Project Title: Infrared Instrument Development for In-Situ Organic Detection
Grant number: NNX08AV85A
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Award Institution: New Mexico State University (NMSU)
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NASA EPSCoR Final Performance Report

This final performance report documents cumulative project activities over the full duration of the grant, and overall performance towards project objectives, as outlined below.

1. Research Accomplishments Measured Against the Proposed Goals & Objectives

The overall aim of our project was develop and test a point spectrometer based on acousto-optic tunable filter (AOTF) technology that may be used for the screening and corroboration of samples collected *in situ* from planetary surfaces. Samples that indicate the presence of organics or other biomarkers of astrobiological interest would be further analyzed using a NASA/GSFC-built miniature laser desorption mass spectrometer (LDMS), which can characterize trace levels of complex organics. The combination of an AOTF IR point spectrometer with an LDMS provides a biological sensing system that is practical, rugged and efficient for a lander platform targeted for Mars, an asteroid, or icy moons of the outer solar system. Our overarching objective was to develop flight-qualifiable instrumentation necessary for astrobiological investigations, enabling participation in flight programs and strengthen the technical and human resources capabilities within New Mexico.

The two scientific objectives for the proposed work were as follows:

1) quantitatively demonstrate that an AOTF-based spectrometer can perform rapid spectral detection of organic species when they are present on the surface of solid samples, and that a combined sample analysis by both the AOTF and the LDMS produces an unambiguous detection of the organic materials present

2) show that this class of spectrometer can reduce ambiguity and improve the time efficiency of an *in situ* LDMS by itself by prescreening samples for the presence of spectral structure arising from organic species.

Both of the above objectives were achieved. In **Year 1**, we built the AOTF breadboard instrument and began laboratory testing. Our GSFC collaborators also completed the redesign of their LDMS instrument to accommodate the addition of our AOTF spectrometer. In **Year 2**,

we completed our laboratory demonstrations and built the AOTF brassboard instrument for eventual integration into the LDMS instrument vacuum chamber. In **Year 3+** (Year 3 plus our no-cost extension period), we successfully integrated the AOTF instrument into the LDTOF vacuum chamber and acquired measurements of reference samples with both instruments. Figure 1 shows the combined instrument in the GSFC laboratory.

