian Large Optical Telescope study.
- Fund an alternative technology, e.g. the Giant Magellan Telescope.
- Address critical technology needs and design tools necessary for a construction effort.
- Provide a basis for a potential down select among possible publicly funded projects.

AURA's proposal will mature technologies identified as critical to any next large aperture telescope initiative. For example, work on site characterization, mirror coatings, detectors, advanced gratings, etc. should benefit the broader community of telescope builders and hopefully beneficial to be broader community of users. The proposal is structured to engage a broad segment of the community in developing studies, prototypes, etc. through the competitive process.

AURA's proposal will result in two sub-awards. On sub-award will be made to the TMT project. Coincident with this, AURA will invite letters of intent for the development of an alternate design. It is anticipated that the GMT project will be constitute a plausible alternate design effort. The second sub-award will be made based on the letters of intent received.

It is envisioned that the design and development phase of a GSMT will take 3 to 4 years to complete. The goal is to have all of the information available that will be needed to support a decision concerning the next step. This will involve a commitment to a specific design for a GSMT including aperture size, a site, scientific and technical performance goals, and a commitment to operational roles and budgets.

At that point the NSF and AURA will need to make a decision concerning further participation and a possible commitment to operate the telescope. As above, AURA's

goal in participation is to ensure that community scientific needs are met during the planning, design, construction, and operations phases.

AURA's Recent Activities and Other Developments

AURA's goal has been to effectively implement the recommendations of the Decadal Survey. The achievement of AURA's goal has been aided by actions taken by the AAAC. In its 2004 March report the AAAC stated that the ambitious science goals of JWST and of a GSMT will only be fully realized if the two facilities operate contemporaneously as demonstrated by HST and large ground based facilities over the past decade. Consistent with the objectives of AURA's proposal to NSF the AAAC called for an aggressive technology development program for GSMT in order to guarantee that it would be developed on the same timescale as JWST and that this program should ramp up in 2005 if possible, with particular support in the FY06 budget.

The AAAC requested that the GSMT SWG in collaboration with the JWST SWG prepare a report on the scientific complementarity between GSMT and JWST in order to highlight the science that would be enabled if the two telescopes were to operate in the same time frame. Draft versions of this report were presented at the 2004 June and October meetings of the AAAC. This report, with input from the JWST SWG is now complete and can be found at http://www.aura-astronomy.org/nv/GSMT_SynergyCase.pdf.

In its 2005 March report the AAAC reaffirmed its view that operation of GSMT in the JWST era would provide major scientific synergies. They also recommended that (1) NSF begin its support for the GSMT technology development program through funding the AURA proposal provided that it meets the standards set by the peer review process. And, (2) that the NSF evaluate its approach to major projects to see if incremental changes could allow it to take advantage of the opportunities provided by major levels of private funding, provided such programs meet the very high peer review standards set for major projects.

The AAAC also noted that continued dialog with the Europeans regarding their plans for an extremely large telescope could be mutually beneficial. AURA is committed to such a continuing dialogue with ESO and other countries with a view towards a potential internationally collaborative program. Such an effort could take several forms.

- A fully integrated program such as Gemini that would involve a pooling of common resources and capabilities
- A collaborative program might involve building matching telescopes in the north and south with a commitment to exchange of time.
- A coordinated program might involve building unique telescopes in the north and south with a commitment to exchange of time.

Any of these would benefit from a technology exchange program early on with possible coordination of technology development responsibilities. It is also feasible to envision a

two-stage process in which collaborators build complementary facilities initially but a more integrated effort later.

At the 2005 January AAS meeting AURA held a special session on the science potential of a GSMT, status reports on the TMT and GSMT designs, and information on how the community can contribute to the ongoing work on the design and development of a GSMT.

