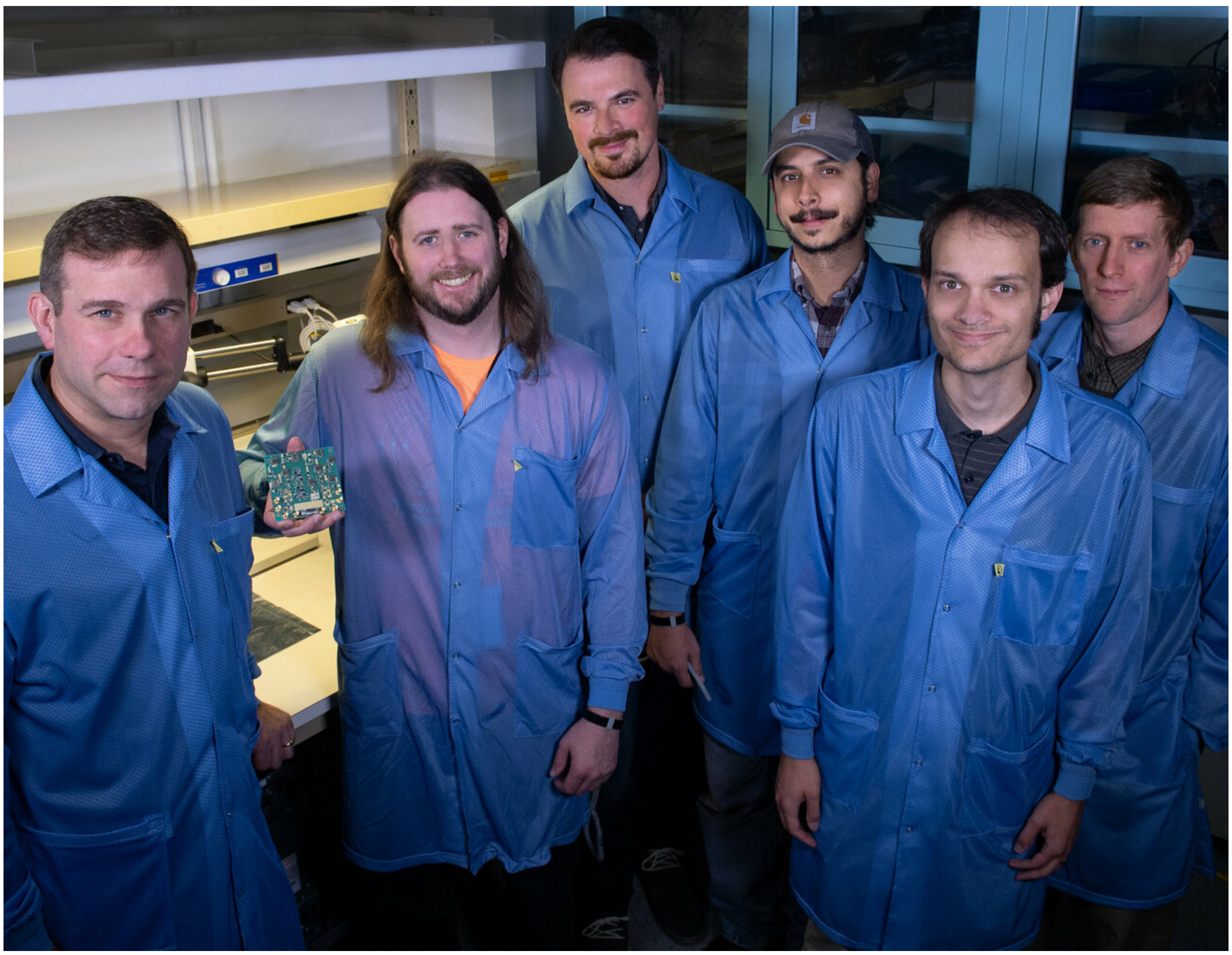
SNoOPI: A flying ace for soil moisture and snow measurements

February 21 2019, by Lori Keesey



Several Goddard technologists are involved in a new CubeSat technology-demonstration mission called SNoOPI, which employs a novel remote-sensing technique for measuring soil-moisture levels. From left to right: Jeffrey Piepmeier, Chase Kielbasa, who is holding a first-generation prototype circuit board for the SNoOPI instrument, Joseph Knuble, Manuel Vega, Michael Coon, and Derek Hudson. Credit: NASA/W. Hrybyk

Work has begun on a new CubeSat mission that will demonstrate for the first time a new, highly promising technique for measuring soil moisture from space—data important for early flood and drought warnings as well as crop-yield forecasts.

The technology-demonstration mission, SigNals of Opportunity: P-band Investigation, will validate a remote-sensing technique called signals of opportunity. Although scientists have proven the concept in ground-based campaigns, SNoOPI, as the mission is also known, will be the first on-orbit demonstration when it's deployed into a low-Earth orbit in 2021.

Ultimately, scientists want to fly a constellation of tiny satellites, all employing the same technique, to determine the amount of water stored in snowpack and that which is present in soil in the root zone —measurements not possible with current space-based technology.

To gather this data, SNoOPI will operate a little differently than other missions. Instead of generating and transmitting its own radio signals toward Earth and then analyzing the returned signal, it will take advantage of already-available telecommunications signals.

Specifically, SNoOPI will retrieve the P-band radio signal, which is sensitive to moisture levels, in transmissions from a telecommunications satellite orbiting 22,000 miles above Earth's surface. As with visible light , these signals hit Earth, interact with the environment, and literally bounce back into space where SNoOPI's sole instrument lies in wait to collect the P-band frequency. By analyzing the returned signals, scientists can derive moisture readings.

