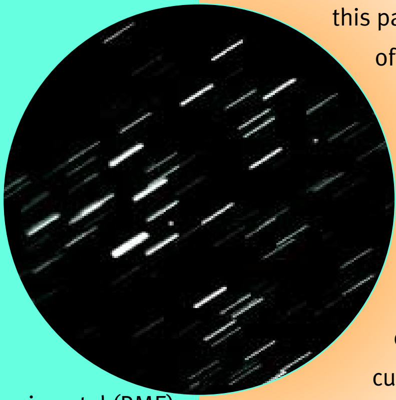
NATION'S FIRST SENSORS TO TRACK MAN-MADE SPACE OBJECTS ARE BACK ON MAUI

Since the launch of Sputnik in 1957, trackable space objects have increased to more than 9,000 objects.

As commercial, government, research, and academic agencies discover new ways to use our Earth's space environment, the number of orbiting satellites and the number of associated debris objects increase. The importance of protecting manned and unmanned space-based assets becomes more evident. The most straightforward method to preserve the safety of on-orbit assets is to keep them from colliding with other assets and debris. Thus, it is imperative to have the ability to measure, determine, and catalog, with high accuracy, the orbits of all objects in the space environment.

With this heightened awareness of the space environment, Detachment 15 of the Air Force Research Laboratory's Directed Energy Directorate has initiated a project to develop and integrate a suite of sensor systems with fields of view greater than one degree. The most interesting of these systems is the Phoenix system, based on one of the original Baker-Nunn camera systems, once retired and now back on Maui. It is being redesigned to be one of AMOS' widest field of view optical sensor systems. This Phoenix Sensor System is being developed and integrated at the Remote Maui Experimental (RME) site in Kihei, Maui.

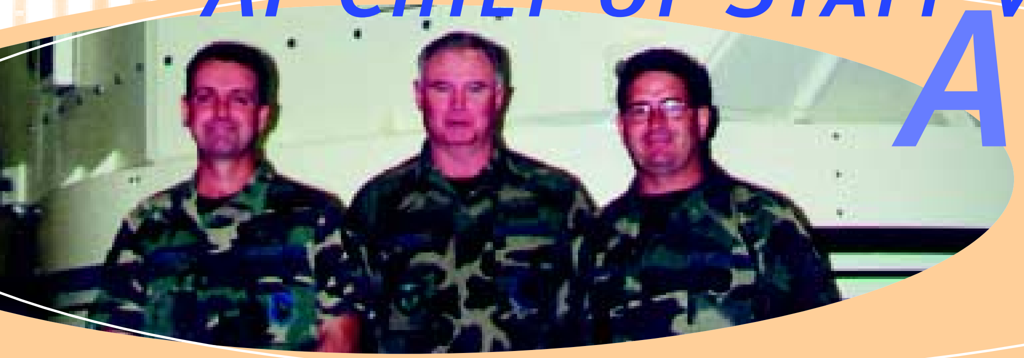


First light obtained with a surrogate CCD, on

The original Baker-Nunn system, designed by James Baker and Joseph Nunn, was implemented in 1957 by the Smithsonian Institute as a global network of twelve telescope/ camera systems dedicated to tracking the Vanguard satellite. These large telescopic cameras, based on the Schmidt telescope, were designed specifically to provide space object tracking information on satellites. Haleakala was one of these global sites. The current Ground-based Electro-Optical Deep Space Surveillance (GEODDS) System replaced the Baker-Nunn system in the early 1980s.

The Baker-Nunn telescopes were stored for almost two decades. It was decided this past year to resurrect one of the original Baker-Nunn telescopes, shown in the photograph, and to retrofit it with a state-of-the-art Charge Coupled Deviced (CCD). Because the original Baker-Nunn camera was based on curved photographic plates, retrofitting it with a flat-faced CCD was not trivial. The new CCD allows for digital imagery with very high sensitivity (~90% quantum efficiency). The Lockheed-manufactured CCD will have 4096 x 4096 x 15 μ pixels, and will provide a field of view of approximately six degrees.

