Earth remote sensing systems of middle and low resolution

Serial on-line remote sensing satellites delivering data available on the world market

V.I. Gershenzon (ScanEx R&D Center)
In 1980, graduated from the Moscow Institute of Physics and Technology with major in radio physics. Ph.D. candidate (physics & mathematics). General Director of ScanEx R&D Center. Area of interests: Earth remote sensing data access and processing technology.

A.A.Kucheiko (ScanEx R&D Center)
In 1982, graduated from the Military Space Engineering Institute with major in radio electronics. ScanEx R&D Center expert. Ph.D. (tech.) candidate. Area of interests: Earth remote sensing systems.

When classifying satellites in terms of their performance, we can discriminate serial operational satellites from experimental ones for testing new Earth remote sensing equipment. The article describes serial operational satellites, which data is available on the international market to any user, with the emphasis on the scanners, allowing for the generation of Earth surface images in visible and infra-red bands without micro-wave radiometers of low resolution.

Earth remote sensing systems of middle resolution

The middle resolution remote sensing data market (10-250 m) was created back in the 80s of the XX century based on the Landsat data of natural resources monitoring and became dominant in the 90s after the manufacturing of competing satellites in other countries (SPOT – France, IRS-1C, 1D – India and Resurs-O1 – Russia).
Despite a quick increase in the market of high resolution images, middle resolution data is still irreplaceable in resolving the tasks of emergency and disaster areas monitoring, natural resources exploration, forestry, agricultural and environmental control, etc.

Table 1. Satellites with the middle resolution imaging equipment

Satellite (country)	Imaging equipment	Resolution, m	Swath width, km	Revisit period, days
Global imaging with a long revisit period				
Landsat-7 (USA)	ETM+	15, 20, 60	185	16
SPOT-2, -4, -5 (France)	HRV_IR HRG	20 5, 10, 20	60–120	2–3 (±27°)
IRS_1C, _1D и IRS_P6 (India)	LISS_3 WiFS AWiFS (P6)	23, 70 188 65	142–148 810 740	24 5 5
«Meteor_3M»_1	MSU-E	50	76	5
CBERS_2A, _2B (last one — 2006) (China, Brazil)	CCD IRMS WFI	20 80 256	113 120 885	3 (±32°) 15 5
DMC II (Britain, Algeria, Nigeria, Turkey and others)	6-camera Optoelectronic Complex	32	600	1 (four satellites fleet)
"Monitor-E" (per plan for 2005-2006)	Optoelectronic Complex	8, 20/40	160	-
Radar imaging				
ENVISAT_1 (European countries)	ASAR	30–1000	100–400	3–4
ERS-2 (Europe)	AMI SAR	30–50	100	12
RADARSAT_1 (Canada)	SAR	10–100	50–500	3–6
RADARSAT_2 (Canada) (per plan for 2006)	SAR	3–100	10–500 in two tracks of 500 km	3–6
ALOS (Japan) (per plan for 2005)	PALSAR	10–100	70–250	5
TerraSAR_X1 (Germany) (plan for 2006)	X_SAR	1–15	10–100	2

Satellites with middle resolution imaging equipment can be classified as follows (Table 1):

- Satellites of **Landsat class** for global imaging with long revisit periods (Landsat-5, -7, SPOT, IRS);
- **Radar imaging satellites** (RADARSAT-1, ERS-2, ENVISAT-1).

Besides, many world countries use experimental mini- and macro-satellites with middle resolution imaging equipment onboard (for hyper-spectral imaging as well).

Fig. 1 Typical example of middle resolution class – American Landsat-7 satellite. Starting in 2003 image sales dropped due to ETM+ scanner malfunctioning

Satellites of Landsat class

Satellites of the **global imaging with a long revisit period of the Landsat class** are the backbone of the middle resolution images market. (Landsat-7, fig. 1, IRS-1C/1D, -P6 and SPOT-2, -4, -5). Serial middle resolution satellites are being developed under the budget-funded governmental programs (SPOT satellites after being launched are handed in to the commercial operator – SPOT Image, where the government department – French Space Agency – plays a crucial role). The NASA and USGS agencies (Landsat systems operators) have failed to draw in private companies to participate in the new LD-CM project to replace Landsat-7 after 2007. Landsat-7 data sales dropped due to a failure on the ETM+ scanner and the demand on IRS-P6 and SPOT data increased as a result. Chinese and Brazilian CBERS-2B and international DMC system data will become available in the nearest future. In 2009, the NPOESS C-1 satellite might be launched with the Landsat type scanner onboard.

The drawback of the Landsat class satellite – a quite long revisit period – is compensated for by the rotation of the optical camera, by optical systems with wide-field imaging modes and by multi-satellite fleets of contemporary and perspective systems. Serial satellites, designed on the basis of mini- and micro-platforms, will do middle resolution imaging in the future.

