COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 04-2 **NSF 04-517** **02/18/04**	**FOR NSF USE ONLY** **NSF PROPOSAL NUMBER** **0425910**
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **ATM - HIGH-PERFORM INSTR AIR PLAT FO**	

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TITLE OF PROPOSED PROJECT **Collaborative Research: An Autonomous Airborne Direct Solar Beam Spectrometer for HIAPER**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **433,446**	**36** months	**10/01/04**	

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PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS **560 Third Street West** **Sonoma, CA 954766502** **United States**
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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
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CERTIFICATION PAGE

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Robert W Bergstrom**	**Electronic Signature**	**Feb 17 2004 6:32PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
707-938-9387	**bergstrom@baeri.org**	**707-938-3984**

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

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NSF 04-517 **02/18/04**

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National Aeronautics & Space Administration Ames Research Center

AWARDEE ORGANIZATION CODE (IF KNOWN)

4100707000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

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NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

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TITLE OF PROPOSED PROJECT **Collaborative Research: An Autonomous Airborne Direct Solar Beam Spectrometer for HIAPER**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **56,864**	**36** months	**10/01/04**	

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PI/PD DEPARTMENT
Earth Science Division

PI/PD FAX NUMBER
650-604-6779

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Moffett Field, CA 94035
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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

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CERTIFICATION PAGE

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Beatrice Morales**	**Electronic Signature**	**Feb 17 2004 5:57PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
650-604-2074	**Beatrice.Morales-1@nasa.gov**	

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Project Summary

A major uncertainty in predicting possible future changes to the Earth system in general, and its climate in particular, stems from the necessary inclusion of atmospheric aerosols in climate models. In fact recent modeling studies claim that tropospheric aerosols are so important that they may hold the key to combat global warming, suggesting that reducing the emission of light-absorbing aerosol into the Earth's atmosphere may be the most feasible way to slow global warming. However other recent modeling studies seem to, at least in part, contradict that notion. The current low confidence in the estimates of aerosol induced perturbations of the Earth's radiation balance is caused by the highly non-uniform compositional, spatial and temporal distribution of tropospheric aerosols owing to their heterogeneous sources and short lifetimes.

To monitor the distribution of aerosols globally requires the combination of continuous observations from satellites, networks of ground-based instruments, and dedicated field experiments.

The use of the NASA Ames airborne tracking sunphotometers (AATS) in many such dedicated campaigns has proven to be a unique link between space-based retrievals of aerosols (plus also O_3 and H_2O) and a diversity of suborbital measurements. A 6-wavelength AATS made its first flights in 1985 and was retired in 2003. A 14-channel instrument (AATS-14) was completed and first flown in 1996. It is now the only instrument in the world capable of continuous airborne measurements of aerosol optical depth, H_2O and O_3 columns. However, due to its size, integration on HIAPER would require modification of the airframe, which is not encouraged under the HIAPER Aircraft Instrumentation solicitation.

The PI's of this collaborative proposal between Bay Area Environmental Research Institute and NASA Ames Research Center propose to build a compact solar spectrometer capable of autonomous transmission measurements of the direct solar beam from the HIAPER aircraft. Compared to AATS-14 the proposed instrument will have increased observational capabilities (continuous spectrum versus discrete wavelengths) yet be considerably smaller and lighter.

The proposed instrument has been designed specifically for integration and safe, economical and fully autonomous operation aboard HIAPER. The design has been iterated with NCAR personnel. Analogous to the existing AATS instruments the sun tracking head of the instrument is mounted external to the aircraft skin. However, light is not detected by diodes in the tracking head but guided by optical fibers into two rack-mounted spectrometers.

The intellectual merit of this research is demonstrated by the uniqueness of the proposed instrument and the utility of the proposed measurements. The proposed instrument will deliver the following scientific quantities: direct solar beam transmittance (at wavelengths 0.35 – 1.7 µm), direct solar beam irradiance ($W/m^2/\mu m$, 0.35 – 1.7 µm), aerosol optical depth (0.35 – 1.7 µm, outside gaseous absorption bands only), and the columnar amounts of H_2O, O_3, and NO_2. If the aircraft performs vertical profiles these quantities can be differentiated with respect to altitude to obtain profiles of aerosol extinction (0.35 – 1.7 µm, outside gaseous absorption bands only), H_2O, O_3, and potentially NO_2 densities. As demonstrated with the existing AATS's, the proposed instrument will deliver valuable data throughout the vertical range of the HIAPER aircraft, from the lower troposphere to the upper troposphere and lower stratosphere.

The broader impact of the proposed activity is that a type of instrument of which currently only one unit is available worldwide will become available to the broader science community (scientists, graduate and undergraduate students). Compared to the current situation where a single research group operates one instrument, integration of the proposed instrument into the HIAPER operation will significantly increase the number of missions where airborne direct beam transmission measurements will be performed. This will yield a much richer global data set on aerosols and radiatively important gases providing significantly more opportunities to link space-based and suborbital retrievals and to assess closure amongst suborbital measurements. This in turn will lead to a better understanding of atmospheric aerosols and their effect on radiation, which is sorely needed to understand and potentially combat global warming.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.C.

	Total No. of Pages	**Page No.* (Optional)***
Cover Sheet for Proposal to the National Science Foundation		
Project Summary (not to exceed 1 page)	1	
Table of Contents	1	
Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**	15	
References Cited	5	
Biographical Sketches (Not to exceed 2 pages each)	4	
Budget (Plus up to 3 pages of budget justification)	10	
Current and Pending Support	2	
Facilities, Equipment and Other Resources	1	
Special Information/Supplementary Documentation	0	
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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

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Project Description

List of Acronyms

AATS-6 (14)	6 (14)-channel Ames Airborne Tracking Sunphotometer
ACE	Aerosol Characterization Experiment
ADAM	Asian Dust Above Monterey
AERONET	Aerosol Robotic Network
AFB	Air Force Base
AIOP	Aerosol Intensive Observation Period
AOD	Aerosol Optical Depth
ARM	Atmospheric Radiation Measurement (Program by DOE)
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CAD	Computer Aided Design
CIRPAS	Center for Interdisciplinary Remotely Piloted Aircraft Studies
CLAMS	Chesapeake Lighthouse & Aircraft Measurements for Satellites
DOE	Department of Energy
FEA	Finite Element Analysis
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
HIAPER	High-performance Instrumented Airborne Platform for Environmental Research
IR	Infra Red
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate-resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
PI	Principal Investigator
POAM	Polar Ozone and Aerosol Measurement
PRIDE	Puerto RIco Dust Experiment
R/V	Research Vessel
PSAP	Particle Soot Absorption Photometer
SAFARI	Southern African Regional Science Initiative
SAGE	Stratospheric Aerosol and Gas Experiment
SeaWiFS	Sea-viewing Wide-Field-of-view Sensor
SGP	Southern Great Plains
SOLVE-2	SAGE III Ozone Loss and Validation Experiment
SSFR	Solar Spectral Flux Radiometer
TARFOX	Tropospheric Aerosol Radiative Forcing Observational Experiment
TOMS	Total Ozone Mapping Spectrometer
UV	Ultraviolet
UW	University of Washington

1 Rationale

A major uncertainty in predicting possible future changes to the Earth system in general, and its climate in particular, stems from the necessary inclusion of atmospheric aerosols in climate models. In fact recent modeling studies claim that tropospheric aerosols are so important that they may hold the key to combat global warming: *Jacobson* (2002), and to some extent also *Hansen et al*. (2000) and *Sato et al.* (2003), suggest that reducing the emission of light-absorbing aerosol into the Earth's atmosphere may be the most feasible way to slow global warming. However other recent modeling studies seem to, at least in part, contradict that notion (*Penner et al.*, 2003 and discussion in *Penner*, 2003). The current low confidence in the estimates of aerosol induced perturbations of the Earth's radiation balance is caused by the highly non-uniform compositional, spatial and temporal distribution of tropospheric aerosols owing to their heterogeneous sources and short lifetimes.

Aerosols can affect climate by a variety of pathways. These pathways include not only aerosol direct effects on the scattering and absorption of radiation, but indirect effects caused by aerosol roles in cloud microphysics, and "semi-direct" effects caused by aerosol modification of atmospheric heating, temperature profiles, convection, and large-scale horizontal transport (e.g., *Ackerman et al*., 2000, *Chameides and Bergin*, 2002; *Lelieveld et al*., 2002; *Menon et al*., 2002). Many of these pathways can affect precipitation, and thus aerosols are intimately linked to the hydrological cycle (e.g., *Ramanathan et al*., 2001, *Rotstayn and Lohmann*, 2002).

To monitor the distribution of aerosols globally requires the combination of continuous observations from satellites, networks of ground-based instruments, and dedicated field experiments (*Kaufman et al*., 2002).

The AErosol RObotic NETwork (AERONET) of ~200 identical globally distributed Sun and sky-scanning ground-based automated radiometers provides measurements of aerosol optical properties, including ten years of observations in some locations (*Holben et al*., 2001). These data are used extensively for the validation of satellite derived aerosol properties (e.g. *Diner et al*., 2001, *Torres et al*., 2002, *Chu et al*., 2003). In-situ measurements of aerosol optical properties and composition are made by numerous ground-based networks around the world (e.g. *Delene and Ogren,* 2002, *VanCuren*, 2003) and ground-based lidar networks, monitoring the vertical distribution of aerosols, are emerging (*Campbell et al., 2002*, *Ansmann et al.*, 2003).

Coordinated field campaigns that include in-situ and remote sensing measurements of aerosols aboard airborne platforms have proven to be a very valuable tool to extend the temporally continuous land-based point observations of such networks to a larger geographical area that includes the oceans and the vertical dimension.

The use of the NASA Ames airborne sunphotometers in many such campaigns has proven to be a unique link between space-based retrievals of aerosols (plus also O_3 and H_2O) and a diversity of suborbital measurements (more discussion in section 2). Figure 1 illustrates the coordination of satellite and suborbital measurements used in many field studies—e.g., TARFOX, ACE-2, PRIDE, SAFARI 2000, ACE-Asia, CLAMS—to maximize the synergy between the different types of measurements.