AF CHIEF OF STAFF VISITS AMOS



GENERAL MICHAEL E. RYAN,

THE CHIEF OF STAFF OF THE U.S. AIR FORCE, VISITED THE AMOS DETACHMENT OF AFRL ON 4 MAY 2001.

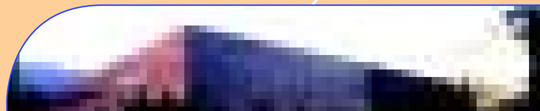
General Ryan is the senior uniformed Air Force officer responsible for the 700,000 active-duty, Guard, Reserve and civilian forces serving in the United States and overseas. He is also a member of the Joint Chiefs of Staff, where he and the other service chiefs of staff function as military advisers to the Secretary of Defense, the National Security Council, and the President of the US.

General Ryan visited the Maui Space Surveillance Complex on Haleakala, as well as the Maui High Performance Computing Center in Kihei. The photo shows, from left to right, TSgt Rob Medrano, General Ryan, and TSgt Dave Covey, standing in front of the 3.6-meter AEOS telescope. Medrano and Covey had just completed a technical briefing to the 4-star general on the capabilities of the AEOS telescope and its state-of-the-art instrumentation.

Before assuming his current position in 1997, General Ryan was commander of U.S. Air Forces in Europe and commander, Allied Air Forces Central Europe, with headquarters at Ramstein Air Base, Germany. General Ryan, who graduated from the Air Force Academy in 1965, is rated a command pilot, with 153 combat missions. As commander of the 16th Air Force and Allied Air Forces Southern Europe in Italy, he directed the NATO air combat operations in Bosnia-Herzegovina which directly contributed to the Dayton Peace Accords.

CONFERENCE UPDATE

The 2001 AMOS Technical Conference
September 10-14, 2001
Wailea, Maui, Hawaii
http://ulua.mhpcc.af.mil
amostech@maui.com



MHPCC

Begins Blind Deconvolution Research

MAUI HIGH PERFORMANCE COMPUTING CENTER (MHPCC) RESEARCHERS HAVE RECENTLY BEGUN NEW CONTRACTUAL WORK ON A BLIND DECONVOLUTION STUDY FOR DETACHMENT 15 OF AFRL. THE OBJECTIVE OF THIS STUDY IS TO EXPLORE THE USEFULNESS OF “BLIND DECONVOLUTION” ALGORITHMS TO ESTIMATE AND REMOVE BLURRING CAUSED BY LIGHT PROPAGATION THROUGH TURBID MEDIA, SUCH AS CLOUDS, IN SUPPORT OF ELECTRO-OPTICAL SENSOR OPERATIONS.

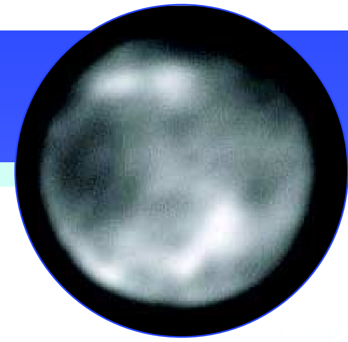
Image restoration involves the removal or minimization of degradation (blurring, noise, etc.) in an image, by using prior knowledge about the degradation phenomena. Blind restoration is the process of estimating the true image and the blurring from the degraded image characteristics. When a beam of light encounters a turbulent flow field that includes density fluctuations, its optical wavefront becomes aberrated causing the beam to be degraded.

If the characteristics of the blurring process are known or can be modeled effectively, an improved image can be reconstructed by “deconvolving” (mathematically removing) the blurring function from the measured image. Only partial knowledge is known about the degradation phenomena in aero-optics; therefore, the use of blind deconvolution is essential. These blind deconvolution techniques that simultaneously estimate and remove the blurring in images, are often useful to remove the blurring due to the scattering of the light.

MHPCC researchers will evaluate different blind deconvolution algorithms that have been presented by other researchers in scientific literature and have the potential to correct imagery blurred due to the scattering of light. These evaluations will be based on real and simulated data. An additional goal of this research is to investigate the implementation of the best-performing algorithms from the evaluations within an interactive data language-based software framework. The researchers would then enhance these algorithms. This research may also lead to the development of new blind deconvolutution algorithms to improve image restoration.

