National Aeronautics and Space Administration

Submillimeter-wave Spectrometers for Small Satellites

Principal Investigator: Goutam Chattopadhyay (386A)
Cecile Jung-Kubiak (389W), Maria Alonso (386A), Adrian Tang (386A), Brian Drouin (329H)
Program: Strategic

Project Objective:

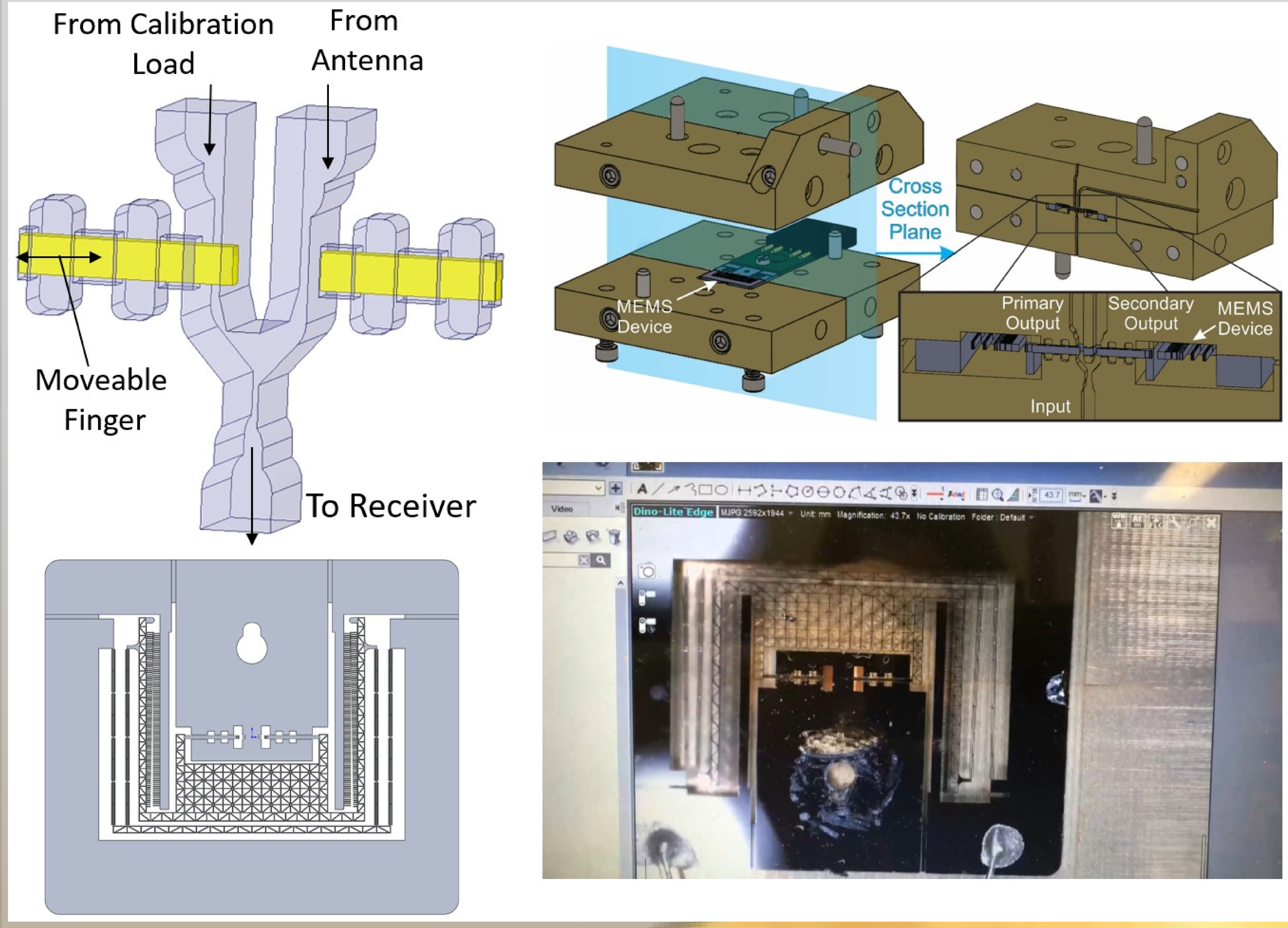
Small spacecraft such as CubeSats are now emerging as focused, yet highly capable platforms for addressing Decadal Survey-level planetary science. JPL's Solar System Exploration program office seeks to develop instruments and technologies for small planetary spacecraft, that will enable exciting and compelling planetary missions at a fraction of the traditional cost. This effort develops a limb sounding instrument for the Venusian atmosphere to characterize the distribution of gases, temperature profile, and gravity waves in the stratosphere and mesosphere.

