Remote Sensing and GIS
2.1 REMOTE SENSING

2.1.1 Introduction

Remote sensing means acquiring information about a phenomenon, object or surface while at a distance from it. This name is attributed to recent technology in which satellites and spacecraft are used for collecting information about the earth's surface. This was an outcome of developments in various technological fields from 1960 onward. The concept is illustrated in the following figure.

![Remote Sensing Stages](image)

2.1.1.1 Stages in Remote Sensing

- Emission of electromagnetic radiation, or EMR (sun/self-emission).
- Transmission of energy from the source to the surface of the earth, as well as absorption and scattering.
Interaction of EMR with the earth's surface: reflection and emission.

Transmission of energy from the surface to the remote sensor

Sensor data output

Data transmission, processing and analysis

2.1.1.2 What We See

At temperature above absolute zero, all objects radiate electromagnetic energy by virtue of their atomic and molecular oscillations. The total amount of emitted radiation increases with the body's absolute temperature and peaks at progressively shorter wavelengths. The sun, being a major source of energy, radiation and illumination, having a sharp power peak around 0.5 μm, allows to capture reflected light with a camera.

Everything in nature has its own unique signature of reflected, emitted and absorbed radiation. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties. In so far as we know the spectral characteristics, we can pick an appropriate detector to make the desired measurement, remembering that for a given collector's field of view we get our greatest spatial resolution where wavelengths are shortest and energies greatest, and that these energies decrease at longer wavelengths and distances.
2.1.2 Electromagnetic Radiation and the Electromagnetic Spectrum

Electromagnetic radiation is energy that propagates in wave form at a velocity of \( C = 3 \times 10^{10} \) cm/sec. The parameters that characterize a wave motion are wavelength (\( \lambda \)), frequency (\( \nu \)) and velocity (\( C \)). The relationship between the above is \( C = \nu \lambda \). The following figure illustrates spectral bands used in remote sensing.

2.1.2.1 Interaction of EMR with the Earth’s Surface

Radiation from the sun, when incident upon the earth's surface, is either reflected, transmitted or absorbed and emitted by the surface. The electromagnetic radiation, on interaction, experiences a number of changes in
magnitude, direction, wavelength, polarization and phase. These changes are detected by the remote sensor and enable the interpreter to obtain useful information about the object of interest. The remotely sensed data contain both spatial information (size, shape and orientation) and spectral information (tone, color and spectral signature).

The (visible and infra-red) wavelengths from 0.3 μm to 16 μm can be divided into three regions. The spectral band from 0.3 μm to 3 μm is known as the reflective region. In this band, the radiation sensed by the sensor is that due to the sun, reflected by the earth's surface. The band corresponding to the atmospheric window between 8 μm and 14 μm is known as the thermal infra-red band. The energy available in this band for remote sensing is due to thermal emission from the earth's surface. Both reflection and self-emission are important in the intermediate band from 3 μm to 5.5 μm.

In the microwave region of the spectrum, active sensors called RADAR are used to collect information about an object. The EMR produced by the radar is transmitted to the earth's surface and the EMR reflected (back-scattered) from the surface is recorded and analyzed. The microwave region can also be monitored with passive sensors, called microwave radiometers, which record the radiation emitted, by the terrain in the microwave region.
Of all the interactions in the reflective region, surface reflections are the most useful and revealing for remote sensing applications. Depending upon whether the surface is smooth or rough, the reflection is specular or diffuse. Surface roughness is a function of the wavelength of incident radiation. According to the rayleigh criterion, if surface height variations are less than \( \frac{\lambda}{8} \), the surface is considered to be smooth, otherwise, it is rough. Hence, the wavelength of the incident EMR determines the surface roughness. For radiowaves, rocky terrain appears smooth to incident EMR, whereas in the optical band, fine sand appears rough. If the surface is flat and smooth, specular reflections occur, which follow the law of reflection (the angle of incidence equals the angle of reflection). Specular reflections are undesirable for remote sensing because they produce solar glint or glare. Water and certain man-made features reflect specularly. A rough or diffuse surface reflects the incident EMR in all directions independent of the angle of incidence. Among the natural features, which display essentially diffuse reflection, are sand, tilled soils and certain types of vegetation. Mixed reflections occur most frequently in nature. In this case, a reflecting surface returns radiant energy both diffusely and specularly. Spectral reflectance, \( \rho(\lambda) \), is the ratio of reflected energy to incident energy as a function of wavelength. Various materials of the earth’s surface have different spectral reflectance characteristics. Spectral reflectance is responsible for the color or tone in a photographic image of an object. Trees appear green because they reflect more of the green wavelength. The values of the spectral reflectance
of objects averaged over different, well-defined wavelength intervals comprise
the spectral signature of the objects or features by which they can be
distinguished. To obtain the necessary ground truth for the interpretation of
multi-spectral imagery, the spectral characteristics of various natural objects
have been extensively measured and recorded. The following figure
illustrates spectral signature of natural features.

2.1.3 Effects of Atmosphere

The sun is the source of radiation, and electromagnetic radiation (EMR) from
the sun that is reflected by the earth and detected by the satellite or aircraft-
borne sensor must pass through the atmosphere twice. Once on its journey
from the sun to the earth and after being reflected by the surface of the earth
back to the sensor. Interactions of the direct solar radiation and reflected
radiation from the target with the atmospheric constituents interfere with the
process of remote sensing and is called as "Atmospheric Effects".
The interaction of EMR with the atmosphere is important to remote sensing for two main reasons. First, information carried by EMR reflected/emitted by the earth's surface is modified while traversing through the atmosphere. Second, the interaction of EMR with the atmosphere can be used to obtain useful information about the atmosphere itself.

The atmospheric constituents scatter and absorb the radiation modulating the radiation reflected from the target by attenuating it, changing its spatial distribution and introducing into field of view radiation from sunlight scattered in the atmosphere and some of the energy reflected from nearby ground area. Both scattering and absorption vary in their effect from one part of the spectrum to the other.

