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**Final Report for AFOSR Award FA9550-05-1-0347
“Consortium for Adaptive Optics and Image Post-Processing”**

P.I. Joseph Janni

Consultant, Maui Economic Development Board
Resident Scientist, AMOS, Universal Technology Corporation

Co-P.I. Stuart Jefferies

Institute for Astronomy, University of Hawaii

Abstract

This was an unusual grant in that it's purpose was to improve ongoing basic research and make it more efficient and effective, rather than to actually sponsor research itself. We are pleased to report that this was being achieved. Activity under this grant is resulting in more effective adaptive optics and image post-processing basic research for the Air Force. In particular, it is enabling cross-organizational communication to a larger extent than had been previously underway, and it has fostered hundreds of interactions that would not have occurred otherwise. It is also strengthening the collegial interchanges and scientific cooperation between Air Force Research Laboratory (AFRL) in-house researchers, on-site contractors, university scientists, and industry (primarily small businesses).

The scientific interactions, information exchanges, and workshops facilitated by this award have produced the following tangible benefits: (1) the implementation of a hyperfine structure Sodium guidestar at the Air Force Advanced Electro-optical Telescope (AEOS) is underway using information transfer begun under this grant, (2) the overall utilization of four DURIP laboratory grants has been increased, (3) the Maui Community College is changing their curriculum to emphasize photonics and adaptive optics, (4) the AEOS visible light Strehl ratio has nearly doubled with part of the credit going to information exchange provided by this grant, and (5) advanced information from the Center for Adaptive Optics has been obtained and applied because of direct participation in workshops and seminars.

The organizations either partially or fully sponsored by this grant are delineated. The dates and purpose of all meetings, workshops, and information exchanges are provided.

Grant Rationale

Many organizations are conducting research on adaptive optics and image post-processing. With a modest infusion of additional funding specifically to foster collegiality, cooperation, and information interchanges, these efforts became more synergistic. Most of the organizations were not funded to achieve this goal; they were funded explicitly to conduct specific research. This grant removed a serious limitation by providing funds for the direct purpose of enhancing cooperation and communication by establishing a virtual consortium for adaptive optics and image post-processing to the benefit of the Air Force.

This grant was being used to enable collegial interchanges between researchers by providing travel and per diem funding primarily for academia and industry with an additional emphasis on small rather than large businesses. Salaries of individuals were not reimbursed under this grant. Government personnel did not receive any funds under this grant.

In some cases the two Principal Investigators (PIs) of this grant have been able to sponsor meetings and bring adaptive optics and imaging scientists together with little expenditure of grant funds, thereby producing additional leverage. The fact that the two PIs have been encouraged to perform this role by the Air Force Office of Scientific Research and are willing to lead these activities, organize them, and arrange informal scientific exchanges, seems to be providing enough encouragement to the community to obtain their cooperation even though all participants are not being funded. The added incentive that some scientists who could not otherwise participate now can be funded to do so has been quite influential.

General Organizational Information

The approach of this report is to provide a summary of the collaborative activities fostered or enabled by this grant, and then to list all of the participants that benefited either directly or indirectly who were in a relevant meeting, workshop, seminar, or other information exchange. All of the following organizations, and some others not mentioned in this section, have benefited directly from this grant. The organizations listed by the names of the participants illustrate that point.

Optical space surveillance research in the Directed Energy Directorate of the Air Force Research Laboratory is conducted primarily at two locations, (1) the Starfire Optical Range on Kirtland AFB and (2) the Advanced Electro-Optical System (AEOS) at Detachment 15 on Maui. This grant has been used to send small business scientists to work in the disciplines of adaptive optics and imaging, primarily but not exclusively, from Maui to the Center for Adaptive Optics, Steward Observatory, and Kirtland AFB for introductory exchanges. It is important to note that none of the Maui scientists on the first trip sponsored under this grant had ever been to the Starfire Optical Range. This trip

and the subsequent face-to-face meetings and communication were educational for all participants.

Each organization met their counterparts in the other organization. This was the beginning of meaningful communication, which has already paid dividends in the adaptive optics and guidestar upgrades now underway at Detachment 15 on Maui.

