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The IEEE GRSS Working Group on Remote Sensing Instruments and Technologies for Small Satellites

INTRODUCTION

The IEEE GRSS Instrumentation and Future Technologies (IFT) Technical Committee (henceforth, IFT-TC) seeks to foster international cooperation in advancing the state-of-the-art in geoscience remote sensing instrumentation and technologies that improve knowledge for the betterment of society and the global environment. The mission of the IFT-TC is to facilitate, engage and coordinate GRSS members and the communities-at-large to: assess the current state-of-the-art in remote sensing instruments and technology, identify new instrument concepts and relevant technology trends, and recognize enabling technologies for future instruments. The IFT-TC is organized into six working groups targeted at current and emerging technology areas relevant to the broad remote sensing community: 1) Active Microwave (RADAR and SAR), 2) Microwave Radiometry, 3) Lidar, 4) Optical Instrumentation, 5) Global Navigation Satellite System, and the newly formed, 6) Remote Sensing Instruments and Technologies for Small Satellites (henceforth the "SmallSat Working Group"), the focus of this article. The SmallSat Working Group currently has over 50 core members and continues to grow.

IFT-TC MISSION:
1) ASSESS THE CURRENT INSTRUMENTATION STATE-OF-THE-ART.
2) IDENTIFY NEW INSTRUMENT CONCEPTS AND TECHNOLOGY TRENDS.
3) RECOGNIZE ENABLING TECHNOLOGIES FOR FUTURE INSTRUMENTS.

SMALL SATELLITE TAXONOMY

There are several useful definitions of what it means to be a "small satellite," but for the purposes of the SmallSat Working Group, we offer the following guidelines and include everything from "femto" to "mini" satellites in our purview:

- Large satellite: > 1000 kg
- Medium satellite: 500-1000 kg
- Mini satellite: 100-500 kg
- Micro satellite: 10-100 kg
- Nano satellite: 1-10 kg
- Pico satellite: 0.1-1 kg
- Femto satellite: <100 g

Of particular interest recently is a class of pico/nano satellites called CubeSats, a type of miniaturized satellite for space research that usually has a volume of exactly one liter (10 × 10 × 10 cm), has a mass of no more than 1.33 kg, and typically uses commercial-off-the-shelf (COTS) components. Larger CubeSats can be developed using multiple "1U cubes", 3U and 6U designs are now common. California Polytechnic State University and Stanford University developed the CubeSat specifications in 1999 to help universities worldwide perform space science and exploration. In less than a decade, CubeSats have evolved from purely educational tools to a standard platform for technology demonstration and scientific instrumentation.

THE EMERGENCE OF SMALL SATELLITES

In the past, the preferred architecture for most spaceborne Earth remote sensing missions was a single large spacecraft platform containing a sophisticated suite of instruments. Following the evolution of the computer from room-sized to pocket-sized, technology has paved the way for a similar shift in satellites. Three distinct advantages arise from going 'small' to compensate for the loss in mass, power and volume. First, small satellites allow for cheap access to space. By flying as secondary payloads and utilizing excess capacity, launch costs can be reduced by an order of magnitude or more. Notably, the NASA CubeSat Launch Initiative (CSLI) has committed to

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providing 89 CubeSat launches in the last 4 years at no cost to selected proposers. Second, small satellites allow for rapid development and lower costs through use of common parts/frameworks. Economies of scale do exist for small satellites, where parts and subsystems are relevant for a wider variety of missions, instead of a single application in traditional flagship missions. Third, small satellites allow for a more relaxed risk posture due to the significantly lower cost. In terms of distributed risk, a single $100 million mission is inherently riskier than one hundred $1 million missions. Radically new mission architectures consisting of very large constellations or clusters of CubeSats promise to combine the temporal resolution of GEO missions with the spatial resolution of LEO missions, thus breaking a traditional trade-off in Earth observation mission design [9]. Figure 1 shows the growing number of launches of nano and pico satellites since the 1990s [2].