2.1.4 Atmospheric Scattering

Scattering is the redirection of EMR by particles suspended in the atmosphere or by large molecules of atmospheric gases. Scattering not only reduces the image contrast but also changes the spectral signature of ground objects as seen by the sensor. The amount of scattering depends upon the size of the particles, their abundance, the wavelength of radiation, depth of the atmosphere through which the energy is travelling and the concentration of the particles. The concentration of particulate matter varies both in time
and over season. Thus the effects of scattering will be uneven spatially and will vary from time to time.

Theoretically scattering can be divided into three categories depending upon the wavelength of radiation being scattered and the size of the particles causing the scattering. The three different types of scattering from particles of different sizes are summarized below.

<table>
<thead>
<tr>
<th>Scattering process</th>
<th>Wavelength Approximate Kinds of particles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approximate dependence Particle size</td>
</tr>
<tr>
<td>Selective</td>
<td></td>
</tr>
<tr>
<td>i) Rayleigh</td>
<td>$\lambda^{-4}$ &lt; 0.1 $\mu$m Air molecules</td>
</tr>
<tr>
<td>ii) Mie</td>
<td>$\lambda^{-4}$ 0.1 to 10 $\mu$m Smoke, haze</td>
</tr>
<tr>
<td>Non-selective</td>
<td>$\lambda^0$ &gt; 10 $\mu$m Dust, fog, clouds</td>
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</tbody>
</table>

### 2.1.4.1 Rayleigh Scattering

Rayleigh scattering appears when the radiation wavelength is much larger than the particle size, for example scattering of visible light (0.4 $\mu$m - 0.76 $\mu$m) by pure gas molecules ($10^{-4}$ $\lambda$ m) in a clear atmosphere. Rayleigh scattering
causes the sky to appear blue. The scattering coefficient is proportional to the inverse fourth power of wavelength. Radiation in shorter blue wavelengths is scattered toward the ground much more strongly than radiation in the red wavelength region. Due to Rayleigh scattering multi-spectral data from the blue portion of the spectrum is of relatively limited usefulness.

It is observed that there is strong scattering in the forward as well as backward directions. The strong backward scattering is responsible for the appearance of hot spots in aerial photographs taken in hazy atmosphere by wide angle cameras at times when the direction of solar radiation falls within the field of view of the sensor.

2.1.4.2 Mie Scattering

Mie scattering occurs when radiation wavelength is comparable to the size of the scattering particles. In remote sensing Mie scattering usually manifest itself as a general deterioration of multi-spectral images across optical spectrum under conditions of heavy atmospheric haze. Depending upon the particle size relative to the wavelength, Mie scattering may fall anywhere between \( \lambda^{-4} \) and \( \lambda^{-0} \). The incident light is scattered mainly in the forward direction.
2.1.4.3 Non Selective Scattering

Non selective scattering usually occurs when the particle size is much larger than the radiation wavelength. Scattering does not depend on the wavelength of radiation. This type of scattering usually occurs when the atmosphere is heavily dust laden and results in a severe attenuation of the received data. There is a uniform attenuation at all wavelength. The whitish appearance of the sky under haze condition is due to non-selective scattering.

Occurrence of this scattering mechanism gives a clue to the existence of large particulate matter in the atmosphere above the scene of interest which itself is a useful data. Using negative blue filters can eliminate the effects of the Rayleigh component of scattering. However, using haze filters cannot eliminate the effects of heavy haze, when all the wavelengths are scattered uniformly. The effects of haze are less pronounced in the thermal infrared region. Microwave radiation is completely immune to haze and can even penetrate clouds.

2.1.5. Refraction

The phenomenon of refraction that is bending of light at the contact between two media also occurs in the atmosphere as the light passes through the atmospheric layers of varied clarity, humidity and temperature. These
variations influence the density of atmospheric layers, which in turn causes the bending of light rays as they pass from one layer to another. The most common phenomena is the mirage like apparitions sometimes visible in the distance on hot summer days.

2.1.6 Atmospheric Absorption

The gas molecules present in the atmosphere strongly absorb the EMR passing through the atmosphere in certain spectral bands. Mainly three gases are responsible for most of absorption of solar radiation viz. ozone, carbon dioxide and water vapor. Ozone absorbs the high energy, short wavelength portions of the ultraviolet spectrum thereby preventing the transmission of this radiation to the lower atmosphere. Carbon dioxide is important in Remote Sensing as it effectively absorbs the radiation in mid and far infrared regions of the spectrum.

![Characteristic of atmospheric spectral transmittance](image)
Absorption relatively reduces the amount of light that reaches our eye making the scene look relatively dull. Consequently these spectral bands are rendered unsuitable for remote sensing. The spectral bands for which the atmosphere is relatively transparent are known as atmospheric windows. Atmospheric windows are present in the visible part (0.4 μm - 0.76 μm) and the infra-red regions of the EM spectrum. In the visible part transmission is mainly effected by ozone absorption and by molecular scattering. The atmosphere is transparent again beyond about 1mm, the region used for microwave remote sensing.

2.1.7 Effects of Atmospheric Haze Scattering in Remote Sensing

The downward component of EMR that illuminates the ground features has two components: direct sunlight and diffused skylight originating from atmospheric scattering. The relative importance of the two depends on the solar zenith angle or the optical path length of the atmosphere. Skylight is bluer than direct sunlight. The upwelling radiation that reaches the remote sensor also has two components: the light that interacts with the earth's surface and is reflected upwards, and the component arising from the backward scattering of radiation from atmospheric particles.
2.1.7.1 Contrast Reduction

The most serious effect of haze is contrast reduction. The downward component of scattered light (skylight) reduces the brightness difference and hence the contrast between sunlit and shaded areas of the ground. The upward component of scattered radiation (sky radiance) increases the irradiance in the camera image plane and reduces the image contrast.

\[
C = \frac{E \cdot \rho_{\text{max}} \cdot \tau A + \pi L}{E \cdot \rho_{\text{min}} \cdot \tau A + \pi L}
\]

E is irradiance due to sun and sky, \( \rho_{\text{max}} \) and \( \rho_{\text{min}} \) are reflectance of scene high light and low light areas, \( \tau \) is atmospheric transmittance and \( L \) is atmospheric radiance.

