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Remote Sensing Technology

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ABSTRACT: We perceive the surrounding world through our five senses. However, we acquire much information about our surrounding through the senses of sight and hearing which do not require close contact between the sensing organs and the external objects. In another words, we are performing Remote Sensing all the time. To understand Satellite Remote Sensing, we need to know the basic concepts of satellite orbit, swaths, resolution, how EM radiation interacts with different targets and the different types of remote sensing. Besides these, we need to know the different type of sensors that can be used and also how data is handled. The problem of space debris needs to be addressed and what are the applications of remote sensing and its future**.**

KEYWORDS: Remote sensing, Remote sensing satellite, Remote sensing technology, Space Debrif

I. INTRODUCTION

Timely and accurate information on various natural resources, both renewable and non-renewable, is very important for the planned development of any country. For any country the necessity of generating continuous and updated information on terrestrial resources and environment needs hardly any emphasis in this context. Such information, among other things, should include aspects pertaining to meteorological, geological, geographical and ecological conditions. In this connection, space-based earth observation systems offer unique possibilities in their ability for synoptic and systematic acquisition of the related data and making available the same, with very short turn-around times to resource managers and planners [1]**.**

1.1 What is Remote Sensing?

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.

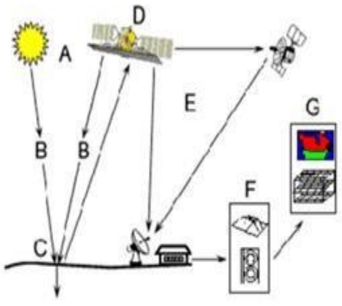

Figure 1: Remote Sensing
Image credit: Canada Centre of remote sensing

1.2 History of Remote Sensing[2]

The scope of the field of remote sensing can be elaborated by examining its history to trace the development of some of it's central concepts.

The period from 1960 to 2015 has experienced some major changes in the field of remote sensing. The background for many of these changes occurred in the 1960s and 1970s. Some of these changes are outlined below.

- First, the term ―remote sensing is was initially introduced in 1960. Before 1960 the term used was generally aerial photography.
- Second, the 1960s and 1970s saw the primary platform used to carry remotely sensed instruments shift from air planes to satellites. Satellites can cover much more land space than planes and can monitor areas on a regular basis.
- Third, imagery became digital in format rather than analog. The digital format made it possible to display and analyse imagery using computers.

Fourth, sensors were becoming available that recorded the Earth's surface simultaneously in several different portions of the electro-magnetic spectrum.

II. Satellite Characteristics

Remote sensing instruments can be placed on a variety of platforms to view and image targets.

- Altitude
- Inclination angle
- Period
- Repeat Cycle

Distance between the satellite and the earth surface is known as the orbit altitude. The altitude influences the area that can be viewed (Coverage) and the details that can be observed (resolution). LEO the Low earth orbit- 150 to 1000km. GEO the Geostationary orbit – 36,000km.

III. Common orbits for RS missions

3.1 Sun- synchronous orbit:

The inclination angle is between 98^0 and 99^0 to achieve this. Most sun synchronous orbits cross the equator at midmorning at around 10:30 hours local solar time. Typically placed in orbit at 600km to 1000km.

3.2 Geostationary orbit:

The orbit in which the satellite is placed above the equator i.e. inclination angle is 0^0.The altitude of placement is 36,000km. At this distance the orbit period of the satellite is equal to the rotational period of the earth, exactly one sidereal day. Used for meteorological and telecom satellites. Combination of geostationary and polar orbit is used in meteorology.

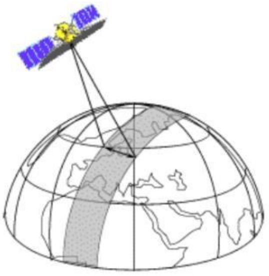

Figure 2: Scanning process
Image credit: Canada Centre of remote sensing

Radiation - Target Interactions:There are three forms of interaction that can take place when energy strikes, or is Incident (I) upon the surface.

