New Mexico NASA EPSCoR
Year 1 Progress Report

Project Title:	Infrared Instrument Development for In-Situ Organic Detection
Grant Number:	NNX08AV85A
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Science PI:	Dr. Nancy Chanover, nchanove@nmsu.edu, 575-646-2567
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This annual report documents program activities over the Year 1 period of performance of the grant, and overall progress towards program objectives, as outlined below. Progress has been made and is continuing on a satisfactory level. Prior to detailing the specifics of our progress to date, it is important to note that although the effective date was 7/3/08, there was a significant delay in getting the funding structure set up at New Mexico State University (NMSU). Specifically, funding became available on the following timetable:

- Official start date: 7/3/08
- Award issued from NASA: 8/5/08
- Index numbers set up at NMSU: 11/12/08

The delay in getting the accounts set up internally at NMSU and NMIM&T was due in part to the fiscal year change. The proposal was written with fringe rates and overhead rates valid through 6/30/2008. Since the contract effective date was 7/3/2008 a change of these rates needed to be made without changing the amount of the contract received from NASA. The delay was also caused in part due to the number of entities receiving these funds (NMSU Department of Astronomy, NMSU Department of Electrical and Computer Engineering, NM NASA EPSCoR Program Office and New Mexico Institute of Mining and Technology (NMIM&T). This, along with the cost-matching requirements, meant that six separate accounts had to be set up at NMSU and two at NMIM&T using the new rates. The net result was that Year 1 progress was delayed by an inability to purchase any optical components and begin testing for the first five months of the project.

1. Research Accomplishments Measured Against the Proposed Goals & Objectives

According to the work plan detailed in our submitted proposal, Year 1 activities were described as follows:

"Significant optical component testing at NMSU will be conducted in the first year, prior to assembling the AOTF breadboard. Performance of the assembled breadboard will be characterized using a combination of calibration sources and targets. In parallel with the AOTF breadboard activities, our GSFC collaborators will conduct staged design and development work in Years 1-2 necessary for integrating the complete TOF-LDMS-AOTF prototype instrument."

Our proposed project timeline for Year 1 focused on the task of the AOTF breadboard development and LDMS redesigns. Specific task elements were:

- AOTF procurement, Finalize breadboard design
- Optical component testing
- Breadboard assembly, characterize, calibrate
- Ion extraction assembly (IEA) redesign/build
- Laser focusing system design modifications

We made significant progress in most of the above areas between November 2008 and April 2009 as follows:

- AOTF procurement: Performance specifications for the device were finalized after numerous technical exchanges with the vendor, Gooch & Housego (formerly NEOS Technologies). The original quotation, which included the spectrometer optical deck, exceeded our budget and was re-negotiated to everyone's satisfaction. The device is currently being fabricated by G & H and should be delivered by early summer 2009.

- Breadboard design: We are maintaining a detailed radiometric model (Excel spreadsheet) that predicts the overall performance of the spectrometer vs. wavelength, in the presence of thermal background. This model is being continuously refined based on component test results. Based on fiber acceptance measurements (see below) and AOTF crystal length, it appears that the design f/# will change from f/2.5 to ~ f/3.5, with accompanying loss of throughput. That issue is still being examined. We expect to receive AOTF drawings from the vendor soon, at which point we can proceed with CAD design of the spectrometer optical deck.

- Optical component testing: Our two big accomplishments in this area were the characterization of the infrared microglowers, which we plan to use as our sample illumination source, and the infrared fibers, which we plan to use to couple the light from the illumination source to our samples.
  - The microglower charcterization work tells us what kind of S/N we can expect to achieve, and provides us with real-world numbers to use in our radiometric spreadsheet rather than estimates. Thus, considerable emphasis was placed on the absolute radiometric testing of the Helioworks lamp source, which represented the largest uncertainty in the spectrometer performance predictions. An all-reflective, multi-spectral test station with throughput matching that of the spectrometer was assembled, calibrated, and used for the lamp testing. Device test results showed slightly higher lamp radiance (T_{eff}=1900 K, and effective emissivity of 16%) than that carried in the spectrometer performance model, so we will continue to proceed with this device. An integrated source assembly consisting of lamp, lens, mini circuit board with logic interface has been designed and several copies (for evaluation, breadboard, and brassboard) will be fabricated.
  - Some testing of the fiber sample was also conducted, with mixed results. The measured numerical aperture (NA), which indicates the acceptance angle for light input to the fiber, is lower than advertised (a measured value of 0.15 compared to the specification of 0.2). This means that there will be some additional loss of signal for our f/2.5 design of the

