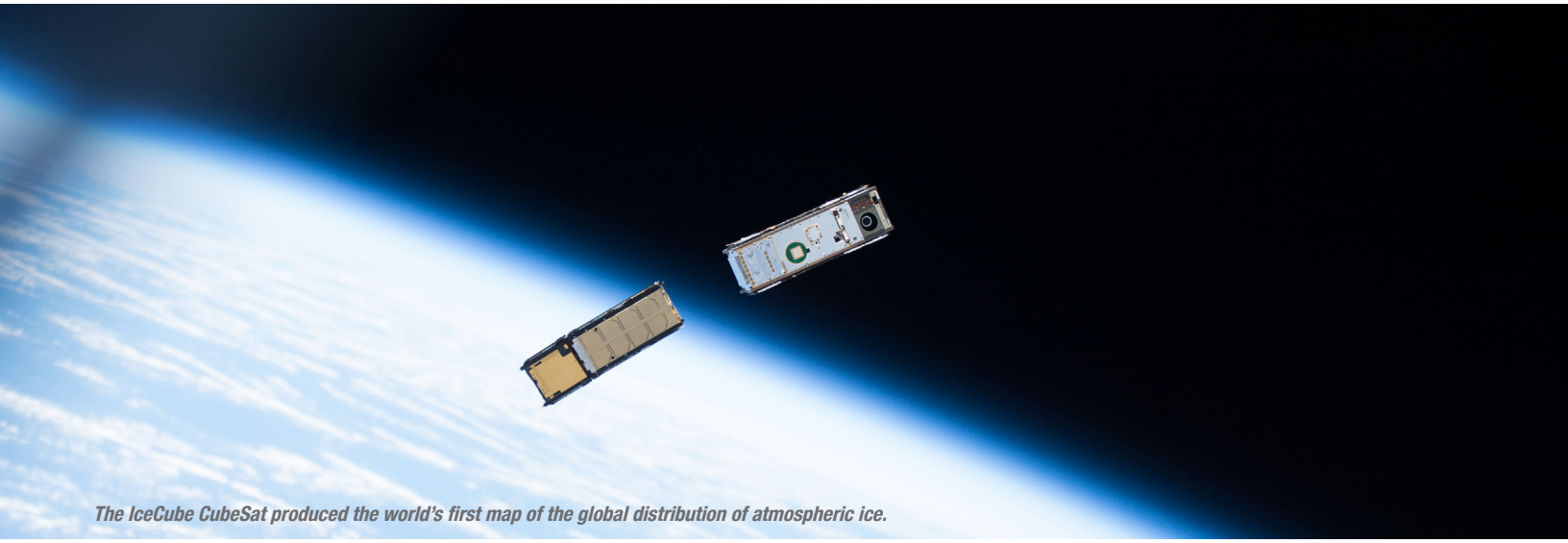
National Aeronautics and Space Administration



The IceCube CubeSat produced the world's first map of the global distribution of atmospheric ice.

CubeSat Measures World's First Ice Cloud Map to Support Climate Research

Challenge

The Earth's climate is carefully balanced by the Earth's energy budget, or the amount of energy that the Earth absorbs from the Sun versus the amount that radiates back to outer space. Ice clouds are a key variable in weather and climate models as they affect Earth's energy budget by reflecting or absorbing the Sun's energy, impacting the emission of heat from Earth into space. While satellites can see through many clouds and estimate the liquid precipitation they hold, they have lacked the sensitivity to measure the amount of small ice particles inside clouds, as these particles are too opaque for infrared and visible sensors to penetrate.

Because ice clouds have an important effect on Earth's energy budget and therefore our climate, it is more important than ever to measure and understand atmospheric ice clouds on a global scale.

Solution

With several awards from the NASA SBIR/STTR Program, Virginia Diodes, Inc. (VDI) has helped further atmospheric research by expanding knowledge and application of one of the lesser developed sections of the electromagnetic spectrum.

