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# THE DEVELOPMENT OF THE EARTH REMOTE SENSING FROM SATELLITE

**Ua** Дистанційне зондування зі супутників – важливий аспект для отримання інформації про земну поверхню, тому має важливе значення у військовій, економічній і геологічної галузях. Дистанційне зондування має на увазі виміри, які зроблені непрямими або «дистанційними» засобами, а не контакт-

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ним датчиком. У цій статті аналізуються датчики для здійснення контролю орієнтації супутника.

**Ru** Дистанционное зондирование со спутников – важный аспект для получения информации о земной поверхности, поэтому имеет немаловажное значение в военной, экономической и геологической областях. Дистанционное зондирование подразумевает измерение, производимые косвенными или «дистанционными» средствами, а не контактным датчиком. В этой статье анализируются датчики для осуществления контроля ориентации спутника.

## Overview of earth remote sensing from satellite

Remote sensing is defined in various ways:

– the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter [1];
– the art of analysing data acquired by a device that is not in contact with the object, area, or phenomenon under investigation [2];
– the observation of the Earth's surface at a distance and interpretation of the images or numerical values obtained by the instrumentation, techniques and methods to acquire meaningful information of particular objects on the Earth.

Remote sensing relied primarily upon either reflected or emitted electromagnetic radiation (optical and microwave) from the Earth to infer changes on the Earth's surface or in the overlying atmosphere in its application to satellite and aircraft instrumentation. Remote sensing also requires the analysis of acquired data and images. Interpretation of data is also important requirement of remote sensing. As a whole, remote sensing includes the following six components: the sun; the Earth's surface; sensor and platform; the ground receiving system; the analyst, which converts using visual and/or digital techniques; the information extracted from the original data for a wide variety of applications [3].

## Benefits of environmental monitoring from satellite sensors

– *Global Coverage* [4].
– Multiscale observations.
– Observations over the nonvisible regions of the Spectrum.
– Repeat observation/
– Immediate transmission [5].
– Digital format [6].
– Atmospheric Observations and Ozone Assessments.

*Satellite-based remote sensing*. Remote sensing based on satellite is a vast, endless, and rapidly changing field. Among other things, battery degra-dation, unexpected failures, and propellant exhaustion are problems that make the life of satellites very short. Geosyn-chronous satellites, for instance, need propellants to keep them in orbit and maintain their altitude in order to properly point the solar panels and antenna. Because of the lack of propellant, therefore, the useful life-time of geosynchronous satellites averages about 15 years. In addition, some missions with polar orbits planned for several years and carrying sophisticated remote sensing equipment lasted less than two years due to power system or instrument failures (http:/coaps.fsu.edu/scatterometry/about/overview.php). Similar problems are faced by communication satellites. There are many different instruments working on board spacecraft's such as active microwave instruments, synthetic aperture radar, wind scatterometer, radar altimeter, radiometer scanner, ozone monitor, microwave sounder, precise range and range equipment, laser reflector, microwave radiometer, LIDAR, precise Doppler locator orbit, laser tracker, GPS tracker, radar precipitation, microwave image. The instruments on board satellites can be distinguished in terms of measured energy into two major groups: passive and active instruments. In the passive group are those instruments which measure the sun energy that the Earth's surface reflects or re-irradiates. The active remote instruments are radar or lidar. Wavelengths in the order of centimeters are used by active remote sensing in the radio frequency range. Lidar are active devices between about 10 $\mu$m (near infrared) and about 250 nm (ultraviolet) in the wavelength range. In remote sensing field a swath, is used to define the portion of the Earth's surface that the sensor "sees". The Earth's rotation determines that in each orbit the instrument on board the satellite cover a new swath, thus the complete Earth's surface is imaged after some regular time. The nomenclature used in the geometry of satellite's radar. The angle between a line directed towards the nadir and the radar beam direction is called the look angle. The depression angle is the complement of the look angle. The incident angle is the angle between the radar beam direction and the normal to the Earth's surface at the point where the radar beam hits the surface. Satellites devoted to acquiring images of the Earth can be classified into two large groups according to their uses; some are designed to study the Earth's resources, while others are devoted to study environmental phenomena. Earth's resources do not change very fast such as crops. it is necessary to have good spatial resolution to evaluate the amount and degree of growth of crops. Therefore, the swath width of these images is less than 200 km, and the spatial resolution is less than 100 m. These satellites require several days to obtain a complete image of the Earth due to the relatively small width of the swaths. In contrast, Environmental satellites need to collect information on the complete Earth's surface daily or hourly. Thus, swaths are of hundreds to thousands of km and the spatial resolution of several hundreds of meters. Thus, the concept of Image Resolution i.e., spatial and time resolutions of the instruments are important to measure environmental parameters and the quality of data gathered.

