THE ROAD TO VENUS SEISMOLOGY VIA OKLAHOMA. S. Krishnamoorthy[1], D. C. Bowman[2], L. Martire[3], A. Komjathy[1], J. A. Cutts[1], M. T. Pauken[1], R. F. Garcia[2], D. Mimoun[2], V. Lai[4], J. M. Jackson[4]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
[2] Sandia National Laboratories, Albuquerque, NM
[3] Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), Toulouse, France
[4] Seismological Laboratory, California Institute of Technology, Pasadena, CA

Introduction: The passage of elastic waves through planetary interiors reveals fundamental characteristics of the subsurface that are difficult to resolve through other methods. The generation of these waves also describes the ongoing geologic activity on planetary bodies. Seismic studies have revealed key structures such as the Earth's inner core and partial melt at the base of the lunar mantle; the upcoming InSight mission to Mars is expected to provide similar information about the Red Planet. In contrast, the interior structure and present activity of Venus is unknown. However, surface conditions on Venus make it impossible to deploy seismic sensors for more than a few hours.

Seismic experiments conducted from aerial platforms offer a unique opportunity to explore the internal structure of Venus without needing to land and survive on its surface for long durations. In particular, the dense atmosphere of Venus allows for balloons to be flown in the mid and upper atmospheric regions. These balloons may be used as vehicles for seismic experiments that can collect infrasound data as indication of seismic waves while floating in the prevailing winds. One possible way to detect and characterize quakes from a floating platform is to study the infrasound (pressure waves with frequency < 20 Hz) signature produced by them in the atmosphere. Infrasonic waves are generated when seismic energy from ground motions are coupled into the atmosphere. The intensity of the infrasound depends heavily on the relative density of the atmosphere and the planet's crust. On Venus, where the surface pressure is 90 atmospheres, the energy from the surface is coupled into the atmosphere 60 times more efficiently than the Earth.

The Use of Earth as a Venus Analog: JPL and its partners (ISAE-SUPAERO, the Seismological Division at the California Institute of Technology, and Sandia National Laboratories) are in the process of developing technologies for detection of infrasonic waves generated by earthquakes from a balloon platform using the Earth as a Venus analog. In the last year, the team has conducted multiple experiments and demonstrated the detection and geolocation of artificially generated seismic events from a balloon platform and the long-range detection of infrasound from rocket launches. Further, our sensors flew on-board a NASA balloon at 38 km altitude as a secondary payload to study the noise characteristics of the stratospheric infrasound background. In November 2018, our sensors will be deployed on balloons to overfly sub-surface chemical explosions in the Nevada desert as part of the Department of Energy's Source Physics Experiment. A brief update from our activities in the last year will be shared in this presentation. The next step in our program is to detect naturally occurring earthquakes from the stratosphere – this will be the primary focus of our presentation.

Presentation Content: The State of Oklahoma has the largest concentration of earthquakes in the continental United States. In 2017 alone, there were 1095 earthquakes of magnitude 2.0 and above, concentrated primarily over a region in North-Central Oklahoma. In addition, Oklahoma's large distance from the ocean compared to seismically active zones on the West Coast and its flat relief make it a particularly viable candidate for developing balloon-based seismic infrasound sensing using the Earth as a Venus analog.

In this presentation, we will illustrate the design of a campaign to detect and characterize naturally occurring earthquakes from balloon-borne barometers in the stratosphere. We aim to conduct a prolonged balloon-based measurement campaign in central Oklahoma, where we will deploy two balloons a day for up to 6 weeks. Each balloon will reach a floating altitude of approximately 20 km, overfly the central band of earthquakes and be terminated a few hours later. Ground truth for earthquake timing and location will be provided by the Oklahoma Geological Survey's ground network of seismometers. Using detailed statistical analysis and trajectory simulations, we will show that our campaign guarantees the successful detection of infrasound from an earthquake from a balloon, the first of its kind. Several earthquake detections are expected, data from which will be utilized to develop algorithms that can discriminate seismic infrasound from other sources. Data will also be combined with seismo-acoustic simulations to learn the dependence of acoustic signal strength on the intensity of the earthquake.

The success of this campaign will demonstrate that quakes can be detected and characterized by barometers suspended from high-altitude balloons. Since Venus is able to couple seismic energy into the atmosphere much better than the Earth, success on Earth will provide a compelling argument for performing aerial seismology on Venus.