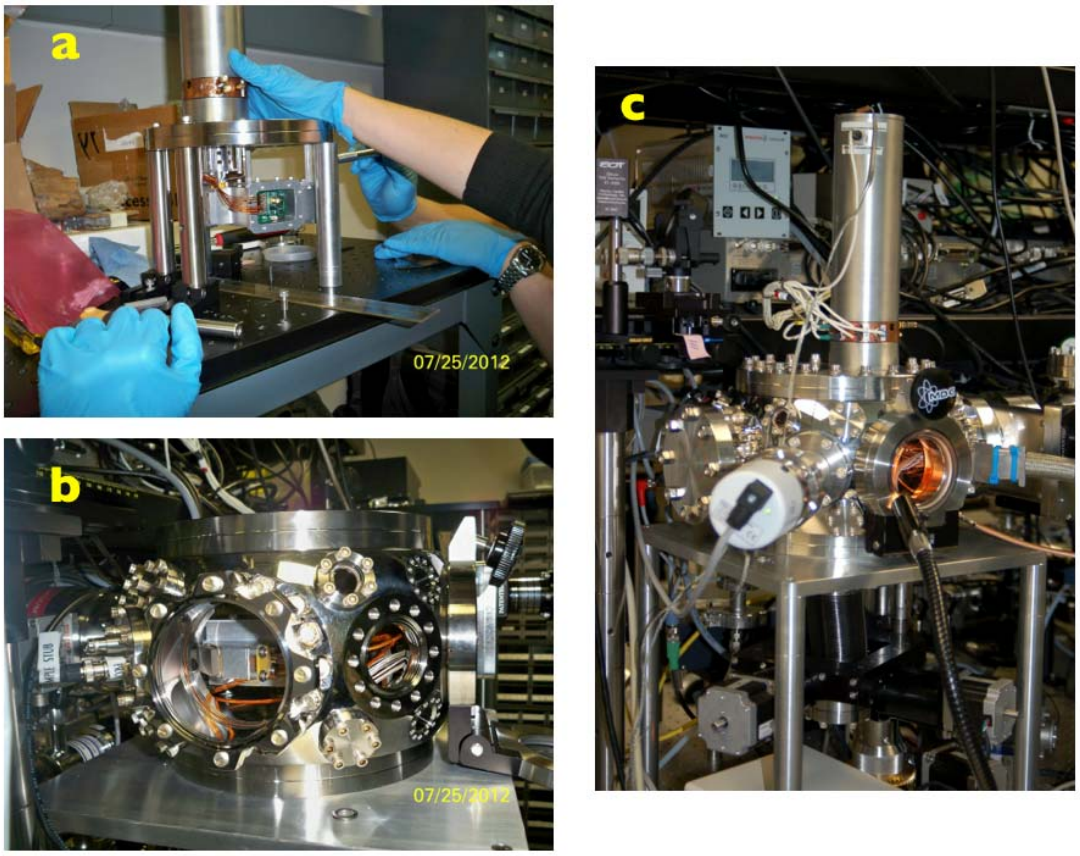

Figure 1. Integration of the AOTF spectrometer into the LDMS vacuum chamber. (a) Photo of AOTF fixture attached to vacuum chamber mounting structure. (b) Photo of AOTF spectrometer inside LDMS mass spectrometer chamber. (c) Photo of the integrated AOTF-LDMS spectrometers.

During our integration activities we conducted near-simultaneous measurements of reference samples with both the AOTF spectrometer and the LDMS. An example is shown in Fig. 2, which contains the AOTF spectrum of calcite (Fig. 2a) plotted along with the LDMS mass spectrum (Fig. 2b). The objective of the instrument integration was achieved: simultaneous mass spectra and AOTF IR spectra were taken from a suite of mineral and organic samples that are representative of planetary surface materials. As seen in Fig. 2, the post-integration mass spectrum indicates the presence of Ca. This, along with the -CO_3 features in the AOTF spectrum, supports the identification of the sample as calcite. **This is a prime example of the**

complementary nature of the two spectral data sets, and a demonstration of the success of our instrument development and integration activities.

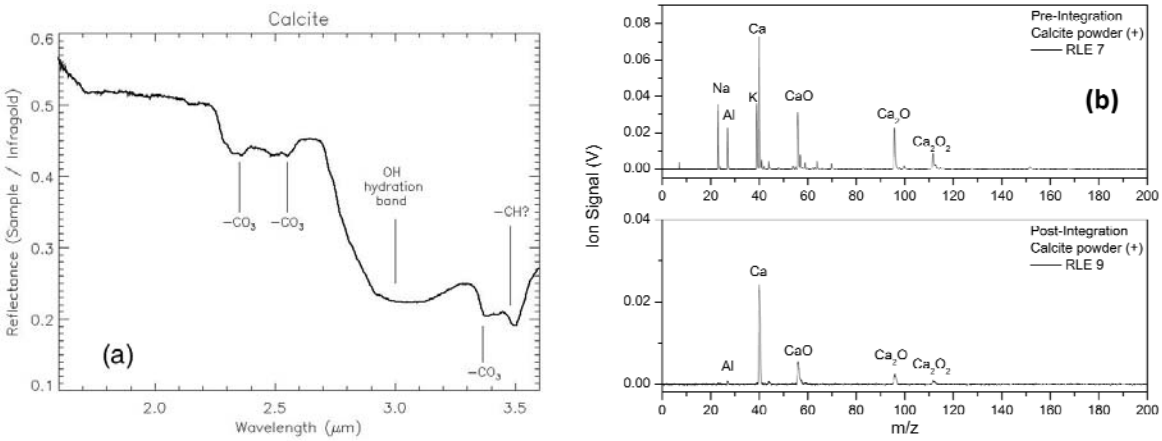

Figure 2. (a) AOTF spectrum of calcite. (b) Coincident LDTOF mass spectrum of the same calcite sample.

2. Systemic Change

A. Improvements in Jurisdiction Research and Development Infrastructure

We improved research and development infrastructure in the jurisdiction of New Mexico through the development of AOTF instrumentation for *in situ* measurement of astrobiological environments.

B. Increased Financial Commitment from the Jurisdiction, Industry, and Participating Institutions

New Mexico State University provided an increased financial commitment to this project by awarding us an Interdisciplinary Research Grant (see Section 6E) for $40,000.

C. Response of Activities to NASA and Jurisdiction Priorities

Our activities have continued to be shaped by NASA priorities, in particular the evolving plans for future Mars exploration. We are currently in discussions with our Co-I's at GSFC regarding the possibility of proposing a joint instrument for the Mars 2020 rover mission.

D. Reordered Jurisdiction and/or Institutional Priorities

NMSU continues to encourage interdisciplinary research within the institution, as well as collaboration across institutions within the jurisdiction (e.g. our continued collaboration with Co-I Penelope Boston at New Mexico Tech). This is not a *new* direction, but rather a continuation of successful research practices.

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

None.