## Image resolution

The image resolution is the ability of the instruments to capture the Earth's surface information with a certain degree of detail. For satellite images it is essential to define for types of resolution. There are four types of resolution:

*Spatial Resolution*: On satellites the camera detects the energy emitted from individual points of an object and convert them into a visual image. An image consists of a matrix of pixels. Depending upon the number of detectors i.e. optical sensors of the camera, the number of pixels varies on image. For example, most cameras for domestic use have 1600 x 1200 pixels which is equal to 1.92 x 106 pixels. Spatial resolution of the camera depends upon the number of pixels. For instance, if the camera flying on board a spacecraft has 4000 x 3000 pixels and the swath is 40 km x 30 km, the spatial resolution would be one hundred square meters. In active remote sensing instruments (radar, lidar etc) it is more complex to quantify the spatial resolution because it depends on several factors: the beam width (linked to the transmitted frequency and antenna), the pulse length and the data processing.

*Spectral Resolution*: Spectral resolution is the amount of spectral channels through which the instrument on board the spacecraft detects the electromagnetic energy coming from the surface of the Earth. Different types of objects on the surface of the Earth may present different spectral responses when illuminated by the sun. Some radiometers on board satellites are called multi-spectral sensors because they record energy over a few separate wavelength ranges. The SPOT 6 satellite, for example, has a spectral resolution of five because it records the following wavelengths: panchromatic (450 – 745 nm), blue (450 – 520 nm), green (530 – 590 nm), red (625 – 695 nm) and near-infrared (760 – 890 nm) (Astrium GeoInformation Services, 2013). More recent radiometers, called hyperspectral sensors, can record hundreds or narrow spectral bands. Obviously, this high spectral discrimination allows more information about the targets to be acquired. Active instruments use few frequencies to " sense" the targets, and then we could say they have reduced spectral resolution. Spectral resolution is defined by the electronics and the transmitting and receiving antennas.

*Radiometric Resolution*: The ability to discriminate very small differences in the amount of energy received is the radiometric resolution. Each optical sensor, which defines a pixel in the image, receives the electromagnetic energy from the surface of the Earth and produces a certain analog output to be converted into a digital output. Each pixel's brightness is discrete according to the onboard instrument's analog-to-digital converter. Many satellites, for example, had 8-bit resolution, while others had 10-bit resolution; that is, the light was translated to 256 or 1024 gray levels, respectively. This discretization is done for each spectral band in hyperspectral radiometers, thereby dramatically increasing the number of resources needed to store or transmit the data.

*Temporal Resolution*: Temporal resolution in satellite refers to the period of time needed for a satellite to sense again the same area. The time it takes for a satellite to complete an entire cycle of orbit is called the revisit period; it is the satellite's time to pass over exactly the same swath again. Due to the ability of some satellites to change the pointing angle of their optical systems and antennas, when the satellite travels in a near but different orbit, the same area could be" viewed" from another orbit. Some satellite can therefore define a temporal resolution smaller than the revisit period. It should be emphasized that they feel the same region but with a different viewing angle. High-resolution satellites have small swaths and a long revisit period, e. g. every 26 days satellites with a swath width of 60 km could cross the same point.

**Instrument's Scanning Geometry**

Scanning geometries associated with a passive or active sensor, but the scanning of the Earth's surface is independent of the instrument. They can be used to point either a passive or an active sensor.

*Across-Track Scanning.* There are different ways of emitting the electromagnetic signal from the Earth's surface to the sensor through the optical arrangement in passive instruments. One of them is called cross-track scanning and consists of a rotating mirror scanning the terrain on the swath in a perpendicular direction to the satellite track It, therefore, calculates the energy traveling an arc from each side of the line to the other, e.g. $90^0$. A new scan is performed as the satellite moves in its path. Successive scans create an image in two dimensions as shown in Figure 3. Although there is only one point where the successive spots are converted from optical to electrical signals, at this point multiple sensors or spectral filters can be placed to obtain spot information of the same surface with different spectral resolutions. The sensor outputs are analog time functions that are sampled at fixed intervals and converted into digital signals. Digitalization must be synchronized with scanning to assign a digital value to a specific spot on the surface of the Earth. The main advantage of this system is that only one reference constant weights all the spots that make up the picture because the sensor is unique.

