Overview of Current and Planned Spaceborne Earth Observation Systems
The primary mission of SAI s to develop and promote the use of space derived data and geo-spatial data from other sources in the service of EU policies, especially those relating to agriculture, fisheries, transport and anti-fraud. SAI also seeks to make the best use of information from space systems, to maximise the return from European investments in space and to help the Union reinforce its role in international action on the environment and sustainable development.
SPACE APPLICATIONS INSTITUTE

Overview of Current and Planned Spaceborne Earth Observation Systems

The Handbook

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(Part 1, Part 2 and Annex)

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SAI, JRC, Ispra
(Part 3)

This report is produced by the Space Applications Institute in the frame of the ASTRON programme
(Applications on the Synergy of satellite Telecommunications, eaRth Observation and Navigation).

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Introduction

This handbook is based on a report under the same title, produced by the University of Innsbruck for the European Commission (EUR 18673 EN). Both the report and the handbook have the objective to allow non-EO experts to understand the basics of Earth observation (EO) and to pave the way to potential synergies with Satellite Communications (satcoms) and Satellite Navigation (satnav). In this handbook, the basic elements of remote sensing are described, existing operational sensors are categorised and their applications are highlighted with examples. The main EO satellite operators and data providers are presented together with their products and mechanisms for ordering & distribution. Finally, the potential synergy of EO with satcoms and satnav is addressed, through a number of application scenarios and on-going research projects.

Other information sources used in the frame of this study include:

- Direct feedback from EO data providers
- The Satellite Communications Survey produced by SAI and Intracom (EUR 17302 EN)
- On-line application demonstrations available from the SSSA Unit and ESA sites.
ASTRON (Applications on the Synergy of satellite Telecommunications, earth Observation and Navigation) is a project supported by the Space Applications Institute (SAI) of Directorate General Joint Research Centre (JRC) of the European Commission (EC). ASTRON was conceived and initiated because of the observation that a number of applications and user groups could benefit from the combined use of satellite technologies. Recent developments in the fields of rapid data dissemination via satellite communications (satcoms) and precise geo-location via satellite navigation (satnav) can greatly increase the utility of satellite earth observation (EO) data, because of more timely delivery and accurate geo-location.

There are two main objectives for ASTRON:

- To investigate the synergy between satellite communications, satellite navigation and earth observation in order to develop and demonstrate innovative and sustainable applications;

- To provide direct support to the EC services responding to their requirements in the areas of the project staff’s competence.

These main objectives can then be split into a number of key objectives:

- To identify applications where synergy between current and planned satellite communications and navigation systems together with Earth Observation can lead to the development of novel operational applications;

- To follow and assess technology evolution and also to take awareness measures in order to demonstrate the opportunities, constraints and required services from current and planned spaceborne systems;

- To undertake studies on market development, space industry structure and trends, socio-economic benefits of space, impact assessment and user requirements;
- To undertake feasibility studies and set up pilot projects in order to demonstrate and validate the viability of innovative integrated space solutions for public interest applications;

- To establish communication channels with all major EU and international players in order to avoid duplication of effort and build on existing EU investment;

- To provide technical and scientific consultancy to other EC services.

To meet its objectives, ASTRON takes measures to follow the market and industry trends, to understand the constraints and opportunities that are offered by the evolution of technology, and to analyse the requirements of the user communities and the different applications.

Based on the results of the ASTRON Pathfinder Phase and the communication with the stake-holders (EC services, space agencies, EO data providers, space segment providers and industry), four major application areas have been identified in the year 1999: 'Saving Resources', ‘Business’, ‘Transport’, ‘Non-transport’.

Four market studies on the first three areas were conducted in the year 2000 in order to understand the new potential services, their related demand and offer, their cost/benefits analysis. The results of these studies were then used to define specific demonstration cases. These focus on European Union environment and security policy priorities, as well as on infomobility services.

Ipswich, May 2000

G. Churchill

Head of Unit, Strategy and Systems for Space Applications
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1. EARTH OBSERVATION SENSORS
Introduction

This section describes some of the basic terms of remote sensing, including spectral-, radiometric-, ground resolution, and orbital characteristics.

Imaging sensors of remote sensing are grouped into high resolution imagers, imaging multispectral radiometers operating in the visible and infrared region of the electromagnetic spectrum, passive microwave radiometers, and active microwave imagers. Spectral channels, radiometric and spatial resolution, and orbit characteristics of various operating and near future sensors are listed in the Annex of this study.

Application examples are highlighted for each sensor group.
The Electromagnetic Spectrum (EMS) - 1

The electromagnetic spectrum used for remote sensing of the Earth's surface ranges from 0.35 μm wavelength in the visible to several tens of cm in the microwave region.
The Electromagnetic Spectrum (EMS) - 2

In Remote Sensing the EMS is commonly split up into the visible, infrared, and microwave regions. Various terminologies are used for the specification of sub-regions in the infrared part of the EMS.

<table>
<thead>
<tr>
<th>Region</th>
<th>Sub-region</th>
<th>Acronym</th>
<th>Wavelength range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible</td>
<td></td>
<td>VIS</td>
<td>~0.40 μm - ~0.75 μm</td>
</tr>
<tr>
<td>Infrared</td>
<td>Near Infrared</td>
<td>NIR</td>
<td>~0.75 μm - 1.3 μm</td>
</tr>
<tr>
<td></td>
<td>Short Wave Infrared</td>
<td>SWIR</td>
<td>~1.3 μm - 3.0 μm</td>
</tr>
<tr>
<td></td>
<td>Mid Wave Infrared</td>
<td>MWIR</td>
<td>~3.0 μm - 6.0 μm</td>
</tr>
<tr>
<td></td>
<td>Thermal Infrared</td>
<td>TIR</td>
<td>~6.0 μm - 15.0 μm</td>
</tr>
<tr>
<td>Microwave</td>
<td></td>
<td>MW</td>
<td>~0.1 cm - 100 cm</td>
</tr>
</tbody>
</table>
Sensor systems

Sensor systems can be organised in three main categories:

- **Photographic sensor systems:**
  - Perspective camera systems e.g. KFA-3000, MK-4
  - Panoramic camera systems e.g. KVR-1000, CORONA

- **Line scanner sensor systems:**
  - Pushbroom scanner - e.g. IRS-1C/D, SPOT-HRV
  - Opto-mechanical scanner - e.g. Landsat TM

- **Microwave sensor systems:**
  - Synthetic Aperture Radar (SAR) - e.g. ERS-1/2, RADARSAT
  - Passive microwave sensors - e.g. SSM/I
Sensor characteristics

Natural targets on the Earth surface have different spectral properties. Depending on the application, the quality of the information retrieval can be improved by selecting optimum spectral bands or band combinations.

- The **spatial resolution** describes the smallest spatial separation of two measurements which can be resolved by the sensor.
- The **spectral resolution** describes the number and width of channels that an instrument samples within the EMS.
- The **radiometric resolution** corresponds to the capabilities of a system to detect energy differences in terms of power, intensity, and temperature. It refers to the number of grey values available in the image product.
Spectral resolution

- Panchromatic: one single channel, which covers a very wide spectral range, in particular in the visible (VIS) and parts of the near infrared (NIR) region; e.g.
  - IRS-1C/D PAN, SPOT PAN in digital format
  - KFA 3000, KVR 1000 in analogue format

- Multispectral: two or more broad spectral bands, which may be non-continuously spaced over a wide spectral range; e.g.
  - Landsat series, SPOT HRV, IRS-1C/D LISS-III in digital format
  - KFA 1000, MK 4 in analogue format

- Hyperspectral: narrow, continuous and contiguous spectral bands. Hyperspectral sensors have a minimum of 15, but in general 30 to 300 spectral bands. The high spectral information allows detailed examination of the observed targets.
  - VIS, IR: e.g. NMP-E01 ALI-IS
Spatial resolution

- The **spatial (or geometric) resolution** describes the smallest spatial separation of two measurements which can be resolved by the sensor, and defines also the size of a pixel.
- The spatial resolution varies from one meter to several kilometers depending on the sensor and the satellite's orbit. Future spaceborne imaging sensors are likely to have higher resolutions due to improved technological developments, e.g. Quick Bird with less than one meter resolution.
The satellite sensor systems can be grouped into the following resolution categories:

- Low resolution imagers (up to several km) e.g. NOAA-AVHRR, SPOT-4 VEGETATION
- Medium resolution imagers (80m-300m) e.g. Landsat MSS, IRS-1C WiFS, RESURS-01
- High resolution imagers (5m-30m) e.g. Landsat TM/ETM+, SPOT, IRS-1C/D, KFA 1000, MK 4
- Very high resolution imagers (1m-4m) e.g. KFA 3000, KVR 1000, IKONOS and for the near future planned systems e.g. Quick Bird, IRS-P5.