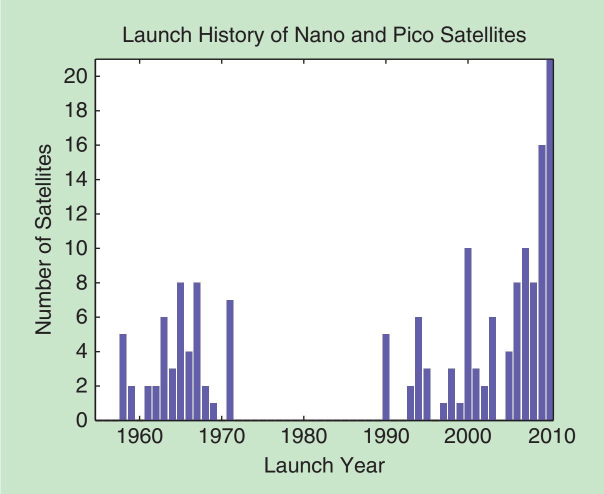

FIGURE 1. Launch history of nano and pico satellites since 1955.

A SNAPSHOT OF CURRENT AND FUTURE MISSIONS

There have been many recent small satellite missions that have successfully launched or are currently in formulation that will demonstrate new technologies for Earth observation (see [5] for examples). The Cyclone Global Navigation Satellite System (CYGNSS), with launch expected in 2016, will make frequent and accurate measurements of ocean surface winds throughout the life cycle of tropical storms and hurricanes. The CYGNSS mission comprises eight Low Earth Orbiting 18-kg spacecraft (see Figure 2) that receive both direct and reflected signals from GPS satellites to determine position and ocean surface roughness. The Canadian CanX-4 and CanX-5 mission will demonstrate two nanosatellites flying autonomously in precise formations with relative position determination accurate to a few centimeters using carrier-phase differential GPS techniques. Its success may someday enable a constellation of nanosatellite