spectrometer illuminator. However, further testing indicates that the coupling to the fiber otherwise is very good, so the lower NA value appears to be tolerable. We are currently developing an end-to-end throughput test procedure that will determine the absolute radiance going into and coming out of the fiber, which will help us decide how to proceed in terms of fiber usage.
  - Short focal length (f/1) off-axis parabolic (OAP) mirrors, arranged back-to-back, are used in the spectrometer optical head to relay the sample reflected light to a cooled InAs detector. Special modifications to the mirror substrates (i.e. an 8 mm diameter circular bore) are necessary in order to mate this optical head to the LDMS unit. This machining was carried out successfully on a spare "evaluation" OAP and hole placement accuracy was demonstrated. Optical obscuration introduced by these modifications still needs to be measured (relative to a reference mirror) in order to verify that obscuration loss is consistent with the performance model. Lenses are used in the tunable light source module to image source radiance through the AOTF and onto the fiber tips. Several lens options were examined, and ray trace analyses show that anti-reflection coated, ZnSe meniscus lenses achieve the required spot size performance over the spectrometer tuning range. Those lens elements have been ordered.
  - A 2 mm diameter InAs detector (Judson) will be used to acquire spectra. The final choice of detector operating temperature (-20 C vs -40 C) and matching circuitry must balance cutoff wavelength and instrument throughput, i.e. the -20 C option extends the long wavelength cutoff by ~ 0.1 μm, but is less sensitive. This choice cannot be made until our component testing is complete.

- <u>Breadboard assembly, characterize, calibrate:</u> The breadboard unit allows us to optimize component placement and evaluate the working performance, including the detector trades and the influence of thermal background. As with the final demonstration unit, the breadboard will be calibrated and used to acquire bench spectra of reference targets and standard samples as they are chosen by the team. An existing IR AOTF (used for previous AOTF camera work at NMSU) has aperture and tuning range similar to the design device, and will be used for the breadboard demonstration. We have begun the breadboard assembly, which is built around commercial optical mounts, tracks and rotation/translation stages, but it requires some custom machining. Completion of the breadboard is closely tied to the component testing and we expect it will take several more months to become operational.

- <u>Ion extraction assembly (IEA) redesign/build:</u> The laser TOF-MS instrument collects laser-desorbed ions by drawing them from the sample surface into the ion extraction assembly (IEA). The IEA is essentially a thin tube extending to a few mm above the sample, in vacuo, with electrostatic lens elements set to voltages that accelerate positive or negative ions into the tube, where they are collimated for analysis in the TOF-MS. In this hybrid instrument, we are making a few modifications to the IEA design, compared to existing prototypes, that (1) accommodate the incidence and collection of light for the AOTF, (2) permit off-axis laser incidence one side of the sample region that is not occluded by AOTF components, and (3) are consistent with expected flight implementations and restrictions, under various mission scenarios. Following a preliminary analysis of alternative geometries and ion optical designs for the IEA, a preliminary design of a "replacement" assembly has been developed, involving the mounting of extraction lenses in a highly-tapered housing to maximize solid angle for collection of light for AOTF. With further detailed mechanical and ion optical design including machining tolerance analysis, the assembly will be fabricated (beginning of Year 2) in an adapter mount that is compatible with one of the existing prototype TOF-MS instruments at Goddard.

- Laser focusing system design modifications: A final optical design that is mutually agreeable to the AOTF and LDMS teams has been selected. The design calls for the illumination sources, both the AOTF fibers and the LDMS laser to illuminate the sample at a slightly oblique angle. The AOTF receiver involves the 1-inch parabolic mirror noted above in the optical testing section with a hole to allow the LDMS ion lens access to the sample.

2. Research Success of Individual Investigators

The design work for this instrument is still in the preliminary stages and therefore has not yet been disseminated for publication. Science PI Chanover presented a poster about the project at the NMSU University Research Council Research and Creative Activities Fair on October 3, 2008. She also gave a talk about the project in the NMSU Astronomy Department on December 1, 2008.

A follow-on proposal for $2,600 will be submitted to the NMSU College of Arts and Sciences minigrant program in April 2009 to purchase an infrared laser. We need a stable laser source for calibration and testing of the MWIR AOTF that will be used in our instrument. The 3.39 micron wavelength is near the long wavelength end of the AOTF sensitivity range and is a critical point for our calibration procedure. We had an infrared laser that we planned to use for this project, but that laser failed in the Fall of 2008. Thus, we are exploring funding options for purchasing a new laser.

A proposal to the NASA Opportunities in Education and Public Outreach for Earth and Space Science (EPOESS) program is in preparation in collaboration with Dr. Jane Aubele at the NM Museum of Natural History and Science in Albuquerque.