4. Evolution of Collaborations

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

- We formed a new collaboration with Dr. Brian Glass at NASA/Ames Research Center, who is conducting field expeditions to the Arctic for astrobiology instrument demonstrations. He supported our EPSCoR/Minority Serving Institution Faculty Engagement Competition proposal as an unfunded collaborator, and we will continue to work with him through those efforts.

- Our collaborators at NASA/GSFC, Drs. Brinckerhoff, Mahaffy, and Getty, have consistently been integral team members of this project. They supported graduate student Kyle Uckert's proposal for a NASA Space Technology Research Fellowship (See Section 6E), and we remain in discussions with this group concerning future directions for our joint instrument.

- During the course of the instrument integration at GSFC we also developed a new collaboration with Drs. Reggie Hudson and Perry Gerakines of GSFC's Cosmic Ice Laboratory. These researchers provided us with irradiated ices to measure with the integrated AOTF-LDMS spectrometer to demonstrate its efficacy of measuring organics in ices, such as those found on Jupiter's moon Europa. We will continue to work with Hudson and Gerakines on the measurement of irradiated ices.

- We formed a new collaboration with Dr. Nancy McMillan in NMSU's Geological Sciences department. Dr. McMillan's expertise is in Laser Induced Breakdown Spectrometer (LIBS) instrumentation, which is related to the LDMS in that LIBS instruments provide elemental compositions of mineralogical samples. Our partnership with Dr. McMillan led to the development of a portable version of our AOTF spectrometer that we plan to take into a cave environment to characterize biosignatures with complementary AOTF and LIBS spectra.

5. Interactions Between and Cooperation with the Jurisdiction's Space Grant Program

During the award period we worked with the New Mexico Space Grant office on the following activities:

- attending NM Space Grant meetings
- attending the NM Space Grant student fellowship recipient presentations
- developing further funding proposals (see Section 6E below)

6. Research Success of Individual Investigators

A. Articles Submitted to or Published in Refereed Journals

The following refereed articles based on research supported by this EPSCoR award have been submitted or published:

Refereed Journals:

Tawalbeh, R., D. Voelz, D. Glenar, X. Xiao, N. Chanover, R. Hull, and D. Kuehn (2013). Infrared acousto-optic tunable filter (AOTF) point-spectrometer for detection of organics on mineral surfaces. *Optical Engineering*, submitted.

Refereed Conference Proceedings:

Chanover, N. J., D. A. Glenar, D. G. Voelz, X. Xiao, R. Tawalbeh, P. J. Boston, W. B. Brinckerhoff, P. R. Mahaffy, S. Getty, I. ten Kate, and A. McAdam (2011). An AOTF-LDTOF spectrometer suite for *in situ* organic detection and characterization. IEEE Aerospace Conference Proceedings, Big Sky, MT, 7-11 March 2011.

Chanover, N. J., R. Tawalbeh, D. A. Glenar, D. G. Voelz, X. Xiao, K. Uckert, P. J. Boston, S. Getty, W. B. Brinckerhoff, P. R. Mahaffy, T. Cornish, and S. Ecelberger (2012). Rapid assessment of high value samples: An AOTF-LDTOF spectrometer suite for planetary surfaces. IEEE Aerospace Conference Proceedings, Big Sky, MT, 4-9 March 2012.

Chanover, N. J., D. G. Voelz, D. A. Glenar, X. Xiao, R. Tawalbeh, K. Uckert, P. J. Boston, S. Getty, W. B. Brinckerhoff, P. R. Mahaffy, and X. Li (2013). Results from an integrated AOTF-LDTOF spectrometer suite for planetary surfaces. IEEE Aerospace Conference Proceedings, Big Sky, MT, 3-8 March 2013.

B. Talks, Presentations, or Abstracts at Professional Meetings

We made a total of 5 oral and 8 poster presentations about the research supported by this EPSCoR award at professional meetings during the award period:

- **Poster Presentation:** American Geophysical Union meeting, December 2009, San Francisco, CA: Chanover et al., "An AOTF-LDTOF Spectrometer Suite for In Situ Organic Detection and Characterization," abstract # P43C-1442.

- **Poster Presentation:** Lunar and Planetary Science Conference, March 2010, The Woodlands, TX: Chanover et al., "An AOTF-LDTOF Spectrometer Suite for In Situ Organic Detection and Characterization," LPI Contribution # 1533.

• **Poster Presentation:** Astrobiology Science Conference, April 2010, Houston, TX: Chanover et al., "An AOTF-LDTOF Spectrometer Suite for In Situ Organic Detection and Characterization," Abstract #5319.