AURA is considering holding a community wide workshop on refining the science case for a GSMT and to discuss a range of operational issues for such a facility. These could include:

a. Meshing cultures: e.g. major private partner observing culture, combined with public observing time model.
b. Big vs. small projects - *e.g.* Hubble Key Programs, Spitzer Legacy projects.
c. PI science
d. Style of observing – queue vs. classical
e. Data pipelines
f. Data archiving – virtual observing

Appendix I

History of AURA's Involvement in the GSMT

Historical Basis for AURA's Interest and Relationship to Other Efforts

In 1998 and 1999 AURA undertook preliminary studies of the feasibility and scientific desirability of constructing a next generation large aperture ground-based telescope (http://www.aura-astronomy.org/nv/rp/1998mw.pdf and http://www.aura-astronomy.org/nv/nuprint.asp?nuid=23). This concept, called MAXAT (Maximum Aperture Telescope) envisioned the scientific case for a 30-50 m telescope that could achieve operations coincident with the Next Generation Space Telescope. These studies resulted in the finding that the scientific case for complementarity with NGST was compelling and that it was plausible to achieve the breakthroughs in adaptive optics that would enable the full capability of such a large aperture telescope. Based on this result, AURA strongly advocated consideration of such a large aperture telescope by the Astronomy and Astrophysics Survey Committee as a part of its Decadal Survey (http://www.aura-astronomy.org/nv/ppresult.asp?ppid=5).

The Decadal Survey incorporated the input of AURA as well as others in articulating as its highest priority for ground based astronomy a 30-m Giant Segmented Mirror Telescope. This would accomplish an order of magnitude increase in collecting area over any existing telescope and was envisioned as a suitable leadership initiative and goal for U.S. astronomy. The GSMT was envisioned as a segmented mirror design based on Keck technology.

Following the release of the Decadal Survey in 2000, AURA formed a New Initiatives Office in January 2001. The NIO was established as a partnership between NOAO and Gemini with the purpose of developing an initial point design for the nominal concept described in the Decadal Survey (http://www.aura-nio.noao.edu/). This point design was completed in early 2002 and made widely available through distribution of compact disks and posting on the AURA, Gemini, and NOAO websites (http://www.aura-nio.noao.edu/book/index.html).

Over this same period of time, the California Extremely Large Telescope, a partnership between Caltech and the University of California, completed its point design. It was recognized by both AURA and CELT that there were many areas of comparability and also differing strengths. These perceptions led to an ongoing exchange and series of discussions.

On June 11, 2003 AURA and the CELT Development Corporation completed negotiations and signed a Letter of Intent to work together in carrying out a design and development effort that would achieve the vision of the Decadal Survey for a Giant Segmented Mirror Telescope (Attachment 1 to Appendix I). This public-private partnership represents a historic step forward in providing for the community access to a world class observing facility.

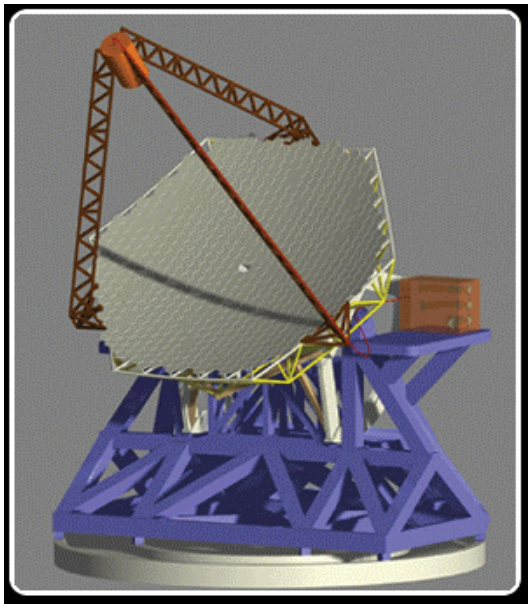
At the time of the Decadal Survey, within the US, the only other significant telescope concepts included the Cornell Atacama Telescope and a concept based on the Hobby Ebberly design. In considering all of these, the Astronomy and Astrophysics Survey Committee recommended the following:

"In addition to…OWL, there are three other programs in the early planning stages: MAXAT, a 30-50m telescope (NIO at NOAO), CELT 30-m class (Caltech & University of California), and ELT, a 25-m scale-up of the HET (Penn State & Texas). The GSMT described here corresponds closely with CELT or MAXAT. Although it is too early to judge the future direction of these projects, we believe that GSMT could evolve directly from either of these initiatives, one from the private, the other from the public sector, or from a joint project created by merging of these two."

