Earth Observation with Smaller Satellites and Ground Stations

› Mr. Gizunterman, Orbit Communications Systems Ltd

Earth Observation

Without most people knowing it, Earth Observation (EO) has become an important part of their lives. Our planet is constantly being monitored, measured and analyzed by universities, weather services, governmental agencies, defense forces and private industry. From hurricane tracking to oil and gas exploration, earth observation data is critical to many applications that affect our daily lives.

To provide EO data, Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites have been launched into orbit to provide optical and radar imaging for analysis of the planet Earth.

EO satellites

EO satellites were designed for civil applications such as environmental monitoring, meteorology, cartography and more. As a rule, EO satellites were designed to operate at altitudes ranging from 450 to 800 km. Almost total global coverage occurs in polar orbits, where a typical LEO satellite orbits the Earth every hour and a half or so.

Below, for example, is a table of NASA satellites, launch dates, altitudes and primary objectives, supported by the Alaska Satellite Facility (ASF). The ASF is part of the NASA-managed Near Earth Network (NEN) system of global satellite-tracking ground stations.

NASA's NEN provides telemetry, ground-based tracking, data and communications services to a diverse range of customers, US and international, governmental and commercial, NASA (Earth Science, Space Science and Human Explorations missions) and non-NASA.

While many point out the low relative cost of launching and operating Low Earth Orbit satellites, there are two other important reasons. The first is Kepler's Law, which reasons that the closer the orbit, the more frequent the updates. The second is optical physics, which delivers better imaging results the closer the satellite is to the Earth's surface.

Of course, there's always a downside. Lower orbits result in greater atmospheric drag meaning that some kind of engine and fuel are required.

The smallsat market

Small satellites, or smallsats, typically weigh in at under 500 kg. The major reasons for the development of smallsats are to reduce the high cost of satellite production and launch vehicles and to increase efficiency in specific areas. For example, an array of many miniature satellites is often more effective than fewer, larger ones for

purposes of scientific data gathering and for signal relay. The technical drawbacks of smallsat construction – such as insufficient power storage or room for a propulsion system – are being overcome with innovative solutions on a continuous basis.

As mentioned earlier, one of the key reasons for miniaturizing satellites is to reduce the cost: bigger and heavier satellites need bigger and heavier rockets with high price tags. Smaller and lighter satellites need smaller and lighter rockets and can sometimes be piggybacked, by taking up the excess capacity on larger launch vehicles. And miniaturized satellites allow for simpler designs and a straight path to mass production.

Another reason for the growing popularity of small satellites is to enable tasks that larger satellites would not be able to address, such as:

- Low-data-rate communications via constellations
- Data gathering from multiple points via formations
- Monitoring of larger satellites while in orbit
- Academic research

According to Rich Smith's Dec 2016 Motley Fool article, "Small Satellites Explode in Popularity - and Size", of the 4,250 satellites in orbit today, 291 (7%) can be classified as small satellites. The International Academy of Astronautics defines a range of smallsats, based on mass, including:

Satellite group name	Mass (kg)
Minisats	100 to 500
Microsats	10 to 100
Nanosats	1 to 10
Picosats	0.1 to 1
Femtosats	Less than 0.1

According to Northern Sky Research (NSR), approximately 80% of all smallsats launched between 2011 and 2015 had a mass of less than 10 kg. But NSR predicts that by 2021 smallsats with as mass of more than 10 kg will account for 45% of the market because the cost of building larger smallsats has come down dramatically. For instance, where a few years ago, specialized equipment for a 20-kg smallsat might have cost $2.5 million, today you can pick up all the same components for around $25,000!

Satellite	Launch date	Altitude (km)	Primary objective – studying Earth's:
AIM	25 Apr 2007	600	Icy mesosphere
Aqua	04 May 2002	705	Water cycle
Aura	15 Jul 2004	705	Atmosphere
IRIS	27 Jun 2013	620	Sun
GRACE	17 Mar 2002	456	Gravity
OCO-2	02 Jul 2014	705	CO2 levels
QuikSCAT	19 Jun 1999	800	Winds
SCISAT	12 Aug 2003	650	Atmosphere
SMAP	31 Jan 2015	685	Soil moisture levels

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Smallsat-tracking ground stations

The smaller the satellite, the less the performance it delivers. To benefit from the data captured by smallsats, a quick and reliable communications link must be established between the fast-moving satellites and the satellite-tracking ground stations on Earth. Communications signals require direct line of sight between the satellite and the ground station. The

image 1: Installation of a smallsat-tracking ground station in a polar environment. **Credit:** courtesy of Orbit Communications Systems, Ltd.