One picture element (pixel) in the 30m image is represented by 900 pixels in the 1m image

Simulated Imagery, courtesy of EarthWatch Incorporated, 1998
Orbital characteristics

- **Sun-synchronous orbit**
  - a certain area is imaged always at about the same local solar time
  - near-polar orbits with a typical altitude of several hundred kilometers, orbital periods of about 100 minutes, and an inclination angle of 95 to 100 degrees from the poles
  - used by most EO satellites due to Sun energy

- **Geo-stationary (=geo-synchronous) orbit**
  - satellite effectively remains stationary over a point at the equator
  - high altitude orbit (about 36,000 km)
  - used by meteorological satellites (e.g. METEOSAT) and various communication satellites

- **Repeat cycle**
  - time period between successive satellite observations from repeated orbits

- **Revisit time (temporal resolution)**
  - describes how often the same point of the Earth will be recorded by an imaging system
  - depends on various parameters such as orbit altitude, swath width and pointing capability of a sensor
  - critical factor in applications for operational use.
Introduction

Imaging sensors for remote sensing of the Earth’s surface may be arranged into the following categories:

- Optical high resolution imagers - HRI
- Imaging multi-spectral radiometers - VIS and IR
- Imaging multi-spectral radiometers - passive microwave (PMW)
- Imaging Radar - active microwave (AMW).

Special sensors for observing the atmosphere and deriving atmospheric parameters (such as limb sounding instruments, atmospheric sounders and chemistry sensors, cloud profile and rain radars) and non-imaging instruments (such as radar altimeters and wind scatterometers) are not covered by this report.
Optical high resolution imagers (HRI)

- Main application is the observation of the Earth’s surface
- HRI are in general panchromatic and multispectral sensors with spectral bands in the VIS and IR range, which are simultaneously recorded
- Spectral bands are selected to coincide with atmospheric windows in order to reduce the atmospheric absorption and to optimise image quality
- Typical spatial resolution is 5 to 100 m, typical swath width is in the order of 60 to 180 km
- Very high resolution digital imagers with a spatial resolution between 1 and 4 m are already available
- The widely used analogue Russian satellite data have a spatial resolution between 2 and 20 m
- The use of the optical sensors for observing the Earth’s surface is limited by weather conditions.
Examples of optical VHR images

The very high resolution IKONOS sensor has 1 m spatial resolution for panchromatic data and 4 m for multispectral data.
Examples of applications of HRV

AGRICULTURE
- Definition of crop type and area
- Crop inventory

NATURAL HAZARDS & DISASTERS
- Damage assessment (flood extension)

GEOLOGY & SOIL
- Geological Mapping
- Land cover

URBAN & SUBURBAN
- Topographic mapping
- Development of urban areas

CARTOGRAPHY
- Map generation and updating
- DEM generation
- Sustainability

ENVIRONMENT
- Waste management
- Environmental planning/monitoring
Multispectral radiometers (MR) - VIS/IR

- Images are used for monitoring the Earth’s surface and atmosphere (not covered in this overview)
- Several narrow, precisely calibrated spectral bands at a lower spatial resolution than HRI (100 m to several km); swath width is several hundred to a few thousand km
- Recent developments include improvements in spatial resolution and in spectral and radiometric accuracy
- Improved sensors:
  - Multi-directional Radiometers: observe the Earth’s surface at more than one incidence angle to get information on the variable atmospheric absorption (TIR channels) and on anisotropies in the reflected and scattered radiation (VIS, NIR)
  - Polarimetric Radiometers: measure the polarisation state of the received radiation in a given band (currently experimental)
- As for HRI the use of these sensors for observing the Earth’s surface is limited to clear weather conditions.
Examples of MS radiometers VIS/IR images

NOAA-AVHRR
1 km ground resolution

VEGETATION - SPOT-4
1 km ground resolution

© DLR / DFD, Oberpfaffenhofen, courtesy of DLR

© CNES 1998
Distribution SPOTIMAGE, courtesy of SPOTIMAGE
Examples of applications of MR VIS/IR

- **AGRICULTURE**
  - Large-scale yield prediction
  - Biomass production
  - Agro-environmental monitoring

- **OCEANS & COASTS**
  - Sea-level monitoring
  - Sea surface temperature
  - Algal bloom monitoring
  - Sea ice

- **FOREST & VEGETATION**
  - Global forest inventories
  - Fire maps
  - Vegetation modelling

- **ENVIRONMENT**
  - Environmental modelling
  - Mapping of land surface types
  - Land cover change
  - Extent of seasonal snow cover
Multispectral radiometers - PMW

- Operate in a number of channels at microwave wavelengths (1 to 100 GHz)
- Channels within 1 to 40 GHz and 80 to 100 GHz are used to get information on the Earth’s surface independent on day/night and with the advantage of cloud penetration and hence all weather capabilities
- Channels between 50 and 60 GHz are used for deriving atmospheric parameters
- Typical spatial resolution is 10 km at about 90 GHz, at lower frequencies the spatial resolution reduces to several tens of km; typical swath width is in the order of 1000 km, current PMW sensors provide global coverage within a few days
- Passive MW images are suitable for global rather than regional or local analysis, which is a consequence of spatial resolution.
**Examples of applications of MR PMW**

<table>
<thead>
<tr>
<th>Category</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCEANS &amp; COASTS</td>
<td>Sea ice concentration</td>
</tr>
<tr>
<td></td>
<td>Sea ice type</td>
</tr>
<tr>
<td></td>
<td>Ocean salinity (contributing)</td>
</tr>
<tr>
<td>GEOLOGY &amp; SOIL</td>
<td>Soil moisture content</td>
</tr>
<tr>
<td></td>
<td>Vegetation health (large scale)</td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>Land surface types mapping</td>
</tr>
<tr>
<td></td>
<td>Monitoring desertification</td>
</tr>
<tr>
<td></td>
<td>Seasonal snow extent</td>
</tr>
</tbody>
</table>
Multispectral radiometers - AMW

- Active sensor technology (Synthetic Aperture Radar - SAR): measures the backscattered signal at a certain frequency (1 to 10 GHz) and a certain polarisation of electro-magnetic signals transmitted by the sensor.
- SAR images have a similar spatial resolution than HRI images, but are independent on the weather conditions and day/night.
- Interpretation of SAR images is complex and in some cases still developing science. However, there has been significant progress in a number of applications.
- Interferometric SAR determines the phase shift between two images recorded at slightly different time and/or slightly different orbit, which can be used for:
  - information retrieval on the motion of surfaces and targets
  - the generation of digital elevation models
- Advanced SAR systems include:
  - selection of one of several beam modes with pointing capabilities
  - multi-polarised SAR
Example of SAR sensor image

ERS-1 Synthetic Aperture Images acquired during the flood disaster caused by the Rhine river (images from more than one date overlayed).