*Sensor types*. Two types of sensors used in remote sensing passive and active sensors. Remote sensors are classified into various types based on their scanning and imaging mechanism. Passive and active sensors are divided into non-scanning and scanning types, which in turn are divided into imaging and non-imaging sensors.

*Passive remote sensors*. Examples of passive remote sensors are: accelerometer, radiometer, imaging radiometer, spectrometer, spectroradiometer, hyperspectral radiometer, and sounders. Some of the prominent passive sensors used in remote sensing data collection in the present day are Linear Imaging Self-Scanning Sensor (LISS), advanced very-high-resolution radiometer

(AVHRR), Coastal Zone Color Scan- ner (CZCS), Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), Moderate-Resolution Imaging Spectroradiometer (MODIS), active Cavity Radiometer Irradiance Monitor (ACRIM II and III), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Imaging Infrared Radiometer (IIR), Clouds and the Earth's Radiant Energy System (CERES), special sensor microwave radiometer (SMMR), airborne visible/infrared imaging spectrometer (AVIRIS), Polarization and Directionality of the Earth's Reflectance (POLDER), and Atmospheric Infrared Sounders (AIRSs).

*Active remote sensors*. Examples of active sensors are RADAR, ranging instruments, scatterometer, LiDAR, laser altimeter, and sounders.

*Spectral characteristics of sensors*. Remote sensing optical sensors are characterized by spectral, radiometric and geo-metric performance. Spectral characteristics that define the types of optical sensors are Observation range of the electromagnetic wave, center wavelength of a band changes at both ends of a band, sensitivity of a band, polarization sensitivity, and ratio of sensitivity difference between different bands

*Radiometric characteristics of sensors*. Few radiometric characteristics of optical sensors are detection accuracy, signal-to-noise ratio (S/N), dynamic range, quantization level, sensitivity difference between pixels, linearity of sensitivity, and noise equivalent power.

*Geometric characteristics of sensors*. Examples of geometric characteristics of optical sensors that classify the sensors Field of view (FOV), IFOV, Registration between different spectral bands, modular transfer function (MTF), and optical distortions.

These sensor characteristics determine the spatial, spectral, radiometric, and temporal resolutions of remote sensing data.

*Remote Sensing Systems—Platforms and Sensors*. Remote Sensing Platforms are Aerial Imaging, Optical Remote Sensing, Hyperspectral Remote Sensing, RADAR and SODAR Remote Sensing, LASER and RADAR Altimetry Imaging, LiDAR Remote Sensing , Microwave Remote Sensing , SONAR and SODAR Remote Sensing , Global Positioning System.

*Upcoming New Satellite Sensor Platforms*. ALOS 2 is a RADAR imaging satellite system operated by the Japan Aerospace Exploration Agency (JAXA) for land resource studies, disaster monitoring, and environmental research.

*Observatory satellite*: Used for real-time accurate information of rain and snow every 3 hour, along with soil moisture, carbon cycle, winds, and aerosol estimation. Hodoyoshi 3 and 4 is an experimental Earth-observing microsatellite built by the University of Tokyo. IRNSS 1B is a satellite-based navigation system developed in India to be compatible with GPS and Galileo. Sentinel-1A is an ESA's two satellite constellation with the prime objective of land and ocean monitoring with C-band SAR continuity. SkySat 2 is a commercial Earth-observing satellite by Skybox Imaging to acquire very-high- resolution images.

Oblique aerial photograph is the latest development in aerial imaging area, which has high potential growth in future years. Oblique aerial photographs or a combination of oblique and vertical photographs, which are widely used for high-density urban land use mapping. Oblique aerial photography has been used since the 1960s, but its advantages in environmental management and other spatial analyses are observed more recently.