This grant also sponsored the same people mentioned in the prior two paragraphs to go to the University of Arizona (a premier optics university) and the Steward Observatory's MMT telescope (6.5 meter primary mirror) outside of Tucson where a bold new type of adaptive optics had just been installed. This travel and the related information exchange would not have been possible without this grant.

A considerable amount of research into adaptive optics is sponsored by the National Science Foundation primarily through their Center for Adaptive Optics at the University of California in Santa Cruz. This AFOSR grant has been used to send many scientists to their advanced summer schools as well as to their workshops. Lectures, and formal as well as informal educational opportunities are provided at these meetings. The sponsored scientists could not have attended without funding support from this AFOSR grant. A great deal of intellectual exchange occurred at these workshops and meetings. Beneficial results are already being applied to the Air Force AEOS 3.5 meter telescope atop Mount Haleakala on Maui.

The University of Hawaii Institute for Astronomy is working on four DURIP grants intended for experimental research into adaptive optics and imaging. A large new building is under construction on Maui that is scheduled for completion in February, 2007. At that time a special DURIP laboratory called the Space Surveillance Simulator (S-Cube) will have been completed and populated with instrumentation and equipment paid for by these four grants. Although these DURIP facilities are available now in temporary quarters, this new first-rate laboratory will be made available for research to personnel both in Hawaii and the mainland. As a result of initial discussions, scientists from the Center for Adaptive Optics have offered to travel to Maui to provide their extensive expertise and to help the Institute for Astronomy to establish this new laboratory. The enabler is that their travel expenses would be paid by this grant. Coordination for this has begun.

The University of Hawaii's Maui campus at the Maui Community College is developing a new laboratory curriculum in electrical engineering emphasizing adaptive optics, as well as being a key participant in the Maui technology student, intern, and education programs that support Air Force activities on Maui. They have participated in many meetings relevant to adaptive optics since this grant was awarded; none of their participation would have happened without sponsorship from this grant.

Grant Initiation and Kickoff Workshops

Two workshops were held on the overall subject of adaptive optics and post-processing teamwork late in CY2004. The goal was to initiate scientific interchanges between a large number of scientists who were working on adaptive optics and image postprocessing. The first meeting was on Maui (17 September, 2004) and the second was at the Center for Adaptive Optics (17 November, 2004) at the University of California in Santa Cruz. Many researchers working in the adaptive optics field were at one or the other of these meetings. The subject of teamwork was discussed. A vote was taken at each meeting and it was universally agreed by all present, with no nay votes, that a consortium of the type being implemented in this grant did not already exist, was needed, and would be very beneficial. With this kind of strong community advocacy, the PIs prepared the grant proposal, submitted it, and AFOSR made the award.

Background of The First Kickoff Meeting (17 September, 2004)

The following people participated in the Maui meeting that provided the initial impetus. Every person who was invited attended, without exception. That outstanding attendance is an indication of the interest the proposed approach generated. It was at this first meeting that all participants strongly recommended that a grant of this type be implemented.

Jack Agee, Air Force Office of Scientific Research
Morris Aizenman, National Science Foundation
Malika Moutawakkil Bell, Center for Adaptive Optics
Lawrence Bradford, Boeing LTS
David Brady, Duke University
David Byers, Air Force Office of Scientific Research
Ranier Dressler, Air Force Research Laboratory, Space Vehicles Directorate
Fariba Fahroo, Air Force Office of Scientific Research
Judy Fennelly, Air Force Research Laboratory, Space Vehicles Directorate
Robert Fugate, then at the Starfire Optical Range, now at New Mexico Tech.
Maile Giffin, Oceanit Maui
Connie Giuliano, Air Force Research Laboratory, Directed Energy Directorate
Doyle Hall, Boeing LTS
Mark Hoffman, University of Hawaii Maui Community College
Rusty Hughes, then at Trex Maui
Lisa Hunter, Center for Adaptive Optics
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Stuart Jefferies, now at the University of Hawaii Institute for Astronomy
Paul Kervin, Air Force Maui Optical and Supercomputing Site
Jeff Kuhn, University of Hawaii Institute for Astronomy
Joseph Liu, Air Force Space Command
Mike Maberry, University of Hawaii Institute for Astronomy