2.1.8 REMOTE SENSING PLATFORMS

2.1.8.1 Types of Platforms

Platform is a stage to mount the camera or sensor to acquire the information about a target under investigation. Based on its altitude above earth surface, platforms may be classified as

(1) Ground borne

(2) Air borne

(3) Space borne
2.1.8.1.1 Ground-based Platforms

The ground based remote sensing system for earth resources studies are mainly used for collecting the ground truth or for laboratory simulation studies.

2.1.8.1.2 Air-borne Platforms

Aircrafts are generally used to acquire aerial photographs for photointerpretation and photogrammetric purposes. Scanners are tested against their utility and performance from these platforms before these are flown onboard satellite missions.

2.1.8.1.3 Space-borne Platforms

Platforms in space are not affected by the earth's atmosphere. These platforms are freely moving in their orbits around the earth, and entire earth or any part of the earth can be covered at specified intervals. The coverage mainly depends on the orbit of the satellite. It is through these space borne platforms, we get the enormous amount of remote sensing data and as such the remote sensing has gained international popularity.
Depending on their altitude and orbit these platforms may be divided in two categories.

- Geostationary
- Polar orbiting or Sun-synchronous

2.1.8.1.3.1 Geostationary Satellites

An equatorial west to east satellite orbiting the earth at an altitude of 35000 km., the altitude at which it makes one revolution in 24 hours, synchronous with the earth's rotation.

These platforms are covering the same place and give continuous near hemispheric coverage over the same area day and night. Its coverage is limited to 70°N to 70°S latitudes and one satellite can view one third of the globe. These are mainly used for communication and meteorological applications viz. GEOS, METOSAT, INTELSAT, and INSAT satellites.

2.1.8.1.3.2 Sun-Synchronous satellites

An earth satellite orbit in which the orbital plane is near polar and the altitude is such that the satellite passes over all places on earth having the same latitude twice in each orbit at the same local sun-time.
Through these satellites the entire globe is covered on regular basis and gives repetitive coverage on periodic basis. All the remote sensing resources satellites may be grouped in this category. Few of these satellites are LANDSAT series, SPOT series, IRS series, NOAA, SEASAT, TIROS, HCMM, SKYLAB, SPACE SHUTTLE etc.

2.1.8.2 Earth Resources Satellites

There are two groups of Earth resources satellites: first, the manned satellites which carry photographic and other sensors for the production of images of the Earth's surface. These images can be interpreted with the aid of photographic interpretation techniques. Second, the unmanned satellites that carry a wide range of non-photographic sensors for the production of images of Earth's surface. These images can be interpreted with the help of both photographic interpretation techniques and digital image processing techniques.

2.1.8.2.1 Manned Earth Resources Satellites

The first manned satellites were designed, and are known, for their participation in the 'space race' while the later satellites, Skylab and Space Shuttle Series, were space stations designed specifically for experimentation.
Example for 'Space Race' satellites are Mercury series (1961), Gemini series (1965) and Appollo series (1967). Space stations were Skylab (1973) and Space shuttle series sent by NASA (from April 1981).

2.1.8.2.2 Unmanned Earth Resources Satellites

<table>
<thead>
<tr>
<th>platform</th>
<th>altitude</th>
<th>observation</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>geostationary satellite</td>
<td>36,000m</td>
<td>fixed point observation</td>
<td>GMS</td>
</tr>
<tr>
<td>circular orbit satellite</td>
<td>500km - 1,000km</td>
<td>regular observation</td>
<td>Landsat, SPOT, MOS-1, etc</td>
</tr>
<tr>
<td>(earth observation)</td>
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<td></td>
<td></td>
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<tr>
<td>space shuttle</td>
<td>240km - 350km</td>
<td>irregular observation</td>
<td></td>
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<td></td>
<td></td>
<td>space experiment</td>
<td></td>
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<tr>
<td>radio-sonde</td>
<td>100m - 100km</td>
<td>various investigations</td>
<td></td>
</tr>
<tr>
<td>high altitude</td>
<td>10km - 12km</td>
<td>reconnaissance</td>
<td></td>
</tr>
<tr>
<td>jet-plane</td>
<td></td>
<td>wide area investigations</td>
<td></td>
</tr>
<tr>
<td>low or middle altitude plane</td>
<td>500m - 8,000m</td>
<td>various investigation</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>aero surveys</td>
<td></td>
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<tr>
<td>aerostat</td>
<td>500m - 3,000m</td>
<td>reconnaissance</td>
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<td></td>
<td></td>
<td>various investigations</td>
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<tr>
<td>helicopter</td>
<td>100m - 2,000m</td>
<td>various investigations</td>
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<td>aero surveys</td>
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<tr>
<td>radio-controlled plane</td>
<td>below 500m</td>
<td>various investigations</td>
<td>aerospace helicopter</td>
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<td></td>
<td></td>
<td>aero surveys</td>
<td></td>
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<tr>
<td>hang-plane</td>
<td>50 - 500m</td>
<td>various investigations</td>
<td>hang-glider</td>
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<td></td>
<td>aero surveys</td>
<td>para-glider</td>
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<tr>
<td>hang-balloon</td>
<td>800m - 500m</td>
<td>various investigations</td>
<td></td>
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<tr>
<td>cable</td>
<td>10 - 40m</td>
<td>archeologic investigations</td>
<td></td>
</tr>
<tr>
<td>crane car</td>
<td>5 - 50m</td>
<td>close range surveys</td>
<td></td>
</tr>
<tr>
<td>ground measurement car</td>
<td>0 - 30m</td>
<td>ground truth</td>
<td>cherrypicker</td>
</tr>
</tbody>
</table>

Unmanned earth resources satellites can be classified as Group one - the first generation satellites which include Landsat 1, 2, & 3, Group two - the second
generation satellites which include SPOT, Landsat 4 & 5, IRS series, Group three - those having thermal infrared sensors, HCMM, Group four - satellites having microwave sensors, Seasat, ERS-1 & 2, Radarsat, JERS-1, Shuttle Imaging Radar (SIR) series.