### Future of Remote Sensing and Evolving Microsatellites

Unmanned aircraft systems (UAS) and Unmanned aerial vehicle (UAV) provide a new controllable platform for remote sensing and permit data acquisition in inaccessible and dangerous environments. UAS or UAVs are the prominent part of the entire system of fling an aircraft and acquiring ultra spatial-resolution imagery. As in most countries aviation regulations are adapted to include UAS and UAV systems into the general airspace, these microsatellite systems will become the preferred platforms of future remote sensing [7]. One of the popular fully autonomous UAV eBee manufactured by a Swiss sensor manufacturer senseFly (senseFly SA, Cheseaux-Lausanne, Switzerland) can acquire 1,5 cm spatial resolution aerial images (photos) that can be transformed into 2D orthomosaics and 3D models. The eBee can cover up to 12 $km^2$ in a single flight as shown in figure 14. When it flies over smaller areas at lower altitudes, it can acquire high resolution imagery at 1,5 cm/pixel with overlap.

UAV senseFly’s eBee used for ultrahigh-resolution orthophoto collection and ancillary derivative data development:(a) eBee UAV, (b) flght path simulated by the Institute of Environmental Spatial Analysis (IESA),(c) all acquired aerial orthophotos by the UAV over UNG Gainesville Campus, (d) mosaicked 2D orthophoto of the campus (partial), (e) stereoscopic analysis– based 3D point cloud, and (f) comparison of digital elevation models developed by imaging through UAV (eBee) and LiDAR technology.

### Future Earth observing sensors

The International Space Station (ISS) U.S. National Laboratory, formerly known as the Center for the Advancement of Science in Space (CASIS). ISS in conjunction with NASA, continues to solicit new sensors that efficiently take advantage of the station as a remote sensing platform. Technologies for multispectral sensors hyperspectral sensors active radar and LiDAR systems continue to advance, providing both instrument developers and end-users with new opportunities in research and applications of remotely sensed data.

*Global Ecosystem Dynamics Investigation* (GEDI)*:* GEDI was Launched in October 2018. Developed at NASA Goddard Space Flight Center. GEDI is a full waveform lidar instrument that makes detailed measurements of the 3D structure of the Earth's surface as shown in figure 15. GEDI is the first spaceborne laser instrument to measure the structure of Earth's forests in high resolution and three dimensions. Ralph Dubayah: principal investigator of the GEDI mission says that it's really critical that we understand what the current carbon content of forests is today. We need a good global map of where the carbon is. The reason we need that is because whenever we cut down trees, we're going to release carbon into the atmosphere and we don't know how much carbon we are releasing. GEDI will tell us how tall the trees are and how much carbon is being lost into the atmosphere.

GEDI has a telescope about 80 centimeters in diameter. It has three laser ports, and shoots out 4 laser beams that are then dithered, really quickly, in between shots. It's really critical that we understand what the current carbon content of forests is today. This produces eight ground tracks; four power and four cover tracks. Footprints are separated by 60 m along-track and 600 m across track. GEDI measurements are made over the Earth's surface between $51{,}6^0$ N and $51{,}6^0$ S. GEDI contains three Nd: YAG lasers, emitting 1064 nm light. These pulse 242 times per second with a power of 10 mJ, firing short pulses of light (14 ns long) down towards the Earth's surface with a beam divergence of 56 mrad, resulting in footprints averaging 25 m in diameter.

GEDI is a laser altimeter, so it's an active optical instruments, that emit pulses of light. They travel down to the Earth, they get reflected from the earth, and then we receive the reflection. When the pulse of light hits the surface, it gets distorted and stretched out by any structure that is there. It looks almost like an echocardiogram. It's a distorted Gaussian waveform, technically speaking. We simply do not know how tall trees are globally. GEDI weight is about a thousand pounds and looks like a refrigerator.

## Conclusion

Earth Remote sensing from satellites can be achieved with the help of active and passive sensors. This article analyses the different sensors which are capable of sensing the earth elements. Unmanned aircraft systems (UAS) and Unmanned aerial vehicle (UAV) provide a new controllable platform for remote sensing and permit data acquisition in inaccessible and dangerous environments. UAS or UAVs are the prominent part of the entire system of fling an aircraft and acquiring ultra-spatial-resolution imagery. GEDI produces eight ground tracks; four power and four cover tracks. LiDAR are the active sensors and capable of handling field of view. After analyzing the UAS, UAV, GEDI and LiDAR are the sensors used for remote sensing.

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