Astronomers Delighted with AEOS Images

Beginning in November 2000, several groups of astronomers have used the 3.6 meter AEOS telescope to obtain images of astronomical objects.



Sponsored jointly by the Air Force Office of Scientific Research (AFOSR) and the National Science Foundation (NSF), these scientists are seeking to advance our understanding of astronomical objects and phenomena. One of the primary areas of interest is in the use of the adaptive optics (AO) system on the AEOS telescope, which compensates for the optical distortions induced by the atmosphere. Objects studied so far include the moons of Jupiter and Saturn, as well as observations of stars to study binary formation and faint companions. Future observations will expand to observations of solar system planets, both major and minor. In addition, there are several groups of astronomers who are developing instrumentation which, although designed for astronomical observations, may also provide an enhanced capability for observations of Earth-orbiting satellites.

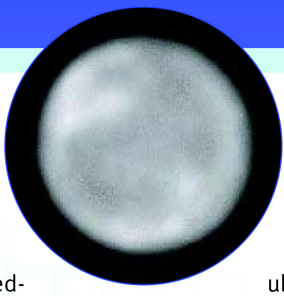
The first program at AMOS sponsored by AFOSR/NSF was entitled **"AEOS Observations of Titan."** The principal investigator was Michael Brown from the California Institute of Technology. Brown, along with his colleagues Antonin Bouchez, also from Cal Tech, and Mitchell Troy from the Jet Propulsion Laboratory, began their observing run on 5 November, and completed the observations on 9 December. Although plagued by unseasonably poor weather during their first set of observations, subsequent observations proved more useful.

Saturn's moon, Titan, has a large thick atmosphere similar to the Earth's in many ways, but differing in that weather is driven by methane, rather than water vapor. Little is known about this unique system. Brown proposed to use AEOS to observe Titan in order to determine the sites of cloud formation, set limits on the frequency of methane rainfall, probe the wind fields of Titan's lower atmosphere, and precisely determine the shape and short- and long-term stability of the AEOS point spread function (PSF). Observations and analysis are being performed by a team with expertise in satellites, atmospheres, weather on Titan, and adaptive optics systems and observing. These observations provide an early opportunity to probe the abilities and characteristics of the AEOS telescope and system while performing cutting-edge science. Preliminary results can be seen on Brown's web page at http://www.gps.caltech.edu/~mbrown/aeos/.

The second group of astronomers sponsored by AFOSR/NSF was led by Jennifer Patience of Lawrence Livermore National Laboratory (LLNL). Her proposal was entitled **"A high resolution AO survey of A stars: studying mass-dependent effects on binary formation."** The purpose of these observations was to address important questions in studies of binary star formation and to perform observations to test several models of binary star formation, concentrating on early-type stars, primarily in two nearby open clusters: the Pleiades and Coma Berenices. Patience and Bruce Macintosh, also of LLNL, conducted a companion search of a large, well-defined sample of early-type stars in nearby open clusters and in the field. At the distances of the cluster, these diffraction-limited I-band images should resolve companions with separations as small as 4-6 astronomical units (AU), comparable to the Sun-Jupiter distance. The ability to study such close separations is critical, since most companions are expected to have separations in the few AU – tens of AU range. The target set is designed to achieve optimal AO performance and to address important questions in studies of binary star formation and stellar X-ray activity. They will measure the fraction of binaries and the distribution of binary mass ratios. This information, combined with previous work on lower mass stars, will test the mass-dependent predictions of several binary formation models. The dataset will also be valuable to search for a correlation between the presence of a companion and X-ray emission. Patience will return in April 2001 for additional observations, and is planning to present a paper on her results at the SPIE conference on "Dual-Use Technologies for Space Surveillance and Assessment" this summer in San Diego.