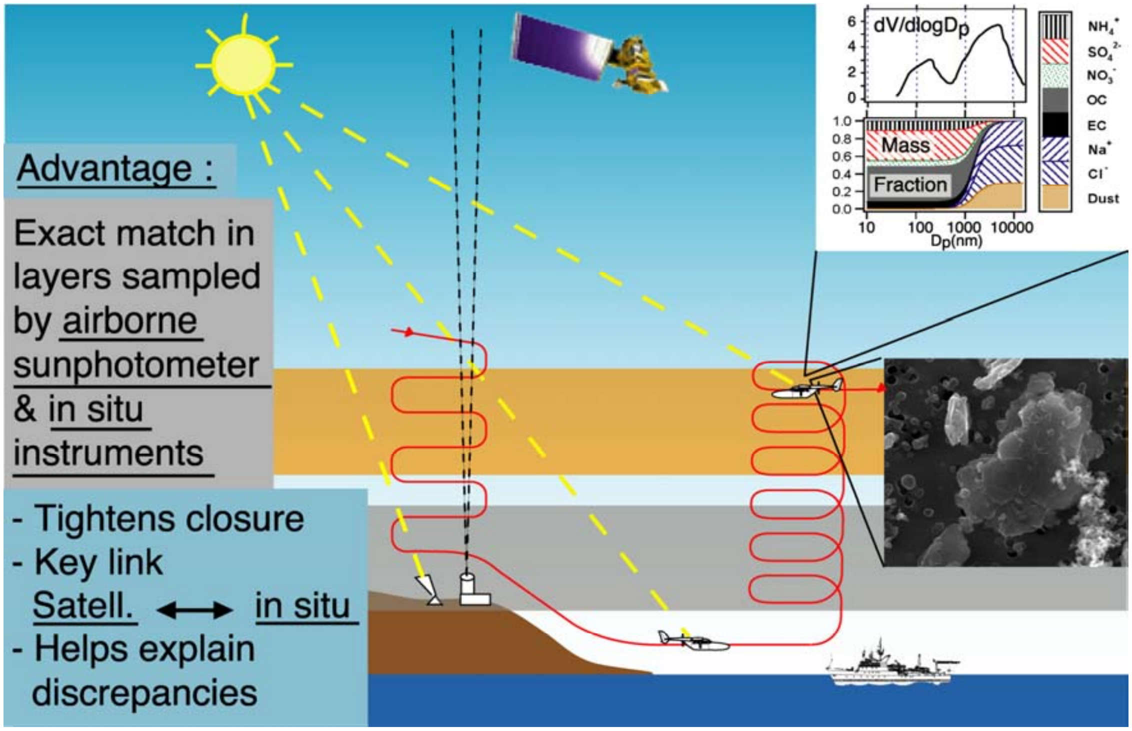

Figure 1: Schematic of the approach used in field experiments that coordinate a variety of suborbital measurements, including airborne sunphotometry, with satellite overflights. Example of size-resolved composition data is from *Wang et al.* (2002). Electron microscope (7 μm wide) image of particles is courtesy of James Anderson, Arizona State University.

The NASA Ames airborne sunphotometers measure the transmission of the direct solar beam in several channels from UV to near-IR wavelengths. The channels are chosen to allow separation of aerosol, water vapor, and ozone transmission. From these slant-path transmissions we retrieve spectral aerosol optical depth (AOD) and the columnar amounts of water vapor and ozone. Flying at low altitudes allows measurement of the entire overlying atmospheric column. Flying at different altitudes over a fixed location allows derivation of layer AOD, H_2O and O_3. Differentiation of AOD, H_2O and O_3 columns obtained in vertical profiles allows derivation of vertical profiles of spectral aerosol extinction, and H_2O and O_3 densities.

We recommend that an instrument with similar or enhanced observational capabilities become part of the instrument pool from which HIAPER will draw for its missions. The data produced by such an instrument will be of particular interest in missions focusing on three of the five science categories identified by the HIAPER Advisory Committee:

- Aerosols and Clouds Microphysics
- Gase Phase Chemistry
- Radiation, Clouds and Climate

The NASA Ames airborne sunphotometers are currently the only instruments in the world capable of continuous airborne measurements of AOD, H_2O and O_3 columns. The older of the two NASA Ames airborne sunphotometers (AATS-6) has recently been retired. Its more capable sibling, AATS-14, is considerably heavier and bulkier. Nevertheless, we have integrated AATS-14 on a variety of aircraft, small and large, such as the CIRPAS Pelican and Twin Otter, the UW CV-580, and the NASA DC-8. However due to the large hole size required in the aircraft skin (diameter >10") an integration on HIAPER would require modification of the airframe which is not encouraged under this instrument solicitation.

Therefore we propose to build a compact solar spectrometer capable of autonomous transmission measurements of the direct solar beam from the HIAPER aircraft. Compared to our current AATS-14 the proposed instrument will have increased observational capabilities (continuous spectrum versus discrete wavelengths) yet be considerably smaller and lighter. Measuring a continuous spectrum with a spectrometer will yield more information and better wavelength accuracy compared to the AATS instruments which use 6 or 14 individual interference filters. This in turn will lead to more spectral information on AOD or extinction. Also, more accurate retrievals of H_2O and O_3, and measurement of gases not attainable with the AATS instruments, such as NO_2 and potentially others, will be possible. These more accurate gas measurements will also improve the accuracy of the aerosol data.

The proposed instrument is designed to be integrated onto HIAPER without requiring modification of the airframe (details are given in section 3). Our schedule (see section 4) foresees the completed, tested and calibrated instrument to be test-flown on HIAPER at the end of the third year. During two years we will accompany the instrument on initial deployments and train NCAR personnel in instrument operation, calibration and data analysis. After that the instrument can be operated and maintained by trained NCAR staff, with some level of involvement of the originating PI. The proposed instrument need not fly on every HIAPER mission but will be available to community users upon request.

The benefit to the science community is that a type of instrument of which currently only one unit is available worldwide will become available to the broader science community. Compared to the current situation where a single research group operates one instrument, integration of the proposed instrument into the HIAPER operation will result in more missions where airborne direct beam transmission measurements will be performed hence yielding a much richer global data set. HIAPER's high speed and large vertical and horizontal range further enhances the dataset.

Access to the proposed instrument aboard HIAPER by users of the atmospheric science community will lead to significantly more opportunities to link space-based and suborbital retrievals and hence lead to a better understanding of aerosols, radiation and climate.

2 Previous Research Relevant to this Proposal

NASA Ames has been the world leader in airborne sunphotometry since the first flights of AATS-6 in 1985 (*Russell et al.*, 1986, *Matsumoto et al.*, 1987). A second, enhanced 14-channel unit, AATS-14, was completed and first flown in 1996 (*Russell et al.*, 1999). Both instruments have been flown in many campaigns focusing on atmospheric aerosol all over the world (see Figure 2).

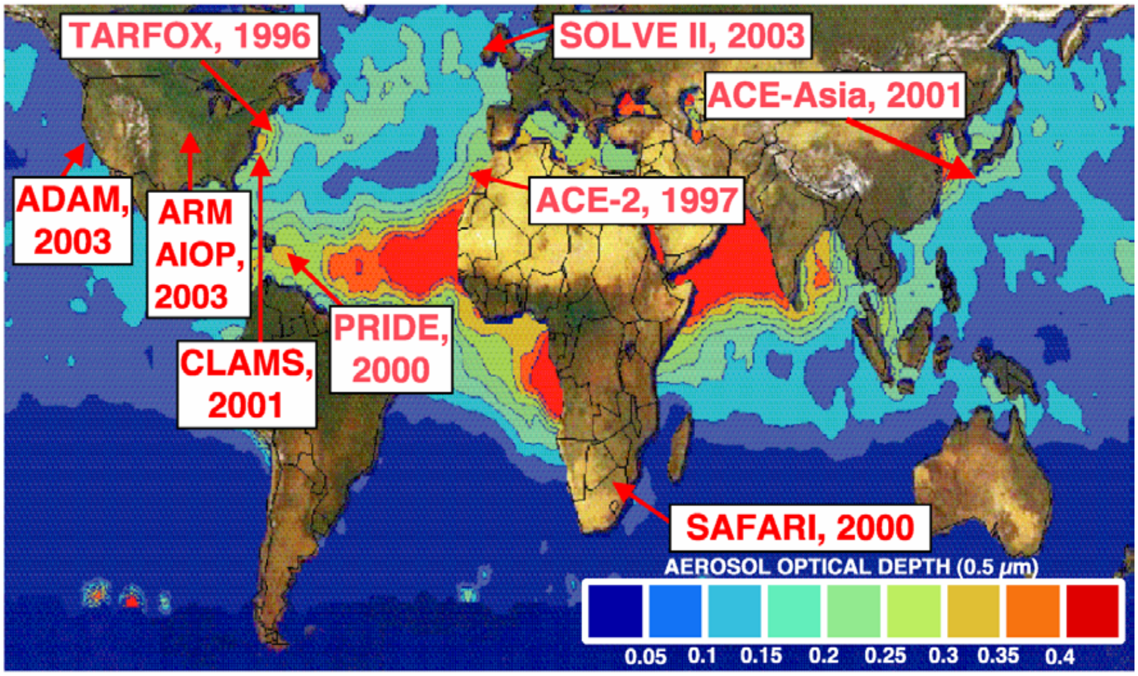

Figure 2: Major aerosol field campaigns in which the NASA Ames Airborne Sunphotometer Group participated, 1996-2003. Background shows June-August aerosol optical depth (AOD) averaged over July 1989 to June 1991, as retrieved by AVHRR/NOAA-11 (*Husar et al.*, 1997). Patterns of continental outflow are evident in the AOD contours.

2.1 Satellite Validation

During many of these campaigns considerable effort was devoted to coordinating aircraft measurements with satellite overpasses. To date AATS data have contributed to validating aerosol and O_3 retrievals from 11 different satellite sensors including AVHRR, ATSR-2, GMS-5, GOES-8, GOME, MISR, MODIS, POAM, SAGE 3, SeaWiFS and TOMS (*Tanré et al.*, 1999, *Veefkind et al.*, 1999, *Durkee et al.*, 2000, *Livingston et al*, 2000 and 2003a*, Schmid et al.*, 2000 and 2003a, *Levy et al.*, 2003a and b, *Wang et al.*, 2003a and b, *Kahn et al.*, 2003, *Redemann et al.*, 2003b). Five examples are discussed here:

MODIS Retrievals in SAFARI 2000: In SAFARI-2000, AATS-14 measured aerosol optical depth spectra aboard the UW CV-580. Figure 3 shows the comparison of AATS-14-derived to MODIS-derived AOD at two locations plus concurrent measurements of AOD by ground-based AERONET sunpotometers. The AATS-14 measurements shown in Figure 3 (left) represent the first published validation efforts of MODIS-derived AODs at wavelengths beyond 1.02 µm. Based on these and similar comparisons involving biomass burning aerosol, the MODIS team adjusted the single scattering albedo in the MODIS inversion algorithm to account for regional and seasonal variations. The new inversion algorithm (labeled "MODIS ver4" in Figure 3, right panel) yields considerably better agreement with AERONET and AATS-14.

MISR Retrievals in SAFARI 2000: During SAFARI-2000, AATS-14 was instrumental in identifying problems in the initial standard MISR retrievals of aerosol optical depth. Some of these problems were instrumental, while others pertained to the completeness of look-up tables used in the inversion of MISR radiance measurements to aerosol optical depth (see *Schmid et al*., 2003a, not shown for brevity).

MISR Retrievals in ACE-Asia. MISR-AATS-6 (and -14) comparisons in ACE-Asia (not shown for brevity) confirmed that early MISR-derived AODs were skewed high for some low-light-level scenes. Subsequent experiments demonstrated that scattered light played a key role in this phenomenon, and led to a revision of the MISR low-light-level calibration (that significantly affects MISR-derived AOD over dark water) (R. Kahn, personal communication).

MODIS Dust Retrievals in PRIDE. Extensive comparisons in the Puerto Rico Dust Experiment (see *Livingston et al*., 2003a, not shown for brevity) demonstrated that when Saharan dust was dominant (typically for AOD >0.2), MODIS-retrieved AOD spectra sloped more steeply than AATS AOD spectra. The likely cause is dust nonsphericity, which causes the MODIS retrieval to substitute more small mode aerosol for nonspherical large mode dust dust (*Remer et al., 2002*). An updated MODIS algorithm that adds nonspherical phase functions is being developed to address this.

POAM and SAGE 3 retrievals in SOLVE-2. While the comparisons discussed so far were made with an AATS flying low over the ocean or land and hence with appreciable AODs, comparisons with the solar occultation sensors POAM and SAGE 3 where made for stratospheric AODs (smaller by 2 orders of magnitude) flying AATS-14 at high altitudes aboard the NASA DC-8 (Figure 4, *Livingston et al*., 2003b).