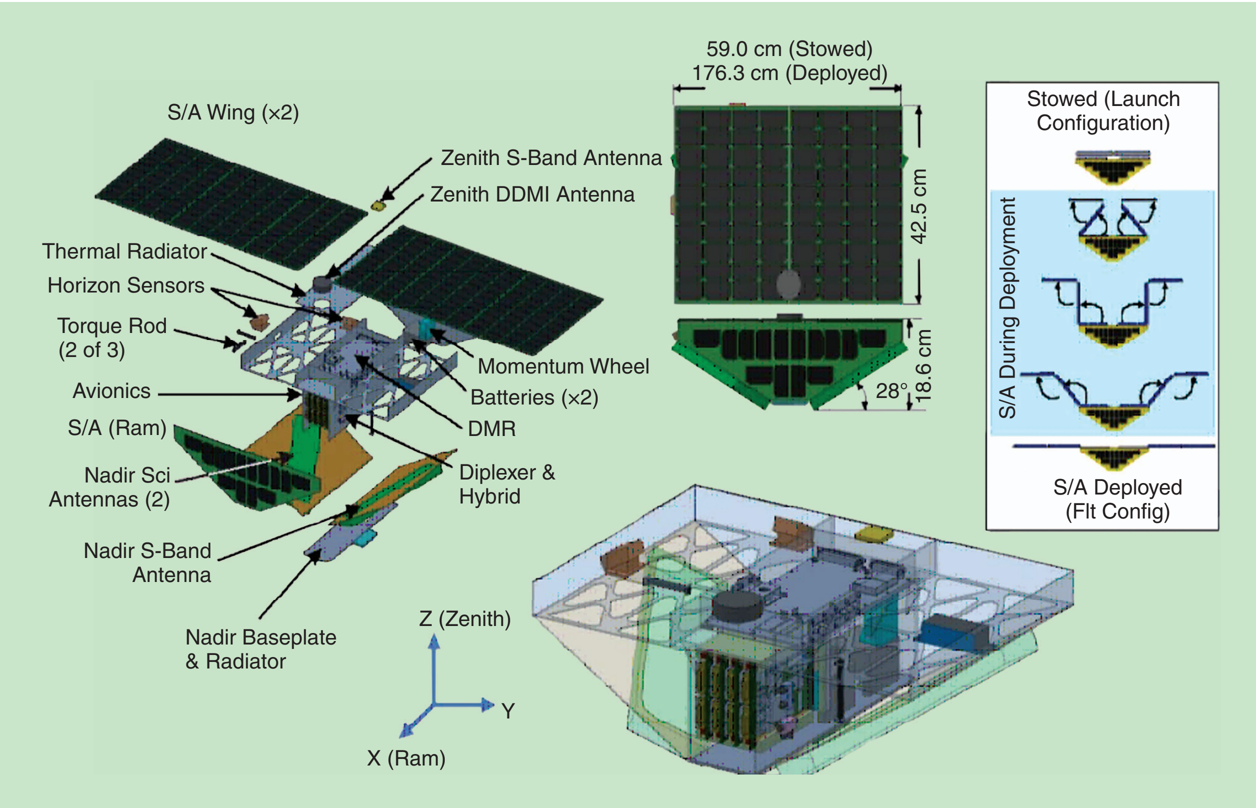

FIGURE 2. The CYGNSS Observatory. The exploded view shows individual subsystems, including the science payload's Delay Doppler Mapping Imager (DDMI) antennas and receiver electronics (DMR).

receivers augmenting an existing SAR transmitter for InSAR applications [6]. The European QB50 Project will soon launch an international network of 50 2U CubeSats to study the temporal and spatial variations of a number of key constituents and parameters in the lower thermosphere [4]. ESA's 140-kg PROBA-V satellite will serve as a miniature engineering lab in orbit. Less than a cubic meter in volume, PROBA-V is hosting five technology experiments, including innovative testing of fiber optics for space. The GEO-CAPE ROIC In-Flight Performance Experiment (GRIFEX) is a 3U CubeSat in development that will perform engineering assessment of an all-digital in-pixel high frame rate Read-Out Integrated Circuit (ROIC). This ROIC has an unprecedented frame rate of up to 12 kHz while consuming less than 2 W of power where the design of analog-to-digital converters in each pixel enables the all-digital design. MicroMAS [1], a 3U CubeSat for 118 GHz sounding, utilizes LTCC SIW filters on the backend to provide channelization with a scanner motor assembly to achieve a cross-track swath. CHARM [3], a 3U CubeSat for 183 GHz sounding, utilizes a state-of-the-art Indium Phosphide low noise amplifier (<20 mW) and novel internal calibration. These two radiometer missions in development have the capability of synergy in the future as a combined 118/183 GHz sounder.

THE EUROPEAN QB50 PROJECT WILL SOON LAUNCH AN INTERNATIONAL NETWORK OF 50 2U CUBESATS TO STUDY THE TEMPORAL AND SPATIAL VARIATIONS OF A NUMBER OF KEY CONSTITUENTS AND PARAMETERS IN THE LOWER THERMOSPHERE.

THE SMALLSAT WORKING GROUP

Operational needs, such as weather forecasting, add a distinct set of requirements for continual and highly reliable monitoring of global conditions [10]. A goal of the SmallSat Working Group is therefore to address these diverse requirements and assesses how they might be met by small satellites, identify the needed core technologies to enable and facilitate small satellite mission development, and bridge the gap between small satellite and instrumentation technologists and remote sensing mission planners. Universities have traditionally led the way in embracing the challenge from the smaller scale. Space agencies worldwide can learn to incorporate some of these practices that may be at odds with traditional space qualification grade missions (e.g., NASA's Class-A/B missions). The broad membership of the SmallSat Working Group can aid in this process. The co-chairs invite readers who are interested in contributing to contact them for membership details.

UPCOMING SPECIAL SESSION AT IGARSS 2013

There is a vibrant community within the GRSS that is taking advantage of the small satellite platform. A full special session at IGARSS 2013 in Melbourne, Australia will be dedicated to past, present and future missions. Among the topics to be discussed are: CubeSats for atmospheric monitoring using microwave radiometry, constellation approaches for improved mission performance, and new sensing technologies offering extremely low size, weight, and power.

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