

Addendum to the Adaptive Optics Roadmap

Background

Since the national adaptive optics community drafted the initial Adaptive Optics Roadmap in 2000, there has been significant technical achievement in developing:

- operational natural guide star AO systems on large telescopes
- certain key AO components (e.g. high power lasers; large deformable mirrors)
- sophisticated simulation tools capable of predicting the performance of complex AO systems
- new tools for assessing the atmospheric conditions that drive AO system performance at current and potential observatory sites
- new systems concepts, particularly for AO on future extremely large telescopes

In response to the recommendations of the participants in the first road-mapping exercise, NSF has now funded the Adaptive Optics Development Program (AODP). The first AODP Announcement of Opportunity, issued by NOAO, solicited an abundance of relevant and technically excellent proposals. Following review by an external panel of senior engineers, managers, and astronomers, initial awards were made in support of one analytical program and five component development programs spanning lasers, small deformable mirrors, and high-speed, low-noise wavefront sensor detectors.

In parallel, major design efforts for next generation optical/infrared telescopes have begun in both in North America and Europe. In that context, multiple consortia (e.g. the Giant Magellan Telescope, Thirty Meter Telescope, OWL, Euro-50) are beginning to make significant investments in the design of adaptive optics systems required to achieve the full scientific potential of Extremely Large Telescopes, as well as in the design and development of the necessary AO components, and in the planning and execution of laboratory and on-telescope experiments to validate new system concepts.

In light of the above, NOAO convened on April 26 and 27, 2004 (1) a meeting involving scientists and engineers drawn from groups and key individuals involved with AO development in the US, Canada and Europe: CAAO, CfAO, ESO, HIA, GMT, TMT, Keck Observatory, Steward Observatory; and (2) a meeting of an Adaptive Optics Steering Committee, comprising a broadly representative group of AO experts charged with recommending updates to the published roadmap and priorities for the Announcement of Opportunity for the AODP. Participants in the first meeting are listed in Table 1; members of the AO Steering Committee are indicated with asterisks.

Table 1: Participants in the 26 April Review of AO-related Activities

Sean Adkins – Keck Observatory
Roger Angel – Steward Observatory
Jacques Beckers – University of Chicago

Laird Close * – Steward Observatory
John Codova – University of Arizona
Richard Dekany* - Caltech
Brent Ellerbroek* - NOAO
Paul Hillman – Kirtland AFB
Matt Johns – OCIW
Edward Kibblewhite * - University of Chicago
Robert Johnson * - Kirtland AFB
Michael Lloyd-Hart – University of Arizona
Claire Max – LLNL, UCSC-CfAO
Bruce McIntosh * - LLNL
Ken Mighell – NOAO
Guy Monnet * - ESO
Thomas Rimmele – NSO
Gary Sanders – Caltech
Paul Schechter * – MIT
Andrei Tokivinen * - NOAO
Mark Trueblood – NOAO
Peter Wizinowich* – Keck Observatory

Recommendations of the AO Steering Committee

Overview

The following represent the unanimous opinion of the Adaptive Optics Steering Committee:

- (1) We strongly reaffirm our support for the AO Roadmap process and recognize the significant efforts within NSF that have enabled the initiation of the AODP.
- (2) We reaffirm the initial AO Roadmap as a sound description of decadal needs, but note the development of important new systems concepts since our initial planning in 2000. Furthermore, with the maturing of the design phases of multiple ELT programs, and there has been significant technical progress and new opportunities for collaboration.
- (3) In light of these developments, we hereby update the Roadmap to reflect the importance in understanding the feasibility of key new systems concepts, and to thus recommend altering the balance between component development and system concept verification.

Specific Recommendations for Investment

The AODP Steering Committee noted that the current AODP funding level is not sufficient to sponsor major investment in both AO component technology and in engineered systems or implementations.

Given current constraints, the Adaptive Optics Steering Committee recommends that *in priority order* the next Adaptive Optics Development Program solicitation should emphasize:

(1) Concept validation by laboratory and on-telescope testing of AO systems critical to current design efforts, along with the associated technologies needed to fully implement such systems. In arbitrary order, the systems and technologies that the Steering Committee believes merit further study and AODP investment include:

- Ground Layer Adaptive Optics (GLAO) – with example investment areas including extensive atmospheric measurements of ground layer contributions both at extant sites and candidate sites for ELTs
- Multi-conjugate Adaptive Optics (MCAO) -- with example investment areas including study of competitive tomographic reconstruction techniques and low-order natural guide stars wavefront sensors (NGS WFS)
- Multi-Object Adaptive Optics (MOAO) - with example investment areas including study of the efficacy of open loop tomography, low-order NGS WFS, and the development of hi-actuator count MEMS
- Extreme Adaptive Optics AO (ExAO)– with example investment areas including high actuator count MEMS, coronagraphic nullers for moderately- to massively segmented pupil ELTs
- Optically powered deformable mirrors – with example investment areas including large deformable secondary and tertiary mirrors
- New wavefront sensor concepts – with example investment areas including design and testing of pyramid sensors, highly linear and large dynamic range Shack-Hartmann sensors, and interferometric approaches

The AO Steering Committee strongly believes that investment in these and associated areas will accelerate the assessment of performance, cost and risk of systems and technologies judged to be critical to ELT design choices and to the design and construction of first light instruments for ELTs.

(2) Innovative small/low-cost and/or risky developments with potential high leverage

(3) Engineered components or subsystems necessary for the next generation of AO system

Other comments by and recommendations of the AO Steering Committee

In the course of plenary meeting on April 26 and the Adaptive Optics Steering Committee meeting on April 27, the following issues were noted, along with recommended actions.

- (1) There is a serious shortage of engineers and astronomers with appropriate background in AO system development, laboratory work, or carrying out frontier

- science with current generation AO systems. The AODP announcement of opportunity should explicitly mention the value of student training, and encourage integration of astronomy and engineering students into AO system simulation and design work. Evaluation of AODP proposals should consider student training as one metric, with weight carefully adjusted to encourage the desired outcome, without unduly disadvantaging proposals from the private sector.
- (2) A series of technical working meetings in support of national and international collaboration - perhaps planned as a series of retreats organized around specific topics (e.g. GLAO systems; alternate wavefront sensing techniques) of mutual interest - would be valuable.
 - (3) Current and pending detector and laser development programs sponsored by the DoD offer an opportunity for coordination with the astronomy community. The Adaptive Optics Steering Committee should meet several times per year via telecon to review ongoing opportunities in this and other areas, and engage the NSF Program Officer responsible for AODP in discussions with appropriate DoD personnel.
 - (4) When options for implementation programs are announced, the AODP announcement of opportunity should clarify the requirements for in-kind provision of community telescope time. In-kind access should only be required for implementation programs which provide a new facility of significant scientific utility, and not for prototype demonstrations and experiments.
 - (5) The Roadmap should henceforth be reviewed annually and updated as necessary
 - (6) The structure and accomplishments of the AODP should be reviewed periodically in order to assess responsiveness to the community, the efficacy and fairness of review procedures, and the returns on NSF investment.