Frequent Flyers

Growth of small-satellite market creates opportunities for parts makers

By William Leventon, Contributing Editor

ÅAC Microtec

Three TechEdSat-1 satellites that were launched from the International Space Station. ÅAC Microtec provided avionics to NASA Ames Research Center, developer of the satellites. In the background are the space station's solar arrays. NASA Ames plans to launch eight new smallsats in 2015 (see page 41).

The trajectory for one aerospace market is straight up.

There is "huge growth" in store for the small-satellite market, according to Carolyn Belle, an analyst for Northern Sky Research, a Wilmington, Del., satellite-industry market research firm. Belle is the author of a recently released report, "Nano and Microsatellite Markets," that examines satellites weighing from 1 to 50 kg. The study focuses on the lighter versions of so-called microsatellites (weighing from 10 to 100 kg), as well as nanosatellites (weighing from 1 to 10 kg). While there were fewer than 200 launches of 1- to 50-kg satellites in the last 5 years, Belle believes there will be about 2,000 launches of these devices over the next 10 years.

Simplifying the task of building and launching these satellites is the industry's CubeSat standard. A basic CubeSat unit is a 1U, which stands for one unit, and measures 10cm × 10cm × 10cm. There are also 2U CubeSats, which basically consist of two stacked 1U units, and even 12U CubeSats. Many CubeSats are launched as "constellations," which can include a few satellites or 100 satellites.

Belle partly attributes the growing popularity of small satellites to their low cost and low risk. "There are significant barriers to entering the market for satellites costing hundreds of millions of dollars," she noted. "But a nano- or microsatellite can be built for about $50,000."

In addition, she said, small satellites are not as complex as their larger counterparts, which means they can be built in months rather than years. That makes it relatively easy to get a service that sells information obtained from the satellites on the market, compared to ones involving larger satellites.

Smallsat apps

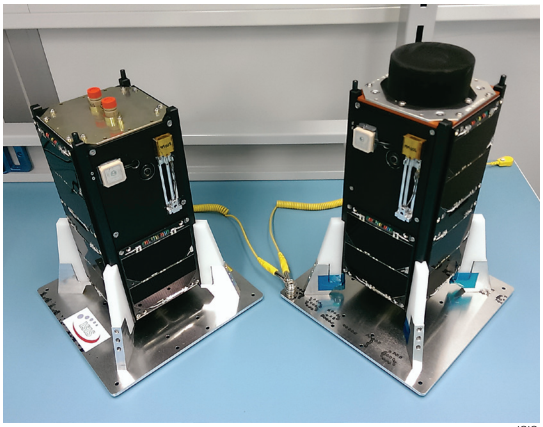
One of the main applications for small satellites has been education. They were originally developed in universities, which design and build inexpensive, small satellites as a hands-on educational experience.

Another application is technology development. Because smallsats are cheaper to build and launch than traditional satellites, Belle said, they are good platforms for testing new components—to see how they function in a microgravity environment, for example.

Research is also a beneficiary of the smallsat boom. "A number of our satellites are used for small-scale science missions," reported Jeroen Rotteveel, CEO of Innovative Solutions in Space (ISIS), a Netherlands-based provider of CubeSat structures and subsystems, as well as small-satellite launch services. These missions include climate-change and upper-atmosphere research.

Over the next 10 years, however, Belle sees most of the growth in the small-satellite market coming from Earth observation. "Because these satellites are inexpensive to build, you can put constellations of them in orbit to cover the same area on Earth more frequently than a larger satellite," she explained. "Instead of getting one picture of Northern California every day, you might be able to get four."

City planners and retailers can use such photos to observe traffic patterns. Observational data could also be used to track ships or aircraft. "Large, remote-sensing satellites will never be able to give you multiple [checks] per day of every spot on the globe, but a network of 100 nanosatellites might be able to do that," Rotteveel said.



ISIS

Nanosatellites from ISIS use standard electronics, such as in these assemblies, to keep costs down and reduce lead times.

On the downside, Belle pointed out that some smallsats fall out of orbit in weeks or months, compared to 10 or 15 years for larger satellites. In addition, the smaller size means smaller payloads, which limits the tasks a single satellite can perform and the types of cameras carried. As a result, "it is basically not feasible to do submeter-resolution imaging from a nanosatellite," Rotteveel said.