-Absorption (A)
-Transmission (T)
-Reflection (R)

Figure 3: Incident (I), Absorption (A), Reflection(R), Transmission (T) [3]

IV. Passive and Active Sensing

The sun provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called **passive sensors**.

Active sensors, on the other hand, provide their own energy source for illumination. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

4.1 Spatial resolution *[3] [4] [5] [6] [7]*

Sensors on board platforms far away from their targets, typically view a larger area, but cannot provide great detail.

The detail discernible in an image is dependent on the spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors depends primarily on their Instantaneous Field of View (IFOV). [3]

The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B). The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the resolution cell and determines a sensor's maximum spatial resolution.

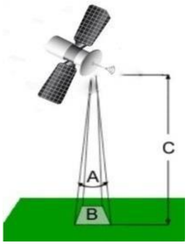

Figure 4: Concept of Spatial resolution [Canada centre of remote sensing]

4.2 Spectral resolution [4]

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength ranges for particular channel or band.

4.3 Radiometric Resolution [5]

Radiometric resolution is defined as the ability of an imaging system to record many levels of brightness (contrast for example) and to the effective bit-depth of the sensor (number of greyscale levels) and is typically expressed as 8bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (065,535).

4.4 Temporal Resolution [6]

In addition to spatial, spectral, and radiometric resolution, the concept of temporal resolution is also important to consider in a remote sensing system.

Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal imagery.

V. Cameras in Remote Sensing [1] [7]

Electro-optical remote sensing involves the acquisition of information about an object or scene without coming into physical contact with that object or scene. Following is a description of main type of cameras used in satellites:

5.1 Strip Camera [7]

Strip cameras record images by moving film past a fixed slit in the focal plane as the camera is moved forward. The slit remains fixed, and image is formed on the film as it moves past the open slit.

5.2 Panchromatic Camera [7]

This is the most widely used camera in satellite imagery applications. Also called the single lens camera, this camera consists of usual optics which focuses light on a Charged Coupled Device (CCD) array. The CCD array converts the light falling on it to voltage, which is then sampled and quantized to get the actual bit stream, which represents the picture in the digital form.

5.3 Panoramic Camera [7]

This is a camera designed to take the photographs of a wide area and therefore it has a lens having a wide field of view. This enables the camera to take the photograph of a large area, typically 40 to 50 kilometres in length and (also) breadth.

5.4 Multi Lens Camera [7]

This camera has four lenses each of which focuses light on its own film roll. Each of these lens assemblies are identical except for the fact that they have different filters. One has a Red Filter, One has a Green, one has a Blue filter, and one has a Infra-Red Filter. We can thus take photographs of exactly the same area on the ground in four different bands.

Table 1: Spectral bands chosen for the IRS – 1 cameras:

Band	*Spectral Range (um)*	*Remarks*
1	0.45-0.52	Coastal environment studies, chlorophyll absorption region
2	0.52-0.59	Green vegetation, useful for discrimination of rocks and soil for their iron content
3	0.62-0.68	Strong correlation with chlorophyll absorption in vegetation, discrimination of soil and geological boundaries.
4	0.77-0.86	Sensitive to green biomass, opaque to water resulting in high contrast with vegetation

[Joseph, George, V. S. Iyengar, RAM RATTAN, K. Nagachenchaiah, A. S. Kiran Kumar, B. V. Aradhye, K. K. Gupta, and D. R. M. Samudraiah. "Cameras for Indian remote sensing satellite IRS-1C." Current science 70, no. 7 (1996): 510-515.]

Classification of Remote Sensing satellites:

Several remote sensing satellites are currently available, providing imagery suitable for various types of applications.

Each of these satellite-sensor platforms are characterized by the **wavelength bands** employed in image acquisition, **spatial resolution** of the sensor, the **coverage area** and the **temporal coverage.**

VI. Data Reception, Transmission, and Processing [9] [1]

Data acquired from satellite platforms need to be electronically transmitted to Earth, since the satellite continues to stay in orbit during its operational lifetime. The technologies designed to accomplish this can also be used by an aerial platform if the data are urgently needed on the surface.