Thus, the strongly implied path for AURA was a merger of CELT and MAXAT as a public-private partnership. AURA has worked toward that end as its highest priority while attempting to maintain an engagement with other groups.

More recently the Magellan partnership has developed a concept for a 20-meter telescope based on a technology evolved from the Large Binocular Telescope. While the technological approach and the aperture size differ from the nominal Decadal Survey concept, this remains a significant effort and constitutes the most prominent alternative to the Thirty Meter Telescope.

In order to provide a meaningful bridge between the Decadal Survey and the actual undertaking of any major investment by the NSF, in 2002, AURA established on behalf of the NSF a community based Science Working Group and charged it with developing a more specific and compelling science case that might merit NSF investment in a GSMT. Although the group was not charged with choosing



"The Giant Segmented Mirror Telescope (GSMT), a ground- based telescope with a mirror approximately 30 meters in diameter, will provide a major advance in ground-based astronomy over the world's largest optical telescopes. The GSMT will have 10 times the light-collecting area of each of the twin Keck Telescopes in Hawaii, which now rank as the world's largest, and more than 20 times the collecting area of the NGST. With its much greater mirror size, the GSMT will play the same role with respect to the NGST that the Keck Telescopes do for the Hubble Space Telescope. Technological progress should enable production of a 30-meter mirror capable of adaptive-optics readjustments at a reasonable cost."

National Research Council

between competing telescope concepts, it has addressed those pacing technologies that might be in common. The Science Working Group issued its first report in June entitled "Frontier Science enabled by a Giant Segmented Mirror Telescope" http://www.nsf-gsmt-swg.noao.edu/SWG_Report/SWG_Report_7.2.03.pdf .

In addition to CELT, AURA has maintained an active dialogue with other potential telescope groups. Of these, the AURA Board identified ESO as particularly interesting in view of their effort to develop a 100-meter Overwhelmingly Large Telescope (OWL) also based on a segmented mirror approach. In December 1999, the AURA Board adopted the following resolution:

"…the AURA Board of Directors authorizes the corporate officers to enter into discussions and negotiations with ESO to develop a partnership that will result in a joint program."

To that end the AURA Board met with ESO in September to review the progress of the respective programs and to examine the possibilities for closer collaboration. ESO stated that their current design concept would be focusing on a 60 m segmented telescope. ESO invited AURA to join in this effort.

General Principles AURA has Followed

Clearly, one feature of a public private partnership is the inherent difficulty in predicting when and to what extent private capital will become available. In formulating a general strategy for prioritizing potential paths for AURA to move forward within this uncertainty, the following principles have evolved:

- AURA priorities should reflect the nominal set of Decadal Survey priorities
- Federal investments made through AURA should benefit as much of the community as practicable
- AURA should enable the user community to have a strong voice in all phases of any program that will have a public aspect. This requires a full intellectual partnership at the outset of the program.

Consistent with the above, let no doors close (i.e. respond to opportunities as they arise, avoid precluding or forgoing participation). Although unforeseen factors will have the potential for introducing substantial changes in the landscape, the implicit priorities that have emerged thus far are CELT, OWL, and the Magellan 20 project.

AURA perceives that, although its primary obligation is to further the specific goals of the Decadal Survey for the building of a thirty meter segmented mirror design telescope through a public private partnership, an additional responsibility exists to maintain a linkage and engagement with other telescope groups including the Magellan 20 group and ESO.

Basis for a CELT AURA Partnership

From its outset, CELT has pursued avenues for private funding and has sought to capitalize on the strengths inherent in the independent observatory community. AURA,

as a public observatory, has attempted to serve the broader community of users. Initial steps towards a merger of these two efforts were taken following a series of meetings in 2002 and early 2003.