Charles Matson, Air Force Research Laboratory, Directed Energy Directorate
Kent Miller, Air Force Office of Scientific Research
Dan O’Connell, then at Oceanit Maui, now at Trex Maui
Scot Olivier, Lawrence Livermore National Laboratory
John Pye, University of Hawaii Maui Community College
Sergio Restaino, Naval Research Laboratory
Clifford Rhoades, Air Force Office of Scientific Research
Joseph Ritter, now at the University of Hawaii Institute for Astronomy
Lewis Roberts, Boeing LTS,
Mike Roggemann, Michigan Tech University
Paul Sidney, Boeing LTS

Background of The Second Kickoff Meeting (17 November, 2004)

The following scientists spoke at the second kickoff meeting, which was held as part of the Center for Adaptive Optics strategic planning activities. All of the following scientists publicly advocated pursuing this grant. Those who spoke are named below, but the much larger group of over 100 scientists were present and were unanimous in advocating the virtual consortium approach providing even greater impetus to initiate a grant of this type.

Kevin Baker, Lawrence Livermore National Laboratory
Colin Bradley, University of Victoria
Robert Fugate, then at the Starfire Optical Range, now at New Mexico Tech.
Don Gavel, University of California at Santa Cruz
Joseph Green, Jet Propulsion Laboratory
Norbert Hubin, European Southern Observatory
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Claire Max, Director of the Center for Adaptive Optics
Scot Olivier, Lawrence Livermore National Laboratory
Over 100 members attending the Center for Adaptive Optics strategic planning activities

Workshop at the Air Force Maui Optical and Supercomputing Site (10 September 2005) on The Adaptive Optics Bench Laboratory

The adaptive optics bench laboratory is located in Kula, Maui, and is called “The Space Surveillance Simulator” (S-Cube). S-Cube is designed to simulate both the atmospheric imaging environment above Mount Haleakala and the Maui Space Surveillance Site (MSSS) adaptive optics design, as well as eventually be useful for the proposed Advanced Technology Solar Telescope. By providing a realistic test bed for new methods and technologies, the S-Cube provides a means to accelerate the transition of new ideas into operational assets. In addition to its role as a research tool, the S-Cube also serves as an instructional tool for the education of undergraduate and graduate students and postdoctoral fellows in research topics directly relevant to the mission of the

Maui Space Surveillance Site. The new University of Hawaii Institute for Astronomy Advanced Technology Research Center will house the S-Cube in a state-of-the-art facility. Construction is planned for completion at the end of this February.

A workshop to introduce a large number of adaptive optics scientists to the S-Cube was held in September, 2005. It began at 0745 hours and finished shortly after 1000 hours. Introductions were made by Joseph Janni, followed by Maile Giffin who summarized the suite of equipment in the DURIP laboratory. Dan O'Connell then discussed near term goals. Stuart Jefferies discussed the laboratory vision and the ties to the AFOSR Partnership for Research Excellence and Transition (PRET) for adaptive optics and image post-processing. Dennis Douglas gave the bench laboratory tours. This was the first time that the S-Cube had been shown to a large group of scientists. Collaboration discussions followed. The following people all participated.

Detailed information on the utility and subsequent activities underway in the S-Cube can be found in the annual report for AFOSR award FA9550-05-1-0245 "Upgrade for Space Surveillance Simulator" recently submitted.

Morris Aizenman, National Science Foundation
Jack Agee, Air Force Office of Scientific Research
David Byers, Air Force Office of Scientific Research
Julian Christou, University of California Santa Cruz, Center for Adaptive Optics
Craig Denman, Starfire Optical Range
Daren Dillon, University of California at Santa Cruz
Dennis Douglas, then at Oceanit Maui, now at Trex Maui
Mike Flanagan, Trex Maui
Bob Fugate, then at the Starfire Optical Range, now at New Mexico Tech.
Don Gavel, University of California at Santa Cruz
Maile Giffin, then at Oceanit Maui
Keith Hege, University of Arizona Tucson
Sharon Heise, Air Force Office of Scientific Research
Mark Hoffman, University of Hawaii Maui Community College
Rusty Hughes, then at Trex Maui
Lisa Hunter, University of California Santa Cruz, Center for Adaptive Optics
Joseph Janni, AF Maui Optical and Supercomputing Site, Universal Technology
Stuart Jefferies, now at the University of Hawaii Institute for Astronomy
Steve Keil, National Solar Observatory
Paul Kervin, Air Force Maui Optical and Supercomputing Site
Curt Leonard, Oceanit Maui
Michael Lloyd-Hart, University of Arizona, Steward Observatory
Mike Maberry, University of Hawaii Institute for Astronomy
Kent Miller, Air Force Office of Scientific Research
Dan O'Connell, then at Oceanit Maui
Scot Olivier, Lawrence Livermore National Laboratory
John Pye, University of Hawaii Maui Community College
Sergio Restaino, Naval Research Laboratory