© ESA, 1993/94. Distributed by EURIMAGE, courtesy of GAF
| Categories and Applications of Sensors | \_
|--------------------------------------|---
| Earth Observation Sensors            | \_
| Environment                          | \_
|  - Land degradation                  | \_
|  - Detection of marine pollution    | \_
|  - Glacier motion                    | \_
| Forest & Vegetation                  | \_
|  - Forest height                     | \_
|  - Deforestation mapping            | \_
| Natural Hazards & Disasters          | \_
|  - Landslides                        | \_
|  - Flood monitoring and mapping     | \_
| Geology & Soil                       | \_
|  - Site monitoring                   | \_
|  - Linear fault mapping              | \_
| Oceans & Coasts                      | \_
|  - Exploration                       | \_
|  - Bathymetry (near coasts)          | \_

Examples of applications of MR AMW:
- Real time ice warning for ships
- Detection of oil spills
2. EARTH OBSERVATION DATA PROVIDERS
Introduction

This section describes current and planned data finding, ordering and delivery mechanisms. Data formats and delivery media are also presented.

The organisations contacted to assess current and planned data distribution mechanisms pertain to the following categories:

- Satellite operators
- Receiving stations
- Data providers
- Data distributors
**Providers**

These providers/distributors are introduced and their services and data are described in more detail. This list is not exhaustive.

<table>
<thead>
<tr>
<th>SPOTIMAGE (France)</th>
<th>SPACE IMAGiNG EUROPE (Greece)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESRIN-ESA (Italy)</td>
<td>RADARSAT Inc. (Canada)</td>
</tr>
<tr>
<td>EURIMAGE (Italy)</td>
<td>ORBIMAGE (USA)</td>
</tr>
<tr>
<td>DLR-DFD(Germany)</td>
<td>SOVINFORMSPUTNIK (Russia)</td>
</tr>
<tr>
<td>EUROMAP (Germany)</td>
<td></td>
</tr>
</tbody>
</table>
Data searching

- Data search is done by data providers/distributors on user request or directly by the user (online catalogues, registration required)
- The WWW is widely used in the industry and many commercial providers have on-line data catalogues
- Usage of on-line data catalogues for some image types is operational but not always complete; the level of user friendliness varies
- Some of the catalogues require a thorough understanding of the subject; this may limit the access to expert users and distributors
- The main search criteria include:
  - Time period of image acquisition (start date - end date)
  - Area of interest specified by latitude/longitude or bounding box, or place names
  - Sensor and/or image product.
Data ordering and delivery

- Current ordering is performed via standard means of communication (fax, telephone, e-mail)
- Order confirmations by fax are requested by almost all providers
- Delivery is via the following channels:
  - Distributors
  - Courier and express mail
  - Electronic downlinks for data delivery (e.g. via the Internet), operationally used only by a few providers.
- Most providers have plans to allow operational purchase and downloading of specific data in the near future via the Internet
- Some providers allow data downloading on closed Intranet solutions
- Telecommunications (other than the Internet) as a means for EO data delivery is still an exception.
Data ordering and delivery

- Delivery time depends on the time required for:
  - image acquisition and generation from raw data (depends on product type)
  - sending the product to the end user; which depends on the type of data delivery and
    the geographic distance between the provider and the end-user.
- Delivery can take from several hours to several days/weeks before the data can reach
  the end customer:
  - a Rush Service (near real time data processing and data delivery within several hours
    after image acquisition) is provided for products from a few sensors, but it will cause
    additional costs.
Format and media

- Most satellite images are stored and distributed in their own specific format. Detailed description on the format are attached to image data on user request.

- Standard Media for data delivery:
  - CD-ROM
  - Digital tapes (Exabyte 8200/8500, CCT).
  - Film and photographic prints

- The Internet - as a medium for data delivery - becomes more and more important, especially for applications where Near Real Time data analysis is needed.
Products

EURIMAGE is an international data distribution centre and offers remote sensing users a multi-mission service. EURIMAGE provides products of the following sensors:

- High Resolution Imagers: Landsat TM/ETM+, KFA 1000 (MIR) KVR 1000 and TK-350 (Kosmos)
- Imaging MS Radiometers-VIS/IR: AVHRR/NOAA; RESURS-O1
- Active Microwave: ERS SAR, JERS-1 SAR.
High Resolution Imagers

Landsat is the satellite series with the longest period of operational use. The resolution has been improved from one sensor generation to the next.

- Landsat 5 was launched in March 1984 and is still operational. The main sensor is the Thematic Mapper (TM) (6 bands VIS+IR/30m, 1 band TIR/120m, swath width 183 km; repeat cycle 16 days)
- Landsat-7 was launched in April 1999 and it is operational. It carries the Enhanced Thematic Mapper ETM+ (PAN/15 m, 6 bands VIS+IR/30 m, 1 band TIR/60 m, swath width: 180 km, repeat cycle: 16 days).
- Resurs-O1 is an operational Russian/CIS satellite. The first satellite in the series was launched in 1985. Currently the third and the fourth generations are operating. The main sensor is the MSU-SK (Multispectral Scanner) on Resurs O1#3 (4 bands VIS+NIR/170 m, TIR/600 m, swath width 600 km) and MSU-SK1 on Resurs O1#4 (4 bands VIS+NIR/225 m, SWIR/810 m, TIR/810 m, swath width 714 km), the repeat coverage at the equator is 4 days.
- The Polar Orbiting Operational Environmental Satellites POES operated by NOAA currently include the space-crafts NOAA 9, 12 and 14. The main sensor is the Advanced Very High Resolution Radiometer AVHRR: 3 bands VIS+IR, 2 bands TIR with a ground resolution at nadir of 1100 m, swath width 3000 km, repeat coverage 12 h.
Active Microwave - SAR

- The ERS satellites were developed by the European Space Agency (ESA). ERS-1 and ERS-2 were launched in July 1991 and April 1995, respectively. ERS-1 was recently deactivated.

The SAR sensor which is on board the ERS satellites has the following characteristics: C-Band VV polarized, spatial resolution 25 m, repeat cycle 35 days, swath width 100 km. During selected periods, ERS-1 and ERS-2 SAR were both turned on for operating together in Tandem Mode to support investigations in SAR interferometry.

- JERS-1 (Japanese Earth Resources Satellite -1) operated from February 1992 to October 1998. The main sensor was the SAR: L-Band HH polarised, spatial resolution 18 m, swath width of 75 km, repeat cycle 44 days.

© ESA / DLR-DFD, 1996. Distributed by EURIMAGE, ERS (wind scatterometer) image, courtesy of EURIMAGE
Services

Eurimage offers three services:

- **EINet**: Online satellite image catalogue browsing system. It allows you to browse quick looks and meta-data of the scenes covering the geographic area and time range of interest.
- **DESCW**: Multi-mission inventory search system for the major ESA-supported missions. The catalogue is updated weekly and is available online. Quick Looks on CD-ROM are available for LANDSAT 5 and ERS SAR. DESCW was developed by EURIMAGE in cooperation with ESRIN/ESA.
- **Earth Watching**: Eurimage's monitoring service for natural disasters and special events. See [http://earth1.esrin.esa.it/ew/](http://earth1.esrin.esa.it/ew/)

Ordering and delivery

- Current ordering is via telephone, fax and Internet
- Courier service direct to customers
- Average of 2 days to reach customers (by courier)
Euromap Satellitendaten-Vertriebsgesellschaft mbH was founded in 1996 as a subsidiary of the Company for Applied Remote Sensing (Gesellschaft für Angewandte Fernerkundung mbH, GAF).

Euromap distributes data from the Indian Remote Sensing Satellite -(IRS-1C) which was launched in Dec. 1995. IRS-1D, a clone of IRS-1C, was launched in Sep 1997. IRS scenes are available on CD-ROM, digital tape, film and photographic prints. Downloading of data via the Internet will be possible in the near future.
Sensors

- The IRS-1C/D satellites carry three sensors: the fine resolution panchromatic (PAN) and multispectral Linear Imaging Self Scanning (LISS-III) sensors, and a coarse resolution Wide Field Sensor (WiFS):

  - **High Resolution Imager**
    - PAN: spectral band 0.5 - 0.75 mm, spatial resolution 5.8 m, swath width 70 km, the off nadir viewing capability of 26° enables a revisit cycle of about 5 days; for cartographic mapping, may be combined with LISS-III data
    - LISS-III: 4 spectral bands: VIS (0.52-0.59 mm, 0.62-0.68 mm), NIR (0.77-0.86 mm) spatial resolution 24 m, SWIR (1.55-1.75 mm) spatial resolution 70 m, swath width 140 km, revisit cycle 24 days; for vegetation discrimination and land cover mapping

  - **Imaging MS Radiometer - VIS/IR**
    - WiFS: spectral bands VIS (0.62-0.68 mm), NIR (0.77-0.86 mm), spatial resolution 188 m, swath width 770 km; revisit cycle of 5 days (overlapping of adjacent tracks).