On February 25 2003, Caltech and the University of California issued a joint statement that they would form a full legal partnership to pursue the design and development of CELT and would support the engagement of AURA in the project. This announcement coincided with a meeting of the AURA Board February 27, 28. The AURA Board held a discussion aimed at identifying the next step that should be taken by the NIO and the issues surrounding the potential partnership with CELT.

With respect to the NIO effort, the point design study clearly identified certain pacing technologies that would need to be matured in order to achieve a successful and affordable and successful program. AURA's current proposal addresses the need emphasized by the Decadal Survey: **"The committee recommends that technology development for GSMT begin immediately and that construction start within the decade. Half the total cost should come from private and/or international partners."** The timeliness of the NIO proposal is directly linked to the broader goal embraced by both AURA and the Decadal Survey that the GSMT actually begin operations during the NGST (now the James Webb Space Telescope) time frame.

Major reasons cited for pursuing a partnership with CELT in particular included the following:

- The clear identification of the CELT and the NIO efforts in the Decadal Survey as logical candidates for a merger and evolution into a public private partnership.
- The desire of the AURA Board to maintain a technical path to a partnership on OWL, a comparable but larger segmented mirror telescope.
- The 2002 recompetition process for NOAO and the expectation that AURA would play a major role in implementing the initiatives of the Decadal Survey and pursuing public/private partnerships. In this regard, the Astronomy and Astrophysics Survey Committee stated the following: ***"It is expected that NOAO, restructured to fulfill the role of a strong national organization.., will play a prominent role in the development of this telescope [GSMT]. This is obviously one of the very large facilities that provides an opportunity for public/private partnering…"*** The goal of this mandate was to provide a public role during the design and development of these facilities and access to them during the operation phase.

On October 16,2003 Caltech announced the first increment of funding received for the TMT from the Moore foundation (Appendix III). The second increment to be awarded to the University of California, is expected soon.

AURA's Role in Decision Making

AURA's intent is to act in the community's interest at all phases of the program. Our primary obligation is to represent the needs of the potential user community. A

secondary, but extremely important, obligation is to support the needs of other telescope builders. At present, the community's scientific interest is best captured by the expressed scientific goals of the Decadal Survey, views from AURA's governance, and the views of the Science Working Group. This later will be evolved to act as a user committee as the immediate task of identifying a compelling science case is fulfilled. This will provide for an ongoing formal input process.

In order to ensure at the outset an avenue for directly gauging the community's views and needs, AURA has established a mechanism for a web based National Dialogue http://corporate2.aura-astronomy.org/Database/StaffQuestionnaire/CELT_Comments_Form.asp . A solicitation drawing attention to this Dialogue and soliciting input was directly sent to several hundred community leaders known to have interest (see Appendix V). Although the response has thus far not been large, it has nevertheless highlighted certain issues in need of our attention and we will ensure that these concerns are a direct input to our participation in the decision making process.

AURA has sought to achieve a structural role in the decision making process at all phases of the program in order to allow community interests to be articulated. A full, formal role in the decision making will be achieved when AURA accedes to the CELT Development Corporation, an incorporation now between Caltech and University of California formed for the purpose of carrying out the design and development effort. AURA will accede to the corporation upon the successful funding of its proposal to the NSF. The formal nature of this will evolve in the following way:

- Prior to June 11, 2003: Discussions with CELT beginning in January have developed an informal working relationship that has fully involved AURA. These primarily addressed basic principles and a general approach to future activities.
- June 11 2003 through the Proposal Period: As a result of the signing of the Letter of Intent, a TMT Board has been established together with an Interim Steering Committee for engineering decisions and a Science Advisory Committee for scientific matters. These bodies reflect the combined interests of the Thirty Meter Telescope group including CELT, AURA and ACURA. Important decisions during this time frame include selection of a Program Manager, initial work on pacing items such as site characterization, initiation of mirror polishing technologies, etc. The Program Manager, when selected, will report to this group.
- Proposal Approval through Design and Development phase: Upon approval of the AURA proposal, AURA will formally accede to the CELT Development Corporation and become a member of the CELT Development Board. AURA's participation is intended to extend to the end of the Design Development phase.

