Acoustic detector and analyzer of atmospheric and near-surface geological activities at planetary bodies

Principal Investigator: Yoseph Bar-Cohen (355); Co-Investigators: Stewart Sherrit (355), Hyeong Jae Lee (355), Xiaoqi Bao (355), Mircea Badescu (355)

Program: FY21 R&TD **Strategic Focus Area: Innovative Spontaneous Concepts**

Objectives - The objective of this task was to develop and demonstrate the feasibility of acoustic sensors that can be used to detect, identify the location and characterize the source of acoustic signals produced by planetary geological and atmospheric activities. Acoustic wave analytical modeling has been done and signal processing used to establish the capability to characterize planetary activities.

Background - An instrument that senses and analyzes sound emitted by atmospheric and near-surface geological activities can provide important in situ scientific data. Generally, sound is emitted and carried in the atmosphere of such bodies as Mars, Titan, Venus, Jupiter, Uranus, Neptune, and can be used to characterize underlying processes. Examples of sound emitting activities/processes include volcanic eruptions, avalanches, rock slides, streams, fluid-falls, geysers, hurricanes, tornados, quakes, fracturing, ice flow, and other geologic and tectonic activities. The sound emitted from such activities is an under-explored source of information that its acquisition and analysis would expand the capabilities of future NASA missions and provide JPL an edge in future proposals. The required instrument can be made compact, low mass and low power, and it can be mounted onto a landed platform or distributed as a sensor network over broad area. The analysis can be supported and enhanced by meteorological data from other instruments. This spontaneous R&TD task has been focused on demonstrating the capability to develop a system that is based on a network of acoustic sensors and analyzer. The task provided a proof of concept and sufficient information that can be used to pursue a follow-on task under NASA funding.

Approach and Results - Acoustic sensors were modeled, constructed and tested to enable the determination of the source direction and potentially characterizing sound-emitting atmospheric and geological activities on other planetary bodies with atmospheres. We investigated the requirements for optimizing the design parameters of the sensors and establish the signal processing capability. The task involved using realistic acoustic signals that can potentially be generated by sound emitting atmospheric and geological processes. The model was applied to analyze known signatures of activities and the parameters that are critical to the breadboard operation of maximum signal-to-noise detection and characterization capability. The analysis included determining the requirements for efficient coupling of the sensors to local specific atmosphere density, acoustic impedance and the specific temperature range of Mars with potential to expand the use to Titan and Venus.

Significance/Benefits to JPL and NASA - This task involved the investigation of a set of acoustic sensors for enabling optimal operation under conditions on other planetary bodies. Acoustic sensors were analytically modeled for suitability to operate on Mars (rarefied atmosphere) and allow to identify the direction of the sound sources. The developed technology gained from this research allowed us to establish solid foundation for developing high sensitivity planetary acoustic instrument. Generally, COTS microphones have been included in past missions, but they were not intended to acquire science information. An entry into an era of acoustic instruments in potential future missions has been opened with this reported Spontaneous R&TD. Efforts were focused on modeling and designing details to account for planetary conditions in order to enable determining the direction and characteristics of sound sources. The task enabled to have sufficient information for submitting a NASA PICASSO proposal that will take the technology to the next level in order to leverage the acoustic sensor development into an instrument prototype.

Publications - Stewart Sherrit, Xiaoqi Bao, Hyeong Jae Lee, M. Badescu, Yoseph Bar-Cohen and M. Malaska, "Acoustic sensor network for planetary exploration" Virtual presentation and proceedings paper, paper #11591-20, SPIE Smart Structures and Materials/NDE Symposium, International Society for Optics and Photonics. March 22-26, 2021,

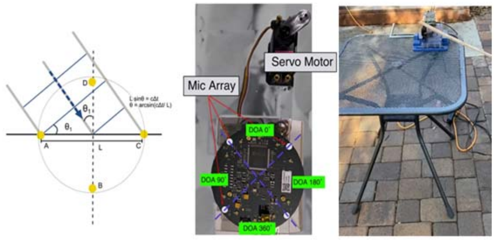

Figure 1: Geometrical configuration of four acoustic sensors (left) and the hardware configuration for sound localization (middle) that was used and programmed. A demo of source tracking of wind sound is shown on the right where we used a balsa stick as a pointer to track the determined direction.

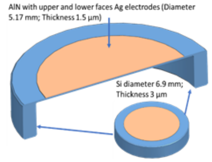

Figure 2: Diagram of piezoelectric unimorph MEMS design (not scaled)

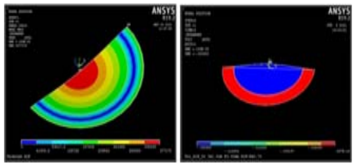

Figure 3: The stress (left) and the voltage (right) under 1 Pa at low frequency.

Table 1: Summary of evaluated MEMS design

	Diameter	Resonance	Sensitivity		Capacitance		Noise level	SNR	Self-noise
	mm	Hz	V/Pa	dB	C (pF)	tanδ	dB	dB	dB
MEMS	7	1300	0.020	-33.8	1189	0.00025	-146.22	112.45	-18.45
B&K 1"	25	8000	0.05	-26	55			84.5	9.50

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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PI/Task Mgr Contact
Email: Yoseph.Bar-Cohen@jpl.nasa.gov

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