© Antrix, SIE, Euromap, 1997 courtesy of GAF
Products

ORBIMAGE is developing a system of 4 imaging EO satellites. Currently OrbView-1 and OrbView 2 are operating, OrbView-3 and 4 are planned for launch in late 2000.

OrbView-1 was launched in April 1995 and provides daily weather images and global lightning information; it carries a single channel sensor with a centre frequency at 0.78 mm, spatial resolution 10 km, swath width 1300 km, revisit time less than 2 days. ORBIMAGE delivers both the lightning and atmospheric data directly to customers in near real-time using the Internet.
Sensors

- OrbView-2 (=SeaWIFS) was launched on 1 August 1997 and provides multispectral images of the Earth; 8 non-overlapping channels between 0.4 mm and 0.89 mm; spatial resolution 1 km, swath width 2800 km, revisit time 1 day
- OrbView-2 data are valuable for monitoring plankton and sedimentation levels in the oceans and assessing the health of land-based vegetation on a global basis
- Individual images can be ordered at ORBIMAGE’s online service; for customers requiring access to large amounts of data, direct downlink licenses are available
- OrbView-3 is planned for launch in 2000; it will carry a high resolution sensor: PAN (0.45-0.9 mm, 1 m spatial resolution), multi-spectral (4 bands between 0.45 and 0.9 mm, spatial resolution 4 m), swath width 8 km, revisit time 3 days.
Active Microwave - SAR

- Radarsat-1 was launched in November 1995. Radarsat has a planned lifetime of five years and is equipped with a Synthetic Aperture Radar (SAR). The Radarsat-1 mission will be followed by Radarsat-2; planned for launch in 2000.

- The Radarsat-1 SAR operates at C-Band HH polarisation, the repeat cycle is 24 days. The steerable sensor can be programmed to work in various beam modes.

RADARSAT data courtesy of Canadian Space Agency/Agence spatiale canadienne 1998. Received by the Canada Centre for Remote Sensing. Processed and distributed by RADARSAT International.
Operating Modes

Radarsat-1 SAR enables to select one of 4 main modes:

- Standard Beam: spatial resolution ~ 28 m
- Wide Swath Mode: spatial resolution ~ 35 m
- Fine Beam: spatial resolution ~ 9 m
- ScanSAR: spatial resolution from 50 to 150m.

Delivery

- Scenes are available on CD-ROM, digital tape, film and as photographic prints
- Downloading of data via Internet will be possible.
- SOVINFOMSPUTNIK, Aerial Images, Inc. and Central Trading Systems Inc. jointly own the SPIN-2 trademark for marketing Kosmos KVR 1000 and TK 350 data.
- The first of a long series of Kosmos satellites was launched in 1981, the latest mission was flown in 1998. Each mission typically lasts for 40 to 45 days. The data are of cartographic quality and are high resolution images with spatial resolutions of 2 m (KVR 1000) and 10 m (TK 350). Within SPIN-2, it is planned to launch two Kosmos missions per year for the next five years.
Sensors

- KVR 1000 - panoramic camera system with a focal length of 1000 mm:
  - panchromatic imagery (0.51 - 0.76 mm)
  - spatial resolution of 2 m
  - frame: 40 km (along track) by 160 km (across track)
  The main application is cartographic mapping.

- TK-350 is a topographic camera system with focal length of 350 mm:
  - panchromatic imagery (0.51 - 0.76 mm)
  - spatial resolution of 10 m
  - full frame: 200 km (along track) by 300 km (across track)
  Stereo pairs (successive frames with 60 - 80% overlap) are used for generating Digital Elevation Models (DEM).

Delivery

- Data are available on CD-ROM, digital tape, film, and paper prints
- Data from around the world will be available on the Microsoft TerraServer at full resolution for purchase.
Products

- The Ikonos spacecraft series is owned by the commercial company Space Imaging Inc., based in Thornton, Colorado. After the launch Ikonos-1 failed, Ikonos-2 was launched in September 1999 and data are already commercially available.

- Space Imaging provides 1-meter panchromatic and 4-meter multispectral images as well as 1-meter pan-sharpened images derived from the other two by means of a special algorithm.

- Products are marketed under the CARTERRA™ trade name. Currently products from other sensors are distributed as well (e.g. IRS-1C/D PAN, LISS-III, WiFS, Landsat TM).

Ispra, Italy CARTERRA 1-PSM (1-meter Pan-sharpened) © Ikonos 2000, courtesy of Space Imaging Europe
Sensors

Ikonos-2 carries a digital camera system with an 11-m swath width capability and two imaging sensors:

- Panchromatic (black and white)
  - 1 band 0.45-0.90 mm, spatial resolution 1 m.
- Multispectral (colour)
  - 4 bands: VIS (0.45-0.52 mm, 0.52-0.60 mm, 0.63-0.69 mm), NIR (0.76-0.90 mm), spatial resolution 4 m.
Products

- The SPOT (Système Pour l'Observation de la Terre) Earth observation programme (Operator SPOTIMAGE) was initiated by France in 1977. SPOTIMAGE was set up in 1982 by the Centre National d'Etudes Spatiales (CNES) to distribute worldwide, satellite imagery returned by the Spot Earth observation satellites.

- Currently SPOT-1 (launched in 1986), SPOT-2 (launched in 1993) and SPOT-4 (launched in 1997) are operating, SPOT-3 failed in 1996. The SPOT satellites series will continue with SPOT-5, which is planned to be launched in 2002.
SPOT 1/2

SPOT 1/2 instruments are pointable in cross-track direction up to ±27° from nadir providing a revisit time of 2.4 days:

- High Resolution Visible - Panchromatic (HRV-P) channel 0.51-0.73 mm, spatial resolution 10m, swath width 60 km
- High Resolution Visible - Multispectral (HRV-XS): 3 channels: VIS (0.50-0.59 mm, 0.61-0.68 mm), NIR (0.79-0.98 mm), spatial resolution 20 m, swath width 60 km.
SPOT-4

SPOT-4 is operating in the same orbit as SPOT1/2. The HRV instruments have improved capabilities compared to their predecessors, additionally SPOT-4 carries the VEGETATION instrument.

- HRV-IR P: 0.61-0.68 mm, spatial resolution 10 m, swath width 60 km, revisit time 2.4 days
- HRV-IR XI: VIS (0.50-0.59 mm, 0.61-0.68 mm), NIR (0.79-98 mm), SWIR (1.58-1.75 mm), spatial resolution 20 m
- The VEGETATION Instrument was designed to monitor crops and the continental biosphere. It provides global coverage on an almost daily basis at a resolution of 1 km, thus making it an ideal tool for observing long-term environmental changes on a regional and worldwide scale. Bands: VIS (0.43-0.47 mm, 0.61-0.68 mm), NIR (0.79-98 mm), SWIR (1.58-1.75 mm), swath width 2250 km.

© CNES 1998 - Image taken by the Vegetation Instrument, courtesy of CNES
Services

- Acquisition programming of SPOT1/2 HRV and HRV-IR Data:
  - Blue Service: for non urgent acquisitions, maximum cloud coverage is defined by the customer
  - Red Service: urgent acquisitions, highest priority for imaging attempts of the study area, monthly reports of imaging attempts are provided to the customer
- Rush Service for data delivery of archived SPOT data is possible within 24 h.
CORONA is a satellite-borne panoramic camera imaging system. The images were collected during 1960-1972 throughout the world with emphasis on Eastern Europe and Asia.