Attachment 1 to Appendix I

AGREEMENT BETWEEN
THE FOUNDING MEMBERS OF THE CELT DEVELOPMENT CORPORATION
AND
THE ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY
(June 11, 2003)

Whereas the highest priority recommendation of the U.S. Astronomy and Astrophysics Survey Committee in ground based astronomy over the next decade is an extraordinarily powerful 30 meter class Giant Segmented Mirror Telescope; and the Committee recognized that such a telescope must be undertaken by a broad partnership of public and private institutions;

Whereas the founding members of the CELT Development Corporation (hereafter CELT, comprised of the California Institute of Technology and The University of California) and Association of Universities for Research in Astronomy (hereafter AURA) through its New Initiative Office have undertaken comparable design efforts aimed at developing such a telescope; and these institutions have entered into discussions with the purpose of working more effectively to achieve complementarities in their respective efforts,

We conclude that:

(1) A formal collaboration between CELT and AURA will provide a basis for examining the feasibility of designing, building, and operating the telescope and its support facilities;

(2) CELT and AURA will seek through their respective means funding for such a project, including the submission by CELT of a proposal to the Moore Foundation and the submission of a proposal by AURA to the National Science Foundation;

(3) An interim process will be established in order to coordinate initial technical and administrative activities of the respective parties until such time as funding and necessary approvals are obtained by each party;

(4) An interim steering committee will be established that will oversee the coordination of initial activities and will work to develop a formal agreement and legal structure that will appropriately join the parties in this undertaking; and

(5) The parties to this Agreement consider that they are bound by this Agreement to work in good faith until such time as they join in a legal entity, or until such time as either party gives notice to the other that despite good faith efforts it is no longer appropriate to work toward the objective of joining together in a legal entity.

Attachment 2 to Appendix I

N E W S R E L E A S E

For Immediate Release
October 16, 2003
Images and an animation are at http://www.astro.caltech.edu/observatories/tmt/

Gordon and Betty Moore Foundation awards
$17.5 million for Thirty-Meter Telescope plans

PASADENA, Calif.--The dream of a giant optical telescope to improve our understanding of the universe and its origin has moved a step closer to reality today. The Gordon and Betty Moore Foundation awarded $17.5 million to fund a detailed design study of the Thirty-Meter Telescope (TMT). This new grant allows the California Institute of Technology and its partner, the University of California, to proceed with formulating detailed construction plans for the telescope.

An earlier, more modest, study completed in 2002 resulted in a roughed-out concept for a 30-meter-diameter optical and infrared telescope, complete with adaptive optics, which would result in images more than 12 times sharper than those of the Hubble Space Telescope. The TMT-- formerly known as the California Extremely Large Telescope--will have nine times the light-gathering ability of one of the 10-meter Keck Telescopes, which are currently the largest in the world.

"Caltech and the University of California will work in close and constant collaboration to achieve the goals of the design effort," states Richard Ellis, director of optical observatories at Caltech. "We've had promising discussions with the Association of Universities for Research in Astronomy and the Association of Canadian Universities for Research in Astronomy, both of whom are considering joining us as major collaborators. Constructing and operating a telescope of this size will be a huge undertaking requiring a large collaborative effort."

According to Ellis, the Gordon and Betty Moore Foundation's early funding will provide crucial momentum to carry the project to fruition. "The major goals of the design phase will include an extensive review and optimization of the telescope design, addressing areas of risk, for example by early testing of key components, and staffing a project office in Pasadena."

With such a telescope, astrophysicists will be able to study the earliest galaxies and the details of their formation as well as to pinpoint the processes which lead to young planetary systems around nearby stars.