2.1.8.2.2.1 IRS Satellite Series

The Indian Space programme has the goal of harnessing space technology for application in the areas of communications, broadcasting, meteorology and remote sensing. The important milestones crossed so far are: Bhaskara-1 and 2 (1979) the experimental satellites which carried TV Cameras and Microwave Radiometers. The Indian Remote Sensing Satellite was the next logical step towards the National operational satellites which directly generates resources information in a variety of application areas such as forestry, geology, agriculture and hydrology. IRS -1A/1B, carried Linear Self Scanning sensors LISS-I & LISS-II. IRS-P2, launched in October 1994 on PSLV-D2, an indigenous launch vehicle. IRS-1C, launched on December 28, 1995, which carried improved sensors like LISS-III, WiFS, PAN Camera, etc. Details of IRS series platforms are given in the following section. IRS-P3 was launched into the sun synchronous orbit by another indigenous launch vehicle PSLV - D3 on 21.3.1996 from Indian launch station Sriharikota (SHAR).
IRS-P4 (OCEANSAT-1)

This mission is for making measurements of the physical and biological oceanographic parameters. An Ocean Color Monitor (OCM) with eight spectral bands and a Multi-frequency Scanning Microwave Radiometer (MSMR), operating in four frequencies will provide valuable ocean-surface related observation capability. OCEANSAT is successfully launched by PSLV in 1999.

2.1.8.2.2.2 Future IRS Satellite Missions

Encouraged by the successful operation of the IRS missions, many more missions have been planned for realization in the next few years. These missions will have suitable sensors for applications in cartography, crop and vegetation monitoring, oceanography and atmospheric studies.

IRS-P5 (CARTOSAT-1)

This mission will have a PAN sensor with 2.5 m resolution with fore-aft stereo capability to cater for applications in cartography, terrain modelling, cadastral mapping etc. CARTOSAT-1 is slated for launch during 2000/2001 by PSLV.

IRS-P6

This mission will mainly cater to applications in agriculture and will have a multi-spectral LISS-IV sensor with a resolution better than 6 m and a swath of
25 km with across track steerability. A improved LISS-III sensor with 23 m resolution and 140 km swath and an advanced WIFS sensor with 80 m resolution and 1400 km swath. IRS-P6 is slated for launch during 2000/2001 by PSLV.

2.1.8.3 Meteorological Satellites

Designed specifically to assist in weather prediction and monitoring, meteorological satellites, or meteosats, generally incorporate sensors that have very coarse spatial resolution compared to land oriented systems. On the other hand, meteosats afford the advantages of global coverage at very high temporal resolution. Accordingly, meteosat data have been shown to be useful in natural resource applications where frequent, large area mapping is required and fine detail is not. Apart from the advantage of depicting large areas at high temporal resolution, the coarse spatial resolution of meteosats also greatly reduces the volume of data to be processed for a particular application.

Numerous countries have launched various types of meteosats with a range of orbit and sensing system designs for example NOAA series (operated by U.S. named after the National Oceanic and Atmospheric Administration). These near-polar, sun-synchronous orbits like Landsat, SPOT and IRS satellites. In contrast GOES and INSAT series satellites are in geo-stationary
orbits. India has launched INSAT series satellites which are telecommunication and meteorological satellites.

**Orbital and sensor characteristics of NOAA**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Date of Launch</th>
<th>Altitude Km</th>
<th>Orbital Period (min)</th>
<th>Temporal Resolution (days)</th>
<th>Equatorial crossing (local sun time) A.M.</th>
<th>Spatial/ Radiometric Resolution</th>
<th>Spectral Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NOAA 6,8,10 &amp;12</td>
<td>06/27/79, 03/28/83, 09/17/86, 05/14/91</td>
<td>833</td>
<td>102</td>
<td>4-5</td>
<td>2700 Km</td>
<td>1.1 Km at nadir/ 10bit</td>
<td>0.58-0.68</td>
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<td>0.72-1.10</td>
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<td>3.55-3.93</td>
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</tr>
<tr>
<td>2.</td>
<td>NOAA 7,9,11</td>
<td>06/23/81, 12/12/84, 09/24/88</td>
<td>833</td>
<td>102</td>
<td>8-9</td>
<td>2700 Km</td>
<td>1.1 Km at nadir/ 10bit</td>
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<td>11.5-12.5</td>
</tr>
</tbody>
</table>

**2.1.8.4 Ocean Monitoring Satellites**

The oceans, which cover more than two-thirds of the earth's surface, have important influences on global weather and climate; yet they represent a natural resource about which comparatively little is known. Satellite imaging
can provide synoptic views of the oceans over large areas and extended time periods. This task is virtually impossible to accomplish with traditional oceanographic measurement techniques.