Cliff Rhoades, Air Force Office of Scientific Research
Thomas Rimmele, National Solar Observatory
Mike Roggemann, Michigan Tech University
Benjamin Wheeler, Trex Maui

Interactions with the Starfire Optical Range (14 December, 2005)

None of the Maui scientists or engineers working on adaptive optics had ever been to the Starfire Optical Range before this visit. The itinerary at the Starfire Optical Range included high-speed, low-noise detectors, modular deformable mirrors, self-referencing interferometer development, Sodium laser progress with preliminary data, and tours of the deformable mirror laboratory and the closed loop test bed. A nighttime guidestar demonstration was also provided. Discussions between participants followed that led to increased cooperation between the two organization. Specifically, the Sodium Guidestar being developed and demonstrated at the Starfire Optical Range is now planned for full implementation on AEOS at Haleakala.

Lawrence Bradford, Boeing LTS
James Brozik, University of New Mexico
Dennis Douglas, then at Oceanit Maui, now at Trex Maui
David Byers, Air Force Office of Scientific Research
Terry Duncan, Starfire Optical Range
Craig Denman, Starfire Optical range
Rob Eager, Boeing LTS
Mark Eickhoff, Boeing LTS
Brent Ellerbroek, California Institute of technology, Thirty Meter Telescope Project
Mike Flanagan, Trex Maui
Robert Fugate, then at the Starfire Optical Range, now at New Mexico Tech
Troy Rhaodarmer, Boeing LTS
Mark Hoffman, University of Hawaii Maui Community College
Rusty Hughes, Trex Maui
Allen Hunter, Trex Maui
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Benjamin Karlow, Starfire Optical Range
Keith Knox, Boeing LTS
Curt Leonard, Oceanit Maui
Scott Newby, Boeing LTS
Scot Olivier, Lawrence Livermore National Laboratory
John Pye, University of Hawaii, Maui Community College
Troy Rhaodarmer, Boeing LTS
Joseph Ritter, now at the University of Hawaii Institute for Astronomy
Scott Schroer, Air Force Maui Optical and Supercomputing Site
Jim Spinhirne, Boeing LTS
Benjamin Wheeler, Trex Maui
John Wynia, Boeing LTS

Interactions with the University of Arizona and the Steward Observatory (15 December, 2005)

The Large Telescope Mirror laboratory underneath the stadium at the University of Arizona in Tucson hosted members of the consortium, followed the next day by a tour of the Steward Observatory on Mt. Hopkins where a bold new type of adaptive optics is located at the second mirror position in the telescope spider (first secondary).

Roger Angel described work in progress on very large primary mirrors and showed some of the world's biggest low-weight high-stiffness honeycomb mirrors for astronomical telescopes. University of Arizona activities in imaging and adaptive optics were discussed.

The University of Arizona (Lloyd-Hart et al.) is working closely with the University of Hawaii (Jefferies & Hope) on the analysis and interpretation of imagery of geostationary satellites. This work has captured the attention of Space Command (Liu) who has requested an expanded study of the limits for detection of small faint objects in the vicinity of communications satellites in geostationary orbits. The University of Arizona will obtain new adaptive-optics compensated imagery of various geosynchronous satellites in January of 2007. These data will be post-processed for atmospheric correction and image enhancement in collaboration with the University of Hawaii team. Direct benefits to the Air Force are envisioned.