- Declassified Corona data were released in February 1995 by President Clinton
- Altogether more than 860,000 scenes are available (film, 2.2" x 30")
- Spatial resolution 6 to 25 ft.
- Costs: 30$ per scene.

courtesy of JOANNEUM RESEARCH
Future missions and satellites

- Envisat is an advanced Earth observing satellite developed by ESA. It is designed to provide measurements of the atmosphere, ocean, land, and the cryosphere over a 5 years period. Envisat is planned for launch in the year 2000 and will carry 9 major instruments including:
  - Advanced SAR (ASAR)
  - Medium Resolution Imaging Spectrometer (MERIS)
  - Radar Altimeter (RA-2)
  - Advanced Along Track Scanning Radiometer (AATSR)

- Terra (EOS AM-1), which is planned for launch in July 1999, is the flagship of NASA’s EOS satellites. The long term EOS mission will be continued by EOS PM1, planned for launch in the year 2000/2001. Terra carries 5 major sensors for observing the atmosphere, ocean, land and ice surfaces, including:
  - Advanced Spaceborne Thermal Emission & Reflection Radiometer (ASTER)
  - Clouds and the Earth’s Radiant Energy System (CERES)
  - Multi-angle Imaging Spectro-Radiometer (MISR)
  - Moderate-resolution Imaging Spectroradiometer (MODIS).
Future missions and satellites

- The Advanced Earth Observation Satellite II (ADEOS-II) is developed by NASDA and is planned for launch in the year 2000. It will carry 6 EO instruments including:
  - Advanced Microwave Scanning Radiometer (AMSR)
  - Global Imager (GLI)
  - Seawinds ( Scatterometer, developed by NASA)
  - Polarisation & Directionality of Earth’s Radiation (POLDER, dev. by CNES)

- The Indian Remote Sensing Satellite series IRS will be extended by several future missions with different objectives and sensors:
  - IRS-P5 (=Cartosat) with a Very High Resolution Panchromatic camera HR-PAN (2.5 m spatial resolution) and a multispectral sensor LISS-IV (10 m spatial resolution), for cartographic applications planned for launch in 2000.
  - IRS-P6 (=Resoursesat) for agricultural applications planned for launch in the year 2000; sensors: Advanced Wide Field Sensor (multispectral, 70 m spatial resolution), LISS-VI.
Future missions and satellites

- The Shuttle Radar Topographic Mission (SRTM) is a short term mission of several days performed in February 2000. Using C-Band, L-Band and X-Band single track interferometry, the mission has the aim to generate global high resolution digital elevation models.

- Radarsat-2 will provide dual polarised C-Band SAR images and is planned for launch in the year 2000.

- SPOT-5 a and SPOT-5 b will continue the SPOT satellite series operated by SPOTIMAGE (launch in the year 2002 and 2004). They will carry the panchromatic and multispectral HRG sensors (same as HRV but improved spatial resolution), and the Vegetation-2 instrument.

- BERS (China-Brazil Earth Resources Satellite) is an Earth observing satellite series developed by China and Brasil. CBERS-1 was successfully launched for launch in 1999. It carries three sensors: CCD Camera: 5 VIS/NIR bands; 20 m resolution; 113 km swath width; IR Multi-Spectral Scanner: 4 VIS-IR bands, 80-160-m resolution; 120 km swath; Wide-Field Imager:2 VIS/NIR bands, 260-m resolution; 900 km swath.
Future missions and satellites

- NOAA L, M, N (=NOAA 16, 17, 18) will continue the long term series of NOAA satellites. They are planned for launch in 2001, 2004, and 2007, respectively. The major sensor is the AVHRR Version 3 sensor (6 bands).
- EarthWatch Incorporated plans to launch QuickBird. QuickBird will offer 1 m resolution (panchromatic) and 4 m resolution (multispectral, 3 bands)
- OrbView-4 will provide 1m panchromatic and 4m multispectral imagery. Orbview-4 will be launched in the year 2001
- Resource-21, a commercial company, plans a constellation of four R21 spacecrafts in the same orbital plans, providing multi-spectral optical images with 10 to 100 m resolution.
3. INTEGRATED SPACE APPLICATIONS
Synergy between Earth Observation, Satellite Communications and Satellite Navigation could be effective in an innovative fashion in a number of applications areas (list is not exhaustive):

- PERSONAL INFO-MOBILITY
- SAFETY OF LIFE AND RESOURCES
- BIG EVENTS OR CRISIS SITUATIONS
- MOBILITY
Introduction

Space technologies can be used to complement terrestrial communication systems (GSM/UMTS) in meeting the needs of the quickly growing trend towards mobile information services at a personal level, through hand-held or vehicle-based terminals.
Applications

1. Virtual Travel Assistant/Tourist Guide
On-the-fly 'pro-active' navigation service ('turn-by-turn') can guide the user on a 'tour' of a specific location. A 'passive' tour guide can inform the user of local points of interest, events, etc. dependent on their current location (town/city/historic site, etc.). Satnav locates the user, satcoms offers broadband information transmission, and EO enriches location-related content.

2. Local Weather Forecaster
Access to weather forecasts for the immediate area where the user is located, can be provided via a fixed or mobile internet-connected terminal. Satnav determines user position, EO is used to derive weather forecasts and provide images, satcoms can deliver detailed image information.

3. Gaming
Fully interactive, multimedia virtual gaming in the 'real' world can be envisaged. Two or more global gamers congregate in a virtual ante-room, decide upon which game to play, virtual location, level of realism, etc. Use of EO derived data for the recreation of the environment and (satellite based) communications and navigation for the moves of the players.
Introduction

High resolution up-to-date EO satellite data (used for 3D real-time visualisation techniques) together with navigation (GPS and eventually Galileo) and satellite communications can provide benefits for planning and monitoring of applications related to the safety of life and resources.
Applications

1. **Logistic Support in Humanitarian Crisis**
Logistical support can be provided for the management of population relocation or evacuation in a crisis situation (civil war, refugees, epidemic etc). EO is used for terrain mapping, site selection, monitoring of crop areas. Satcoms are used for overall provision of fixed and mobile communications. Satnav is used to support operations related to relief supply and ground surveys.

2. **Terrestrial Search and Rescue Operations**
Enhanced co-ordination and support of search and rescue operations on land. Satnav is used to support location of victims and rescue forces operations. Satcoms are used for communication between the management centre and rescue teams. EO is used to visually enhance the operations scenario for the decision makers.

3. **Oil Spills**
Identification and monitoring of illegal pollution of oceans and coastal zones, aiming to alert authorities and support actions to reduce the impact on the environment. Satellite derived radar data are effective to detect oil spills at sea. Once a spill is detected, offending vessel positions are identified with the support of satellite navigation, provided that the vessels are obliged to continuously transmit their position.
Satellite technologies in combination with terrestrial technologies can provide innovative solutions for mobility applications relevant to big events (e.g. Olympic Games) or crisis situations (e.g. earthquakes) when large population densities occur in metropolitan areas for limited periods of time.
Applications

1. **Traffic Monitoring and Fleet Management**
   A Fleet Management System can be used to manage several accredited or public transportation vehicles (heavy-goods trucks, mini-buses and public transportation buses), commuting to pre-determined spots through the least congested routes.

2. **Emergency Services Operation**
   Crisis situations (such as earthquakes or terrorist attacks) require an emergency system with a high degree of integrity and reliability for coordination of all security and support measures. Satellite technologies could support real-time surveillance of the incident area and could provide direct links between the headquarters and the officers in the place of incident.

3. **Personalised Tracking**
   The position and status of every high security-rated group of visitors during great events, or out-door security related employees can be monitored in real time, through an interactive system used to track the individual person and to establish voice or data communication (one-way or two-way).
Introduction

Navigation techniques bundled with Communication means and EO-derived products can be used for the development of innovative systems for road guidance-assistance to private vehicles and fleet management of public transportation vehicles. The three satellite technologies might also support specific applications in rail, air and maritime navigation.
Applications

1. Dynamic Route Guidance
An interactive car navigation system enables on-the-move updating of the road database within the car, with data on preferable routes to selected destinations, according to real time traffic information (e.g. blocked roads, traffic jams etc) and up-to-date meteorological and environmental information.

