Satellite Remote Sensing - Introduction

- definition for this class
- three essentials
- examples
- notes on human perception and display of information

Seasat 1978
## UCS Satellite Database

### 2-1-15 Satellite Database Downloads (includes launches through 1/31/15)

<table>
<thead>
<tr>
<th>Downloads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database (Excel format)</td>
</tr>
<tr>
<td>Database (text format)</td>
</tr>
<tr>
<td>Database, official names only (Excel format)</td>
</tr>
<tr>
<td>Database, official names only (text format)</td>
</tr>
</tbody>
</table>

### Download Links

- Changes to the database (pdf)
- Quick Guide to Using the Database (pdf)
- Common misconceptions (pdf)
- User’s manual (pdf)

The UCS Satellite Database is a listing of the more than 1000 operational satellites currently in orbit around Earth.

Our intent in producing the database is to create a research tool for specialists and non-specialists alike by collecting open-source information on operational satellites and presenting it in a format that can be easily manipulated for research and analysis.

It is available as both a downloadable Excel file and in a tab-delimited text format. A version is also provided in which the “Name” column contains only the official name of the satellite in the case of government and military satellites, and the most commonly used name in the case of commercial and civil satellites.

### Satellite Quick Facts (includes launches through 1/31/15)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,265</td>
</tr>
<tr>
<td>United States</td>
<td>528</td>
</tr>
<tr>
<td>Russia</td>
<td>131</td>
</tr>
<tr>
<td>China</td>
<td>132</td>
</tr>
<tr>
<td>Other</td>
<td>474</td>
</tr>
<tr>
<td>LEO</td>
<td>669</td>
</tr>
<tr>
<td>MEO</td>
<td>94</td>
</tr>
<tr>
<td>Elliptical</td>
<td>37</td>
</tr>
<tr>
<td>GEO</td>
<td>465</td>
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<tr>
<td>Total U.S.</td>
<td>528</td>
</tr>
<tr>
<td>Civil</td>
<td>18</td>
</tr>
<tr>
<td>Commercial</td>
<td>229</td>
</tr>
<tr>
<td>Government</td>
<td>121</td>
</tr>
<tr>
<td>Military</td>
<td>160</td>
</tr>
</tbody>
</table>

Definition for this class

• satellite or aircraft remote sensing of the Earth or other planets

• information carried by electromagnetic waves

• sensing of land, ocean, and ice (will not cover atmosphere)
Advantages and disadvantages of satellite remote sensing

advantages

• global data set of uniform quality
• rapid data acquisition
• no need to obtain permission to gather data
• can revisit on a regular basis for lifetime of satellite (5-10 years)
• spacecraft provide stable platforms

disadvantages

• high cost of satellite systems
• takes 10 years + to develop, build, test, and launch
• possibility of single point failure
CryoSat I failure
October 2005

CryoSat-2
April 8, 2010

CryoSat Mission lost due to launch failure

8 October 2005
ESA PR 44-2005. Today at 21.00 CEST
Mr Yuri Bakhvalov, First Deputy
Director General of the Khrunichev
Space Centre on behalf of the Russian
State Commission officially confirmed
that the launch of CryoSat ended in a
failure due to an anomaly in the launch
sequence and expressed his regret to
ESA and all partners involved.

Preliminary analysis of the telemetry
data indicates that the first stage
performed nominally. The second stage
performed nominally until main engine
cut-off was to occur. Due to a missing
command from the onboard flight
control system the main engine
continued to operate until depletion of
the remaining fuel.
As a consequence, the separation of
the second stage from upper stage did
not occur. Thus, the combined stack of
the two stages and the CryoSat satellite
fell into the nominal drop zone north of
Greenland close to the North Pole into
high seas with no consequences to
populated areas.

Space is a risky business, it always
has been, it doesn't always go
perfectly Prof Duncan Wingham,
Cryosat chief scientist

"It is a very sad event for many
scientists around Europe and also
for the teams involved in industry
which built the satellite," he said.

http://www.esa.int/esaCP/SEM3Q5Y3EE_index_0.html
Applications of Remote Sensing

- **Meteorology** - profiling of atmospheric temperature, pressure, water vapor, 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 . . . (This is where most of the US funding for remote sensing goes.)
Electromagnetic Spectrum

Rees, 2001
Three Essentials for Remote Sensing

source of radiation
  sunlight or thermal emissions or active sensor

transmission
  attenuation and phase delay of waves in atmosphere and ionosphere

receiver
  sensor, platform, and orbit selection
Source

Blackbody Radiation

Rees, 2001
Transmission through atmosphere and ionosphere
Receiver and Orbits

Figure 4. Opposite and above: polar and geostationary orbits for NOAA satellites. Note that the polar orbit rotates one degree per day; this is to make it synchronous with the sun. The geostationary satellite stays continuously above one spot on Earth.
Possible Instruments (Earth)
human vision (see notes online)