Lawrence Bradford, Boeing LTS

Dennis Douglas, then at Oceanit Maui, now at Trex Maui

Brent Ellerbroek, California Institute of technology, Thirty Meter Telescope Project

Mike Flanagan, Trex Maui

Mark Hoffman, University of Hawaii Maui Community College

Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology

Benjamin Karlow, Starfire Optical Range

Keith Knox, Boeing LTS

Curt Leonard, Oceanit Maui

Michael Lloyd-Hart, University of Arizona, Steward Observatory

Scot Olivier, Lawrence Livermore National Laboratory

John Pye, University of Hawaii Maui Community College

Joseph Ritter, now at the University of Hawaii Institute for Astronomy

Scott Schroer, Air Force Maui Optical and Supercomputing Site

Benjamin Wheeler, Trex Maui

Center for Adaptive Optics Spring Workshop (27 March, 2006)

Information obtained from participation in this workshop was the pivotal element in the Electrical Engineering Department of the Maui Community College reorienting their Electrical Engineering curriculum by introducing adaptive optics. This grant enabled the initial meeting and information exchange that resulted in the Maui College now having an adaptive optics laboratory simulator based on a design by the Center for Adaptive Optics. This occurred because both organizations worked together. They started with the original bench demonstrator, made improvements, and implemented a laboratory simulator at the Maui Community College.

This provides a new approach for Maui technical graduates, many of whom have been hired by the Maui technology community. Participants from Maui are given below. Quite a few others from the Center for Adaptive Optics were involved.

Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Dennis Douglas, Trex Maui
Mark Hoffman, University of Hawaii Maui Community College
Mike Flanagan, Trex Maui
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Benjamin Wheeler, Trex Maui
Personnel from the Center for Adaptive Optics Contributed

DURIP Maui Adaptive Optics Laboratory (S-Cube), Kula Setup Meeting (26 April, 2006)

During 2006 there was an unexpected change in the Principal Investigator and both Co-Investigators on the S-Cube grant because they changed employers. As a result, the S-Cube equipment was relocated from the Oceanit offices in Kihei, Maui, to the University of Hawaii, Institute for Astronomy's buildings in Kula, Maui. The move also caused a change in the scientists directly involved in the simulator as well as a change in direction.

The Principal Investigator's move from the University of New Mexico to the University of Hawaii has provided the possibility of consolidating the equipment from four DURIP awards. Once construction is completed on the University of Hawaii's Advanced Technology Center in Pukalani, Maui, the equipment from all four awards will be consolidated into a single, state-of-the-art optics laboratory for research and education in topics directly relevant to the mission of the MSSS. The completion date is scheduled to be the end of this February.

Here is the list of people who were briefed at the temporary laboratory in Kula shortly after it was moved from the Oceanit facility. For a list of activities that subsequently took place in the S-Cube laboratory please refer to Table 1 on the next page.

Chip Beckner, Air Force Research Laboratory

Bill Bradford, Boeing LTS

Mike Flanagan, Trex Maui

Douglas Hope, then at the University of New Mexico, now at the Institute for Astronomy

Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology

Jeff Kuhn, University of Hawaii, Institute for Astronomy

Amy Magnus, Air Force Office of Scientific Research

Kent Miller, Air Force Office of Scientific Research

Mara Payne, Boeing LTS

Joseph Ritter, University of Hawaii, Institute for Astronomy

Lewis Roberts, Boeing LTS

Benjamin Wheeler, Trex Maui

The overall level of activity was limited by several months of down time due to the relocation and re-establishment of instrumentation, as well as the loss of Oceanit manpower. We expect a significant increase in the use of S-Cube once it is transferred to the new Advanced Technology Center (in February 2007).

Table 1
Some of the activities performed using the S-Cube in the past twelve months

Category	Project	Affiliation & PI	Comments
<i>Research: Adapt Opt</i>	Testing Hokupa'a DM for Gemini	University of Hawai'i	Piezo DM actuation anomaly characterization
	Calibration of AEOS DM system	TREX	SLM used to calibrate system at AEOS
	Laser guide star developments	GEMINI Observatory	Optics development
	Polymer DM test	Triton/IFA	AFOSR Phase II SBIR
	Photoactive polymer coupon tests	IFA	NASA Institute for Advanced Concepts Phase I study
<i>Research: Other</i>	Rebuild Computed Tomography Imaging Spectrometer	University of Arizona (Hege)	Also testing using spectrograph and integrating sphere
	Filter characterization	University of Hawai'i	Multiple instruments
	Testing of silicon carbide samples	TREX	Lightweight SiC mirror coupon tests
	Panoramic imaging mirror tests	IFA	ONR/NUWC funded Hawaii Undersea Vehicle Panoramic IR imaging system
	Fluorescence and absorption spectroscopy of Silicon nanoparticles	University of Illinois/University of Hawai'i	Filmed for public television. Ongoing talks with NASA Langley and KSC NDE for testing nanoparticle tile (TPS) and foam crack detection system for Shuttle and CEV programs.
<i>Optical Metrology</i>	Optical surfaces characterization	University of Hawai'i (Jefferies)	NSF-funded solar instrument
	Optical surfaces characterization	GEMINI Observatory	Prototype DM figure tests
	Optical surfaces characterization	Hv Photonics	Local optics small business
<i>Education</i>	Filter and SiC sample tests	CFAO/TREX	Summer intern use