2. Law Enforcement - Professional Drivers
A satellite-based law-enforcement system could provide a wide-area monitoring of traffic violations by professional drivers. This might allow actions at different authorisation levels mainly contributing to enhancing passive safety. Such a system could be particularly beneficial for hazardous goods transport and car rental companies.

3. Small Aircraft Navigation Support
Private small plane (or helicopter) navigation might be enhanced achieving increased air safety under visual flight rules (VFR). EO is used for improved and updated flight charts and terrain models. Terrains may include airport areas (where small planes do not have all necessary information) and also areas away from airports where helicopters might need to land.
Introduction

This section gives an overview of current and near future Earth observing imaging sensors classified in three categories:

- High Resolution Imagers
- Imaging Multispectral Radiometers
- Passive Microwaves Radiometers
## High Resolution Imagers

<table>
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<tr>
<th>Sensor</th>
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<th>Spectral range</th>
<th>Number of channels</th>
<th>Spatial Resolution</th>
<th>Image Frame / Swath width</th>
<th>Repeat Cycle</th>
<th>Repeat Coverage</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>KFA-1000 Photocamera</td>
<td>Resurs F1M Priroda-5</td>
<td>PAN</td>
<td>1</td>
<td>6.7 m</td>
<td>120 km</td>
<td></td>
<td></td>
<td>periods since 1979</td>
</tr>
<tr>
<td>KFA-1000 Photocamera</td>
<td>Resurs F1M Priroda-5</td>
<td>VIS, NIR</td>
<td>2</td>
<td>10 m</td>
<td>120 km</td>
<td></td>
<td></td>
<td>periods since 1979</td>
</tr>
<tr>
<td>KFA-3000 Photocamera</td>
<td>Resurs F1M Priroda-5</td>
<td>PAN</td>
<td>1</td>
<td>2 m</td>
<td>21 km</td>
<td></td>
<td></td>
<td>periods since 1979</td>
</tr>
<tr>
<td>TK-350 Photocamera</td>
<td>COSMOS</td>
<td>PAN</td>
<td>1</td>
<td>10 m</td>
<td>200 x 300 km$^2$</td>
<td></td>
<td></td>
<td>periods since 1981</td>
</tr>
<tr>
<td>KVR-1000 Photocamera</td>
<td>COSMOS</td>
<td>PAN</td>
<td>1</td>
<td>2.3 m</td>
<td>40 x 40 km$^2$</td>
<td></td>
<td></td>
<td>periods since 1984</td>
</tr>
<tr>
<td>TM</td>
<td>Landsat 4,5</td>
<td>VIS, NIR, SWIR</td>
<td>4</td>
<td>30 m, 30 m, 120 m</td>
<td>183 km</td>
<td>16 days</td>
<td>16 days (0° Lat)</td>
<td>1982, 1984</td>
</tr>
<tr>
<td></td>
<td>Landsat 4,5</td>
<td>SWIR</td>
<td>2</td>
<td>30 m</td>
<td>185 km</td>
<td>16 days</td>
<td>16 days (60° Lat)</td>
<td>1982, 1984</td>
</tr>
<tr>
<td>MSS</td>
<td>Landsat 4,5</td>
<td>VIS, NIR</td>
<td>4</td>
<td>79 m</td>
<td>185 km</td>
<td>16 days</td>
<td></td>
<td>1982, 1984</td>
</tr>
<tr>
<td>HRV-XS</td>
<td>SPOT 1-3</td>
<td>VIS, NIR</td>
<td>3</td>
<td>20 m</td>
<td>60 km</td>
<td>26 days</td>
<td>2.4 days (mid Lat)</td>
<td>1986</td>
</tr>
<tr>
<td>HRV-P</td>
<td>SPOT 1-3</td>
<td>PAN</td>
<td>1</td>
<td>10 m</td>
<td>60 km</td>
<td>26 days</td>
<td>7.4 days (mid Lat)</td>
<td>1986</td>
</tr>
<tr>
<td>MK-4 Photocamera</td>
<td>Resurs-F2</td>
<td>PAN</td>
<td>1</td>
<td>6.7 m</td>
<td>150</td>
<td></td>
<td></td>
<td>periods since 1990</td>
</tr>
<tr>
<td>MK-4 Photocamera</td>
<td>Resurs-F2</td>
<td>VIS, NIR</td>
<td>2</td>
<td>10 m</td>
<td>150</td>
<td></td>
<td></td>
<td>periods since 1990</td>
</tr>
</tbody>
</table>
# High Resolution Imagers