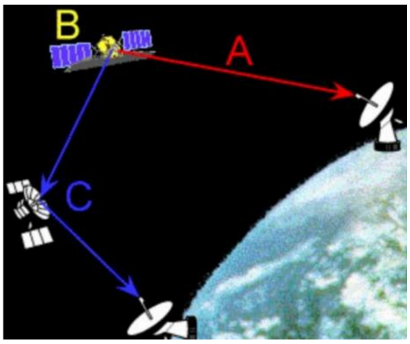

Figure 5: Communication chain between satellite and GRS and TDRSS.
Image credit: CCRS

There are three main options for transmitting data acquired by satellites to the surface. The data can be directly transmitted to Earth if a Ground Receiving Station (GRS) is in the line of sight of the satellite (A). If this is not the case, the data can be recorded on board the satellite (B) for transmission to a GRS at a later time. Data can also be relayed to the GRS through the Tracking and Data Relay Satellite System (TDRSS) (C), which consists of a series of communications satellites in geosynchronous orbit. The data are transmitted from one satellite to another until they reach the appropriate GRS.

VII. On-board Data Analysis [8]

Enabling on-board data processing introduces many advantages, such as the possibility to reduce the data down-link bandwidth requirements at the sensor by both preprocessing data and selecting data to be transmitted based upon predetermined content-based criteria. On-board processing also reduces the cost and the complexity of ground processing systems so that they can be affordable to a larger community.

Digital Image Processing *[10] [11] [12 [13]*

Digital Image Processing is largely concerned with four basic operations: image restoration, image enhancement, image classification, image transformation. Image restoration is concerned with the correction and calibration of images in order to achieve as faithful a representation of the earth surface as possible, a fundamental consideration for all applications. Image enhancement is predominantly concerned with the modification of images to optimize their appearance to the visual system. Visual analysis is a key element, even in digital image processing, and the effects of these techniques can be dramatic. Image classification refers to the computer assisted interpretation of images—an operation that is vital to Geographic Information System (GIS). Finally, image transformation refers to the derivation of new imagery as a result of some mathematical treatment of the raw image bands.

VIII. Advantages of Remote Sensing Satellites:

In space borne remote sensing, sensors are mounted onboard a spacecraft (space shuttle or satellite) orbiting the earth. At present, there are imagery for research and operational applications. Space borne remote sensing provides the following advantages: several remote sensing satellites providing large area coverage.

- Frequent and repetitive coverage of an area of interest.
- Quantitative measurement of ground features using radio metrically calibrated sensors.
- Semi-automated computerized processing and analysis.
- Relatively lower cost per unit area of coverage.
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IX. Applications of Remote Sensing Satellites

- **Meteorology** - profiling of atmospheric temperature, pressure, water vapour, and wind velocity.
- **Oceanography** - measuring sea surface temperature, mapping ocean currents, and wave energy spectra.
- **Glaciology** - measuring ice cap volumes, ice stream velocity, and sea ice distribution.
- **Geology** - geomorphology, identification of rock type, mapping faults and structure.

- **Geodesy** - measuring the figure of the earth and its gravity field.
- **Topography and cartography** - improving digital elevation models.
- **Agriculture, forestry, and botany** - monitoring the biomass of land vegetation, monitoring the health of crops, mapping soil moisture, forecasting crop yields.
- **Hydrology** - assessing water resources from snow, rainfall and underground aquifers.
- **Disaster warning and assessment** - monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.
- **Planning applications** - mapping ecological zones, monitoring deforestation, monitoring urban land use.
- **Oil and mineral exploration** - locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.
- **Military** - developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements.

X. Space Debris

10.1 What is Orbital Debris?[14] [15]

Orbital debris is the term for any object in Earth orbit that no longer serves a useful function. These objects include nonoperational spacecraft, derelict launch vehicle stages, mission-related debris, and fragmentation debris.

10.2 Debris Management [14] [15]

Engages with international bodies, such as the United Nations and the Inter-Agency Space Debris Coordination Committee (IADC), to discuss issues associated with orbital debris, set guidelines for international action, and develop protocols for moving forward.