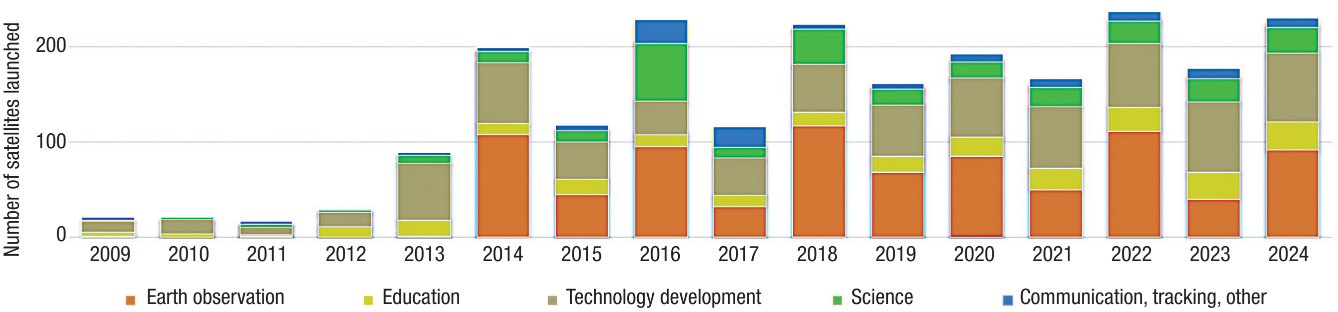
LEGO-like subsystems

Rotteveel's company offers nanosatellite subsystems such as flight computers, radios, antennas and solar arrays as standard components. These standardized subsystems "are very modular, so you can select and click them together like LEGOs to put the core of your satellite together," he said. "At the start of the design process, you see which of the standard building blocks come closest to [delivering] the performance you require, and on day two you basically have a detailed design of 60 to 70 percent of your spacecraft."

Designed for the CubeSat footprint, the subsystems usually consist of a single 10cm × 10cm printed circuit card with a number of components. ISIS technicians hand-solder most of the boards in-house.

According to Rotteveel, satellite firms

Global forecast for launches of 1- to 50-kg satellites



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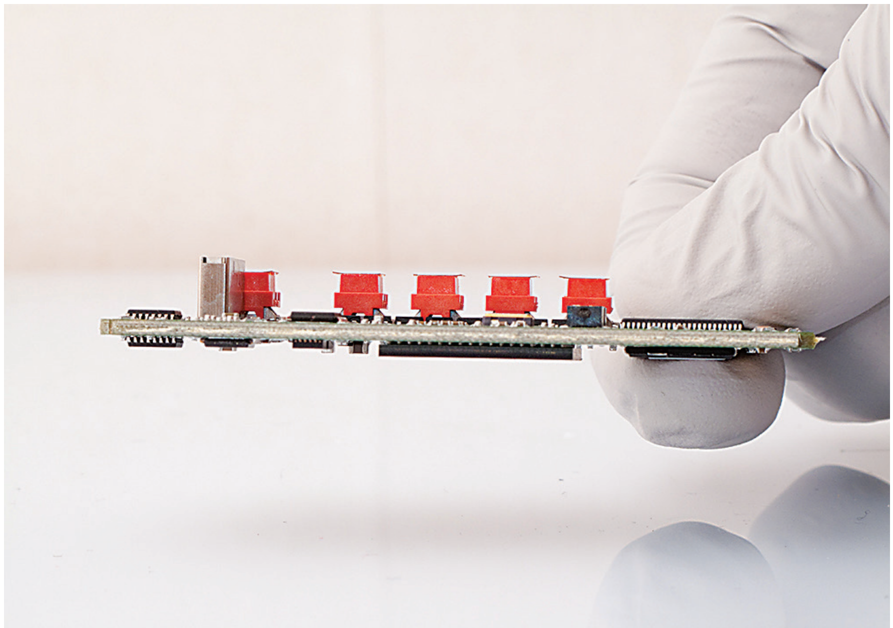
normally have to wait weeks, months or even years for components specially manufactured to meet the requirements of the space environment. But his company strives to keep lead times short and prices low by not selecting space-grade components. “We would rather rely on industrial electronics components that work well in space,” which can be deduced from testing and interpreting data sheets, he explained.

These off-the-shelf components are used in devices such as smartphones, laptops and automobiles. For example, “we use automotive FPGAs (field-programmable gate arrays) that are not as resilient in space as radiation-hardened FPGAs, but are resilient enough,” Rotteveel said. “We typically design our satellites to last 3 years in low-Earth orbit, compared to 10 years for a conventional satellite. Industrial-grade components do not survive 10 years in orbit, but they do survive three if you select them carefully.”



ÅAC Microtec

The OBClite is an onboard computer for small satellites.