### Orbital and sensor characteristics of OCM Satellites

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Launch Date</th>
<th>Altitude</th>
<th>Temporal Resolution (days)</th>
<th>Sensor</th>
<th>Swath (Km)</th>
<th>Spatial/ Radiometric Resolution</th>
<th>Spectral Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NIMBUS 7</td>
<td>Oct 1978</td>
<td></td>
<td></td>
<td>CZCS</td>
<td>1566</td>
<td>825 m at Nadir/8bit</td>
<td>0.43-0.45</td>
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<td></td>
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<td>0.51-0.53</td>
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<td>10.5-12.5</td>
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<tr>
<td>2.</td>
<td>MOS 1A</td>
<td>Feb 1987</td>
<td>909 Km</td>
<td>17</td>
<td>MESSR</td>
<td>100</td>
<td>50m/8bit</td>
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<td>MOS 1B</td>
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<td>1500</td>
<td>900(Vis)/8bit</td>
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<td>2700(Ther)/8bit</td>
<td>6.00-7.00</td>
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<td>10.5-11.5</td>
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<td>11.5-12.5</td>
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<td></td>
<td>MSR</td>
<td>317</td>
<td>32</td>
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<td></td>
<td></td>
<td></td>
<td>23</td>
<td>0.96cm</td>
</tr>
</tbody>
</table>
2.1.8.5 INSAT Series

INSAT satellites are basically communication satellites used for telecommunication and broadcasting which carried meteorological sensor for weather monitoring. These satellites are used in day to day weather forecasting, cyclone monitoring etc. The sensor is Very High Resolution Radiometer (VHRR). Among this series, the most powerful satellite is INSAT-1C, launched from French Guyana on December 1995 weighing 2070 kg in a geo-stationary orbit. This satellite has heralded a new era in telecommunication by introducing mobile phones. The details are given below.

**Orbital characteristics of INSAT series satellites**

<table>
<thead>
<tr>
<th>Altitude</th>
<th>36000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature</td>
<td>Geostationary</td>
</tr>
<tr>
<td>Repetitive</td>
<td>3 hr</td>
</tr>
<tr>
<td>Sensor</td>
<td>VHRR</td>
</tr>
<tr>
<td>Resolution</td>
<td>2.75 km</td>
</tr>
<tr>
<td>Spectral bands</td>
<td>0.55 - 0.75 μm</td>
</tr>
<tr>
<td></td>
<td>10.5 - 12.5 μm</td>
</tr>
</tbody>
</table>
2.1.9 Remote Sensing Sensors

Sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigation. These may be active or passive depending on the source of energy.

Active sensors use their own source of energy. Earth surface is illuminated through energy emitted by its own source, a part of its reflected by the surface in the direction of the sensor is received to gather the information. Passive sensors receive solar electromagnetic energy reflected from the surface or energy emitted by the surface itself. These sensors do not have their own source of energy and can not be used at night time, except thermal sensors.

LANDSAT satellites carried RBV, MSS & TM sensors. High resolution visible camera (HRV) is used on board SPOT satellite. First Indian resource satellite IRS-1A is using LISS-I and LISS-II sensors.

2.1.9.1 Instantaneous Field Of View (IFOV)

It is defined as angular subtence at a given instant of the limiting detector aperture at the second principal point of the system. IFOV is both a linear and angular quantity.
\[ \text{IFOV} = \frac{D}{F} \text{ radian} \quad \text{where } D = \text{ detector dimension, } F = \text{ focal length,} \]
\[ \text{GRE} = \left( \frac{D}{F} \right) \times H \text{ metres} \quad \text{and } H = \text{ flying height} \]

2.1.9.2 Resolution

Resolution is defined as the ability of the system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and/or radiation quantity (radiometric).

2.1.9.2.1 Spatial Resolution

Scanners spatial resolution is the ground segment sensed at any instant. It is also called ground resolution element (GRE).

\[ \text{Ground Resolution} = H \times \text{IFOV} \]

2.1.9.2.2 Spectral Resolution

Sampling the spatially segmented image in different spectral intervals, thereby allowing the spectral irradiance of the image to be determined. It is a measure of both the discernibility of the band widths and the sensitivity of the sensor to distinguish between gray levels.
2.1.9.2.3 Radiometric Resolution

Dividing the total range (B to W) of the signal output of the sensor into a large number of just discriminable levels so as to be able to distinguish ground features differing only slightly in radiance or reflectance.

2.1.9.2.4 Temporal Resolution

Obtaining spatial and spectral data at certain time intervals. Temporal resolution is also called as the repetitive of the satellite in the case of satellites.

2.1.9.3 Microwave Sensors

Microwave data can be obtained by both active and passive systems. Passive system monitor natural radiation at a particular frequency or range of frequency. Data may be presented numerically as line trace data or as imagery. Active systems (like SLAR and SAR) transmit their own energy and monitor the returned signal.

Characteristics of such imagery both in SAR and SLAR and their resolution depends on various parameters like frequency of the signal, look
direction, slant range, dielectric constant of the objects, phase, antenna length etc. Spatial resolution in range and azimuth direction varies in different manners.

2.1.9.3.1 RADAR (SAR)

These imageries have been obtained from satellite SEASAT, ERS, RADARSAT and space shuttle missions SIR-A, SIR-B and SIR-C using synthetic aperture radar which has all weather capability. Such data products are useful for studies in cloud covered region of the earth and in oceanography.

There could be other situations when one or more detectors of the sensor are not usable. In such situations, adjacent pixels are used to estimate the values. Similarly, if an entire scan line is lost due to other transmission/recording response, interpolations between adjacent lines is done. These are more of cosmetic in nature. There are studies to correct for atmospheric effects but this value is not very significant normally. In such general, the data is calibrated and normalized for uniform detector response. Other types of corrections are done by the user.
2.1.10 Value of Remote Sensing to The Community

With the present demand for resources throughout the world, there is an increasing need for a detailed inventory and management of what is available at any time for sustainable development. The map is one form of data storage, but is frequently out of date, and rarely shows the data required for resource purposes. For example, the areas planted and the expected yield of the main agricultural crop grown as the staple diet for a certain country are unlikely to be obtained from maps. The area and the yield will remain an estimate until the crop is harvested. A random sample by Remote sensing techniques at critical times during the growing season of the crop may produce a more reliable estimate and may also reveal signs of disease unnoticed on the ground, which can be treated before the crop is destroyed. Another example is "How is land use changing? What proportional changes are occurring in rural areas as urban sprawl and transportation networks encroach on them". It is useful to have information on what is happening in any local area, but what is often not available is knowledge of what is happening on the national scene or even the international scene.