2.2 Sunphotometer Intercomparisons

AATS-6 AOD and H_2O data served as standard in ground-based intercomparisons involving up to 5 sunphotometers (*Schmid et al*., 1999 and 2001). *Schmid et al*. [1999] showed that the concurrent measurements of aerosol optical depth in the spectral range of 380 to 1020 nm determined from AATS-6 and an AERONET instrument agreed to within 0.012 (rms) or better.

That level of agreement was achieved with AATS-6 operating on the ground. However, there have been a number of opportunities during field campaigns to compare with the data of one of the AERONET instruments during fly-bys of AATS-6 or AATS-14. For instance, Figure 5 shows a comparison of AATS-14 derived aerosol optical depth from the CLAMS experiment in July 2001, when the instrument was operated aboard the UW CV-580 aircraft. While the agreement is very good, the rms-differences are somewhat larger than those found in the ground-based side-by-side comparison. We attribute this to the fact that AOD values observed in CLAMS were generally larger but also to the spatial separation of the aircraft (AATS-14) from the ground-based AERONET instrument. This assumption is supported by the variability estimates shown in Figure 5.

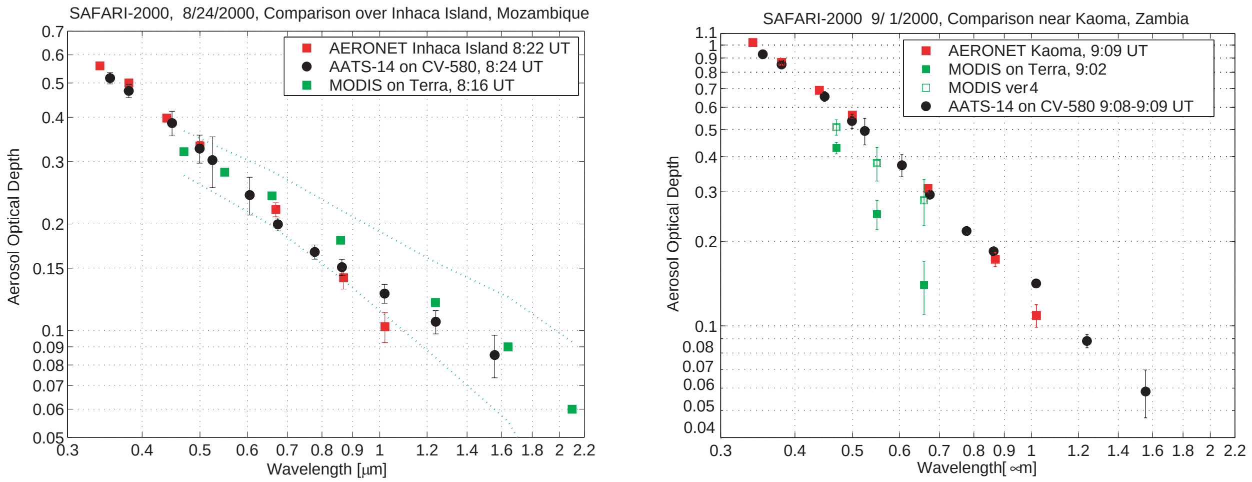

Figure 3: Comparisons of AOD spectra measured by AATS-14 and MODIS-Terra in SAFARI-2000, *Schmid et al.* (2003).

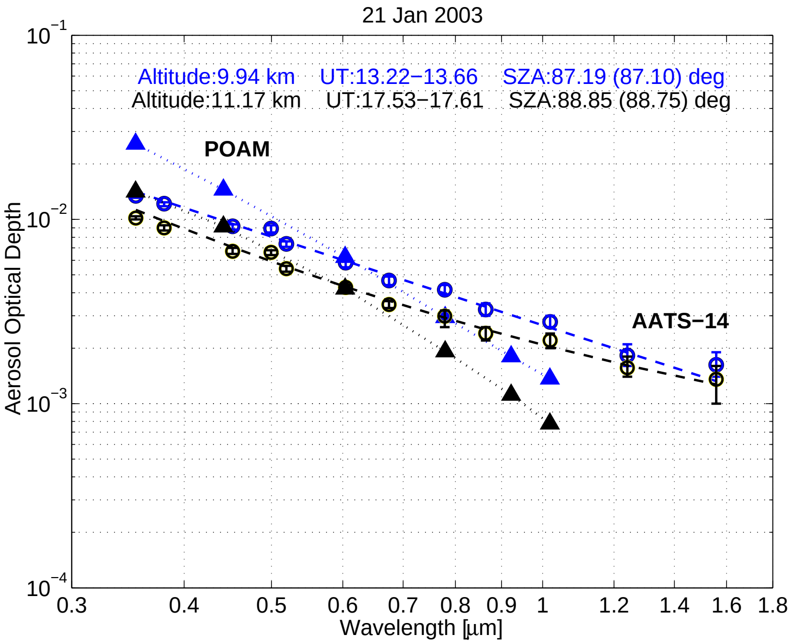

Figure 4: Comparison of stratospheric aerosol optical depth spectra from POAM (▲) and AATS-14 (○) flying at two different altitudes, during SOLVE-2, *Livingston et al*., (2003b).

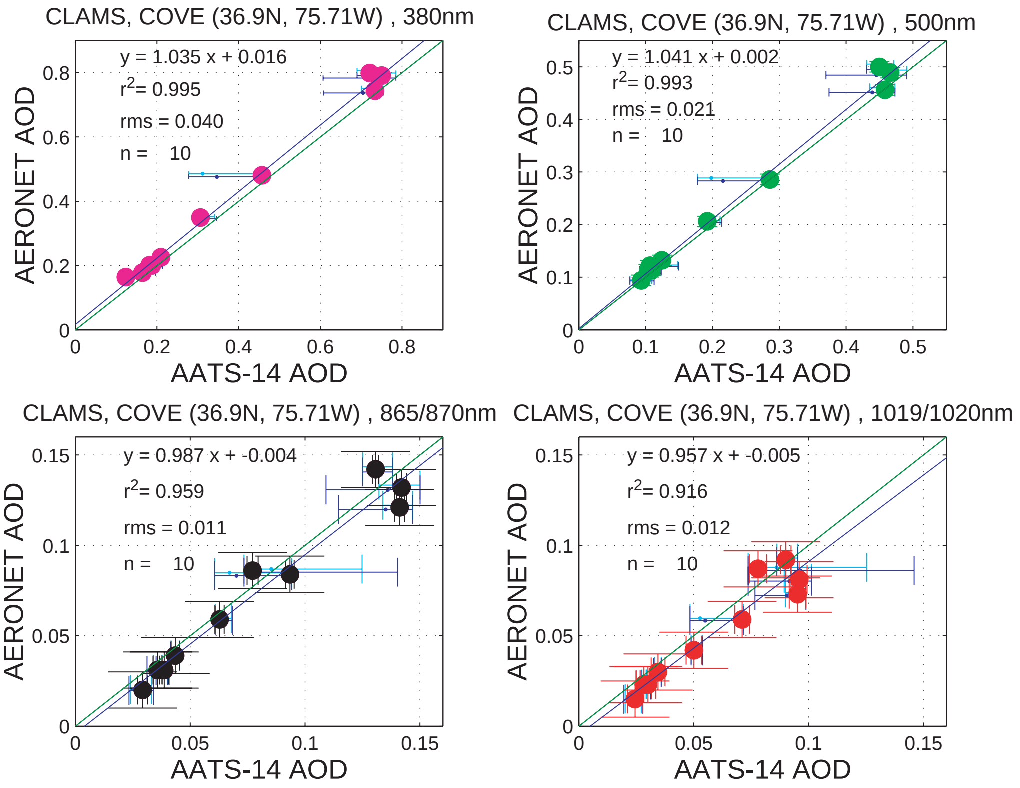

Figure 5: Statistical comparison of AOD at 380, 500, ~870 and ~1020nm as observed by AATS-14 and the Chesapeake Lighthouse AERONET instrument during fly-by's of the CV-580 aircraft in CLAMS, *Redemann et al.* (2003b). Variability estimates represent the range of AODs observed within a distance of 10km (light blue) and 50km (dark blue) from the ground-based instrument.

2.3 Aerosol and H_2O Vertical Profiles

Differentiation of AOD, H_2O and O_3 columns obtained by an AATS during an aircraft ascent or descent profiles allows derivation of profiles of spectral aerosol extinction and the densities of H_2O and O_3 (e.g. *Schmid et al.*, 2003b, *Livingston et al.*, 2003b). Examples are shown in (Figure 6 and Figure 7).

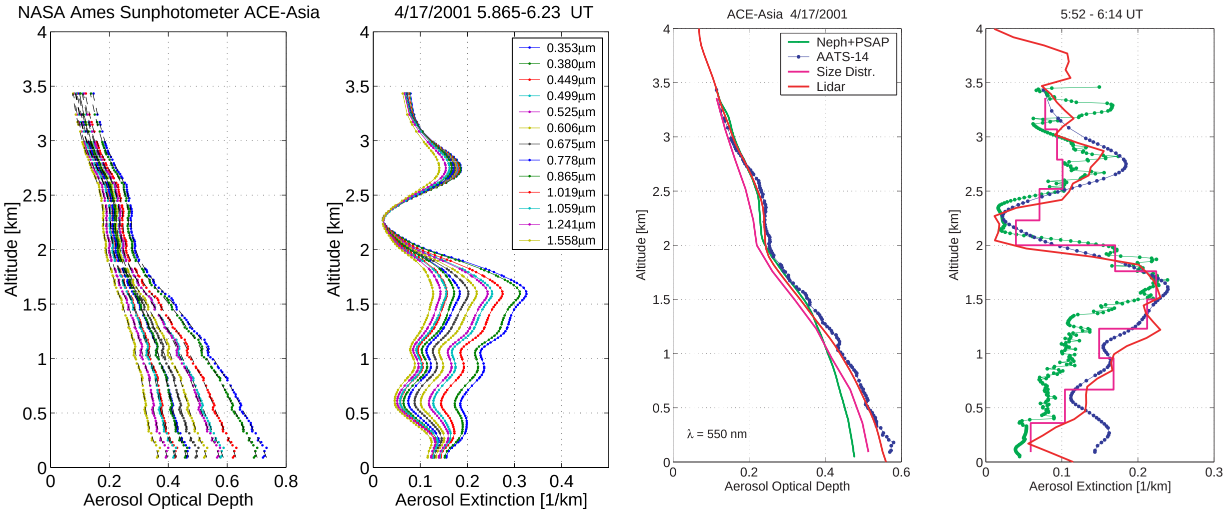

Figure 6: Left two panels: Example of AOD profiles and derived extinctions at 13 wavelengths from 354 to 1558 nm calculated from AATS-14 measurements acquired during an aircraft ascent south of Korea on 17 April 2001 during ACE-Asia. Right two panels: Comparison of AOD and extinction for the same profile from AATS-14 measurements, aerosol size distributions, the sum of aerosol scattering (nephelometer) and absorption (PSAP), and lidar measurements on R/V Ron Brown.