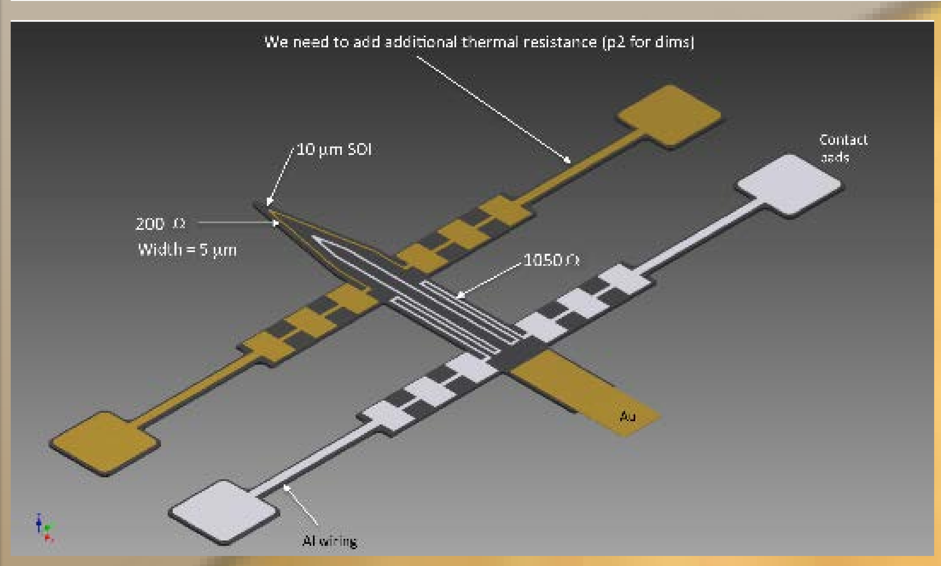
Several technical objectives are pursued to enable integration into a small satellite or CubeSat platform that reduce the size, mass and power consumption of submillimeter-wave spectrometer instruments:

- **Enable a waveguide-based calibration system**
- **Develop low-profile, high-gain antennas to ease integration of the system with smaller platforms**
- **Integrate low-power CMOS components for LO generation and spectrum acquisition (See poster Tang, "Infusion of CMOS")**

Results: MEMS Waveguide Calibration Switch and Load

Calibration of the spectrometers is achieved by a waveguide calibration switch placed before the antenna. This is necessary because calibration by a quasi-optical flip-mirror to a free-space load is not possible with the high-gain flat-antenna. A Micro-Electrical-Mechanical-System (MEMS) single-pole double-throw switch is developed to route to the receiver either the received signal from the antenna or the noise power from a temperature controlled blackbody. Losses of the switch must be minimized to avoid increasing the noise temperature of the receiver.





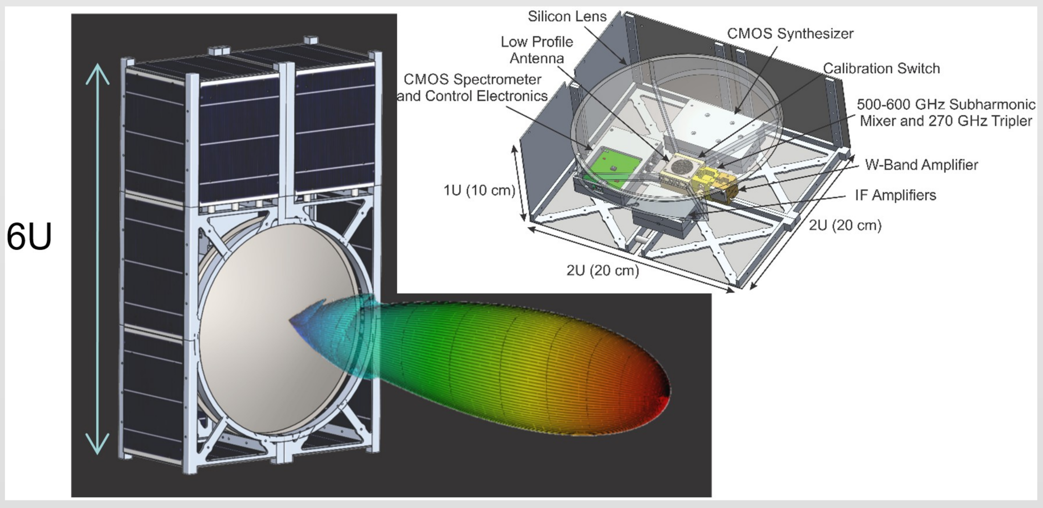
Isolation is also important to avoid contaminating the received signal with the calibration power, and need to be 25 dB or greater. Shown is the switch module design (top), and the temperature controlled load. The load will allow multi-temperature calibration.