The reasons for a better database particularly in developing countries like India are population explosion, the rising standard of living which all people want to experience and the increasing rate of technological change. The capability for modifying the earth's surface has so increased that landscape
can be changed overnight. Even though forethought is given to the possible effects of change, the real test is the observed result. When changes are so rapid, so extensive and so numerous that their cumulative effect can produce unforeseen results, the kind of monitoring which has reserved in the past will no longer suffice at present and certainly not in future. What are needed are quantities and types of information never previously imagined. The ability to collect information must be improved and remote sensing offers a way to achieve this. For these purposes, the earth should be viewed from both the macro scale (large areas) for matters of international interdependence (weather trade etc) and the micro scale (small areas) for isolated local problems. The techniques of remote sensing offer new ways of procuring data on natural phenomena with the following main advantages.

- The large distance between the sensor and object prevents interference with the environmental conditions to be measured.
- The potentiality for large scale and even global surveys yield a new dimension for investigations of the environmental parameters.
- The extremely wide spectral range covered by the whole diversity of sensors discloses many properties of the environmental media not detectable within a single band.
- The potentiality of systems to produce temporal data regularly helps in monitoring the natural resources and hazard management.
2.1.11 Applications

The following are sample of application areas of remote sensing

Water

- Water resources inventory and management of agricultural and industrial use
- Storage of water in the snow and ice cover and run-of forecast.
- Distribution of humidity of the soil.
- Water quality (Chemical, thermal and biological waste discharge control)
- Coastal zone, estuary and harbor activities.

Land and Vegetation

- Land use (inventory and planing)
- Soil classification and conservation (agricultural production, irrigation)
- Mineral inventory and exploration planning
- Control of plant diseases (crop and forest protection)
- Disaster assessment and prediction (volcanoes, earth quakes, land slides etc.)
- Land pollution control (waste disposal, contamination)
Atmosphere

- Global weather mapping
- Pollution
- Survey of earth’s radiation belt (Interaction with non-terrestrial phenomena)

Others

- Wild life control and protection
- Survey of radiation hazards from nuclear power plants
- Updating of the growth of urban areas
- Traffic surveying and control.

There may be very different priorities for the utilisation of remotely sensed environmental data in different regions of the world. But obviously there exists and urgent need for the availability of Remote sensing tools as an aid for developing nations like India in field’s such as

- Basic land use surveys and inventories of resources
- Location of areas for mineral and energy prospects
- Establishing and updating of maps.
2.2 GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

2.2.1 Introduction:

We are presently at the beginning of the twenty first century with the fast growing trends in computer technology information systems and virtual world to obtain data about the physical and cultural worlds, and to use these data to do research or to solve practical problems. The current digital and analog electronic devices facilitates the inventory of resources and the rapid execution of arithmetic or logical operations. These Information Systems are undergoing much improvement and they are able to create, manipulate, store and use spatial data much faster and at rapid rate as compared to conventional methods.

An Information System, a collection of data and tools for working with those data, contains data in analog form or digital form about the phenomena in the real world. Our perception of the world through selection, generalization and synthesis give us information and the representation of this information that is, the data constitute a model of those phenomena. So the collection of data, the data base is a physical repository of varied views of the real world representing our knowledge at one point in time. Information is derived from the individual data elements in a database, the information directly apparent i.e. information is produced from data by our thought processes, institution or
what ever based on our knowledge. Therefore in a data base context the terms data, information and knowledge are differentiated. It can be summarized that the data is very important and added value as we progress from data to information, to knowledge. The data, which has many origins and forms, may be any of the following:

- Real, for example the terrain conditions etc.
- Captured, i.e. recorded digital data from remote sensing satellites or aerial photographs of any area.
- Interpreted, i.e. land use from remote sensing data.
- Encoded i.e. recordings of rain-gauge data, depth of well data etc.
- Structured or organized such as tables about conditions of particular watershed.

2.2.2 Developments In the field of Information Systems

Geographic Information Management Technology encompasses many fields including Computer Science, Cartography, Information Management, Telecommunications, Geodesy, Photogrammetry and Remote Sensing and is flavored with it's applications of engineering, environmental analysis, land use planning, natural resource development, infrastructure management, and many others. Geographic Information Management Technology has almost as many names and acronyms as uses.
Automated Drafting
Engineering Design
Drawing Production

Facilities Management
Plant Inventory
Work order
Management

Automated Mapping
Graphic Quality
Map Production

Geoprocessing &
Network Analysis
Demographic
Analysis
Address Matching

Geographic Information System
Spatial Analysis
Area Network
Modeling

Geographic Information Technology
2.2.3 Definitions of GIS

The definitions of a GIS given by various authors are as follows:

- "A spatial data handling system" (Marble et al., 1983).
- "A computer-assisted system for the capture, storage retrieval, analysis and display of spatial data, within a particular organization" (Clarke, 1986).
- "A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world" (Burrough, 1987).
- "An internally referenced, automated, spatial information system" (Berry, 1986).
- "A system which uses a spatial data base to provide answers to queries of a geographical nature" (Goodchild, 1985).
- "A system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the Earth" (DOE, 1987:132)
- "Any manual or computer based set of procedures used to store and manipulate geographically referenced data" (Aronoff, 1989:39)
- "An institutional entity, reflecting an organizational structure that integrates technology with a database, expertise and continuing financial support over time" (Carter, 1989:3)
- "An information technology which stores, analyses and display both spatial and non-spatial data" (Parker, 1988:1547)
• “A special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines and areas to retrieve data for ad hoc queries and analyses” (Dueker, 1979:106)