"The key new capabilities promised by the Thirty Meter Telescope will include unprecedented angular resolution, necessary to resolve detail in early galaxies and forming planetary systems, and of course the huge collecting area for studying the faintest sources, which are often the most important to understand, but are beyond the reach of current facilities."" adds Chuck Steidel, professor of astronomy, who chaired a science committee charged with making the case for the proposed facility.

Following the Gordon and Betty Moore Foundation-funded design study, the final phase of the project, not yet funded, will be construction of the observatory at a yet undetermined site in Hawaii, Chile, or Mexico. The end of this phase would mark the beginning of regular astronomical observations, perhaps by 2012.

Ellis says TMT is a natural project for Caltech to undertake, given its decades of experience in constructing, operating, and conducting science with the world's largest telescopes. Before Caltech and the University of California's jointly-operated Keck Observatory went on-line in the 1990s, Caltech's 200-inch Hale Telescope at Palomar Observatory was the largest optical instrument in the world. Today, 54 years

after its first light, the Hale Telescope is still in continuous use as a major research instrument.

"This project takes Caltech's success in ground-based astronomy to the next level of ambition," Ellis says. "The TMT will also build logically on the successful demonstration of the segmented primary mirrors of the Keck telescopes, a major innovation at the time but now recognized as the only route to making a primary mirror of this size."

Caltech is currently in the process of hiring a project manager to lead the technical effort for the TMT.

The Gordon and Betty Moore Foundation was created in November 2000 with a multibillion-dollar contribution from its founders. The mission of the Foundation is to seek and develop outcome-based projects that will improve the quality of life for future generations. The majority of the Foundation's grant making concerns large-scale initiatives in four general program areas: the environment, higher education, science, and San Francisco Bay Area projects.

Contacts:

Robert Tindol
Caltech Media Relations
(626) 395-3631
tindol@caltech.edu

AURA PROPOSAL FOR DESIGN AND DEVELOPMNET OF A THIRTY METER TELESCOPE

*****SUMMARY*****

We propose to carry out the Design and Development phase (D&D Phase) of a project aimed at building and operating a Thirty-Meter Telescope (TMT) observatory. When complete, the TMT will be able to image and analyze galaxies at their birth—when the first stars formed in the universe and began the processes that resulted in the world on which we live. The TMT will provide detailed views of stars and solar systems in the process of formation, and allow direct observation of planets in orbits around other stars.

Our proposed program builds on the results of two thorough, independent feasibility studies, one undertaken by the University of California and Caltech, and the other by AURA's New Initiatives Office (NIO). Each study represents two years of effort at a cost of $2M. Both assessed the technical feasibility of a 30-m segmented mirror telescope and its key subsystems, and estimated their capital cost. Although each study identified areas of technical complexity and areas requiring advances in technology, the two studies came to the same conclusion: A TMT observatory can be built for a cost consistent with that recommended by the NRC decadal survey and on a schedule to begin operations early in the James Webb Space Telescope (JWST) era—thereby satisfying the decadal survey's highest recommendation for ground-based astronomy.

The proposed D&D Phase will use the results of the two feasibility studies as the starting point to define the TMT system architecture. Key areas of technical, cost, and schedule risk will be addressed in order to advance technologies crucial to enabling the TMT and its instruments and to develop a preliminary design. In accomplishing D&D Phase objectives, we propose to combine in a public-private partnership the talent and experience embodied in the institutions responsible for designing and building the four largest telescopes in the United States. We plan to do this by assembling an integrated, co-located project team led by a strong project manager and project scientist who will be charged by the TMT board of directors to

