YEAR ONE TECHNICAL PROGRESS REPORT

For the period

September 15, 1990 through March 15, 1991

For the grant

HIGH SPECTRAL RESOLUTION MEASUREMENTS
FOR THE
ARM PROGRAM

Henry E. Revercomb, Principal Investigator (608) 263-6758

Fred A. Best, Program Manager (608) 263-6777

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UNIVERSITY OF WISCONSIN

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1.0 INTRODUCTION

The DOE grant to the University of Wisconsin (UW) teamed with the University of Denver (UD) for the design and fabrication of high spectral resolution FTIR (Fourier Transform Infrared) instrumentation for the CART sites of the Atmospheric Radiation Measurement (ARM) Program began on September 15, 1990. This year-one report summarizes progress from the start date to March 15, 1991. The project is currently on schedule to achieve the primary objectives of the first year.

The ultimate objective of this grant is to develop three different types of instruments, named the AERI, AERI-X, and SORTI. The Atmospheric Emitted Radiance Interferometer (AERI) is the simplest. It will be available for early deployment at the first ARM site and will be deployable at several locations in the extended network to give horizontal coverage. The AERI will be an 0.5 cm^{-1} resolution (unapodized) instrument, which measures accurately calibrated radiance spectra for radiation studies and for remote sensing of atmospheric state variables. It would also be feasible to design an AERI for an aircraft or tethered balloon platform, although this is not a part of the current grant.

The AERI-X and the SORTI are higher spectral resolution instruments for obtaining the highest practical resolution for spectroscopy at the ARM central sites. The AERI-X, like the AERI, will measure atmospheric emitted radiance, but with resolutions as high as 0.1 cm^{-1}. The Solar Radiance Transmission Interferometer (SORTI) will measure the total transmission of the atmosphere by tracking the sun as the atmospheric air mass changes. The large solar signal makes it practical for this instrument to offer the ultimate in spectral resolution, 0.002 cm^{-1}.

This report includes the progress of the whole program, including both the UW and the UD activities. The UW has the primary responsiblity for the AERI and the UD for the higher resolution instruments. However, many of considerations for data system design, data format, software design, and calibration hardware are common. Coordination of activities in these areas is considered to be very important and is underway.

As described in detail below, there has been considerable progress made since the start of the grant. In general, the first year activities outlined in the original proposal are on schedule and within budget. Plans and requested funding for year two remain the same as outlined in the original proposal.

2.0 GENERAL SUMMARY OF PROGRESS

As proposed, the activities of the first year make heavy use of existing instrumentation at both UW and UD for design evalutions and to help define tradeoffs related to instrument procurement. The AERI procurement is currently underway with delivery scheduled for the end of March, while procurements for the higher resolution instruments are scheduled for subsequent years.

2.1 AERI Progress

The general tasks planned for the first year include (A) Design Concept Verification, (B) Subsystem Design, Fabrication and Testing, and (C) Prototype System Integration. Many activities related to tasks A and B have been completed and are underway, while task C will begin later this first year and be completed next year. Our schedule is tied to having a reasonably complete AERI instrument available for participation in the Spectral Radiance Experiment (SPECTRE) in conjunction with the NASA FIRE Project in November 1991. This should put us in a good position to be ready for tests at the first ARM Site in 1992.

Design Concept Verification activities have made use of the AERI prototype instrument, the UW "baby" HIS (High-resolution Interferometer Sounder). Many tests have been conducted to define the performance of the current system and to identify areas where improvements are desirable. The major results have been that (1) we have adopted a primary calibration plan based on using hot and ambient temperature reference blackbody views to avoid errors associated with using cold sources in humid environments, (2) temperature uncertainties of the current system are adequate for accurate calibrations, but improvements in implementation have been identified, and (3) a deficiency of the hot blackbody temperature controller design was discovered and corrective measures have been identified.

In the area of Subsystem Design, Fabrication and Testing, a new temperature controller has been developed which is amenable to computer control and which does not suffer from the problem discovered with the original controller. In addition to hardware, numerous new software modules have been written and tested, to allow data to be acquired in the same form as that of the new AERI instrument.

A focus for our recent activities has been preparing for participation in the ARM portion of the Winter Icing and Storm Program (WISP), which began 26 February and will run until 15 March. This program has provided an excellent opportunity to test the new hardware and software in the field. In addition, it has stimulated new design ideas and has provided a valuable data set for evaluating calibration performance.

2.2 AERI-X and SORTI Progress

The UD has candidate instruments from two vendors set up and operating for evaluation. Each instrument is configured to view the sun through a port in the wall of the Physics building at UD, using a solar tracker mounted outside. Both have the resolution necessary to do the SORTI measurements.