Abbreviations: DM (Deformable mirror), TPS (Thermal Protection System), KSC (Kennedy Space Center), NDE (Non Destructive Evaluation group), CEV (Crew Exploration Vehicle), NSF (National Science Foundation).

AEOS Adaptive Optics Upgrades Recommendations (5 April, 2006)

Ben Oppenheimer is an AEOS visiting experimenter who is an adaptive optics expert with a joint grant from the AFOSR and the NSF to use the AEOS adaptive optics system to try and image exosolar planets. This process requires “extreme adaptive optics” because extraordinarily high-contrast imaging is needed in order to distinguish a dim planet surrounding a star. Contrasts well beyond 10^6 are required. Only a high-order adaptive optics system can achieve such contrasts. There will be tangible benefits to other Air Force projects if this can be achieved.

In using AEOS extensively he garnered a exceptional insights into the adaptive optics system. He was funded by this grant to return to Maui specifically to convey his insights and recommendations to the site. His recommendations were independent, thorough, and well founded. They included specific recommendations regarding the performance of the deformable mirror, the guard ring surrounding the mirror, the tip/tilt system, improved resolution, the wave-front sensor, primary mirror actuators, and more.

This information was very valuable, has been assessed, and is being used in the major upgrade to the AEOS adaptive optics system that is now underway. One major result of the upgrade so far that has already been achieved is a doubling of the visible light Strehl at AEOS. Although several others were involved, four of the key people are listed below.

Ben Oppenheimer, American Museum of Natural History, Lyot Project
Jim Riker, Air Force Maui Optical and Supercomputing Site
Lewis Roberts, Boeing LTS
Benjamin Wheeler, Trex Maui
Michael Flanagan, Trex Maui

Center for Adaptive Optics Summer School (9 August, 2006)

The Center for Adaptive Optics Summer School is a professional training workshop on adaptive optics. It covers the concepts, specifics, and design of adaptive optics systems. The topics included wavefront sensing, beam compensation, wavefront reconstruction, control system algorithms, different types of adaptive optics systems, related image processing techniques, and laboratory and computer demonstrations. It is the premier educational vehicle for advanced training in adaptive optics.

Rita Cognion, Oceanit Maui
William Demeo, Textron Maui
Dennis Douglas, Trex Maui
Mark Hoffman, University of Hawaii Maui Community College
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Alistair Knox, Oceanit Maui
Harvey Motomura, University of Hawaii Community College (on the Big Island)
Many members of the Center for Adaptive Optics

Briefings to the National Science Foundation and the Air Force Office of Scientific Research (31 August, 2006)

The educational outreach program sponsors undergraduate students, graduate students, summer intern positions, and more, with benefits to the field of adaptive optics. Our Maui education and outreach team met on 31 August, 2006, in Arlington. During that meeting we briefed the National Science Foundation on our five-year proposal for future work beginning in FY08. A major theme of this proposal is to train Maui students in the subject of adaptive optics. In addition to NSF funding, we requested \$125K per year of education and outreach funds from AFOSR over a five-year period. We submitted our proposal with the suggestion that the NSF evaluation and peer review process be used. We all felt that NSF would be the appropriate contracting/granting agency. It is a unified proposal, involving Maui organizations working in collaboration using the expertise and past accomplishments of each organization. The partnering organizations are: The Center for Adaptive Optics, The University of Hawaii Maui Community College, AFRL Detachment 15, and the Maui Economic Development Board. The NSF calls this funding approach a "collaborative research" proposal to differentiate it from an award/subaward arrangement. It is related to AFOSR Award FA9550-05-1-0347 because it broadens the base for adaptive optics on Maui.

Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Mark Hoffman, University of Hawaii Maui Community College
Leslie Wilkins, Maui Economic Development Board (Grant Administrator)
Lisa Hunter, University of California Santa Cruz, Center for Adaptive Optics
Jeff Kuhn, University of Hawaii, Institute for Astronomy
Mike Maberry, University of Hawaii, Institute for Astronomy
Including 15 scientists from the NSF and three from AFOSR

Interaction with Adaptive Optics Scientists of The Advanced Technology Solar Telescope (ATST) (18 October, 2006)

The science working group of the Advanced Technology Solar Telescope met for a week on Maui, providing an opportunity for their adaptive optics experts to meet with those from AEOS. A meeting was set up. This meeting was held to introduce the adaptive optics designers of the ATST to the AEOS experts on Maui. This was the first meeting between these scientists. Each group (AEOS, Trex, IfA, NSO) summarized their research activities and then discussed in reasonable detail their approach and design issues. This marks the first time that serious cross organizational communication on a technical level took place between these scientists on the subject of the ATST.

James Campbell, Trex Hawaii
Dennis Douglas, Trex Hawaii
Mike Flanagan, Trex Hawaii
Rao Gudimetla, Air Force Maui Optical and Supercomputing Site
Robert Hubbard, National Solar Observatory

Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Stephen Keil, National Solar Observatory
Jeff Kuhn, University of Hawaii, Institute for Astronomy
Lewis Roberts, Boeing LTS
Thomas Rimmele, National Solar Observatory
Jeremy Wagner, National Solar Observatory
Benjamin Wheeler, Trex Hawaii

Coordination with the AFRL/DE Starfire Optical Range (28 November, 2006)

The primary discussion centered on a recent breakthrough by the Starfire Optical Range that will greatly enhance the Sodium photon return from the Earth's Sodium layer.

First, the total photon return from the Sodium layer can be doubled by using circular rather than linear polarization, depending on the magnetic field strength at the Sodium layer. The effectiveness depends on having a reasonably strong vertical component of the earth's magnetic field.

Second, an additional 60% increase in the photon return from the Sodium layer can be achieved by exciting a hyperfine atomic level. The new method uses a low power (10W) Sodium laser tuned to excite the hyperfine level in conjunction with a primary 50W Sodium laser for excitation of the primary level, which is the one being used now for all Sodium guidestar applications.

Recent assessments indicate that getting twice the photon return to the AEOS telescope from the Sodium layer would greatly improve future performance. Since it is currently impossible to obtain a Sodium laser over 50W but it is relatively easy to obtain an additional add-on 10W laser, this new approach could yield a greatly increased photon return for a minimal additional investment. This approach was strongly recommended to Air Force management where it is currently under consideration.

An introduction to the new Starfire Optical Range two-story laboratory building was provided. State-of-the-art equipment was demonstrated. An agreement was reached to cooperate in several areas of advanced adaptive optics. The participants are listed below.

As a result of these information exchanges, applications of this breakthrough technology are under serious consideration to be incorporated into the planned installation of a Sodium guidestar on AEOS. A dramatic increase in the number of Sodium photons at the telescope can greatly improve the performance of the AEOS system.

Craig Denman, Starfire Optical Range
Paul Hillman, Starfire Optical Range
Joseph Janni, Air Force Maui Optical and Supercomputing Site, Universal Technology
Mike Maberry, University of Hawaii Institute for Astronomy
Earl Spillar, Starfire Optical Range

Leslie Wilkins, Maui Economic Development Board (Grant Administrator)

Advanced Optical and Supercomputing Conference in September 2007

The 8th annual Advanced Maui Optical and Space Surveillance Technologies Conference was held in September 2008 on Maui, Hawaii. The conference series always aims to provide a stimulating and thought-provoking forum for sharing the latest technical developments and ideas in adaptive optics and telescopes, space surveillance, optics, and high performance computing. It is intended for scientists, engineers, and technical managers from academia, industry, government, and military programs. This was an unclassified conference consisting of pre-conference tutorials, optional technical tours, featured speakers, a technical program, poster sessions, and exhibits. Over 100 papers were presented with opportunities for networking and technical discussions – all in an environment that stimulated the imagination and intellect of participants.