• **Oral Presentation:** Applied Industrial Optics: Spectroscopy, Imaging, and Metrology meeting, June 2010, Tucson, AZ: Tawalbeh et al., "AOTF Reflectance Spectroscopy: A Diagnostic of Organically Modified Surfaces," presentation # ATuA5.

• **Poster Presentation:** American Astronomical Society Division for Planetary Science Conference, October 2010, Pasadena, CA: Chanover et al., "An AOTF-LDTOF Spectrometer Suite for In Situ Organic Detection and Characterization," Bull. Amer. Astron. Soc. 42, 1005.

• **Oral Presentation:** IEEE Aerospace Conference, March 2011, Big Sky, MT: Chanover et al., "An AOTF-LDTOF Spectrometer Suite for In Situ Organic Detection and Characterization," Presentation # 2.13.

• **Poster Presentation:** European Planetary Science Congress - American Astronomical Society Division for Planetary Sciences Joint Meeting, October 2011, Nantes, France: Chanover et al., "Rapid Assessment of High Value Samples: A Miniature AOTF-LDTOF Spectrometer Suite for Planetary Surfaces," 2011 EPSC Conference Proceedings, p. 1653.

• **Oral Presentation:** First International Planetary Caves Workshop, October 2011, Carlsbad, NM: Chanover et al., "Rapid Assessment of High Value Samples: A Miniature AOTF-LDTOF Spectrometer Suite for Cave Environments," Presentation # 8019.

• **Poster Presentation:** Conference on Life Detection in Extraterrestrial Samples, February 2012, San Diego, CA: Uckert et al., "A Miniature AOTF-LDTOF Spectrometer Suite for the Detection of Biomarkers on Planetary Surfaces," Presentation # 6042.

• **Oral Presentation:** IEEE Aerospace Conference, March 2012, Big Sky, MT: Chanover et al., "Rapid Assessment of High Value Samples: A Miniature AOTF-LDTOF Spectrometer Suite for Planetary Surfaces," (presentation given by Tawalbeh), Presentation # 2.0906.

• **Poster Presentation:** Astrobiology Science Conference, April 2012, Atlanta, GA: Uckert et al., "A Miniature AOTF-LDTOF Spectrometer Suite for the Detection of Biomarkers on Planetary Surfaces," Presentation # 4442.

• **Poster Presentation:** American Astronomical Society Division for Planetary Science Conference, October 2012, Reno, NV: Chanover et al., "A Miniature Spectrometer for the Detection of Organics and Identification of their Mineral Context," Presentation # 215.21.

• **Oral Presentation:** International Workshop on Instrumentation for Planetary Missions, October 2012, Greenbelt, MD: Chanover et al., "Miniature Spectrometer for the Detection of

Organics and Identification of their Mineral Context," (presentation given by Glenar), Abstract # 1142.

C. Articles Submitted to NASA Venues

None.

D. Patents and Patent Applications

None.

E. Follow-on Grant Proposals Submitted/Funded

The following proposals were submitted as a result of the advances made through the work conducted under the auspices of our EPSCoR award:

Proposal Title	PI	Agency	Amount	Award Period	Status
Exploring Surface Texture and Reflectivity of Cave and Related Surface Environments as Harbingers of Life	P. Hynes (Science PI: N. Chanover)	NASA/EPSCoR Minority Serving Institution Faculty Engagement Competition	$250,000	6/12 - 5/14	awarded
Searching for Life in Extreme Environments: A New Mexican Cave as a Solar System Analog	N. Chanover	NMSU Vice President for Research Interdisciplinary Research Grant	$39,747	1/13-12/13	awarded
Optimizing a Two-Step Laser Time-of-Flight Mass Spectrometer for In Situ Astrobiology Investigations	K. Uckert (faculty advisor: N. Chanover)	NASA Space Technology Research Fellowship Program	$180,000	9/13 - 8/16	pending

7. Demographic Information on Participants

PIs/CoIs:
Patricia Hynes, New Mexico State University (White, female)
Nancy Chanover, New Mexico State University (White, female)
David Voelz, New Mexico State University (White, male)
David Glenar, New Mexico State University (White, male)
Penelope Boston, New Mexico Institute of Mining and Technology (White, female)

Students:
Rula Tawalbeh, New Mexico State University (Middle Eastern, female)
Vinush Depala, New Mexico State University (Asian, male)
Kyle Uckert, New Mexico State University (White, male)
Ariel Boston, New Mexico Institute of Mining and Technology (White, female)
Fred Hanson, New Mexico Institute of Mining and Technology (White, male)
Alex Hernandez, New Mexico Institute of Mining and Technology (Hispanic, male)