• “A database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database” (Smith, 1987:13)

• “An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data” (Ozemoy, Smith and Sicherman, 1981:92)

• “A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world” (Burrough, 1986:6)

• “A decision support system involving the integration of spatially referenced data in a problem solving environment” (Cowen, 1988:1554)

• “A system with advanced geo-modeling capabilities” (Koshkarirov, Tikunov and Trofimov, 1989:259)

• “A form of MIS (Management Information System) that allows map display of the general information” (Devine and Field, 1986:18)

Although the above definitions cover wide range of subjects and activities best refer to geographical information. Some times it is also termed as
Spatial Information Systems as it deals with located data, for objects positioned in any space, not just geographical, a term for world space. Similarly, the term 'a spatial data' is often used as a synonym for attribute data (i.e. rainfall/ temperature/ soil chemical parameters/ population data etc are referred as attribute data).

2.2.4 Components of a GIS

A GIS has three important components

- Computer Hardware
- A set of application software modules and
- Trained personnel

2.2.4.1 Computer Hardware

Computer Information System is essentially a computer-assisted system running specialized software. The CPU is the heart and brain of the computer. The computer or central processing unit is linked to disk drive storage unit, which provides space for storing data and programs. A digitizer or any other input device is used to convert data from maps into digital form. A plotter or any output device is used to present the results of the data inputted. A Tape drive is used to store the large volume of data on magnetic tape or to store the data for future use or to move data from one computer.
to another. VDU (video display unit) is the monitor which should be a color monitor of high resolution (minimum SVGA- 16 bit) for GIS activity. Now a days Compact disks, Optical disks come into picture. They store large volumes of data.

2.2.4.2 GIS Software Modules

GIS may be considered as a subsystem of an information system which itself has five major component subsystems including:

- Data input processing
- Data storage, retrieval and data base management
- Data manipulation and analysis
- Display and product generation, and
- A user interface.

Data input covers all aspects of transforming spatial and non-spatial (textural or feature attribute) information from both printing and digital files into a GIS database. To capture spatially referenced data effectively, a geographical information system should be able to provide alternative methods of data entry. These usually include digitizing (both manual and automatic), satellite images, and scanning and keyboard entry. The data may come from many sources such as existing analogue maps, aerial photographs, and remote
sensing surveys and other information systems. Often the data require operations of manual or automated processing prior to encoding, including format conversion, data reduction and generalisation of data, error detection and editing, merging of points into lines, edge matching, rectification and registration, interpolation etc. The level of measurement of these data may vary and range from categorical to ratio and from fuzzy and stochastic information to precisely measured data.

Database management functions control the creation of and access to the database itself. For the storage, integration and manipulation of large volumes of different data types at a variety of spatial scales and levels of resolution, a GIS have to provide the facilities available within a Data Base Management System (DBMS). Most commercial GISs have a dual architecture. The non-spatial attribute information is stored in a relational database management system and the spatial information in a separate subsystem, which enables to deal with spatial data and spatial queries. Such architecture, however, reduces the performance because objectives have to be retrieved and compiled from components stored in the two subsystems. This problem is not easy to solve. Spatial data processing is performed with vector, raster or a combination of these geometric data formats.

The most important distinguishing feature, which a GIS has over a mere computer mapping systems or CAD, is the ability to manipulate and analyse
spatial data. The manipulation and analysis procedures, which are usually integrated in a GIS, are often limited, however to simple spatial operations such as:

- Geometric calculation operators such as distance, length, perimeter, area, closest intersection and union.
- Topological operators such as neighborhood, next link in a polyline network, left and right polygons of a polyline, start and end nodes of polyline.
- Spatial comparison operators such as intersect inside, larger than, outside neighbor of, etc.
- Multilayer spatial overlay involving the integration of nodal, linear and polygon layers, and to
- Restricted forms of network analysis.

Product generation is the phase where final products from geographical information systems are created. The displays and products may take various forms such as statistical reports, maps and graphics of various kinds, depending upon the characteristics of the media chosen. These include video screens for an animated time – sequence of displays similar to movie, laser printers, inkjet and electrostatic plotters, color film recorders, microfilm devices and photographic media.
The final module of a geographical information system consists of software capabilities, which simplify and organise the interaction between the user and the GIS software via, for example menu driven command systems.

It is note-worth that most current geographical information systems are strong in the domains of data storage and retrieval and graphic display. Their capabilities for more sophisticated forms of spatial analysis and decision making make them best suitable for natural resources management. As mentioned earlier, the analytical possibilities basically and usually refer to polygon overlay with logical operations, buffering in vector maps, interpolations, zoning and simplified network analysis. GIS capabilities for location-allocation problems, optimal land use allocation and management routing vehicles for delivery of goods and services.

2.2.4.3 Trained Personnel

Trained people are integral and yet largely forgotten and unnoticed component of GIS. GIS need people in order to operate. Although Hardware, Software and data are essential, trained people constitute the most important component of GIS.
2.2.5 GIS Analysis Functions

GIS is used to perform a variety of Spatial analysis, including overlaying combinations of features and recording resultant conditions, analyzing flows or other characteristics of networks and defining districts in terms of spatial criteria. Its uses in various fields are: facility management, planning, environmental monitoring, population census analysis, insurance assessment, health service provision, hazard mapping and many other applications. Although GIS and AM/FM Systems have similar capabilities, GIS traditionally has refer to systems that emphasize Spatial Analysis and modeling while AM/FM systems management of geographically distributed facilities. A complete GIS or Spatial Information System consists hardware, Software, humanware (i.e. trained experts in GIS).