Fig. 2. The biggest and the most expensive RS satellite in the world – the European giant ENVISAT-1. ESA refuses to launch such bulky satellites in the future

Middle resolution SAR satellites

Satellites with **synthetic aperture radars (SAR)** are very close to the Landsat series in certain specifications (resolution, swath width). They provide for the imagery with middle resolution of 10-100 m at swath width of 100-500 km. Canadian **RADARSAT-1** and European **ERS-2** and **ENVISAT-1** satellites (fig. 2) are used for commercial purposes.
In 2005-2007, at least four new commercial radar satellites will be launched: **ALOS** with a L-band SAR (Japan, JAXA agency); **RADARSAT-2** with a C-band SAR of high resolution (Canada); dual purpose **COSMO** satellite with a X-band SAR (Italy); commercial **TerraSAR-X1** (Germany) with a X-band SAR of 1 m resolution.

In the visible future the considerable increase in number of SAR satellites will be lead to a further increase in sales and to a drop of radar imaging equipment prices (fig. 3). The main areas of application are: ecological monitoring, emergency situations control, oil & gas field exploration, navigation and fishery monitoring, agriculture, insurance, cartography, construction. Business activities, connected with GIS- applications and digital elevation models (DEM), will experience further development.

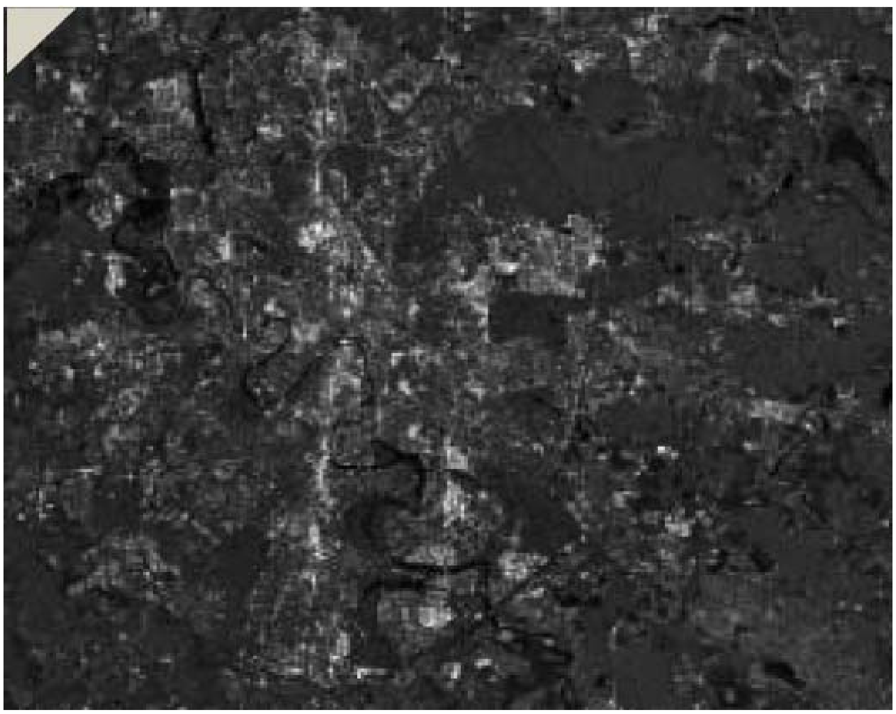

Fig. 3. Radar image of Moscow, acquired on September 6, 2004 from RADARSAT-1 satellite by the Moscow UniScan-36 ground station (8 m resolution). RADARSAT Data © Canadian Space Agency/Agence spatiale canadienne 2004. Distributed under license by RADARSAT International, Inc. All rights reserved. Data received and processed by RDC ScanEx

Basic trends in sphere of radar imaging:

- improvement of radar equipment resolution up to **1-3 m** (RADARSAT-2, COSMO, TerraSAR);
- possibilities of polarimetric imaging in several channels at the same time with the signals of different polarization (ENVISAT-1, RADARSAT-2, ALOS, TerraSAR);
- increase in demand for pairs and triplets of radar images for **interferometric processing** to create 3-D DEMs, to study elevation changes, etc.

Middle resolution satellite data is downlinked during the communication passes to a network of ground receiving station in X-band (at an average rate of 50-150 Mbps). Space systems of middle resolution use a centralized data distribution together with pre-coordinated activities of large networks of ground stations abroad. Usually, the ground stations are equipped with a bulky parabolic antenna of a 7-20 m diameter, costing 10-20 million dollars. However, ScanEx R&D Center has recently developed a technique allowing for the middle resolution data reception by a much cheaper universal UniScan stations with ∅2.4-3.6 m antennas.