VDI, a small business based in Charlottesville, VA, was founded in 1996 by Dr. Thomas Crowe and was primarily a vendor of diodes for scientific

Project

IceCube, a small satellite (CubeSat) for mapping ice clouds at submillimeter wavelengths

Mission Directorate

Science

Phase III Success

VDI's commercial sales of terahertz components and systems directly attributed to the results of NASA-funded SBIR research is in excess of $45M

Snapshot

Virginia Diodes, Inc. received NASA SBIR Awards to fund research and development for a lesser developed region of the electromagnetic spectrum—terahertz waves. Their work led to funding from NASA ESTO, and the resulting CubeSat (named IceCube) captured the world's first ice cloud map, which will contribute to our understanding of Earth's climate

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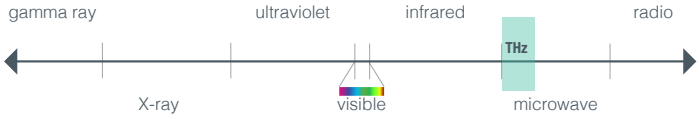
applications, including radio astronomy and high frequency radar. In 2001 the company received two NASA SBIR Phase I Awards to develop technologies that measure terahertz frequencies, which exist between infrared and microwaves on the electromagnetic spectrum.

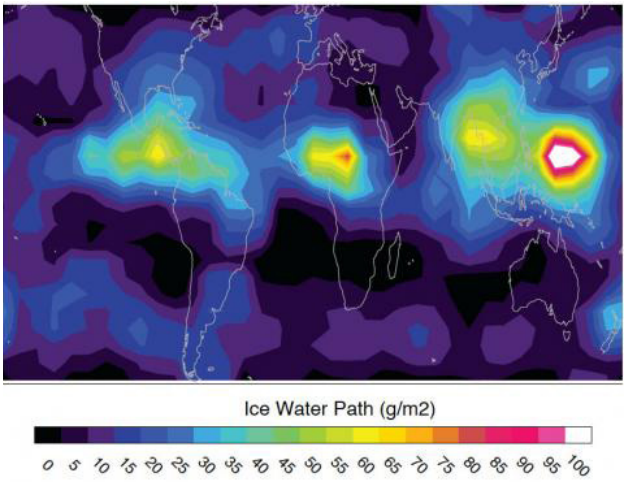
In the 1990s, NASA was using high frequency microwaves to measure the moisture and ice content of clouds. However, ice clouds were extremely difficult to measure due to the small particle sizes of ice. Existing sensors had difficulty measuring ice particles using electromagnetic waves—there was a region of the electromagnetic spectrum between infrared and microwaves that was largely inaccessible due to limitations of technology at the time.



Terahertz on the electromagnetic spectrum

With technology and research stemming from several NASA SBIR Awards and a Phase III Award from NASA's Earth Science Technology Office (ESTO), VDI supplied a submillimeter receiver for IceCube, a miniature satellite (called a CubeSat) for space research. The bread loaf-sized satellite was deployed from the International Space Station in May 2017 and measured ice clouds in low-Earth orbit until October 2018. Its measurements have produced the world's first map of the global distribution of atmospheric ice. The map was captured at 883 gigahertz (0.883 terahertz), one of the most sensitive parts of the spectrum to ice clouds, providing information about cloud ice mass inaccessible using visible, infrared, or microwave wavelengths.

> "Back then SBIR was a very big part of what we did, and it is still influential in what we do. The SBIRs allow us to really focus on technology and push us to work hard on research and new ideas. It's money to research, which is really how we're able to come up with new solutions.
>
> – Thomas Crowe
> CEO and President of Virginia Diodes, Inc.



Global cloud ice map generated by IceCube in 2017. Source: science.nasa.gov

Business Impact

Since then, VDI has continued to pioneer research, application, and commercialization of products that make use of terahertz measurements. VDI directly attributes more than $45M in commercial sales of terahertz components and systems to the results of NASA-funded SBIR research. Their success with IceCube is only one part of their journey—according to Crowe, who serves as the CEO and President of VDI, their mission is to develop terahertz technologies that make this region of the spectrum as useful for scientific and commercial applications as the microwave and infrared bands are today. VDI has already expanded the applications of terahertz technology by building test equipment that is in use by laboratories around the world. For example, their frequency extension modules have extended the range of vector network analyzers to 1.5 THz–enabling the further development of the terahertz technology and, in particular, sensor development.

When VDI first received awards from the SBIR program, Crowe says the funds accounted for 40% of their revenue. Now, as the company has expanded heavily in sales and products, Crowe asserts SBIR Awards count towards approximately 5% of their funds in recent years, though he emphasizes that these awards are still highly valuable for their growth.

SBIR·STTR America's Seed Fund™ POWERED BY NASA