Ideal Application

For the SNoOPI mission, the signals-of-opportunity technique is ideal, said Jeffrey Piepmeier, one of several engineers at NASA's Goddard Space Flight Center in Greenbelt, Maryland, involved in the mission led by Purdue University Professor James Garrison. NASA's In-Space Validation of Earth Science Technologies, or InVEST, program is funding SNoOPI's development.

coefficient squared) of the surface. Recent theory (Yueh et al., 2017) and experiments (Shah et al., 2017) have also confirmed that the reflection coefficient phase is proportional to SWE. Frequencies below 400 MHz are better due to soil and biomass penetration, coherent scattering, and a longer unwrapping period.

P-band SoOp has now reached a critical juncture in which further advancement of this technique requires in-space demonstration. Airborne and tower campaigns only provide validation within small geographic areas giving little variety in the range of surface cover, soil type, and topographic conditions. The geometry for a spaceborne measurement is also quite different than that for an airborne demonstration—not only creating a much larger differential Doppler and shorter decorrelation time but also exposing the instrument to a more challenging radio frequency interference (RFI) environment due to terrestrial sources within the antenna footprint. Conditions of a **relevant environment**, required to advance to TRL6 and higher, **are only met in orbit**.

SigNals of Opportunity: P-band Investigation (SNoOPI) (depicted in **Figure 2)** will be the first demonstration of the P-band SoOp technique from orbit and will advance our prototype instrument to TRL7 to verify our assumptions about reflection coherence, robustness to the in-orbit RFI environment, and our ability to capture and process the transmitted signal in space. This is a necessary risk-reduction step on the path to a science mission as defined in our **Relevancy Scenario.**

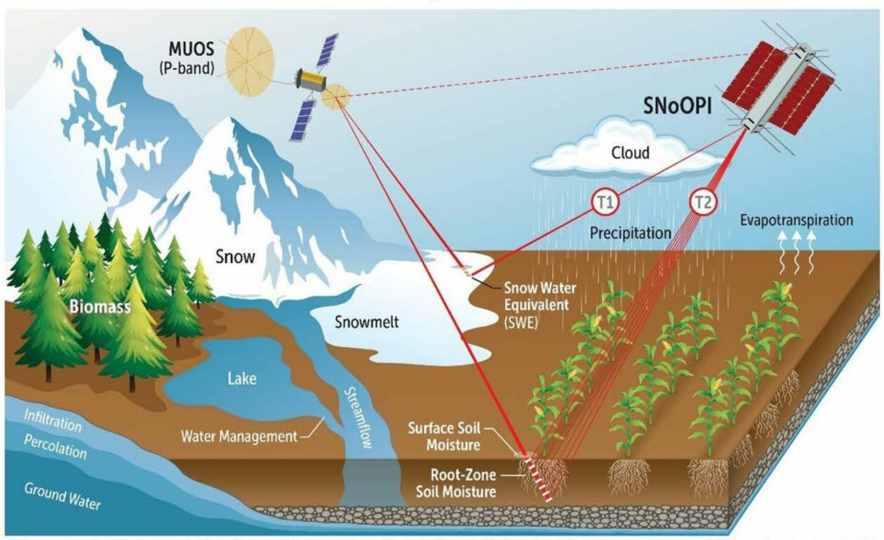


Figure 2. P-band SoOp will be the **first feasible technique capable of measuring two important water cycle variables; RZSM and SWE** from small satellites. This figure illustrates key components of the inter-dependent water cycle influenced by these variables and shows the two modes of operation for SNoOPI. At time t1, when over a snow-covered region, SWE will be estimated from the reflected signal phase. At time t2, when over un-frozen ground, RZSM will be estimated from the magnitude of the reflection coefficient.

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This graphic shows how a technology-demonstration CubeSat, called SNoOPI, will collect soil-moisture measurements at the root level. Credit: NASA

NASA's Soil Moisture Active Passive, or SMAP, mission is currently gathering moisture data. However, instead of P-band, it employs another radio frequency—the higher-frequency L-band—to map the amount of water in the top two inches of soil everywhere on Earth's surface. However, SMAP can't gather moisture readings at the root level. It also encounters difficulties when measuring soil moisture in forested and mountainous areas.

Lower frequencies, like the P-band, can travel four times deeper into the soil or snowpack, thereby overcoming the L-band limitation. But P-band has its own shortcomings. Because traditional P-band instruments are prone to radio interference caused by signal spillover from neighboring spectrum users, they require a large antenna to actively transmit and receive signals to obtain sufficient spatial resolution.

Because SNoOPI reuses already-existing telecommunications signals, it doesn't need a transmitter. Furthermore, the telecommunications signal SNoOPI ultimately captures after it bounces back into space is extremely powerful, eliminating the need for a large antenna, Piepmeier explained.

"The signal efficiency makes this technique very cost effective," Piepmeier said. "Because we eliminate the need for a large antenna, it enables the technique's use on a CubeSat, which can be the size of a loaf of bread."

Goddard and the Jet Propulsion Laboratory in Pasadena, California, are building SNoOPI's instrument and an external vendor will provide the CubeSat bus. Garrison, who conceived the P-band signals-of-opportunity technique, is managing the overall mission-development effort.

Should the technique prove effective in space, the team believes NASA could fly as many as nine small satellites along a polar orbit to build root-zone maps needed by weather forecasters, water managers, farmers, and power-plant operators.

Small satellites, including CubeSats, are playing an increasingly larger role in exploration, technology demonstration, scientific research and educational investigations at NASA, including: planetary space exploration; Earth observations; fundamental Earth and space science; and developing precursor science instruments like cutting-edge laser communications, satellite-to-satellite communications and autonomous movement capabilities.

Provided by NASA's Goddard Space Flight Center