Since many smallsat manufacturers can’t afford radiation-hardened electronic products, ÅAC Microtec AB sells them fault-tolerant electronics with triple-mode redundancy. These consist of three parallel processors that can correct for errors caused by radiation. “If one processor makes an error, there are two other processors in parallel to correct it,” explained Johan Bäckstrom, vice president of sales and marketing for the Uppsala, Sweden, maker of microsatellites, CubeSats and CubeSat subsystems.

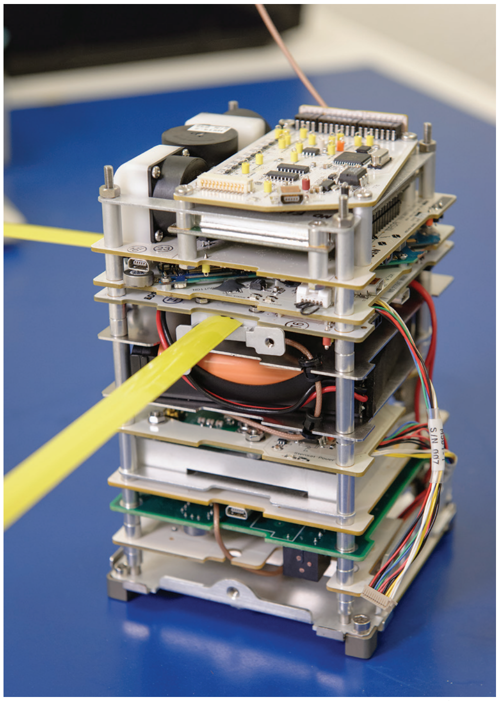
The company’s smallest product for the small-satellite market is the nanoRTU. Roughly the size of a postage stamp, this computer is used as an interface between scientific payloads and the satellite bus.

While ÅAC Microtec outsources soldering work on the nanoRTU, it does perform some in-house manufacturing processes, such as thin-film metallization, flip-chip soldering, wire bonding, and assembly and packaging of advanced hybrid modules.

The firm also offers component miniaturization design services that have been qualified by the European Space Agency. As an example, if a customer has a printed circuit board that's too big for a CubeSat, his company can redesign it to fit the allotted space.

Communication demonstration

ÅAC Microtec's nanoRTU customers include NASA, which has long been active in the small-satellite field. A current NASA project is the Edison Demonstration of Smallsat Networks, also known as EDSN. The NASA Ames Research Center is readying eight EDSN satellites for a 60-day mission scheduled to begin in early 2015.



NASA Ames Research Center

Nine electrical subassemblies are interconnected via a single backplane PCB in this EDSN satellite, which uses a Nexus S smartphone as its main processor.

"EDSN is the first nanosatellite network we know of that will try to do scientific measurements that are shared among the satellites," said James Chartres, lead systems engineer for EDSN. The idea is for all the satellites to communicate with each other, but for only one to send data to the ground. In other networks, Chartres explained, each satellite sends data to the ground.

"EDSN is a proof-of-concept, so that when we go to tens or hundreds of satellites, we don't need a large ground-station infrastructure to communicate with each individual satellite," he said.

Once in orbit, the EDSN satellites will form a "hub and spoke" network. The hub satellite is called the captain, and the spokes are lieutenants. (Each satellite is equipped to serve as both a captain and a lieutenant.) The captain collects data from the lieutenants and sends that data to the ground. To test and demonstrate the technology, as the mission proceeds each EDSN satellite will take a turn as captain.

The EDSN satellites are 1.5U CubeSats weighing about 2 kg apiece. Onboard each satellite is a GPS receiver telling the satellite its position. Also onboard are three radios. One is used to locate the satellite, another is a transceiver that allows the satellites to talk to each other and the third is for transmitting data to the ground station.

In addition, NASA Ames uses Google Nexus S smartphones to run the satellites. Chartres and his colleagues took the motherboard out of the phone and integrated it with one of their electronic boards to produce the main satellite processor. Chartres said the advantage of using these phones is that they're commercially available and the software libraries already exist, which drastically reduces software development time.

Other small EDSN components include mountings for antennas and the wheels used to control satellite orientation. The prototypes for these are made by 3D printers; final versions are machined from composite plastics.

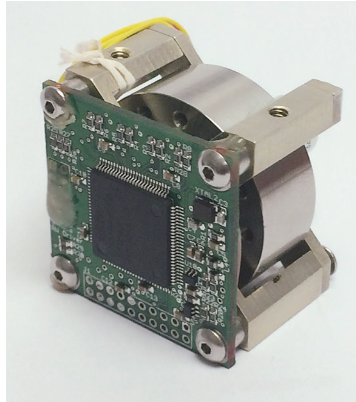
Some of the satellite's smallest parts are surface-mount components such as chips, resistors and capacitors. Chartres and his colleagues design these components into PCBs, which are manufactured in Silicon Valley.