10.3 Types of Debris [15]

- Non-Operational Spacecraft
- Derelict launch vehicle stages
- Mission-related debris
- Fragmentation debris

Figure 6:Example of recovered satellite components . Photo Credit: NASA

10.4 Proposed Methods of Debris Removal [16]

Lasers

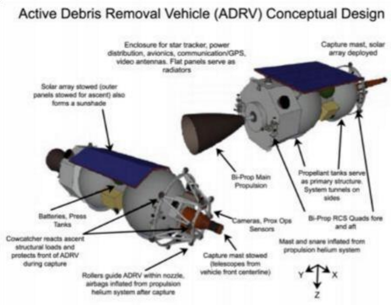
Laser technologies could potentially remove a large quantity of small debris. The concept is to lock onto the orbital debris using ground-, air-, or space-based lasers, then vaporize some part of the debris, creating a thrust that causes the debris to alter its orbit.

Space Tugs[15]

A space tug is actually a spacecraft that would be used to move multiple pieces of debris to disposal orbits in GEO. In this scenario, a tether is attached to one object; after a link is achieved, the object is transferred to disposal orbit, and the process is repeated with a second piece of orbital debris. This approach could be effective for disposing of objects in GEO, and its multi-target capability makes it attractive.

Other Debris-Removal Techniques [15]

There are additional proposed means of removing debris from orbit, ranging from solid rocket propulsion modules to magnetic sails.



Space tugs are spacecraft that would be used to remove large objects from GEO. These tugs are particularly attractive due to their multi-target capability. Above figure depicts an ADRV conceptual design. Image credit: NASA

XI. Future trends of remote sensing[23]

There are themes which are apparent in technology development for Earth remote sensing that will likely continue for decades in the future. Key optical and radiofrequency technologies for future systems have been described .[25] If there is one underlying technology area that governs the rate of progress in all of these areas, it seems to be materials. New materials enable shrinking circuit sizes, they allow lower power operation for 3-dimensional packaging, they extend the spectral range and performance of detectors, they provide the strength with low mass for large structures, they enable higher power, more efficient transmitters, and they enable compact optical systems.

11.1 Miniaturization of electronics

The use of 3-dimensional chip making will become widespread as cooling and connection problems are solved. Overall packaging sizes will dramatically decrease with order of magnitude decreases in volume and mass. The same trend is occurring in analog electronics, for example, the use of monolithic microwave integrated circuit (MMICs) is enabling significant decreases in the size and mass of radiofrequency circuits. MMICs are still relatively new and higher integration levels will follow in the future Earth Science Technology Office (ESTO) projects developing a precipitation radar [16], high frequency MMICs [17], and a photovoltaic long-wave infrared detector [18] have furthered this trend.

11.2 High-performance on board computing

Along with the decrease in size of electronics will come further astounding increases in processing speed, both for programmable and general-purpose processors. By the time today's technologies are fully exploited, radical new technologies, such as quantum and biological computing, will be realized. Storage density will continue its steady progression. The ultimate result will be, for all practical purposes, unlimited computing power on orbit within the sensor itself. ESTO-funded development of a holographic memory [19] is a step in this direction.

11.3 Large, lightweight structures

Measurements with higher spatial resolution will require larger apertures. The technology for large deployable antennas and mirrors will progress steadily. The approaches to large deployable mesh and membrane antennas being pursued today will be extended to larger and larger systems of 10's of meters with lower and lower mass density. Deployable mirror and adaptive optics technology will advance to enable low-mass, multi-meter optical systems. ESTO's work on a 6 meter inflatable radar antenna [20] and large, sparse aperture radiometers [21] are examples of this progress.

11.4 Compact optics

Increased coverage through multiple copies of sensors can be facilitated by smaller instruments. Many innovative approaches to refractive and reflective optics are under development. Compact Fourier transform and grating spectrometers will allow reductions in overall size and mass of optical instruments. Efficient new coolers will extend these size benefits far into the infrared. Technology for an infrared sounder using compact refractive optics [21] has been funded by ESTO, as well as work on an optical cry cooler. [22]

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