The current idea is to choose the same instrument for the AERI-X and the SORTI. One of the candidates is from BOMEM, of Quebec, Canada and the other from Bruker, of Germany.

The evaluation criteria for choosing the basic interferometer for the AERI-X and the SORTI include both radiometric performance, and other important operational factors and practical considerations. Currently, it appears that the radiometric performance of the two instruments is very good and quite similar. The sensitivity for both solar and emission measurements has been evaluated by tracking the sun and by looking off the sun at the sky. Integration times of 10 to 30 minutes appear adequate. The zero level stability is still being investigated. Initial results suggest that improvements involving the reduction of the number of mirrors used for beam input and output may be necessary (especially for the Bruker).

The criteria other than performance may become the deciding factors. These include the computer and software interfaces, and the company hardware and software support capabilities. While both instruments are provided with PC analysis computers and array processors for fast Fourier transforms, the specific implementations differ considerably. For example, Bruker is preparing an OS2 software package for multi-tasking, and BOMEM has not moved in that direction. Also, Bruker has been provided impressive support to date and is building a customized prototype with their own funding.

In addition to these evaluation activities, UD is investigating the nature of non-linear detector response in support of the calibration design activities for AERI and AERI-X. The effects of non-linearities for the solar instrument can reach 10-15% compared to less than about 1% for the AERI system, because of the differences in photon flux. Therefore, the solar system provides the opportunity to characterize the non-linearity under conditions in which it is large, and to develop models to compensate for its effects.

Finally, as mentioned in the next section, UD has ordered a Sterling cooler to begin investigations of interfacing it to the interferometers.

3.0 PROGRESS ON SPECIFIC TASKS

This section provides further details of progress on individual subtasks. As noted above, the two major areas where progress has been made to date are (A) Design Concept Verification and (B) Subsystem Design, Fabrication, and Testing. The subtasks listed below were originally defined in the budget breakdown that was provided to DOE as part of the "Budget Explanation" which was submitted as "Additional Information" to our original proposal.

3.1 Design Concept Verification

3.1.1 Test Cooling Options for Detectors

Discussions with Bomem Inc., the interferometer manufacturer, have led us to believe that new and significant Sterling Cooler options suitable for cooling our infrared detectors will be available within this coming year. Bomem is supporting a research effort to develop a long life Sterling Cooler and they advised us to wait until this becomes available before we conduct extensive bench top evaluations. The University of Denver (UD) has procured a promising integrated detector and Sterling cooler (which is manufactured in Israel) from InfraRed Laboratories. UD will be performing evaluation testing on this unit during the next year.

3.1.2 Warm Blackbody Tests

The feasibility of replacing the LN2 cold blackbody with a blackened cavity blackbody near ambient temperatures has been studied using a four-view calibration procedure. Sequential observations of Hot BB (330 K), LN2 (77 K), Ambient BB (≈290 K), and SKY have been made using the existing up-looking HIS system. With this procedure the SKY view can be calibrated using HBB and LN2, or HBB and ABB and the results compared. Preliminary results are very encouraging, leading us to anticipate the elimination of LN2 as the principal cold calibration target. Replacement of the LN2 blackbody with the ambient cavity blackbody will greatly reduce the operational complexity of the AERI system.

3.1.3 Linearity Tests-Variable Temperature Blackbodies

Using the four view calibration procedure described in task 1.2, the linearity of the PC MCT detectors over the required dynamic range have been investigated. An especially sensitive test is the calibration of the LN2 target using the HBB and the ABB. Residual non-linearities have been found to be less than 1%. Tests will continue to further understand and quantify these non-linearities.

3.1.4 Shortwave Detector (InSb) Test

This test will be performed using the two channel interferometer system after it is delivered and integrated.

3.1.5 Closed Cycle Sterling Cooler

The UW purchase of a closed cycle Sterling cooler will await test results of a candidate cooler who's development is being supported, in part, by Bomem, Inc. . UD is in the process of evaluating an Israeli Sterling cooler (see 1.1).

3.1.6 Coordination Meetings With UD

We have been in contact with UD and we are currently in the process of establishing ground rules and formats for the software that we will provide them. Our Local Area Network concepts have been communicated to UD; further discussions will be held on this issue.

A meeting between UD and UW personnel took place in early March during our participation in the Winter Icing Storm Program (WISP) being conducted in Platteville, CO. This meeting allowed the UD to see the existing up-looking HIS instrument performing in the field. They saw first hand the operation of our instrument, environmental monitoring system, control software, data analysis software, and networking hardware and software. This demonstration provided an excellent means to illustrate our system philosophies and will help UW and UD better understand each others requirements and how these requirements can be best satisfied.

