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Temporal Experiment for Storms and Tropical Systems Technology Demonstration (TEMPEST-D) 6U CubeSat Mission: Early Results and Potential for Atmospheric Science

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Global observations of clouds and precipitation are essential to improve monitoring and prediction of hurricanes, tropical cyclones and severe storms with substantial impacts on human life and property. To understand cloud and precipitation processes that lead to rain, snow, sleet and hail in a variety of climate environments, rapid revisit observations on a global basis are necessary. To this end, geostationary satellites have substantially improved weather prediction by providing visible and infrared measurements with temporal resolution on the order of a few minutes. However, to improve understanding of the rapid and dynamic evolution of deep convection and the water vapor that fuels them, we require fine time-resolution millimeter-wave radiometric observations capable of penetrating into the storm to where the microphysical processes leading to precipitation occur.

To address this critical observational need, Temporal Experiment for Storms and Tropical Systems (TEMPEST) mission deploys a closely-spaced train of 6U CubeSats carrying identical low-mass, low-power millimeter-wave radiometers. The TEMPEST train samples rapid changes in convection and the surrounding water vapor by observing every three to four minutes for up to 25-30 minutes. The millimeter-wave radiometers on TEMPEST provide soundings of mid-tropospheric water vapor to improve understanding of its role in the growth and organization of convection in various large-scale environments. The TEMPEST-D instrument observes at five millimeter-wave frequencies from 89 to 182 GHz. By rapidly sampling the life cycle of convection, TEMPEST fills a critical observational gap and complements existing and future satellite missions.

For TEMPEST, 6U CubeSat satellites are chosen to provide substantial margins on mass, power, ground communications and microwave radiometer calibration. To demonstrate that such a train of 6U CubeSats has the capability to contribute to NASA Earth science goals, the TEMPEST Technology Demonstration (TEMPEST-D) mission is underway. TEMPEST-D is a partnership among Colorado State University (Lead Institution and validation), NASA/Caltech Jet Propulsion Laboratory (instrument and calibration) and Blue Canyon Technologies (spacecraft and mission operations). The TEMPEST-D satellite was launched on May 21, 2018 on Orbital ATK's ninth commercial resupply mission to the International Space Station and successfully deployed into orbit from the ISS by NanoRacks on July 13, 2018, from an initial orbit with 400-km altitude and 51.6° inclination to demonstrate that TEMPEST-D radiometer calibration can meet the needs of the TEMPEST investigation.

After achieving first light on September 5, 2018, the TEMPEST-D mission has successfully achieved TRL 7 for both the instrument and spacecraft systems. TEMPEST-D performed its first full-swath orbital observations over Hurricane Florence on September 11, 2018, seeing through the thick clouds to the rain bands inside of the storm using a millimeter-wave radiometer on a CubeSat. The TEMPEST-D mission will continue to cross-calibrate the instrument with other on-orbit sensors with similar frequency channels, such as the NASA/JAXA Global Precipitation Mission Microwave Imager and the Microwave Humidity Sounders on NOAA and EUMETSAT operational meteorological satellites.