photoreceptors

cones
  6-7 million
  sensitivity in 3 bands

rods
  75-100 million
  broadband and low light sensitivity

2 eyes = stereo

Robertson, 1992
### Spatial and Spectral Resolution

<table>
<thead>
<tr>
<th>Spectral Characteristics</th>
<th>Panchromatic</th>
<th>Multispectral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>450 to 900-nm</td>
<td>450 to 520-nm</td>
</tr>
<tr>
<td>Pixel Resolution(^1)</td>
<td>61-cm to 72-cm</td>
<td>2.44 to 2.88-m</td>
</tr>
<tr>
<td></td>
<td>(2 to 2.4-ft)</td>
<td>(8 to 9.4-ft)</td>
</tr>
<tr>
<td>Scene Dimensions</td>
<td>27,552 x 27,424 pixels</td>
<td>6,888 x 6,856 pixels</td>
</tr>
<tr>
<td>Scene Size(^2)</td>
<td>272-km(^2) (nadir) to 435-km(^2) (25° off-nadir) (105 to 168-mi(^2))</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.5-km(^2) (nadir) to 20.8-km(^2) (25° off-nadir) (10.3 to 12.9-mi(^2))</td>
<td></td>
</tr>
</tbody>
</table>

### Image Accuracy

<table>
<thead>
<tr>
<th>Positional Accuracy(^3)</th>
<th>CE 90%</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23-meters (75-feet)</td>
<td>14-meters (46-feet)</td>
</tr>
</tbody>
</table>
passive visible – IKONOS – multispectral 2.5 m
passive visible – IKONOS – panchromatic 0.7 m
<table>
<thead>
<tr>
<th>Band</th>
<th>Spectral Range (microns)</th>
<th>Electromagnetic Spectrum</th>
<th>Ground Resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.45 to .515</td>
<td>Visible blue-green (reflected)</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>.525 to .605</td>
<td>Visible green (reflected)</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>.63 to .690</td>
<td>Visible red (reflected)</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>.75 to .90</td>
<td>Near Infrared (reflected)</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>1.55 to 1.75</td>
<td>Mid-Infrared (reflected)</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>10.40 to 12.5</td>
<td>Thermal Infrared (emitted)</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>2.09 to 2.35</td>
<td>Mid-Infrared (reflected)</td>
<td>30</td>
</tr>
<tr>
<td>Pan</td>
<td>.52 to .90</td>
<td>Visible light (reflected)</td>
<td>15</td>
</tr>
</tbody>
</table>
Landsat TM - 0.48 μm, 0.56 μm, 0.66 μm (MATLAB)
passive microwave – Aqua – AMSR-E

Northern Hemisphere Winter 2006

Northern Hemisphere Summer 2006

Minnett, Our Changing Planet, 2007
passive microwave – Aqua – AMSR-E

Minnett, Our Changing Planet, 2007
To Understand and Protect Our Home Planet

ICESat

Earth Science Enterprise • Earth Observing System
Ice, Cloud, and Land Elevation Satellite • Geoscience Laser Altimeter System

NASA Goddard Space Flight Center
ICESat laser altimeter

- Surface elevations along a ground track determined from laser time of flight, combined with precise orbit and pointing information
- Laser-beam pointing determined from star-trackers and internal angle system
- ICESat had 3 lasers
ICESat’s detection of Antarctic subglacial lakes

Fricker et al., 2007
Detecting changes of Antarctica’s ice sheet
active microwave – radar altimetry
active microwave – Geosat altimetry
active microwave – TOPEX altimetry

Fu, Our Changing Planet, 2007
active microwave – TOPEX altimetry

Variability in Sea Surface Topography (cm)

Fu, Our Changing Planet, 2007
active microwave – ERS SAR
active microwave – Seasat SAR
The San Andreas Fault: Adjustments in the Earth’s Crust

The sudden release of energy along a major earthquake is one of the most destructive forces of nature. During the 1906 San Francisco earthquake, poorly constructed buildings collapsed in a matter of seconds, killing thousands of occupants. This was followed by fires that destroyed 28,000 buildings and left more than half of the residents of the city (225,000) homeless. Destructive earthquakes, such as the 1906 event, almost always occur along the boundaries of the tectonic plates, which are well mapped globally. While most plate boundaries...
An early discovery was that the ice moves both by creeping and by sliding, creeping under its own weight over most of the ice sheet, but in some areas, known as ice streams, sliding over its bed. One of the most invaluable roles of satellites has been to reveal the extent of these 'river of ice.' These ice streams reach hundreds of kilometers inland and in many cases create sufficient momentum to form huge floating shelves of ice, up to 1 km thick, attached to the continent but floating hundreds of kilometers across the ocean. The Ross ice shelf, for example, covers an area the size of half a million square kilometers, approximately the size of Spain. These ice shelves for the breeding grounds for most of the truly massive icebergs. 

Nioghalvfjerdsfjorden Zachariæ Isstrøm Storstrømmen

100 km 500 m/yr

Velocity (m/yr)

0 1200

Rignot and Joughin
Our Changing Planet, 2007
Conclusions

• Study the electromagnetic spectrum. Should know the basic categories and their typical wavelengths.
• Sources of EM radiation: passive - Sun and Earth; active – spacecraft.
• Blackbody radiation – coming lecture
• Transparency of atmosphere: “windows” in visible, IR, and microwave, otherwise opaque.
• Main categories of remote sensing: passive visible; passive IR; passive microwave; active visible; active microwave.
• Types of orbits and their applications: geostationary – communications and weather; low Earth polar orbit (LEO) – all types of remote sensing; sun synchronous – passive visible remote sensing.