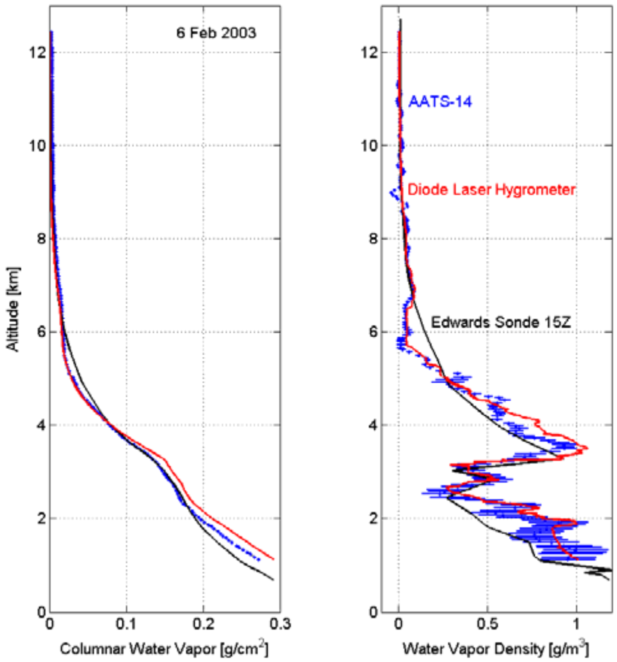

Figure 7: Comparison of H_2O columns and density from AATS-14, a Diode Laser Hygrometer and a radiosonde during a DC-8 descent into Edwards AFB, CA.

2.4 AATS-14 Profiles for Closure among Suborbital Measurements

An important class of extinction closure studies addresses the question: "Can in situ measurements of aerosol properties account for the solar beam attenuation (extinction) by an aerosol layer or column?" Such closure studies reveal important insights about airborne aerosol sampling. Instrumental is the measurement of aerosol optical depth and columnar water vapor with an Ames Airborne Tracking Sunphotometer (AATS-14 or AATS-6), because inlet effects (e.g., loss or enhancement of large particles, shrinkage by evaporation of water, organics, or nitrates) and filter effects are avoided.

Measuring solar beam attenuation by an AATS on the same aircraft as in situ sensors allows a close match in the aerosol layers described by the attenuation and in situ measurements. Such a match avoids the ambiguity that occurred in previous experiments when the only sunphotometer was on the surface and thus provided no information on what fraction of column optical depth was above the aircraft's maximum sampling altitude.

An example from ACE-Asia where the in situ extinction is computed as the sum of scattering (from humidified nephelometry) and absorption (PSAP instrument) is shown in Figure 6. Figure 6 also shows a concurrently measured aerosol extinction profile derived from a ship-based lidar system (e.g. *Welton et al.*, 2002) and values calculated from Mie theory using measured size distributions and size-resolved composition (used to determine the complex refractive indices) (*Wang et al.*, 2002).

Column closure studies as presented in Figure 6 can illustrate instrumental deficiencies as well as the strengths of the various techniques involved. AATS data have contributed to numerous "closure" studies in field campaigns such as TARFOX, ACE-2, SAFARI 2000, ACE-Asia, CLAMS, and ARM AIOP (*Hegg et al.*, 1997, *Hartley et al.*, 2000, *Collins et al.*, 2000, *Schmid et al.*, 2000 and 2003b, *Wang et al.*, 2002, *Magi et al.*, 2003a and 2003b, *Redemann et al.*, 2000 and 2003a).

2.5 Other AATS-14 Applications

AATS data have been frequently compared to ground-based, ship-based and airborne aerosol lidars (*Ferrare et al.*, 2000, *Redemann et al.*, 2000, *Livingston et al.* 2000, *Welton et al.*, 2000, *Schmid et al.*, 2000, 2003a, 2003b, *McGill et al.*, 2002, *Kaufman et al.*, 2003, *Murayama et al.*, 2003).

AATS data have also been used to derive aerosol single scattering albedo by combining airborne spectral flux measurements from the SSFR instrument and AOD from AATS-14 (*Pilewskie et al.*, 2000 and 2003, *Bergstrom et al.*, 2003a and 2003b). AATS-14 data have been used as input for atmospheric correction of airborne surface reflectance measurements (*Gatebe et al.*, 2003). Most recently, airborne AATS-14 data were also used to evaluate the performance of aerosol transport models (e.g. *Colarco et al.*, 2003). An example pertaining to longe-range transport of Siberian smoke aerosol to Oklahoma is shown in Figure 8.

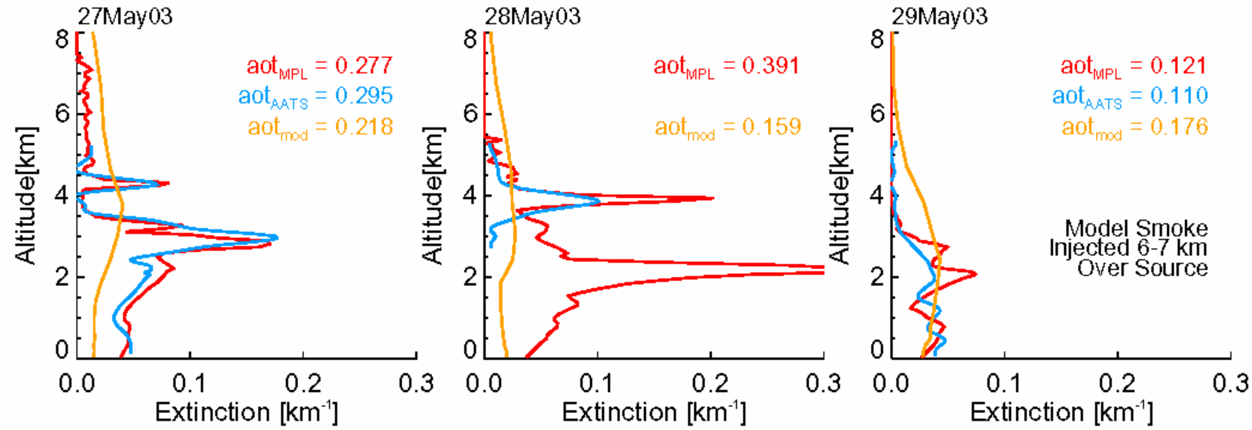

Figure 8: Aerosol extinction vertical profile over the DOE ARM SGP site on Oklahoma as measured by airborne sunphotometry (blue), ground-based MircoPulse lidar (red) and modeled with an aerosol transport/process model (yellow). The model is unable to reproduce the observed thin elevated layers of smoke that originated in Siberia.

3 Approach

The existing Ames airborne sunphotometers have solved many experimental challenges to airborne measurements of the direct solar beam. For example, the tracking head is mounted outside the aircraft skin to minimize blockage by aircraft structures and to avoid data contamination by aircraft-window effects. Motors controlled by sun-sensing detectors maintain solar pointing accuracies of a few tenths of a degree in spite of aircraft maneuvers, turbulence, and aerodynamic drag. Feedback-controlled heaters have prevented window fogging and maintained detector temperatures in a range of a few degrees or less over wide excursions in ambient temperature. Pointing the window inward (”parking the head”) has prevented dirt deposition during flight legs in salt spray and clouds. Weather shields and seals have protected the instruments sufficiently to permit measurements both before and after flight legs through clouds and rain.

In August 2003, Mr. Teck Meriam joined BAER Institute and the sunphotometer team at NASA Ames. He holds a B.S. and an M.S. in Mechanical Engineering focusing in Mechatronics (marriage of Mechanics and Electronics). He has 13 years of practical experience including mechanical and electro-mechanical design, CAD and FEA analysis, high precision motion controls, machine shop practice, and more. Building on our team’s experience with designing, building, operating, calibrating and maintaining our current airborne sunphotometers, Mr. Meriam made rapid progress in designing a compact, autonomous, auto-tracking, direct-solar-beam spectrometer targeted at small (potentially unmanned) airborne platforms. In December 2003 we started to target our design efforts for such an instrument to be integrated and operated aboard HIAPER.

Our design work for the envisioned HIAPER instrument benefits from considerable synergism with a recent successful proposal to NOAA’s Atmospheric Composition and Climate program which contains a task to study concepts and designs that address regular vertical profiling of aerosols. In this NOAA task we will produce *designs* that address the issues of marrying smaller aircraft with smaller, lighter, lower-power, automated instruments. This includes designing miniaturized instruments with the capabilities of the existing AATS-14 instrument, as well as instruments with increased capabilities. The synergy between the NOAA task and the effort proposed here allows us to reduce the number of work months charged to this proposal, resulting in a reduction of the proposed total cost.

3.1 Instrument Design

The design has been iterated with NCAR personnel (D. Friesen, M. Lord, R. Shetter, B. Lefer) and takes into account the considerations/constraints listed in the HIAPER solicitation and experimenter handbook, such as instrument volume, power consumption, safe, economical and autonomous operation, allowed materials, aircraft speed, vertical and horizontal range.

As with the existing AATS instruments the tracking head of the instrument is mounted external to the aircraft skin (Figure 9). Potential mounting locations on HIAPER are shown in Figure 10. Unlike with the AATS instruments light is not detected by diodes in the head but collected through a quartz window and entrance optics which is attached to a bundle of optical fibers (Figure 11). The near-IR enhanced fibers guide the light from the tracking head into two rack-mounted spectrometers (Figure 12).

Azimuth and elevation motors point the entrance optics at the sun using tracking-error signals from a quad-cell photodiode. Position feedback signals and power are transported through cables to the rack-mounted power supply, motor amplifiers, motion-control unit and data acquisition computer (Figure 12).

3.2 Integration on HIAPER

The instrument head is designed so it can be mounted in any of the 7 by 10” inlet aperture pads on the upper fuselage numbered 1 through 5 (see Figure 10). If mounted in pads #1 or #2, #4 or #5 the instrument is oriented tilted with respect to vertical (see Figure 12) however this does not impact its operation. The instrument head does not extend into the cabin (see Figure 12) as virtually all of its volume is absorbed into the space between the outer aircraft skin and the inner envelope defined by the aircraft’s frames, panels, etc.

If mounted as shown in Figure 9, the instrument head (top of dome) sticks out by about 10.85” from the aircraft skin which results in a frontal surface area of 0.77 ft^2. Aircraft speed of Mach 0.61 at sea level, an aerodynamic load factor of 1.25, skin friction drag and separate drag force coefficients for the dome and the fairing yields a drag force of 253 lbs and a lift force of 100 lbs. The drag force could be made smaller by mounting the instrument lower and shortening the vertical extent of the fairing shown in Figure 9. This lowered mounting would be possible in pads that are offset form the centerline (#1, #2, #4 and #5), but likely not in pad #3 without some obstruction in the cabin. Discussion with the HIAPER Aeronautical Engineer (M. Lord) indicated that a drag force of 253 lbs would be acceptable.

A strength analysis for the drag effect (using FEA with the drag force distributed evenly over the surface) shows that the design is structurally sound. Maximum stress of 14 kpsi occurs at the mounting-hole locations. Using Aluminum 7075-T7351 (as recommended in the HIAPER Experimenters Handbook) will provide a safety factor of more than 5.