3. Systemic Change

Our EPSCoR program is contributing to systemic change at NMSU that is aimed at fostering interdisciplinary research collaborations. In 2005, the 21st Century Space and Aerospace Cluster was established as one of five interdisciplinary research clusters on the NMSU campus. The mission of the Aerospace Cluster is to "form a mutually supportive group of educators, researchers, and practitioners to advance 21st century space-related opportunities for research, teaching, and economic development at NMSU and in the region." Our EPSCoR program is a model for intra-department collaboration, one that even spans multiple academic Colleges within NMSU, and is frequently highlighted as a major activity within the 21st Century Space and Aerospace Cluster. Our success has motivated other researchers at NMSU and NMIM&T to pursue similar collaborations for opportunities such as the 2009 EPSCoR program and the NMSU Interdisciplinary Research Grants.

While there has been no increase in financial support of our program from the NMSU administration, the Vice President for Research continues to be supportive of our efforts. He pledged institutional support for a 2009 EPSCoR proposal led by NMSU investigators, indicating that NMSU remains committed to furthering interdisciplinary research collaborations.

4. Examples of Successful Transfer of Technology to the Private Sector

None to date.

5. Evolution of Collaborations

Several collaborations have evolved as a result of our EPSCoR program:

- In July 2009 Nancy Chanover (NMSU) and Penny Boston (NMIM&T) will submit an E/PO proposal to the NASA EPOESS program in collaboration with Dr. Jane Aubele at the NM Museum of Natural History and Science. This proposal will leverage EPSCoR funds to optimize the scientific and educational impact of our program within the state of New Mexico.
- Both Chanover and Boston are involved in proposals to the 2009 EPSCoR program, thus extending their collaborations with other researchers in New Mexico.
- Glenar will spend the Fall 2009 semester in residence at NMSU, where he will have increased contact with the students and faculty involved in our EPSCoR program as well as other EE and Astronomy graduate and undergraduate students. Glenar retired from NASA/GSFC in December 2007 and remains an Emeritus Scientist in the Planetary Systems Branch at NASA/GSFC. His dual affiliation between NASA and NMSU ensures effective communication between the New Mexico and the NASA/GSFC team members and provides an important contact for our students.
- Our collaborators at NASA/GSFC, Drs. Brinckerhoff, Mahaffy, Simon-Miller, and Moore, are integral team members of this project. We conduct monthly telecons for the entire collaboration (all NM and GSFC team members who are available) to discuss progress, pitfalls, and near-term action items. This ensures that all team members remain informed about all aspects of the project. We also maintain a wiki, which is a collection of web pages that all team members can access and contribute to or modify content. We use the wiki for recording meeting minutes and agendas, sharing instrument design specifications, and uploading reference materials.

6. Furthering of Jurisdiction Priorities

As stated above in the discussions of Systemic Change and the Evolution of Collaborations, our EPSCoR activities have motivated new interdisciplinary collaborations within the state of New Mexico. These collaborations have resulted in several new funding proposals.

7. Interactions with the Jurisdiction Space Grant Program

Team members Chanover and Boston attended the annual New Mexico NASA EPSCoR and Space Grant meeting in Cloudcroft, NM, in July 2008. This served as a kick-off meeting for our program since at that time we had recently learned that our proposal was selected for funding. The meeting provided an excellent opportunity for us to meet other EPSCoR funding recipients within New Mexico. We also were able to meet members of the NM NASA EPSCoR Technical Advisory Committee, who provided us with valuable input for our proposal.

Chanover has two students working with her, one graduate and one undergraduate, who received research funding from the NMSGC (albeit not specifically for this project). She attended the NMSGC student presentations on October 31, 2008, and listened to four student talks describing their research projects. Boston received funding from NMSGC to conduct a summer-2010 field experience for New Mexico teachers enrolled in the NMT Masters in Science Teaching Program. Teachers will participate in studies on desert varnish and other microbial materials that will be used in our testing program.

8. Demographic Information on Participants

- PI
    - Patricia Hynes (White, female)
- CoIs:
    - Nancy Chanover (White, female)
    - David Voelz (White, male)
    - David Glenar (White, male)
    - Penelope Boston (White, female)
- Graduate students:
    - Rula Tawalbeh (White, female)
    - Adam McKay or Charles Miller (White, male) [will be hired in June 2009]

9. Longitudinal Tracking of Students

- Rula Tawalbeh is a graduate student in Electrical Engineering at New Mexico State University.

10. Schedule of Project Activities

The focus of our Year 1 activities was sensor development and functional testing. In Year 2, we will complete these activities and conduct laboratory measurements of natural samples and analogs of astrobiological interest. A quarterly schedule for Year 2, which spans July 2009 - June 2010, is shown below.

Activity	Q1 (Jul-Sep)	Q2 (Oct-Dec)	Q3 (Jan-Mar)	Q4 (Apr-Jun)
Breadboard assembly, characterize				
Ion extraction assembly redesign/build				
Sample measurements				
DPS or AGU meeting presentation				
LPSC meeting presentation				
AbSciCon meeting presentation				