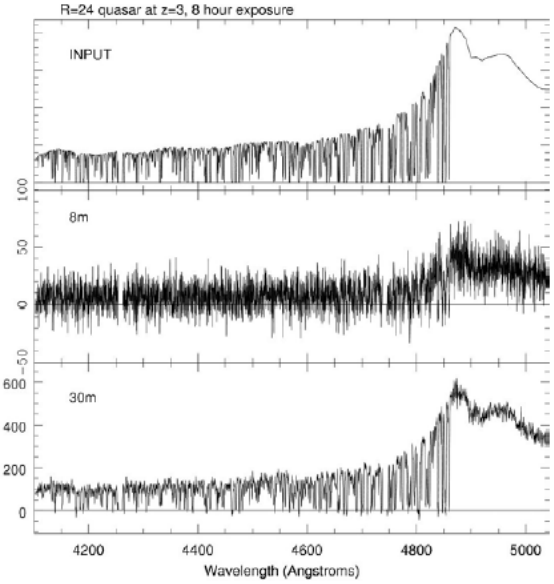


Figure 2. A plot depicting a simulation of the "forest" of hydrogen and metal absorption lines as they might appear observed against the spectrum of a faint quasar (top). The middle spectrum reveals the best result we could expect for today's 8–10-m diameter telescopes, even with an all-night exposure. The bottom spectrum illustrates the potential of the TMT to deliver spectra capable of analyzing these absorption features and deducing the distribution, chemical composition, and motions of intergalactic gas. To gather the million-galaxy sample capable of providing a tomographic map of the intergalactic medium will require nearly two full years of observation, even with the TMT. *Simulation courtesy: J. Bechtold (U. Arizona).*

follow a design-to-life cycle cost philosophy and management principles appropriate to a project of ultimate cost approaching $700M.

Completing the D&D Phase will require $70M. The funds ($35M) requested here from the NSF represent the public half of the total needed to complete the D&D Phase. We propose to invest these federal dollars in multiple programs to advance key technologies—detectors, durable coatings, adaptive optics components, and large format gratings—that are essential to meeting D&D Phase objectives and that are of significant benefit to existing large telescopes and other ongoing programs to explore next-generation telescope concepts. We plan to engage the community broadly in the technology development program via solicitations open to all community groups.

NSF investment now will ensure: (1) a strong community voice in shaping the design and operating modes of this flagship facility, (2) public access to the TMT in proportion to the invested funds, and (3) the completion of a facility available to the US community early in the JWST era.

Because the TMT has the power to address questions that engage the imagination of the public as well as scientists, it offers a superb platform from which to stage and develop educational and public outreach activities. We propose a science education plan that links with both the exciting science that can be done with the TMT and the technology and engineering critical to this stage of the project. Our proposed activities emphasize national educational needs in Science, Technology, Engineering, and Math (STEM) education, use strategic educational partnerships to address these needs, and rely on educational innovation that builds solidly on the broad experience of our partners.

Our proposal takes a major step toward meeting the goal set by the decadal survey: to build a GSMT (TMT) that will be ready early in the JWST era and to do so by combining federal and private resources. As such, it offers a historical opportunity to the NSF: to shape the direction of US astronomy in the 21st century by ensuring that the best minds in the community are engaged in developing the TMT design and making use of it a decade from now.

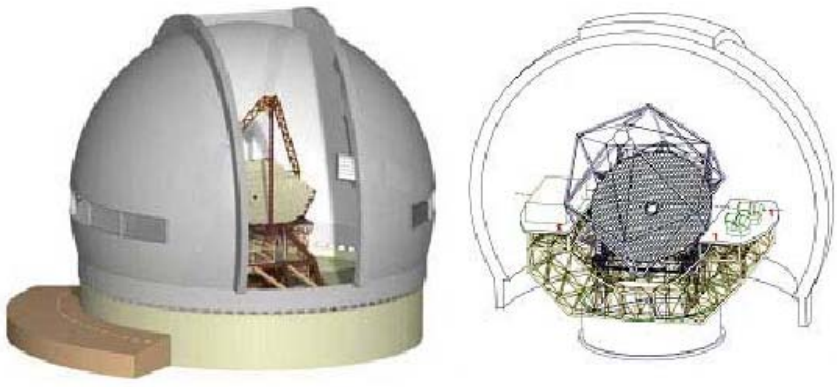


Figure 2. The GSMT point design (left) and the CELT point design (right).