Millimeter-wave Sounder/Imager on a CubeSat Providing Global Observations for Atmospheric Science for More than Two Years on Orbit: Temporal Experiment for Storms and Tropical Systems - Demonstration (TEMPEST-D) Mission

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Global observations of clouds and precipitation processes are essential to improve monitoring and prediction of tropical cyclones and severe storms with substantial impacts on human life and property. Convection plays an important role in influencing global weather patterns, distributing fresh water and producing severe weather. However, fundamental gaps remain in our understanding, resulting in one of the 2017 Earth Science Decadal Survey's "most important" science questions, "Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do?"

To improve understanding of cloud and precipitation processes in various environments, global observations with short revisit times are necessary. To partially address this need, geostationary satellites provide visible and infrared weather observations with temporal resolution on the order of a few minutes. However, improving understanding of the processes of deep convection and the surrounding water vapor environment requires millimeter-wave atmospheric sounding observations, which penetrate deep inside storms where precipitation originates. In addition, passive microwave sounding of the Earth's atmosphere provides one of the most valuable quantitative contribution to weather prediction and climate models.

To address this critical observational need, the Temporal Experiment for Storms and Tropical Systems (TEMPEST) mission enables constellations of 6U CubeSats with identical low-mass, low-power millimeter-wave radiometers observing at five channels from 87 to 181 GHz. TEMPEST constellations rapidly sample convective processes, filling a critical gap in observations, as well as complementing existing and future science and operational missions.

To demonstrate the first CubeSat-based multi-frequency microwave sounder with global observations, the TEMPEST Demonstration (TEMPEST-D) satellite was launched on May 21, 2018 and was deployed from the ISS on July 13, 2018, into an initial orbit at 410-km altitude and 51.6° inclination. With more than two years of operations to date during three hurricane seasons, TEMPEST-D met its mission requirements in the first 90 days and achieved TRL 9 for both instrument and spacecraft systems. Comparisons of on-orbit measurements with five reference sensors, including GPM/GMI and MHS on four NOAA and EUMETSAT satellites, indicate that TEMPEST-D is a very well-calibrated, low-noise, highly stable radiometer on a CubeSat, capable of performing useful atmospheric science observations that are indistinguishable from those of larger, more expensive operational sensors.