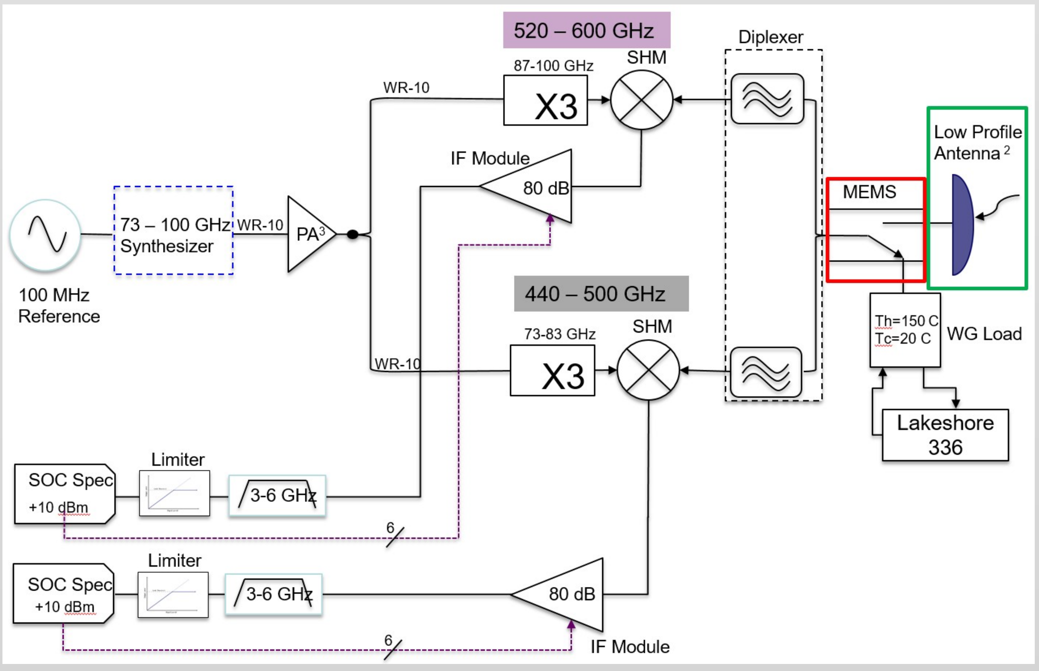
Benefits to NASA and JPL:

This effort develops the first in a new class of extremely compact, low-power submillimeter-wave instruments, resolving long-standing (mass and power) issues with the integration of these instruments into flight payloads. Operation on a Cubesat platform is the baseline, but the advances made by this project will facilitate integration of submillimeter-wave instruments into Discovery or New Frontiers class missions.