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<tr>
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<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPS</td>
<td>JERS-1</td>
<td>VIS, NIR, SWIR</td>
<td>4</td>
<td>18.3 x 24.2 m</td>
<td>75 km</td>
<td>44 days</td>
<td></td>
<td>Feb 1992 - Oct 1992</td>
</tr>
<tr>
<td>MOMS-02</td>
<td>MIR / Priroda</td>
<td>VIS, NIR PAN PAN (Stereo)</td>
<td>4, 3, 2</td>
<td>18, 6, 18</td>
<td>92 km, 44 km, 192 km</td>
<td>14 days</td>
<td></td>
<td>May 1996</td>
</tr>
<tr>
<td>AVNIR</td>
<td>ADEOS-1</td>
<td>VIS, NIR PAN</td>
<td>4, 1</td>
<td>16 m, 8 m</td>
<td>80 km</td>
<td>41 days</td>
<td>3 days sub-cycle</td>
<td>Aug 1996 - Jul 1997</td>
</tr>
<tr>
<td>LISS-III</td>
<td>IRS-1C</td>
<td>VIS, NIR SWIR</td>
<td>3, 1</td>
<td>23.5 m, 70.8 m</td>
<td>142 km, 148 km</td>
<td>24 days</td>
<td>5 days</td>
<td>1996, 1997</td>
</tr>
<tr>
<td>PAN</td>
<td>IRS-1C</td>
<td>PAN</td>
<td>1</td>
<td>5.8 m</td>
<td>70.5 km</td>
<td>24 days</td>
<td>5 days</td>
<td>1996, 1997</td>
</tr>
<tr>
<td>HRV-XI</td>
<td>SPOT 4</td>
<td>VIS, NIR SWIR</td>
<td>3, 1</td>
<td>20 m</td>
<td>60 km</td>
<td>26 days</td>
<td>2.4 days (mid Lat)</td>
<td>1998</td>
</tr>
<tr>
<td>HRV-P</td>
<td>SPOT 4</td>
<td>PAN</td>
<td>1</td>
<td>10 m</td>
<td>60 km</td>
<td>26 days</td>
<td>2.4 days</td>
<td>1998</td>
</tr>
<tr>
<td>ETM+</td>
<td>Landsat-7</td>
<td>PAN, VIS, NIR SWIR, TIR</td>
<td>1, 4, 2, 1</td>
<td>15, 30, 30, 60</td>
<td>180 km</td>
<td>16 days</td>
<td></td>
<td>Apr 1999</td>
</tr>
<tr>
<td>QBP</td>
<td>QuickBird</td>
<td>PAN</td>
<td>1</td>
<td>0.82 m</td>
<td>22 km</td>
<td>1 - 5 days (2 satellites)</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>QBM</td>
<td>QuickBird</td>
<td>VIS, NIR</td>
<td>4</td>
<td>3.28 m</td>
<td>22 km</td>
<td>1 - 5 days (2 satellites)</td>
<td>2000</td>
<td></td>
</tr>
</tbody>
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<tbody>
<tr>
<td>Carterra</td>
<td>Ikonos2</td>
<td>PAN VIS/NIR</td>
<td>1 4</td>
<td>1 m 4 m</td>
<td>11 km</td>
<td>2-3.5 days</td>
<td>Sep 1999</td>
</tr>
<tr>
<td>ASTER</td>
<td>Terra (EOS-AM1)</td>
<td>VIS, NIR SWIR TIR</td>
<td>3 6 5</td>
<td>15 m 30 m 90 m</td>
<td>60 km</td>
<td>16 days</td>
<td>Dec 1999</td>
</tr>
<tr>
<td>Orbview-3</td>
<td>Orbview-3</td>
<td>VIS, NIR PAN</td>
<td>4 1</td>
<td>4 m 1 m</td>
<td>8 km</td>
<td>&lt; 3 days</td>
<td>2000</td>
</tr>
<tr>
<td>HR-PAN</td>
<td>IRS-P5 (Cartosat)-1</td>
<td>PAN</td>
<td>1</td>
<td>2.5 m</td>
<td>30 km</td>
<td>26 days</td>
<td>2000-2001</td>
</tr>
<tr>
<td>LISS-IV</td>
<td>IRS-P5 (Cartosat)-1</td>
<td>VIS/NIR SWIR</td>
<td>7</td>
<td>-6 - 23 m</td>
<td>40 km</td>
<td>22 days</td>
<td>2000-2001</td>
</tr>
<tr>
<td>ALI-PAN</td>
<td>NAP EO-1</td>
<td>PAN</td>
<td>1</td>
<td>10 m</td>
<td></td>
<td>Summer 2000</td>
<td></td>
</tr>
<tr>
<td>ALI-MS</td>
<td>NAP EO-1</td>
<td>VIS/NIR/ SWIR</td>
<td>6</td>
<td>30 m</td>
<td></td>
<td>Summer 2000</td>
<td></td>
</tr>
<tr>
<td>ALI-1S</td>
<td>NAP EO-1</td>
<td>VIS/NIR/ SWIR</td>
<td>315</td>
<td>30 m</td>
<td></td>
<td>Summer 2000</td>
<td></td>
</tr>
<tr>
<td>IRMSS</td>
<td>CBERS-1</td>
<td>VIS, NIR SWIR TIR</td>
<td>2 1</td>
<td>80m 80m 160 m</td>
<td></td>
<td>26 days</td>
<td>1999</td>
</tr>
<tr>
<td>CCD Camera</td>
<td>CBERS-1</td>
<td>PAN VIS,NIR</td>
<td>1 4</td>
<td>20m 20m</td>
<td>113 km</td>
<td>26 days</td>
<td>1999</td>
</tr>
</tbody>
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</thead>
<tbody>
<tr>
<td>Carea</td>
<td>NIKK-Kuban</td>
<td>VIS,NIR</td>
<td>1</td>
<td>2 m (at 250 km altitude)</td>
<td>0.43 of orbit altitude</td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Gemma (Camera)</td>
<td>NIKK-Kuban</td>
<td>VIS,NIR</td>
<td>9</td>
<td>3 - 5 m (at 250 km altitude)</td>
<td>0.43 of orbit altitude</td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Orbview-4</td>
<td>Orbview-4</td>
<td>PAN, VIS/NIR, VIS/NIR/ SWIR</td>
<td>1</td>
<td>1 m</td>
<td>8 km</td>
<td>&lt; 3 days</td>
<td>2001</td>
<td></td>
</tr>
<tr>
<td>M10</td>
<td>Resource 21</td>
<td>VIS,NIR, SWIR</td>
<td>4</td>
<td>10 m 20m-100 m</td>
<td>205 km</td>
<td>3-4 days</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>LISS-IV</td>
<td>IRS-P6 Resoscat</td>
<td>VIS,NIR, SWIR</td>
<td>7</td>
<td>6 - 23 m</td>
<td>40 km</td>
<td></td>
<td>2001, 2002</td>
<td></td>
</tr>
<tr>
<td>AWIFS</td>
<td>IRS-P6 Resoscat</td>
<td>VIS, SWIR</td>
<td>3</td>
<td>70 m</td>
<td>142 km</td>
<td></td>
<td>2001, 2002</td>
<td></td>
</tr>
<tr>
<td>Imaging Spectrometer</td>
<td>ARIES-1</td>
<td>VIS,NIR, SWIR</td>
<td>32</td>
<td>30 m (at nadir)</td>
<td>15 km</td>
<td></td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Panchromatic Sensor</td>
<td>ARIES-1</td>
<td>PAN</td>
<td>1</td>
<td>10 m (at nadir)</td>
<td>70 km</td>
<td>5 days</td>
<td>2000</td>
<td></td>
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ANNEX

SENSORS CHARACTERISTICS
## High Resolution Imagers

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Spectral range</th>
<th>Number of channels</th>
<th>Spatial Resolution</th>
<th>ImageFrame/Swath width</th>
<th>Repeat Cycle</th>
<th>Launcher Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRG-P</td>
<td>SPOT5a SPOT 5b</td>
<td>PAN (stereor)</td>
<td>1</td>
<td>2.5 and 5m</td>
<td>60 km</td>
<td></td>
<td>2002 2004</td>
</tr>
<tr>
<td>HRG-X</td>
<td>SPOT5a SPOT 5b</td>
<td>VIS,NIR WIR</td>
<td>3</td>
<td>10 m 20 m</td>
<td>60 km</td>
<td></td>
<td>2002 2004</td>
</tr>
<tr>
<td>PRISM</td>
<td>ALOS</td>
<td>PAN</td>
<td>1</td>
<td>3 m</td>
<td></td>
<td></td>
<td>2003</td>
</tr>
<tr>
<td>AVNIR-2</td>
<td>ALOS</td>
<td>VIS,NIR</td>
<td>4</td>
<td>10-15 m</td>
<td>70 km</td>
<td></td>
<td>2003</td>
</tr>
</tbody>
</table>

**ANNEX**

**SENSORS CHARACTERISTICS**
# Imaging Multispectral Radiometers

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Spectral range</th>
<th>Number of channels</th>
<th>Spatial Resolution</th>
<th>Image Frame / swath width</th>
<th>Repeat Cycle</th>
<th>Repeat Coverage</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>DMSP F1-F14</td>
<td>VIS/NIR TIR</td>
<td>1 1</td>
<td>560 m (fine) 2700 m (smoothed)</td>
<td>3000 km</td>
<td>12 hours</td>
<td></td>
<td>1976</td>
</tr>
<tr>
<td>AVHRR</td>
<td>NOAA-POES 9-14</td>
<td>VIS, NIR, MWIR, TIR</td>
<td>2 1 2 2</td>
<td>1100 m 1000 m 1000 m 20000 m</td>
<td>2400 km</td>
<td>12 hours</td>
<td></td>
<td>1982</td>
</tr>
<tr>
<td>ATSR-1</td>
<td>ERS-1</td>
<td>SWIR TIR MW</td>
<td>2 2 2 2</td>
<td>1000 m 1000 m 20000 m 500 km</td>
<td>600 km 14 days</td>
<td>4 days (0° lat) 2 days (50° lat)</td>
<td>1991</td>
<td></td>
</tr>
<tr>
<td>MSU-SK</td>
<td>Resurs-01 #3</td>
<td>VIS, NIR TIR</td>
<td>4 1 600 m 600 m</td>
<td>170 m 600 m</td>
<td>600 km</td>
<td>14 days 2 days (50° lat)</td>
<td>1994</td>
<td></td>
</tr>
<tr>
<td>ATSR-2</td>
<td>ERS2</td>
<td>VIS,NIR SWIR TIR MW</td>
<td>2 2 2 2</td>
<td>1000 m 1000 m 1000 m 20000 m</td>
<td>500 km</td>
<td></td>
<td>1995</td>
<td></td>
</tr>
<tr>
<td>WiFS</td>
<td>IRS-1C IRS-1D</td>
<td>VIS, NIR</td>
<td>2</td>
<td>188.3 m 810 km</td>
<td>16 days 5 days</td>
<td>5 days</td>
<td>1996 1997</td>
<td></td>
</tr>
<tr>
<td>AVHRR/3</td>
<td>NOAA-K(15)</td>
<td>VIS, NIR, MWIR, TIR</td>
<td>2 2 1</td>
<td>1100 m ca 3000 km</td>
<td>500 km</td>
<td>12 hours</td>
<td>May 1998</td>
<td></td>
</tr>
<tr>
<td>VEGETATION</td>
<td>SPOT-4</td>
<td>VIS, NIR SWIR</td>
<td>3 1 1150 m 2200 km</td>
<td>2200 km 26 days</td>
<td>1 day (&lt;35° lat)</td>
<td></td>
<td>1998</td>
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## Current and Future Sensors - Imaging MS Radiometers