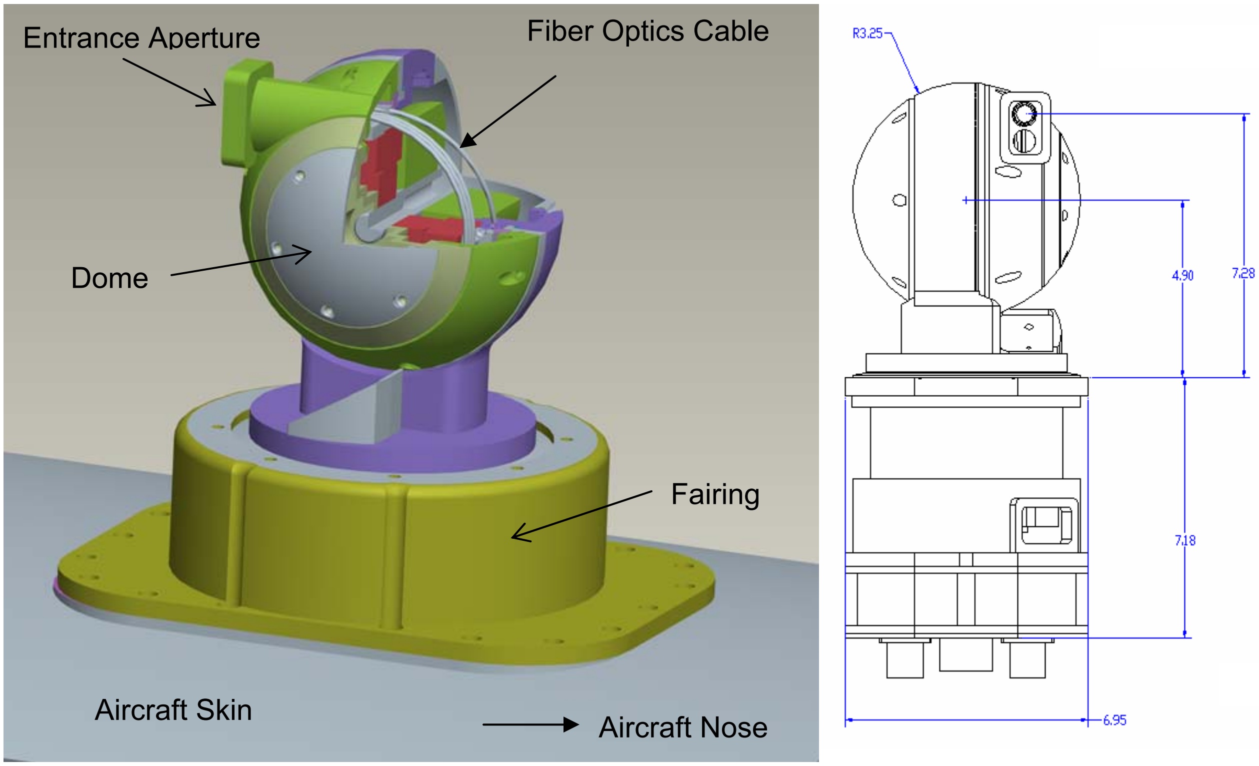

Figure 9: Partially sectioned model (left) and dimensioned drawing (right) of instrument head. Dimensions are in inches.

3.3 Pressure Seals

O-ring seals between stationary surfaces and rotary seals between moving surfaces will hold more than any relevant atmospheric pressure differential between the inside of the instrument head and the outside of the aircraft. The rotary seal and motor combination is specified to operate at the required precision up to a pressure differential of 1013 hPa and over a temperature range of -90°C to +50°C. The inside of the tracking head is also sealed from the cabin by passing the optical fiber and the cables through customized sealed connectors. This will prevent cabin air from leaking into the instrument.

The seals will also prevent moisture from entering the instrument head where it could condense on the optical entrance window. As an additional measure the optical window will be heated by a heater foil. Finally, the head area can also be purged with zero air or nitrogen between flights to remove residual moisture. Compared to our current AATS-14 instrument the seals specified for the new design should be more effective and hence infrequent purging should be sufficient.

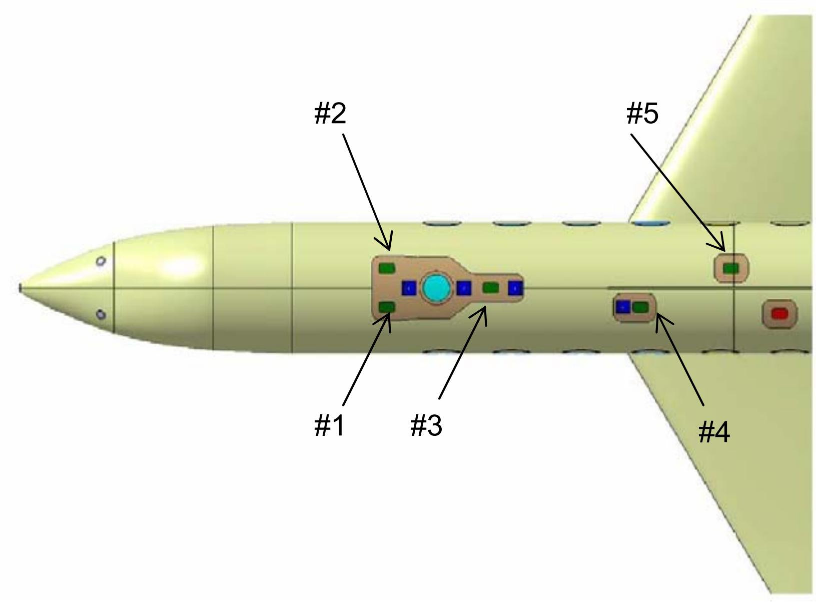

Figure 10: View of HIAPER upper fuselsage. Instrument can be mounted in any of the green 7 by 10” inlet aperture pads numbered 1 – 5.

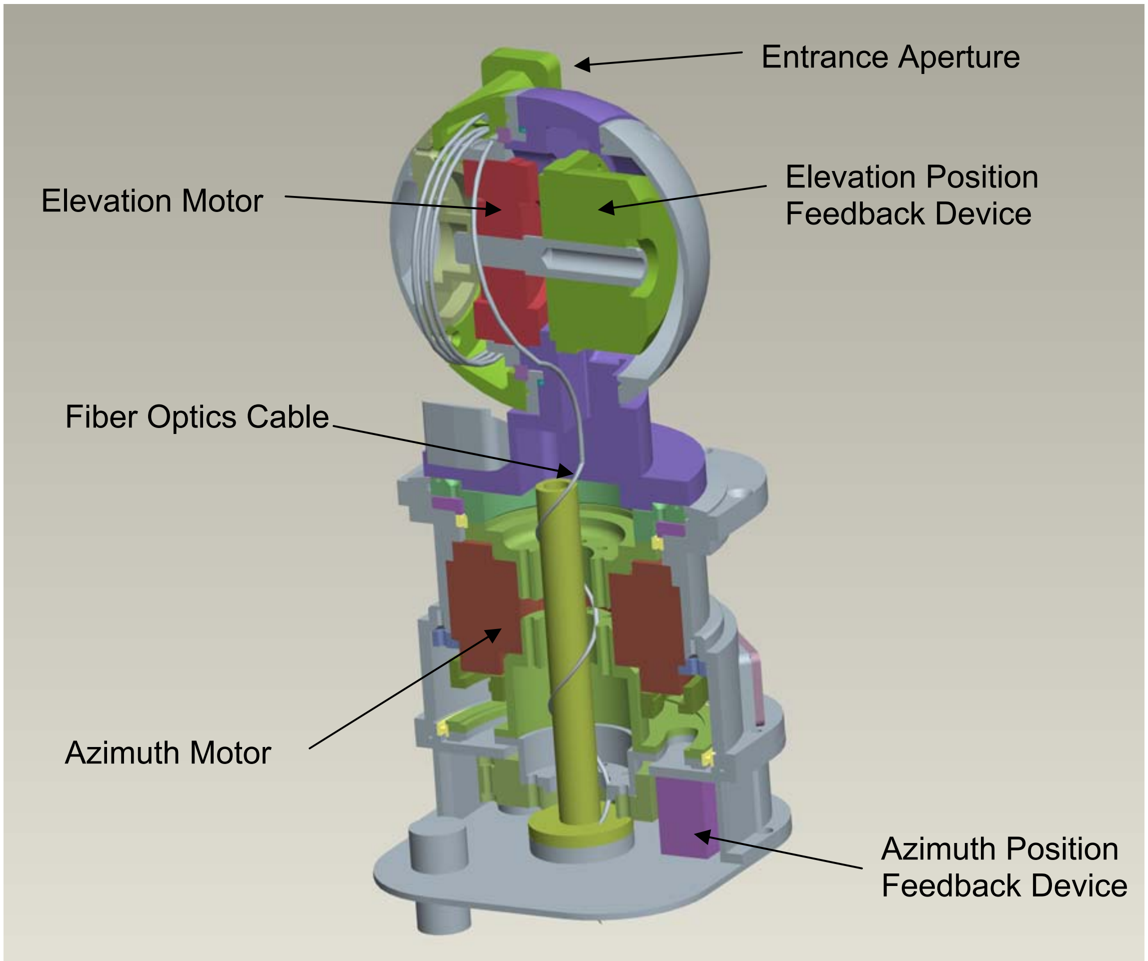

Figure 11: Sectioned instrument head.

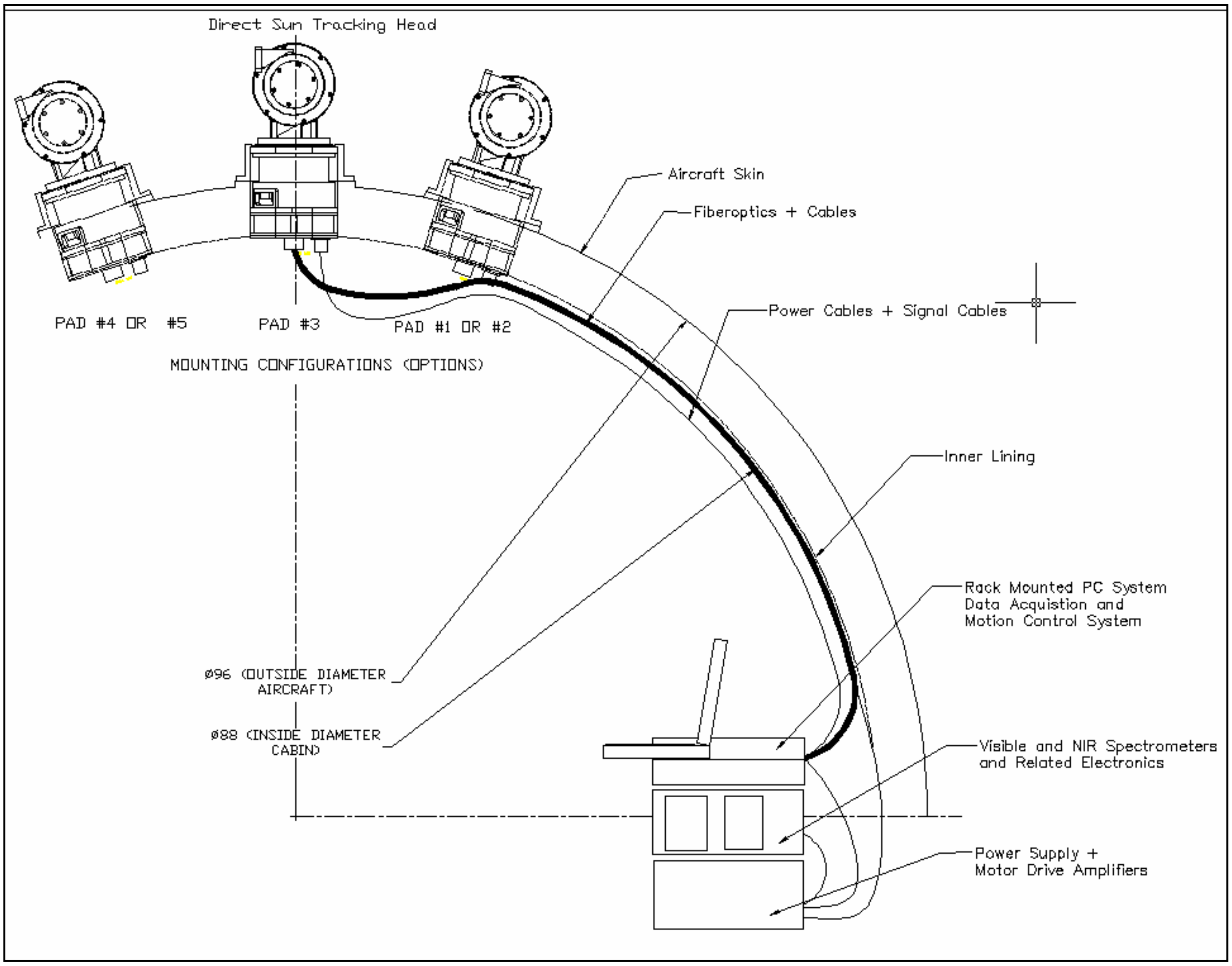

Figure 12: Schematic of instrument integrated on HIAPER in pad #3. Two alternate mountings (corresponding to pads 1&2 or 4&5) are shown as well.