The ability to study such close separations is cri

The third group of AFOSR/NSF-sponsored scientists was led by Michael Mendillo of Boston University, with observations supporting **"Imaging studies of the transient atmospheres of Jupiter's moons."** Michael was accompanied by Jeff Baumgardner and Jody Wilson, also from Boston University. The purpose of the observations this group made, and will make again later this year, were to use the unique abilities and flexibility of AEOS to obtain high-resolution emission-line images of the atmospheres of Io and Europa, two moons of Jupiter. Their focus was on potassium gas, which is a useful tracer species in the atmospheres of both moons, and to determine which processes are most important in supplying and removing potassium to and from these atmospheres. One emphasis was on locating the source of the neutral potassium "jet" produced by the escape of Io's ionosphere. In addition to these science objectives, they are field testing the image-slicer component of a new high-definition imaging system to be used for observations of various transient planetary atmospheres.



The following AFOSR/NSF sponsored programs are scheduled for later this year, and will be the subject of future AMOS Newsletter articles:

"A faint companion search and multiplicity survey of O and B stars," led by Theo ten Brummelaar of Georgia State University. The purpose is to search for low luminosity close companions of O and B type stars, to measure the differential magnitude of all binaries found, and investigate mass ratios and companion initial mass function, to help understand the binary formation method.

"Astronomical applications of a computer tomography imaging spectrometer (CTIS) with an adaptive optics telescope," led by E. Keith Hege of the University of Arizona. The purpose is to investigate the applications of the CTIS, which utilizes a computer-generated two-dimensionally dispersing holographic grating to provide multi-spectral imaging. The science objectives are to obtain multi-spectral imaging of extended regions around compact sources and spectrophotometric imaging of time-variable sources.

tical . . .

Many of these scientists are members of the Center for Adaptive Optics (CfAO), one of a number of science and technology centers funded by the NSF. One of the goals of this Center is to develop and apply AO observations to astronomical targets which are of important scientific interest and to also investigate system performance and science return for faint objects, high contrast objects, crowded field objects, and extended objects. These scientists have significant experience in observing on telescopes with compensated imaging systems. The dialogue between CfAO member scientists and AMOS scientists has proven very valuable for observations of Earth-orbiting satellites.

AMOS Collaborates with NASA on Albedo Measurements

An important piece of information which is extremely valuable in evaluating the number of debris objects in orbit around the Earth is the size of the objects observed. The primary estimates of object size come from either radar observations or optical observations. For radar observations, the interpretation of the size of an object is based upon the observed radar cross-section (RCS) of the object. NASA has developed a mapping function between RCS and size (diameter of the object, assuming a sphere) called the size estimation model (SEM). This model was derived from radar data collected in the laboratory on about 40 debris pieces produced from a hypervelocity collision.

Optical observations provide an apparent brightness, measured as a visual magnitude. The visual magnitude scale has been used by astronomers since Hipparchus in the second century BC, while a more formal, quantitative definition has been in place for almost 150 years. This observed brightness information must be combined with albedo information before object size can be inferred. Albedo is defined as the fraction of incident light that is reflected from the surface. An average albedo has been estimated from a comparison of optical brightness with radar derived size. This comparison has been made using about 100 cataloged objects detected by the 3-meter diameter liquid mirror telescope. The same average albedo is used for objects too small to be cataloged. It is critical that a thorough, independent measurement of the optical albedos of small space debris be made.

NASA and AMOS are collaborating on a project to determine the albedos of a large number of Earth-orbiting satellites in order to better understand this size distribution. The NASA Johnson Space Center has identified a set of one hundred orbiting objects to be included in the study. Forty-five of the objects are satellites and debris which are currently being extensively measured in the radar spectrum by MIT/Lincoln Laboratory. The rest are smaller objects which have been detected and tracked by the Cobra Dane radar but are too small to be cataloged.

To obtain albedo, one observes the object in visible light as well as infrared light. Ideally this is done simultaneously, to eliminate the effect of satellite rotation on the results. The concept is that objects with high albedo will be brighter in the visible (reflected sunlight), while objects with low albedo will be brighter in the infrared (warmer, emitting infrared). The basic orbital debris thermal model, similar to the model used by astronomers for determining asteroid size, is that surface temperature variations are insignificant; that the object radiates isothermally; that objects are spheres in radiative equilibrium with their environment; and that absorbed energy is uniformly distributed to and radiated from the entire surface. Equations defining the interaction can be combined to solve for the albedo and radius.