Pumpkin's shells

The outer aluminum shell for the EDSN satellites comes from Pumpkin Inc., a San Francisco-based maker of CubeSat components and kits, as wells as complete nanosatellites.

Most of Pumpkin's aluminum satellite shells are fabricated from sheet metal. In this process, "there is a lot of scrappage because of the tolerances involved," noted Andrew Kalman, Pumpkin's president. "The CubeSat design specification only allows 4 mils of variance over the full length of the satellite, which is an insanely tight tolerance for sheet metal."

Pumpkin has higher-level chassis, like those for the EDSN project, EDMed. The process allows Pumpkin to add special features, like integrated hinges, to the structure. "When you EDM the chassis, getting to the required tolerance is not an issue, but the costs go up quite a bit because you're starting from solid billets and throwing out 98.5 percent of the material to get the structure you want," Kalman said.



Maryland Aerospace

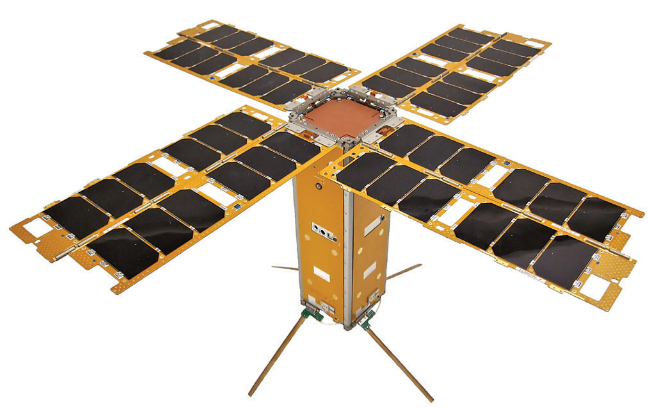
The MAI-400 reaction wheel measures 1.5" on a side and consumes 0.4w of power. The wheel provides attitude stabilization and control for miniature satellites in Earth orbit.

Sheet metal fabrication and EDMing are outsourced, mostly to firms in Silicon Valley. "We couldn't afford [to hire] operators of the quality we would need to do the work," Kalman explained.

Pumpkin 3D-prints small-part prototypes in-house, such as hinges and release mechanisms.

The company also outsources 3D printing of prototypes to shops that use Windform composite materials for selective laser sintering. These materials, produced by the CRP Group of Italy, include polyamides filled with other materials—carbon fibers, fiberglass, aluminum and glass—and polystyrenes. These strong materials have been vibration-tested in extreme environments, according to Kalman. Resolution of Windform parts "tends to be around 6 to 8 mils, which is on the high side for us," he said. "But we have worked with those companies [that make the Windform prototypes] so they can produce acceptable printed parts for us." Examples include prototype CubeSat enclosures.

To adjust the orientation of some of their nanosatellites in space, Kalman and his colleagues integrate ADACS (attitude determination and control system) products from a couple of suppliers. An ADACS can determine the attitude or orientation of a satellite from photos of the surrounding stars. To change the



Pumpkin

A MISC 3 satellite (center) with solar panels attached in a propeller configuration.

satellite's orientation, the system, made by Pumpkin supplier Maryland Aerospace Inc. (MAI), Crofton, Md., uses micromotors to apply torque to one or more of three 1"-dia. reaction wheels arranged orthogonally to each other. The resulting reaction torque can be used to point the satellite at a target on the ground or in space.

MAI's latest ADACS for smallsats measures 10cm × 10cm × 5cm, or 0.5U. Manufacturing of the reaction wheels is outsourced to local machine shops, according to company president Steve Fujikawa. At present, Fujikawa purchases the motors for his ADACS—though the company plans to make higher-torque, lower-power motors in-house—as well as the digital CMOS (complementary metal-oxide semiconductor) sensors used to photograph the stars. A local fab shop solders the sensor to a circuit board that also holds a computer that controls the camera and determines satellite attitude.

Smaller still?

According to ISIS's Rotteveel, there are people who say that 1-kg satellites aren't small enough. Others are trying to improve the utility of nanosatellites by making them larger so they can handle bigger payloads.

Partly because of nonscalable expenses like satellite licensing and insurance, which will grow in importance if satellites are miniaturized still further, Rotteveel is comfortable with the size of current nano- and micro-satellites. "I feel that somewhere from 1 kg to 50 kg is the sweet spot for the most mass- and cost-efficient small satellites." µ

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