3.4 Automatic Window Cleaning

Although AATS-14 can be operated autonomously, the above mentioned “parking the head” to avoid dirt deposition on the optical window requires an operator. In the proposed design the optical window covering the apertures of the entrance optics and the quad-sensor comes to rest on a slanted pedestal when the tracking head is brought into its “park” position (Figure 13). We envision a design and realization whereby retractable brushes (using solenoids) clean the optical window in this “park” position. During flight the head would automatically park itself briefly at preset intervals for the in-flight cleaning process, thereby eliminating operator interaction. The cleaning mechanism will be tested during mountain calibration to be sure dirt removal is sufficient for the optical accuracies required (i.e. transmission constant to ~0.2%).

3.5 Spectrometers

One of the spectrometers will be optimized for the visible and near-IR optical range (wavelengths 0.35 – 0.98 µm). We plan to use the Zeiss MCS instrument. All components in that unit are permanently glued to each other resulting in a quasi-monolithic module with no moving parts. The spectrometer body is made of ceramic material and the detector is a photo-diode array with 1024 pixels resulting in a resolution of 2-3 nm. The second spectrometer will cover the near-IR from 0.9 to 1.7 µm. Here we are currently evaluating a near-IR version of the Zeiss MCS (resolution 8-12 nm) or the model NIR 512 from Ocean Optics (resolution 3 nm).

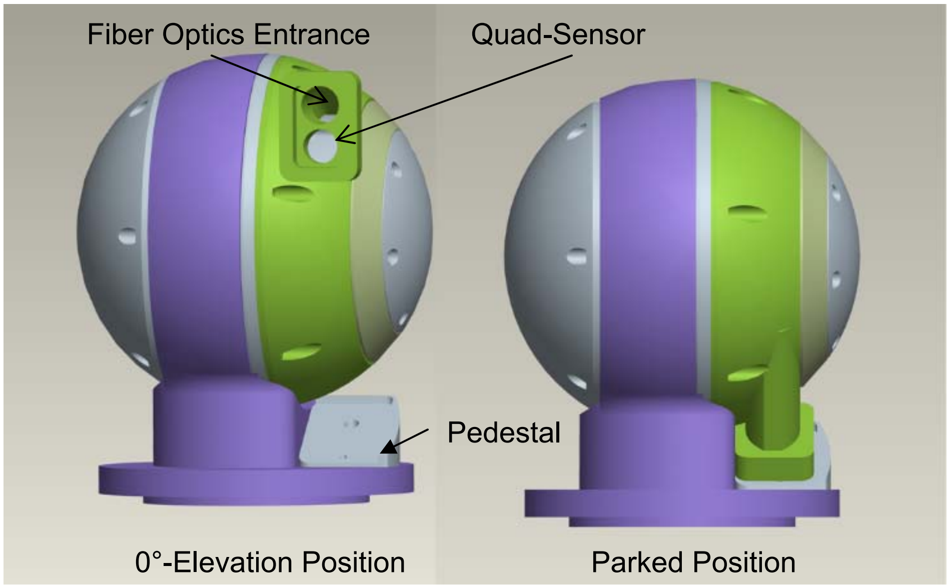

Figure 13: Dome section of proposed instrument.

3.6 Fiber Transmission Tests

A major difference between the well proven AATS instruments and the proposed instrument is that in the new design the light will be transported through optical fibers to rack-mounted spectrometers whereas in the AATS design the light is detected by individual photodiodes which are mounted inside the dome. Transporting light from a non-moving head through optical fibers to rack-mounted spectrometers is a proven concept used with the SSFR instrument (e.g. *Pilewskie* et al., 2003).

However in the proposed instrument the fibers will endure sustained bending and twisting: In elevation the tracking head is allowed to move from its parking position to about 10° beyond zenith. In azimuth the head is allowed to turn by 400° in each direction before it will "unwind" quickly and re-acquire the sun.

To answer two questions: a) Does the structure of the fiber endure sustained bending and twisting? and b) How does the spectral transmission of the fiber change upon bending and twisting? we performed detailed tests with various types of optical fibers (fiber bundle vs. mono-fiber, fibers with different core diameters).

The tests were carried out by Dr. Rainer Schmitt (Metcon Inc., Boulder, CO) in the period of December 2003 to February 2004 on tests-stand in the laboratory using a highly stable (better than 0.1%) 1000 Watt FEL-lamp. Results indicate negligible transmission change (<0.2% over the wavelength range of 0.3 – 1.7μm) upon dynamic bending of the fiber for bending radii used in our design. However we realized that the fiber design must be chosen carefully for use in a given wavelength range and geometry.

3.7 Instrument Calibration

The instrument will be calibrated by a combination of high-altitude Langley-plot calibration and laboratory calibration using FEL lamps (see *Schmid et al*., 1995 and 1998). As site for the Langley calibration we propose Mauna Loa Observatory, HI. Based on the long-term experience of the AATS team this site offers the best chance for cloud-free, stable and clear atmospheric morning conditions.

Due to the high ceiling altitude of the HIAPER aircraft a calibration using the in-flight Langley method is particularly attractive. This alternative calibration method requires the aircraft to fly at high and constant altitude with no clouds overhead while the sun raises or sets through elevation angles 8-30°. AATS-14 has been successfully calibrated using this in-flight method during ACE-2 (*Schmid et al*., 2000).

3.8 Data Analyses

The BAER Institute/NASA Ames team is recognized worldwide for its leading role in analyses of solar direct beam measurements. The algorithms used for the proposed instrument will be adapted from the algorithms the team currently uses for the AATS instruments (*Russell et al.* 1993, and 2003, *Schmid et al.*, 1996, 1997, 1999, 2000, 2001, 2003a and b, *Redemann et al.*, 2003a, *Livingston et al.*, 2003b). Dr. Schmid also has experience with spectrally resolved datasets from ground-based instruments (*Schmid et al.*, 1999, *Kiedron et al.*, 2001). The data reduction requires that time, geographical latitude and longitude, altitude and ambient (static) pressure be provided by the HIAPER data system. Static temperature and dew-point temperature are desired as well. As with the AATS instruments, a subset of the science quantities the proposed instrument will deliver can be displayed at the rack mounted computer display. This capability has shown to be very useful for the mission scientist aboard the airplane (or on the ground when the data are relayed by SATCOM) for adjustments to the planned flight track.

4 Deliverables and Schedule

	Schedule of tasks											
Task	2004	2005				2006				2007		
Quarter	4	1	2	3	4	1	2	3	4	1	2	3
Mechanical system layout	⬛											
Electrical system layout	⬛											
Design review	⬛											
Mechanical detail design												
Head Unit		⬛										
Azimuth motor flange unit		⬛										
Rack mounted set up		⬛										
Electrical Detail design												
Interconnect diagrams, PC boards etc..			⬛									
Servo system, power supply detail specfications			⬛									
Data acquisition system - detail specification			⬛									
Procurement												
Mechanical (machining, standard parts etc..)			▨	▨								
Mechanical (machining, rack mount, aircraft mount)								▨			▨	
Electrical (power supply, PC boards, motors, cables, connectors..)				▨								
Spectrometers, Data acqusition computer hardware, etc..				▨	▨							
Integration- Laboratory												
Mechanical assembly of components					🟦							
Wiring and testing, fiber routing					🟦	🟦						
Hardware integration, servo system, power supply,						🟦	🟦					
Spectrometer data acqusition system, etc.						🟦	🟦					
Software integration												
Data acquistion system (spectrometer, etc..)							🟥	🟥				
Code generation and tuning servo system								🟥	🟥			
Adaptation of AATS 14 codes to the new instrument								🟥	🟥	🟥		
Fully operational lab test										🟨		
Field test/ check operation at temperature extremes												
Servo system performance											🟩	
Data acqusition system performance											🟩	
Calibration and comparison of data to AATS 14											🟩	🟩
Test flight and integration												🟥
Prepare a master catalogue with												
Mechanical and electrical drawings												🟨
Parts list and vendor information												🟨
Operational procedure												🟨
Software code (data acq., control, data analysis)												🟨
Preliminary preventive maintenance procedure												🟨
Trouble shooting guides												🟨

Our schedule foresees the completed, tested and calibrated instrument to be test-flown on HIAPER at the end of the third year (i.e. the development phase of the instrument will be 3 years). Per NSF guidance (e-mail from Mr. J. Hunning (NSF) to A. Strawa (NASA Ames), dated February 6, 2003) funding for instrument deployments and funding for support of the instrument by the PI would come from a separate source of money (Research and Related Activities) and are therefore not included here. Mr. Milne further suggested including a narrative on what the expected ongoing maintenance/support by the originating PI would be.

In this respect we plan to accompany the instrument on initial deployments (and calibrations bracketing deployments) for about 2 years. During that period we will train NCAR personnel in instrument operation, calibration and data analysis. After that the instrument can be operated and maintained by trained NCAR staff, with some level of involvement of the originating PI. The proposed instrument need not fly on every HIAPER mission but will be available to community users upon request.

Science quantities the proposed instrument will deliver are: Direct solar beam transmittance (at wavelengths 0.35 – 1.7 µm), direct solar beam irradiance W/m2/µm (0.35 – 1.7 µm), AOD (0.35 – 1.7 µm, outside gaseous absorption bands only), H_2O and O_3 column above aircraft.

Science quantities the proposed instrument will deliver but which will, at least initially, require some level of involvement of the originating PI are: Aerosol extinction (0.35 – 1.7 µm, outside gaseous absorption bands only), H_2O O_3 and NO_2 densities (these quantities require vertical profiling of aircraft), and NO_2 column above aircraft.

As demonstrated with the existing AATS's, the proposed instrument will deliver valuable data throughout the vertical range of the HIAPER aircraft, from the lower troposphere to the upper troposphere and lower stratosphere.