A GIS can acquire and store data by import from external sources or by capture from maps and reports. Once in storage the data must be kept backed up, and updated when new information becomes available. Since more than 70% of the cost in GIS Project lies in data capture; the database is the primary asset of a GIS. Spatial data is collected from a variety of sources. Remotely sensed data from satellite is a primary data source. The other information coming from modern survey instruments is also a primary data source as it can lead directly into GIS similar to remote sensing data. Where as the secondary data capture involves processing information which
has already been compiled but requires converting into a computer readable format by manual or automatic digitization.

2.2.5.1 A classification of GIS Analysis Functions

The development of GIS techniques has provided a constantly growing number of evermore sophisticated analysis functions. A description of even the most common functions would quickly overwhelm the uninitiated. Following are the classification of GIS analysis functions.

1. Maintenance and Analysis of the Spatial data

- Format transformations
- Geometric transformations
- Transformation between map projections
- Conflation
- Edge matching
- Editing of graphic elements
- Line coordinate thinning.
2. Maintenance and analysis of the attribute data

- Attribute editing functions
- Attribute query functions.

3. Integrated analysis of spatial and attribute data

- Retrieval
- Classification
- Measurement
- Overlay operations
- Neighborhood operations
- Search
- Line in polygon and point in polygon
- Topographic functions
- Theissen polygons
- Interpolation
- Contour generation
- Connectivity functions
- Contiguity measures
- Proximity
- Network
• Spread
• Seek
• Intervisibility
• Illumination
• Perspective view.

4. Output Formatting

• Map annotation
• Text labels
• Texture patterns and line styles
• Graphic symbols.

The first level of classification contains four groups namely Maintenance and analysis of the spatial data, Maintenance and analysis of the attribute data, Integrated analysis of spatial and non-spatial data and output formatting. Each major group is subdivided into types of functions. The distinction among these categories are somewhat artificial and not clear, but they do provide a useful framework.

The way that a GIS function is implemented depends on such factors as the data model (e.g. raster versus vector), the hardware and performance criteria (e.g. how fast it must run, what options must be provided). These details are
important and require considerable expertise to properly evaluate. However, this level of details is not needed to understand the types of analysis functions that a GIS can provide, how they are used and why they are valuable.

2.2.6 Applications

Some of the GIS applications includes

- Agricultural and Land use Planning,
- Forestry and Wildlife Management,
- National, State, Country, Regional, Local mapping and geographic inventory
- Archaeology
- Geology
- Oil and Gas exploration and production
- Civil engineering,
- Urban and regional planning,
- Transportation planning,
- Watershed Management
- Municipal Applications
  - Streets
  - Property cadastre
  - Facilities
o Utilities-
  * water, sewer, storm sewer

o Environment

o Areas/Districts

- Utility Applications-
  o Electric
  o Gas
  o Telephone
  o Cable Television

- Business and Commercial applications.

The easy acceptability and implementation of GIS are making it very popular for various applications. The three dimensional analysis is having applications in terrain evaluation, highway route allocation, canal planning etc.

2.2.6.1 Applications of GIS and Remote Sensing

- Agricultural development
- Land evaluation analysis
- Change detection of vegetated areas
- Analysis of deforestation and associated environmental hazards
- Monitoring vegetation health
- Mapping percentage vegetation cover for the management of land
- Degradation
- Crop acreage and production estimation
- Wasteland mapping
- Soil resources mapping
- Groundwater potential mapping
- Geological and mineral exploration
- Snow-melt run-off forecasting
- Monitoring forest fire
- Monitoring ocean productivity etc.

2.2.7 Trends in GIS

- Natural Resources Management
- Telecom GIS
- Automated mapping and facility management
- Virtual 3-D GIS
- Internet GIS
- Spatial Multi-media
- Open GIS
- Object Oriented GIS
- Spatial Decision Support System
- OLAP & Data Mining etc.
2.2.8 GIS Objectives

- Maximise the efficiency of planning and decision making
- Provide efficient means for data distribution and handling
- Elimination of redundant data base - minimise duplication
- Capacity to integrate information from many sources
- Complex analysis/query involving geographical referenced data to generate new information.

For any application there are five generic questions a GIS can answer:

- Location - What exists at a particular location?
- Condition - Identify locations where certain conditions exist.
- Trends - What has changed since?
- Patterns - What spatial pattern exists?
- Modelling - What if ......?

2.2.9 Implementing a GIS

The implementation of a GIS is where technology and people meet. One of the reasons for the complexity of the implementation process is that it is, necessarily political. It is the people in an organisation that adopt and learn to use the technology. The implementation of GIS can be seen as a six phase process.
a) **Awareness**: People within the organisation become aware of GIS technology and the potential benefits to their organisation. Potential uses and users of GIS are postulated.

b) **Development of Systems Requirement**: The idea that a GIS could benefit the organisation is formally acknowledged and a more systematic and formal process is instituted to collect information about technology and to identify the potential users and their needs. A formal need analysis is often done at this stage.

c) **System Evaluation**: Alternative systems are proposed and evaluated. The evaluation process takes into account the need analysis of the previous phase. At the end of this phase a formal decision must be made whether or not to proceed with acquisition of a GIS.

d) **Development of an Implementation Plan**: Having made the decision to proceed with acquisition of a system, a plan is developed to acquire the necessary equipment and staff, make organisational changes and fund the process. This plan may be a formally accepted document or a more or less informal series of actions.

e) **System Acquisition and Start-up**: The system is purchased, installed, staff is trained, creation of database is begun and operating procedures
begin to be established. Creation of the database is usually the most expensive part of the implementation process. Considerable attention is needed to establish appropriate data quality controls to ensure that the data entered meet the required standards and that suitable updating procedures are implemented to maintain the currency and integrity of the database.

f) **Operational Phase:** By this stage the initial automation of the database is complete and operating procedures have been developed to maintain the database and provide the information services that the organisation requires. In this phase procedures are developed to maintain the GIS facility and upgrade services so that the GIS continues to support the changing information needs of the organisation. Operational issues concerning the responsibilities of the GIS facility to provide needed services and to guarantee performance standards become more prominent.