The funds remaining on the grant in 2007 were used primarily to foster interchanges at this conference between scientists working on Adaptive Optics related to the AMOS missions. The Advanced Maui Optical and Space Surveillance Technologies Conference was a key part of that. Dr Robert Fugate is a recognized world expert in adaptive optics; he intended to host a session at this conference and invite the top adaptive optics experts to participate. However, most of these scientists did not have funds sufficient to pay for their travel and expenses. This grant provided the necessary funds and Dr Fugate was able to invite the experts and host the session. The full proceedings of this conference are available on a compact disk from the Maui Economic Development Board.

Michael Lloyd-Hart, University of Arizona Steward Observatory
Dan Eklund, University of Arizona Steward Observatory
Richard Dekany, California Institute of Technology
Bruce Macintosh, Lawrence Livermore National Laboratory
Daren Dillon, University of California Santa Cruz Lick Observatory
Don Gavel, University of California Santa Cruz Lick Observatory
Mark Pesses, Science Applications Incorporated
Stuart Jefferies, University of Hawaii Institute for Astronomy

**List of Scientists Funded Since Grant Award (Inverse Chronological Order)
Through End of Grant.**

The following individuals had their travel and expenses either partially or fully funded by means of this grant. In all cases, this funding was an enabling factor in their participation with colleagues. The meetings they attended are all delineated on the previous pages. The names are in chronological order with the oldest disbursement at the top of the list.

Dennis Douglas, then at University of Arizona, now at Trex Maui (June, 2005)
Allan Hunter III, Trex Maui (September, 2005)
Julian Christou, Center for Adaptive Optics (September 2005)
Maile Giffin, Oceanit Maui (September 2005)
Benjamin Wheeler, Trex Maui (September 2005)
Stuart Jefferies, University of Hawaii Institute for Astronomy (September 2005)
Mike Flanagan, Trex Maui (December 2005)
Rusty Hughes, Trex Maui (December 2005)
Joseph Janni, AMOS UTC (December 2005)
Mike Flanagan, Trex Maui (December 2005)
Dennis Douglas, then at Oceanit Maui (December 2005)
Brent Ellerbroek, California Institute of Technology (December 2005)
John Pye, Maui Community College (December 2005)
Mark Hoffman, Maui Community College (December 2005)
Joseph Ritter, University of Hawaii Institute for Astronomy (December 2005)
Curt Leonard, Oceanit Maui (December 2005) \$2017.96
Jeanne Skog, Bus Rental, Maui Economic Devel. Board (December 2005)
Benjamin Wheeler, Trex Maui (December 2005)
Rusty Hughes, Trex Maui (March 2006)
Mark Hoffman, Maui Community College (March 2006)
Dennis Douglas, Trex Maui (April 2006)
Benjamin Wheeler, Trex Maui (April 2006)
Mark Hoffman, Maui Community College (April 2006)
Mike Flanagan, Trex Maui (April 2006)
Dennis Douglas, Trex Maui (April 2006)
Ben Oppenheimer (April 2006)
Dennis Douglas, Trex Maui (August 2006)
Mark Hoffman, Maui Community College (September 2006)
Rita Cognion, Oceanit Maui (September 2006)
Alister Knox, Oceanit Maui (September 2006)
William Demeo, (September 2006)
J. Wu, (September 2006)
Leslie Wilkins, Maui Economic Development Board (October 2006)
Joseph Ritter, University of Hawaii Institute for Astronomy (December 2006)
William Bradford, Boeing LTS Maui (May 2007)
Douglas Hope, University of Hawaii Institute for Astronomy (June 2007)
Hilary O'Bryan, Center for Adaptive Optics (June 2007)

Scott Seagroves, Center for Adaptive Optics (June 2007)
Michael Lloyd-Hart, University of Arizona Steward Observatory (September 2007)
Dan Eklund, University of Arizona Steward Observatory (October 2007)
Richard Dekany, California Institute of Technology (October 2007)
Bruce Macintosh, Lawrence Livermore National Laboratory (October 2007)
Daren Dillon, University of California Santa Cruz Lick Observatory (October 2007)
Don Gavel, University of California Santa Cruz Lick Observatory (October 2007)
Mark Pesses, Science Applications Incorporated (October 2007)
Stuart Jefferies, University of Hawaii Institute for Astronomy (November 2007)
Joseph Janni, Universal Technology Corporation (November 2007)