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Professional Preparation

Institution	Degree	Field	Dates
University of Bern, Switzerland	Liz. Phil. Nat. (M.S.)	Physics	1991
University of Bern, Switzerland	Ph.D.	Physics	1995

Appointments

1997 – Present	Senior Research Scientist, Bay Area Environmental Research Inst., Sonoma, CA
1995 – 1997	Research Assistant (Postdoctoral Researcher), University of Bern, Switzerland
1995 (Oct.) – 1996 (Jan.)	Visiting Scientist, University of Arizona, Tucson, AZ
1989 – 1995	Research Assistant, University of Bern, Switzerland

Publications Most Closely Related to the Proposed Project:

Schmid B., D. A. Hegg, J. Wang, D. Bates, J. Redemann, P. B. Russell, J. M. Livingston, H. H. Jonsson, E. J. Welton, J. H. Seinfeld, R. C. Flagan, D. S. Covert, O. Dubovik, and A. Jefferson. Column closure studies of lower tropospheric aerosol and water vapor during ACE-Asia using airborne sunphotometer, airborne in-situ and ship-based lidar measurements. *J. Geophys. Res., 108*(D23), 8656, doi:10.1029/2002JD003361, 2003. http://geo.arc.nasa.gov/sgg/AATS-website/recent_pubs/2002JD003361.pdf

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Five Other Scientific Publications (total peer-reviewed publications = 33):

Livingston J. M., P. B. Russell, J. S. Reid, J. Redemann, **B. Schmid**, D. A. Allen, O. Torres, R. C. Levy, L. A. Remer, B. N. Holben, A. Smirnov, O. Dubovik, E. J. Welton, J. R. Campbell, J. Wang, S. A. Christopher, Airborne sunphotometer measurements of aerosol optical depth and columnar water vapor during the Puerto Rico Dust Experiment, and comparison with land, aircraft, and satellite measurements, *J. Geophys. Res.*, 108 (D19), 8588, doi:10.1029/2002JD002520, 2003. http://geo.arc.nasa.gov/sgg/AATS-website/recent_pubs/2002JD002520.pdf

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Synergistic Activities:

- Associate Editor, *Journal Geophysical Research* – Clouds and Aerosols (2002- present)
- Employed NASA Ames Airborne Sun photometers in campaigns all over the world and made processed data available to the research community through web-based archives
- Co-led planning of DOE ARM May 2003 Aerosol Intensive Observation Period. Responsible for defining airborne payload on the CIRPAS Twin Otter aircraft. Led Twin Otter investigators (10 PI's) during field campaign as platform scientist.

Collaborators on a Project, Book, Article, Report, or Paper within the Last 48 Months:
T. Anderson (U. Wash), M. Andreae (MPI Mainz, Germany), P. Arnott (DRI), J. Barnard (PNNL), D. Bates (U. Miami), A. Bucholtz (NRL), J. Campbell (U. Fairbanks), D. Chu (SSAI), A. Clarke (U. Hawaii), P. Colarco (UMBC), D. Collins (Texas A&M), D. Covert (U. Wash.), D. Diner (JPL), O. Dubovik (UMBC), P. Durkee (NPS), T. Eck (UMBC), J. Eilers (NASA ARC), R. Elleman (U. Wash), R. Ferrare (NASA LaRC), R. Flagan (Caltech), P. Formenti (U. Evora, Portugal), S. Gassó (NASA GSFC), H. Gordon (ret.), R. Halthore (ONR), D. Hegg (U. Wash.), M. Helmlinger (JPL), D. Hlavka (SSAI), P. Hobbs (U. Wash), B. Holben (NASA GSFC), S. Howell (U. Hawaii), C. Hsu (UMBC), T. Ingold (U. Bern, Switzerland), A. Jefferson (NOAA CMDL), H. Jonsson (CIRPAS), R. Kahn (JPL), G. de Leeuw (TNO, The Netherlands), J. Liljegren (ANL), J. Livingston (SRI Intl), S. Masonis (U. Wash.), M. McGill (NASA GSFC), C. McNaughton (U. Hawaii), J. Michalsky (NOAA CMDL), T. Murayama (TUMM, Japan), K. Noone (MISU Stockholm), E. Öström (British Met. Office), P. Pilewskie (NASA ARC), J. Pommier (BAER Inst.), D. Powell (PNNL), B. Provencal (Los Gatos Res. Inc), J. Reagan (U. Arizona), J. Redemann, (BAER Inst.), L. Remer (NASA GSFC), K. Ricci (Los Gatos Res. Inc), T. Rissman (Caltech), C. Robles Gonzalez (TNO, The Netherlands), P. Russell (NASA ARC), J. Seinfeld (Caltech), D. Slater (ret.), I. Slutsker (SSAI), J. Spinhirne (NASA GSFC), A. Strawa (NASA ARC), O. Torres (UMBC), T. VanReken (Caltech), K. Voss (U. Miami), J. Wang (BNL), E. Welton (NASA GSFC)

Graduate Advisor: N. Kämpfer, University of Bern
Postgraduate Scholar Sponsor for: (none)
Student Advisor for: (none)

Jens Redemann
Senior Research Scientist
Bay Area Environmental Research Institute
Sonoma, CA

Professional Preparation

Institution	Degree	Field	Dates
Free University, Berlin, Germany	M.S.	Physics	1995
UCLA	M.S.	Atmospheric Sciences	1997
UCLA	Ph.D.	Atmospheric Sciences	1999

Appointments

1999 – Present	Senior Research Scientist, Bay Area Environmental Research Inst., Sonoma, CA
1995 – 1999	Graduate Student Research Assistant, UCLA
1994 – 1995	Graduate Student Research Assistant, Free University, Berlin, Germany

Publications Most Closely Related to the Proposed Project:

Redemann, J., B. Schmid, J. A. Eilers, R.A. Kahn, R. C. Levy, P. B. Russell, J. M. Livingston, P. V. Hobbs, W. L. Smith Jr., B. N. Holben, Suborbital measurements of spectral aerosol optical depth and its variability at sub-satellite grid scales in support of CLAMS, 2001, *J. Atmos. Sci.*, special issue on CLAMS, submitted, 2003.

http://geo.arc.nasa.gov/sgg/AATS-website/recent_pubs/CLAMSpaperRedemann111003.pdf

Redemann J., S. Masonis, B. Schmid, T. Anderson, P. Russell, J. Livingston, O. Dubovik, A. Clarke, Clear-column closure studies of aerosols and water vapor aboard the NCAR C-130 in ACE-Asia, 2001, *J. Geophys. Res.*, *J. Geophys. Res., 108*(D23), 8655, doi:10.1029/2003JD003442, 2003.

http://geo.arc.nasa.gov/sgg/AATS-website/recent_pubs/Jens_ACEAsia.pdf

Redemann, J., R.P. Turco, K.N. Liou, P.B. Russell, R.W. Bergstrom, B. Schmid, J.M. Livingston, P.V. Hobbs, W.S. Hartley, S. Ismail, R.A Ferrare, E.V. Browell, Retrieving the vertical structure of the effective aerosol complex index of refraction from a combination of aerosol in situ and remote sensing measurements during TARFOX, *J. Geophys. Res.*, *105*, 9949-9970, 2000.

Redemann, J., R.P. Turco, K.N. Liou, P.V. Hobbs, W.S. Hartley, R.W. Bergstrom, E.V. Browell, and P.B. Russell, Case studies of the vertical structure of the direct shortwave aerosol radiative forcing during TARFOX, *J. Geophys. Res.*, *105,* 9971-9979, 2000.

Redemann, J., R.P. Turco, R.F. Pueschel, M.A. Fenn, E.V. Browell and W.B. Grant. A Multi-Instrument Approach for Characterizing the Vertical Structure of Aerosol Properties: Case Studies in the Pacific Basin Troposphere, *J. Geophys. Res.*, *103,* 23,287 - 23,298, 1998.

Five Other Scientific Publications (total peer-reviewed publications = 17):

Wang, J., S.A. Christopher, F. Brechtel, J. Kim, B. Schmid, J. Redemann, P.B. Russell, P. Quinn, and B.N. Holben, Geostationary Satellite Retrievals of Aerosol Optical Thickness during ACE-Asia, *J. Geophys. Res.*, *108*, doi:10.1029/2003JD003580, 2003.

Russell, P.B., J. Redemann, B. Schmid, R.W. Bergstrom, J.M. Livingston, D.M. McIntosh, S. Hartley, P.V. Hobbs, P.K. Quinn, C.M. Carrico, M.J. Rood, E. Öström, K.J. Noone, W. von Hoyningen-Huene, and L. Remer, Comparison of aerosol single scattering albedos derived by diverse techniques in two North Atlantic experiments, *J. Atmos. Sci.*, *59*, 609-619, 2002.

Redemann, J., P.B. Russell, M.P. McCormick, D.M. Winker, On the feasibility of studying shortwave aerosol radiative forcing of climate using dual-wavelength lidar-derived aerosol backscatter data, *'Advances in Laser Remote Sensing'*, A. Dabas, C. Loth, J. Pelon (eds.), pp. 159-162, 2001.

Redemann, J., P.B. Russell, and P. Hamill, Dependence of aerosol light absorption and single scattering albedo on ambient relative humidity for sulfate aerosols with black carbon cores, *J. Geophys. Res.*, *106*, 27,485-27,495, 2001.

Pueschel, R.F.; D.A. Allen, C. Black, S. Faisant, G.V. Ferry, S.D. Howard, J.M. Livingston, J. Redemann, C.E. Sorensen, S. Verma, Condensed Water in Tropical Cyclone "Oliver", 8 February 1993, *Atmospheric Research*, 38, pp.297-313, 1995.

Synergistic Activities:

- Employed NASA Ames Airborne Sun photometers in campaigns all over the world and made processed data available to the research community through web-based archives
- Taught general education undergraduate classes in Atmospheric Sciences and involved students in satellite validation activities.
- Currently planning a satellite validation experiment for the validation of MODIS IR aerosol optical depth.

Collaborators on a Project, Book, Article, Report, or Paper within the Last 48 Months:
T. Anderson (U. Wash), G. Arnold (L-3CAC), P. Arnott (DRI), R. Bergstrom (BAERI), E. Browell (NASA LaRC), A. Bucholtz (NRL), B. Cairns (Columbia U.), T. Charlock (NASA LaRC), J. Chowdhary (Columbia U.), D. Chu (SSAI), A. Clarke (U. Hawaii), P. Colarco (UMBC), D. Covert (U. Wash.), O. Dubovik (UMBC), J. Eilers (NASA ARC), R. Elleman (U. Wash), R. Ferrare (NASA LaRC), R. Flagan (Caltech), C. Gatebe (UMBC), P. Hamill (SJSU), D. Hegg (U. Wash.), P. Hobbs (U. Wash), B. Holben (NASA GSFC), S. Howell (U. Hawaii), C. Hsu (UMBC), S. Ismail (NASA LaRC), Z. Jin (SAIC), H. Jonsson (CIRPAS), R. Kahn (JPL), Y. Kaufman (NASA GSFC), M. King (NASA GSFC), R. Levy (SAIC), J. Livingston (SRI Intl), K. Liou (UCLA), A. Lyapustin (UMBC), V. Martins (UMBC), S. Masonis (U. Wash.), P. McCormick (Hampton U), C. McNaughton (U. Hawaii), M. Mishchenko (NASA GISS), T. Murayama (TUMM, Japan), P. Pilewskie (NASA ARC), M. Pitts (NASA LaRC), J. Reid (NRL), L. Remer (NASA GSFC), P. Russell (NASA ARC), C. Rutledge (SAIC), J. Seinfeld (Caltech), W. Smith Jr. (NASA LaRC), J. Wang (BNL), E. Welton (NASA GSFC), B. Wenny (SAIC), D. Winker (NASA LaRC)

Graduate Advisor: R. Turco, UCLA
Postgraduate Scholar Sponsor for: (none)
Student Advisor for: (none)

Philip B. Russell
Research Scientist and Leader, Sunphotometer-Satellite Group
Atmospheric Chemistry and Dynamics Branch, NASA Ames Research Center
Moffett Field, CA

Professional Preparation

Institution	Degree	Field	Dates
Wesleyan University	B.A.	Physics	1965
Stanford University	Ph.D.	Physics	1971
Stanford University	M.S.	Management	1990

Appointments

1995 – Present	Research Scientist, Atmospheric Chemistry and Dynamics Branch, NASA Ames Research Center
1989-95	Chief, Atmospheric Chemistry and Dynamics Branch, NASA Ames Research Center
1988-89	Acting Chief and Acting Deputy Chief, Earth System Science Division, NASA Ames Research Center
1982-89	Chief, Atmospheric Experiments Branch, NASA Ames Research Center
1972-82	Physicist to Senior Physicist, Atmospheric Science Center, SRI International
1971-72	Postdoctoral Appointee, National Center for Atmospheric Research (at University of Chicago and NCAR)

Patent and Publications Most Closely Related to the Proposed Project:

U.S. Patent No. 4,710,618: Airborne Tracking Sunphotometer Apparatus and System, awarded 1987.