AMOS will use two systems for these observations. The contrast mode photometer (CMP) and advanced multicolor tracker for AMOS (AMTA) share the light path on one of the twin 1.2 meter telescopes, and can be used simultaneously. The other, more powerful instrument which will be used to obtain albedo measurements is the advanced radiometer system (ARS) which is at a trunnion position on the 3.6 meter telescope. This system collects data simultaneously in four spectral bands, from 0.4 μ through 23 μ. The ARS has a separate focal plane array supporting each of the four spectral bands, each with its own set of filters. Not only is the ARS a more capable sensor, because it is associated with a 3.6 meter telescope it will detect much fainter objects.

GEODSS GETS A FACELIFT

C-5 aircraft landing in Maui? If you were on the island back in November that's exactly what you would have seen as members of the 439th AW from Westover Air Reserve Base in Springfield, Massachusetts. delivered three new Ground-based Electro-Optical Deep Space Surveillance (GEODDS) telescopes to Detachment 3 of the 18th Space Surveillance Squadron. These $1.1M Contraves-built telescopes were installed over a period of 45 days with final integration completed on 15 December 2000.

The GEODSS system, a dedicated sensor of the Space Surveillance Network (SSN), consists of passive telescopes used to observe deep space artificial satellites. Deep space satellites are defined as satellites whose orbital periods are greater than 225 minutes. The telescopes are connected to very sensitive low-light television cameras and are remotely tasked and scheduled by the GEODSS Optical Command, Control, and Communications Facility (OC3F) at Edwards Air Force Base, California. They are able to track more than 500 satellites daily.

"The positional data we gather on satellites is critical," said Maj. Sam McNiel, Det. 3, 18th Space Surveillance Squadron commander. "It helps the Air Force keep track of the location of almost all of the nearly 9,000 satellites in orbit. That helps governments and private companies keep their satellites from colliding with one another. It also helps NASA ensure the safety of the space shuttle or the international space station. Our Hawaii location is very important because it allows us to provide data for a large part of sky over the Pacific Ocean."

The telescope replacement project, called the GEODSS Telescope Refurbishment program, replaces the existing GEODSS telescopes with completely rebuilt ones. The existing GEODSS telescopes were installed in 1983 and have not been refurbished since then. "The new optics and mirrors in these refurbished telescopes should allow us to detect even smaller objects," said McNiel. "With the old telescopes we could see a basketball 22,000 miles away. Hopefully, we can substantially improve on that. It's important we be able to track as small an object as possible because things in orbit are going about 17,000 miles per hour, so a collision with even a small object can cause a catastrophic failure for a spacecraft."

Based on how it is tasked, GEODSS will generate either metrics or space object identification (SOI) data. Metric data consists of very accurate measurements of the satellite position and the time the measurements were taken. The metric observations are usually generated in sidereal track mode, moving the telescope to keep the stars fixed in the field of view. A series of frames are recorded and processed using a maximum value projection method for background subtraction, and cluster/moment processing for streak detection. The pointing angle data is derived from the mount angular encoders, while the time comes from the global positioning system (GPS) satellites. SOI data consists of recording the satellite brightness as a function of time, typically at 100 Hz. SOI data is collected in rate track mode, moving the telescope to keep the image of the satellite on a single pixel.

The Deep-space Surveillance Technology Advancement & Replacement for Ebsicons (Deep STARE) upgrade, presently in acquisition, will introduce in-frame metrics. In-frame metrics utilizes the well-known position of the stars present in the field of view to accurately determine the location of the target objects. Implementation of in-frame metrics, performed only in sidereal tracking mode, will eliminate the now-stringent dependence on the

mount model and the mount encoders in the development of metric observations.

In-frame metrics, also know as astrometry, has been used for several years at AMOS by both the Raven and NEAT programs.