3.2 Subsystem Design, Fabrication, and Testing

3.2.1 *Two Channel Interferometer*

Considerable difficulty has been encountered in ordering our two channel interferometer from Bomem Inc. Even though our proposal was selected by DOE based on the assumption that a Bomem interferometer would be purchased for the AERI instrument, the UW procurement system would have forced us to obtain a Governors Bid Wavier to go directly to Bomem. This process can take from 4 to 6 months which is not compatible with our schedule. We therefore added the appropriate funds to the University of Denver (UD) subgrant so that they could purchase the interferometer from Bomem. They have an arrangement whereby they can purchase interferometers directly from Bomem in a timely fashion.

The interferometer order for the AERI was finally submitted to Bomem by UD in January and delivery is expected at UW in early April 1991. In the meantime, we are in the process of setting up a "Non-Generic Specification" purchasing arrangement with Bomem, Inc. If approved, this arrangement will allow us to purchase MB Series Interferometers (and any associated maintenance or refurbishment) directly from Bomem, Inc.

3.2.2 *Two Detector Control Software*

The software to acquire spectral data from the Bomem Michelson series interferometer has been delivered to UW and has been successfully used with the existing single detector system. The acquisition software is currently under evaluation at UW.

3.2.3 *Lan Interface*

The hardware and software interface of the acquisition computer has been successfully tested with the baseline Novell network using the existing Up-looking HIS system. It is expected the same interface will work with the AERI prototype system.

3.2.4 *Data Base Manager Hard Disk*

The purchase of this hard disk has not been made. More research is needed to evaluate the most suitable product for our needs.

3.2.5 *Environmental Control and Packaging Considerations*
There has been no activity on this task.

3.2.6 *Optics Bench and Support Table*
There has been no activity on this task.

3.2.7 *Scene Mirror Motor and Controller*
Several motor and motor controller vendors have been contacted and the most suitable product is currently being evaluated.

3.2.8 *Blackbody Calibration Sources*
Extensive testing has been performed on the black body cavities that are currently being used on our existing up-looking HIS instrument. These tests were designed to characterize these cavities in terms of temperature accuracy and temperature stability. Each source of error contributing to overall accuracy was identified. Tests have been performed to measure the contribution of each of these error sources to the overall error budget. These tests have suggested temperature sampling strategies and a hardware modification that will insure temperature measurements will be made within our stated tolerance of 0.05°C.

The hardware modification to the the cavity heater control system involved a redesign that eliminates a temperature stability problem that was discovered during the blackbody characterization testing. It was found that the cavity temperature set point was overly sensitive to the controller ambient temperature. When power was demanded by the control system to heat the cavity, the controller itself heated up in the process of delivering this power. This in turn increased the ambient temperature of the controller which (because of the temperature sensitivity of the controller) changed the temperature set point. It was found that under certain thermal environments the controller would be in a runaway control condition which was ultimately limited by the saturation of a power transistor. The cavity controller redesign eliminates the stability problem and provides a simple computer control interface which the old design lacked. The new system uses a thermistor within the cavity for the temperature control sensor instead of the resistance of the heater windings. Preliminary evaluation testing of the new controller circuit indicates a vast improvement in temperature stability. Further testing will be required to optimize circuit parameters for more precise control.

Detailed design and fabrication of the blackbody calibration sources will begin in the near future.

3.2.9 *Alignment Tooling*
In order to simplify the alignment of the scene mirror and calibration blackbodies to the interferometer, it was desired to have Bomem provide us an alignment reference which defined the center of the interferometer optical

axis. Discussions with Bomem about their alignment procedures have led us to the conclusion that such a reference cannot be provided because the retroreflectors used for the interferometer mirrors make the definition of an interferometer optical axis very difficult. Bomem has suggested that, in general, the procedure that was developed for aligning the existing up-looking HIS system should be followed for the AERI system. We are also investigating an alignment scheme that involves placing a quartz-halogen lamp at the system field stop to define the optical axis of the front end optics.

3.2.10 Environmental Monitoring System

Several meetings were held internally to discuss the system concept for the Environmental Monitoring System. This concept is still evolving but will be finalized in the near future. As part of this effort, requirements documents and specifications for the different components of the Environmental Monitoring System are being generated.

As part of the blackbody cavity characterization tests (described above) we have learned in detail what system performance is required of the data acquisition system, which is a major component of the Environmental Monitoring System.

3.2.11 Noise Testing and Gain Adjustments to Interferometer

This task will be performed on the integrated AERI system.

3.2.12 Integrated System Software

The existing Up-looking HIS system is being used to develop the integrated acquisition and calibration software. This is work in progress.

3.2.13 Co-Aligned Video Imagery

Investigation into frame grabber products and integration of these into our system continues, though at a low priority.

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