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Spectral range</th>
<th>Number of channels</th>
<th>Spatial Resolution</th>
<th>Image Frame (Swath width)</th>
<th>Repeat Cycle</th>
<th>Repeat Coverage</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSU-SK1</td>
<td>Resurs-01 #4</td>
<td>VIS, NIR SWIR TIR</td>
<td>4 1 1</td>
<td>225 m 810 m 810 m</td>
<td>714 km</td>
<td>16 days</td>
<td></td>
<td>July 1998</td>
</tr>
<tr>
<td>POLDER</td>
<td>ADEOS-I</td>
<td>VIS, NIR</td>
<td>15</td>
<td>6000 m</td>
<td>2400 km</td>
<td>41 days</td>
<td></td>
<td>Aug 1996 to Jul 1997</td>
</tr>
<tr>
<td>OCTS</td>
<td>ADEOS-I</td>
<td>VIS, NIR SWIR TIR</td>
<td>8 2 2</td>
<td>700 m</td>
<td>1400 km</td>
<td>41 days</td>
<td>3 days</td>
<td>Aug 1996 to Jul 1997</td>
</tr>
<tr>
<td>VIRS</td>
<td>TRMM</td>
<td>VIS SWIR TIR</td>
<td>1 2 2</td>
<td>2000 m 8000 m 8000 m</td>
<td>720 km</td>
<td>1 day</td>
<td></td>
<td>1997</td>
</tr>
<tr>
<td>SeaWIFS</td>
<td>OrbView-2</td>
<td>VIS,NIR</td>
<td>8</td>
<td>1100 m 4500 m</td>
<td>1500 km 2800 km</td>
<td>1 day</td>
<td></td>
<td>July 1997</td>
</tr>
<tr>
<td>MODIS</td>
<td>Terra (EOS-A01)</td>
<td>VIS,NIR, SWIR, TIR</td>
<td>36</td>
<td>250 - 1000 m</td>
<td>2330 km</td>
<td>&lt; 2 days</td>
<td></td>
<td>Dec 1999</td>
</tr>
<tr>
<td>WIS</td>
<td>NWP EO-1</td>
<td>NIR SWIR</td>
<td>103 216</td>
<td>30 m</td>
<td></td>
<td></td>
<td></td>
<td>Summer 2000</td>
</tr>
<tr>
<td>MERIS</td>
<td>EnVISAT-1</td>
<td>VIS,NIR</td>
<td>15</td>
<td>300 m (1200 m)</td>
<td>1150 km</td>
<td></td>
<td>&lt; 3 days</td>
<td>June 2001</td>
</tr>
<tr>
<td>AATSR</td>
<td>EnVISAT-1</td>
<td>VIS,NIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>June 2001</td>
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### ANNEX

**SENSORS CHARACTERISTICS**
## Current and Future Sensors - Imaging MS Radiometers

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Bands</th>
<th>Channels</th>
<th>Spatial Resolution</th>
<th>Repeat Cycle</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLI</td>
<td>ADEOS-II</td>
<td>VIS,NIR, SWIR, TIR</td>
<td>23/7/9</td>
<td>250-1000m / 250-1000m / 1000m</td>
<td>1600 km</td>
<td>2000</td>
</tr>
<tr>
<td>POLDER</td>
<td>ADEOS-II</td>
<td>VIS, NIR</td>
<td>15</td>
<td>6000 m</td>
<td>2400 km</td>
<td>2000</td>
</tr>
<tr>
<td>MODIS</td>
<td>EOS-PM</td>
<td>VIS, NIR, SWIR, TIR</td>
<td>36</td>
<td>250 - 1000 m</td>
<td>2330 km</td>
<td>&lt; 2 days Dec 2000</td>
</tr>
<tr>
<td>VEGETATION</td>
<td>SPOT-5a, SPOT-5b</td>
<td>VIS, NIR, SWIR</td>
<td>3/1</td>
<td>1000 m / 1000 m</td>
<td>2200 km / 2200 km</td>
<td>2002 / 2004</td>
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</table>
## Current and Future Sensors - Microwave

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Spectral range</th>
<th>Number of channels</th>
<th>Spatial Resolution</th>
<th>Image Frame / Swath width</th>
<th>Repeat Cycle</th>
<th>Repeat Coverage</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSM/I</td>
<td>DMSP F8-14</td>
<td>MW</td>
<td>7</td>
<td>15 to 60 km</td>
<td>1400 km</td>
<td>12 hours</td>
<td></td>
<td>1987</td>
</tr>
<tr>
<td>RM-0.8</td>
<td>OCEAN 01 N7</td>
<td>MW</td>
<td>5</td>
<td>20 km</td>
<td>550 km</td>
<td></td>
<td></td>
<td>1994</td>
</tr>
<tr>
<td>AMSR</td>
<td>ADEOS-II</td>
<td>MW</td>
<td>16</td>
<td>5 km to 50 km</td>
<td>1600 km</td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>AMSR-E</td>
<td>EOS-M1</td>
<td>MW</td>
<td>6</td>
<td>7 to 75 km</td>
<td>1445 km</td>
<td></td>
<td></td>
<td>Dec 2000</td>
</tr>
<tr>
<td>MSMR</td>
<td>IRS-P4 (OCEANSAT-1)</td>
<td>MW</td>
<td>4</td>
<td></td>
<td>1360 km</td>
<td></td>
<td></td>
<td>1999/2000</td>
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</tbody>
</table>

**ANNEX**

**SENSORS CHARACTERISTICS**
### Current and Future Sensors - Microwave

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Platform</th>
<th>Spatial Resolution</th>
<th>Repeat Cycle</th>
<th>Repeat Coverage</th>
<th>Launch or Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI-SAR</td>
<td>ERS 1</td>
<td>C-BND-VV</td>
<td>25 m</td>
<td>100 km</td>
<td>35 days</td>
</tr>
<tr>
<td></td>
<td>ERS 2</td>
<td></td>
<td>1</td>
<td></td>
<td>16 days</td>
</tr>
<tr>
<td>RLSBO (RAR)</td>
<td>OCEAN-01 N7</td>
<td>X-BND</td>
<td>1.5 - 2 km</td>
<td>450 km</td>
<td>1994</td>
</tr>
<tr>
<td>SAR</td>
<td>Radarsat-1</td>
<td>C-BND HH</td>
<td>6 to 28 m</td>
<td>50 to 150 km</td>
<td>24 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>2-5 days (0° lat)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-1.5 days (60° lat)</td>
</tr>
<tr>
<td>SAR</td>
<td>JERS-1</td>
<td>L-BND HH</td>
<td>18 m</td>
<td>75 km</td>
<td>44 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>Feb 1992 to Oct 1998</td>
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<tr>
<td>SRTM</td>
<td>SpaceShuttle</td>
<td>C, L, X- BND</td>
<td>12.5 m</td>
<td>50 km</td>
<td>Sept 1999</td>
</tr>
<tr>
<td>Light SAR</td>
<td>Light SAR</td>
<td>L-BND HH, HV, VH, VV</td>
<td>1 (polarimetric)</td>
<td></td>
<td>End 1999</td>
</tr>
<tr>
<td>ASAR</td>
<td>ENVISAT</td>
<td>C-BND</td>
<td>30 to 150</td>
<td>56 to 406 km</td>
<td>35 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>3 days with beam steering</td>
</tr>
<tr>
<td>SAR</td>
<td>Radarsat-2</td>
<td>C-BND HH, VV HV &amp; VH</td>
<td>10 - 100 m</td>
<td>10 - 500 km</td>
<td>24 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1-2 days (&gt;48° lat)</td>
</tr>
<tr>
<td>PALSAR</td>
<td>ALOS</td>
<td>L-BND</td>
<td>10 - 100 m</td>
<td>350 km</td>
<td>2003</td>
</tr>
</tbody>
</table>

**ANNEX**

**SENSORS CHARACTERISTICS**
The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.
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