communications "time window" is only a few minutes for every LEO satellite pass, so the goal is to make the most out of that time while it lasts.
Critical decisions depend on such communications, which is why high-accuracy, high-performance ground stations are needed for tracking LEO satellites. Well-planned ground stations should be cost-effective, scalable and be able to support a range of antenna sizes.
The top 10 requirements for smallsat-tracking ground stations are:
1. Continuous tracking capabilities with no "key hole"
2. High availability and reliability via an EL, Tilt and AZ 3-axis system
3. High performance via an integrated step-tracked Advanced Control Loop
4. Remote operation functionality
5. Maximum agility via total control and scheduling software
6. Anytime/anywhere/all-weather radome
7. One platform with multiple configurations (from L- to K-band)
8. Multi-topography installations with field-proven reliability
9. Low maintenance
10. The flexibility to support every type of project, from low-budget, academic research to government-sponsored services downloading massive amounts of continuous data
Look for end-to-end ground station solutions that can integrate fully into existing infrastructures and be modular enough to scale from roof-mounted GIS tracking antennas to an entire ground station solution including high data-rate receivers and control software.

EO via smallsat trends

Imaging satellites are getting smaller and more accurate thanks to optics technology, with more compact, higher-quality cameras being developed all the time.
The market is changing significantly.

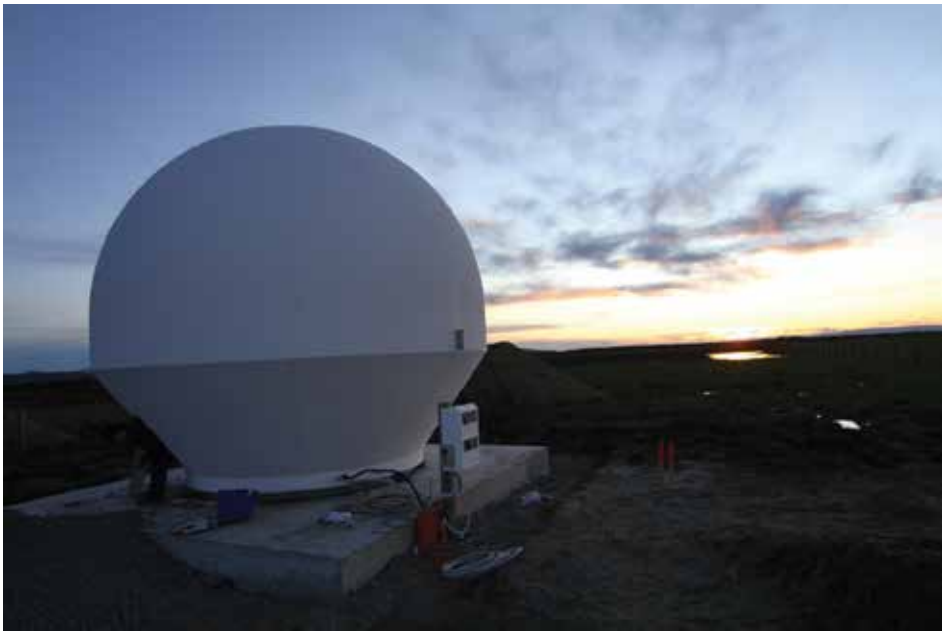

image 2: Installation of a smallsat-tracking ground station in a polar environment. **Credit:** Orbit Communications Systems Ltd

An almost exclusively military domain is now being overtaken by commercial and research projects. Today, around 60% of all smallsats are defense-related, but that market share is falling rapidly thanks to smarter and faster solutions.
Due to the drastically reduced cost of both building and launching smallsats, everyone seems to be getting involved. A host of new companies has appeared on the scene, dealing in ventures ranging from space exploration, through planetary resource monitoring, to asteroid mining. High Schools and universities are also raising the funds to send up swarms of their own birds. What has piqued the interest of both entrepreneurial companies and academic institutions alike are the cost-effective, easily managed and flexible solutions available today. For example, not only can the same system now support X-band (for higher data-rate continuous image transmission) as well as S-band (for lower data-rate telemetry and control) at the same time, it can now also be combined with UHF for very low data-rate applications.

2020 foresight

Clear evidence for the rapid growth of the market, is that more smallsats are being launched today than ever before. A well-known launch service that sends up a payload of smallsats once a month today, is already planning for weekly launches in 2019, and daily launches by 2020.
In the same way that satellites are getting smaller and smaller in size, so are their respective ground-station antennas. A well-known EU operator used to use 7 to 13-meter antennas for smallsat tracking. It now uses 2 to 5.5-meter antennas.

Mr. Gizunterman , VP R&D at Orbit Communications Systems Ltd.