Results: Instrument Concept and System Design

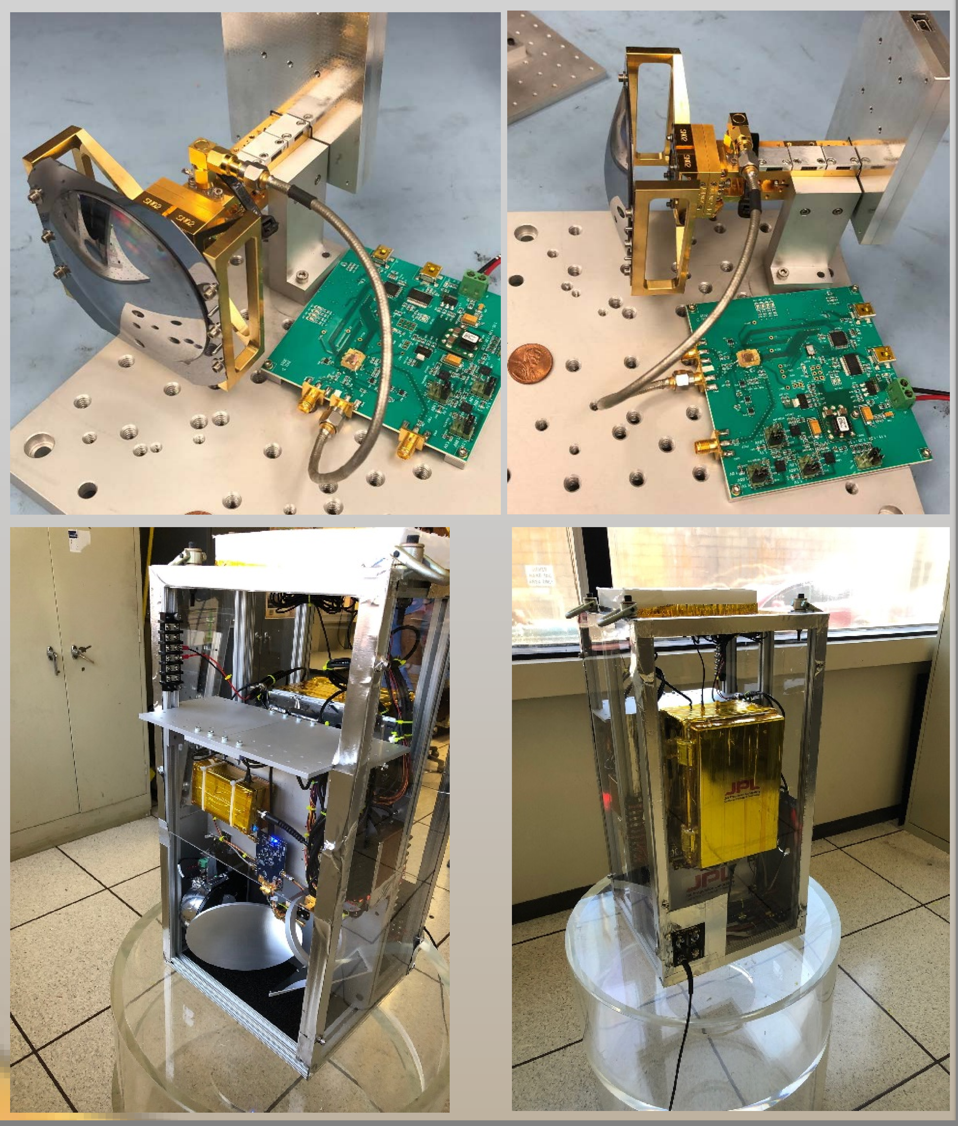
A two channel heterodyne spectrometer centered at 460 GHz and 560GHz is chosen to capture a wide variety of atmospheric species and two CO lines to characterize the temperature and wind velocity. The instrument concept, in a 6U CubeSat package, is shown at the top. The system block diagram is shown at the bottom. The RF signal collected by the low-profile silicon lens antenna goes through the MEMS calibration switch to the sub-harmonic mixer. The IF signal is processed at the back-end spectrometer.





Integrated Instrument and Demonstration on a Balloon

The low-profile silicon lens-based leaky-wave antenna was integrated with the MEMS calibration switch and the rest of the front-end. The local oscillator system used the silicon system on a chip (SoC) based W-band synthesizer and Schottky diode based frequency multipliers that pumped a subharmonic mixer. The IF signal was processed with a high-gain IF processor and a SoC high-resolution spectrometer. Figure at top shows the integrated instrument. Figure at the bottom shows a version of the instrument integrated on a balloon platform which will be launched in Oct. '19.



Publications:

1. G. Chattopadhyay, M. Alonso-delPino, C. Jung-Kubiak, J. Kooi, J. Siles, and C. Lee, "Highly Integrated Submillimeter-wave Spectrometers for CubeSats," Proceedings of the IRMMW-THz Symposium, Paris, France, September 2019.
2. G. Chattopadhyay, M. Alonso-delPino, C. Jung-Kubiak, T. Reck, J. Siles, C. Lee, and A. Tang, "Planetary/CometarySubmillimeter-Wave Instruments on Ultra-Small platforms," Proceedings of the 30th International Symposium on Space Terahertz Technology (ISSTT), Gothenburg, Sweden, April 2019.

PI/Task Mgr. Contact Information:
Goutam Chattopadhyay; 3-7779; goutam@jpl.nasa.gov

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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