Russell, P, B, J. M. Livingston, O. Dubovik, S. A. Ramirez, J. Wang, J. Redemann, B. Schmid, M. Box, and B. N. Holben, Sunlight transmission through desert dust and marine aerosols: Diffuse light corrections to Sun photometry and pyrheliometry, *J. Geophys. Res,* ms No. 2003JD004292, accepted 2004.

Russell, P. B., J. Redemann, B. Schmid, R. W. Bergstrom, J. M. Livingston, D. M. McIntosh, S. Hartley, P. V. Hobbs, P. K. Quinn, C. M. Carrico, M. J. Rood, E. Öström, K. J. Noone, W. von Hoyningen-Huene, and L. Remer, Comparison of aerosol single scattering albedos derived by diverse techniques in two North Atlantic experiments, *J. Atmos. Sci., 59*, 609-619, 2002

Russell, P. B., and J. Heintzenberg, An Overview of the ACE 2 Clear Sky Column Closure Experiment (CLEARCOLUMN), *Tellus B 52*, 463-483, 2000.

Russell, P. B., J. M. Livingston, P. Hignett, S. Kinne, J. Wong, and P. V. Hobbs, Aerosol-induced radiative flux changes off the United States Mid-Atlantic coast: Comparison of values calculated from sunphotometer and in situ data with those measured by airborne pyranometer, *J. Geophys. Res., 104*, 2289-2307, 1999.

Five Other Scientific Publications (total peer-reviewed publications = 111):

Russell, P.B., J. M. Livingston, R. F. Pueschel, J. A. Reagan, E.V. Browell, G. C. Toon, P.A. Newman, M.R. Schoeberl, L.R. Lait, L. Pfister, Q. Gao, and B. M. Herman, 1993: "Post-Pinatubo Optical Depth Spectra vs. Latitude and Vortex Structure: Airborne Tracking Sunphotometer Measurements in AASE II," *Geophys. Res. Lett.*, *20*, 2571-2574, 1993.

Russell, P. B., S. Kinne, and R. Bergstrom, "Aerosol Climate Effects: Local Radiative Forcing and Column Closure Experiments," *J. Geophys. Res. 102*, 9397-9407, 1997.

Russell, P. B., J. M. Livingston, R. F. Pueschel, J. J. Bauman, J. B. Pollack, S. L. Brooks, P. J. Hamill, L. W. Thomason, L. L. Stowe, T. Deshler, E. G. Dutton, and R. W. Bergstrom. "Global to Microscale Evolution of the Pinatubo Volcanic Aerosol, Derived from Diverse Measurements and Analyses." *J. Geophys. Res.* , *101*, 18,745-18,763, 1996.

Russell, P. B., J. M. Livingston, E. G. Dutton, R. F. Pueschel, J. A. Reagan, T. E. DeFoor, M. A. Box, D. Allen, P. Pilewskie, B. M. Herman, S. A. Kinne, and D. J. Hofmann, 1993: "Pinatubo And Pre-Pinatubo Optical Depth

Spectra: Mauna Loa Measurements, Comparisons, Inferred Particle Size Distributions, Radiative Effects, And Relationship To Lidar Data, *J. Geophys. Res., 98*, 22,969-22,985.

Russell, P.B., and M.P. McCormick, 1989: "SAGE II Aerosol Data Validation and Initial Data Use: An Introduction and Overview," *J. Geophys. Res.*, *94*, 8335-8338.

Synergistic Activities:

- Editor and Editor-in-Chief, *Geophysical Research Letters* (1993-96)
- Chair, American Meteorological Society International Committee on Laser Atmospheric Studies (1979-82)
- Member, National Research Council Committee on Army Basic Research (1979-81)

Collaborators on a Project, Book, Article, Report, or Paper within the Last 48 Months:
T. Anderson (U. Wash), M. Andreae (MPI Mainz, Germany), T. Bates (NOAA PMEL), J. Bauman (NASA Ames), M. Bergin (Ga. Tech.), R. Bergstrom (BAER Inst.), M. Box (UNSW, Australia), A. Bucholtz (NRL), C. Carrico (Ga. Tech.), S. Christopher (U. Alabama), A. Clarke (U. Hawaii), P. Colarco (UMBC), D. Collins (Texas A&M), D. Covert (U. Wash.), D. Diner (JPL), O. Dubovik (UMBC), P. Durkee (NPS), T. Eck (UMBC), J. Eilers (NASA ARC), R. Ferrare (NASA LaRC), R. Flagan (Caltech), P. Formenti (U. Evora, Portugal), S. Gassó (NASA GSFC), M. Geller (SUNY), H. Gordon (ret.), R. Halthore (ONR), P. Hamill (SJSU), D. Hegg (U. Wash.), M. Helmlinger (JPL), P. Hignett (UK Met. Off.), D. Hlavka (SSAI), P. Hobbs (U. Wash), B. Holben (NASA GSFC), W. von Hoyningen-Huene (U. Bremen), S. Howell (U. Hawaii), C. Hsu (UMBC), B. Huebert (U. Hawaii), H. Jonsson (CIRPAS), R. Kahn (JPL), G. de Leeuw (TNO, The Netherlands), R. Levy (UMBC), J. Livingston (SRI Intl), H. Maring (NASA HQ), S. Masonis (U. Wash.), M. McGill (NASA GSFC), C. McNaughton (U. Hawaii), J. Michalsky (NOAA CMDL), T. Murayama (TUMM, Japan), T. Nakajima (U. Tokyo), K. Noone (MISU Stockholm), E. Öström (British Met. Office), P. Pilewskie (NASA ARC), J. Pommier (BAER Inst.), D. Powell (PNNL), P. Quinn (NOAA PMEL), J. Reagan (U. Arizona), J. Redemann, (BAER Inst.), J. Reid (NRL), L. Remer (NASA GSFC), M. Rood (U. Illinois), J. Seinfeld (Caltech), J. Spinhirne (NASA GSFC), A. Strawa (NASA ARC), O. Toon (U. Colorado), O. Torres (UMBC), K. Voss (U. Miami), Jian Wang (BNL), Jun Wang (U. Alabama), E. Welton (NASA GSFC), J. Xu (Ga. Tech.)

Graduate Advisor: S. Hanna, Stanford University (Nuclear physics)
Postgraduate Scholar Sponsor for: (none)
Student Advisor for: Jill Bauman, SUNY Stony Brook

BAER Institute - Facilities, Equipment, and Other Resources

The Bay Area Environmental Research Institute ("BAER Institute"; http://www.baeri.org/) is a California 501(c)3 not for profit corporation dedicated to promoting and conducting research in the environmental sciences, particularly atmospheric science. Established in 1993 by Director of Research, Robert W. Bergstrom, and Chief Executive Officer, Sharon A. Sittloh, BAER Institute scientists have worked with state and federal agencies on a wide variety of research topics.

BAER Institute is well recognized nationally for its significant contributions to the area of environmental research. Since its founding, BAER Institute has been guided by a fundamental commitment to original research.

BAER Institute's areas of expertise include the general areas of biology, chemistry and physics. Specific projects range in scale from the study of microbes and how they develop in primitive atmospheric conditions to utilizing satellite data to monitor and understand the Earth and Martian atmospheres. Currently, BAER Institute's scientists are working in conjunction with scientists at the NASA Ames Research Center (and other institutions) on a number of projects.

All administrative and clerical work proposed here will be performed at the BAER Institute office in Sonoma, CA. The BAER Institue has a number of computers as well as telephone, faxes, internet access and copy equipment. Drs. Beat Schmid, Jens Redemann and Mr. Teck Meriam will perform most of the proposed work at NASA Ames Research Center (NASA ARC). NASA ARC provides office and lab space, phone lines, fax, copy equipment, access to computers and network (including remote access) required for this research. The associated facility costs are included in a collaborative proposal by NASA ARC (PI Dr. P. Russell).

Drs. Beat Schmid, Jens Redemann and Mr. Teck Meriam will have access to lab space, tools, shops, test facilities, databases etc. at NASA ARC required to complete the proposed work. This includes the Ames Airborne Sensor facility (ASF)** which is of particular relevance to this project.

**ASF will offer support in the areas of instrument calibration, electro-optic design consultation, and hardware fabrication, as needed. The ASF maintains an optical calibration laboratory specifically designed to support airborne spectro-radiometers. It includes primary and secondary radiometric sources, and various spectral measurement devices. The laboratory is under the technical supervision of the NASA EOS Calibration Scientist at GSFC, and is a regular participant in “round-robin” exercises with NIST and other national facilities. This laboratory is well suited to characterize stray-light and polarization effects, as well as to establish fundamental system response. The ASF also has extensive experience with the design and implementation of optical and electronic systems for the NASA airborne science program, including the MODIS and ASTER Airborne Simulators flown on the ER-2 and DC-8 aircraft. Their experience with state-of-the-art analog signal digitization and data-capture systems on these infrared systems should prove valuable to this project. In addition, ASF engineers have many years of collective experience in maintaining well-calibrated systems in the problematic airborne environment. Other assets will be used as needed, including packaging design and precision machining services.

NASA Ames Research Center - Facilities, Equipment, and Other Resources

NASA Ames Research Center provides office and lab space, phone lines, fax, copy equipment, access to computers and network (including remote access) required for this research. The associated facility costs are included as Allocated Service Pool costs.

Dr. Russell and his team have access to lab space, tools, shops, test facilities, databases etc. required to complete the proposed work. This includes the Ames Airborne Sensor facility (ASF)** which is of particular relevance to this project

**ASF will offer support in the areas of instrument calibration, electro-optic design consultation, and hardware fabrication, as needed. The ASF maintains an optical calibration laboratory specifically designed to support airborne spectro-radiometers. It includes primary and secondary radiometric sources, and various spectral measurement devices. The laboratory is under the technical supervision of the NASA EOS Calibration Scientist at GSFC, and is a regular participant in “round-robin” exercises with NIST and other national facilities. This laboratory is well suited to characterize stray-light and polarization effects, as well as to establish fundamental system response. The ASF also has extensive experience with the design and implementation of optical and electronic systems for the NASA airborne science program, including the MODIS and ASTER Airborne Simulators flown on the ER-2 and DC-8 aircraft. Their experience with state-of-the-art analog signal digitization and data-capture systems on these infrared systems should prove valuable to this project. In addition, ASF engineers have many years of collective experience in maintaining well-calibrated systems in the problematic airborne environment. Other assets will be used as needed, including packaging design and precision machining services.