Low resolution remote-sensing systems and meteosystems

Satellites with low resolution wide field of view systems (over 250 m) provide for the collection of data, required for weather forecasts, integral assessment of ocean surface, land cover, soil, forests and ice conditions. Images are made in several spectral bands at the same time, which are selected depending on the data thematic application.

Low resolution data market is formed based on the imaging data of meteo-satellites on polar and geo-stationary orbits. Current meteosystems are funded by the state budget. Additional segment of the low resolution data market is occupied by the satellites with wide-field-of-view multi-channel optical sensors for global imaging of ocean surfaces, land cover, etc. Certain sensors have been designed under commercial programs.

Table 2. Basic operational imagery satellites with low resolution sensors

Satellite (country)	**Sensors**	**Spatial resolution, km**	**Swath width, km**	**Number of spectral channels**
NOAA-12, 14, 15, 16, 17 (USA)	AVHRR	1 and 4	3000 3000	5
FY-1D (China)	MVISSR	1, 1 and 4	3000	10
Earth global imagery				
Terra, Aqua (USA)	MODIS	0,25; 0,5; 1	2330	36
ENVISAT-1 (Europe)	MERIS	0,3-1,2	1150	15
SPOT-4, -5 (France)	Vegetation	1	2200	4
Meteor-3M – 1 (Russia)	MSU-SM	0,13-2,4	2250	2
Sich-1M (Russia-Ukraine)*	MSU-M	1,5-1,7	2000	4
Ocean surface imagery				
OrbView-2 (USA)	SeaWiFS	1	1500-2800	8
IRS-P4 (India)	OSM	0,24-0,5	1420	8
Kompsat-1 (Korea)	OSMI	0,85	800	6
HY-1 (China)	COCTS	1,1	1400	8

* Service plans unknown

Low resolution satellites can be divided into three basic categories (Table 2):

- **Low orbit and geostationary meteo-satellites** from the USA, Russia, China, Europe, India and Japan with the sensors of 1-8 km resolution to deliver “big pictures” of the Earth;
- **Global operational imagery** satellites with low resolution wide-field-of-view sensors (250-1000 m): Terra, Aqua (MODIS), ENVISAT/MERIS, as well as the satellites for land cover imagery (SPOT/Vegetation scanners, Meteor/MSU-SM, etc.);
- Special satellites with multi-channel equipment for **ocean surface imagery** manufactured in the USA, India, China and Taiwan.

Low orbiting meteo-satellites

Meteo-data from the American NOAA (two operational and two backup satellites), military DMSP (data available via NOAA server) and Chinese FY-1D satellites became very popular worldwide. Main radiometric equipment of the meteo-satellites was created in 70-80s of the XX century and provide for the 1 and 4 km resolution data downlink using international APT and HRPT formats.
In 2006-2009, a new generation of meteo-satellites will enter the scene (NPOESS, METOP, FY-3, Meteor-M) with the sensors delivering more accurate information (maximum resolution will increase up to 250-400 m). The USA and European countries are going to create an integrated meteosystem based on NPOESS and METOP satellites.

Low resolution satellites for global operational imagery

Satellites for global operational imagery with wide-field multispectral optical systems are placed between the middle resolution satellites of Landsat class and the meteo-satellites with the spatial resolution of 250-1000 m, providing for the data collection for different purposes: ocean, land and ice cover research work; study of atmosphere, clouds, humidity distribution, etc.

Fig. 4. American Terra satellite, like the Aqua satellite, manufactured under the EOS program. The satellites became very popular worldwide due to free MODIS data

The most popular are the data of the 36-channel MODIS radiometer (Moderate Resolution Imaging Spectroradiometer), installed on the Terra and Aqua satellites (fig.4). These satellites were designed under the global EOS program, managed by NASA starting from the 80s. The data with 250-1000 m resolution are downlinked and distributed in the direct broadcast mode for free and are used in different areas (weather forecasts, ecological monitoring, detection of fires, geology, etc.) (fig.5). Availability, efficiency and practical value of these MODIS scanners boosted the creation of an international network of around 90 receiving stations. A new VIIRS scanner will be manufactured in the nearest future based on the MODIS spectroradiometer for NPP and NPOESS meteorological satellites with 400-800 m resolution.

Fig. 5. Ice situation in the Gulf of Finland and on the Lake Ladoga, according to the MODIS scanner data from Terra satellite (February 9, 2005, resolution 250 m)

French (SPOT/Vegetation), European (ENVISAT/MERIS) and Indian (IRS/WiFS) satellites are used for **low resolution land surface imagery**.

Satellites for ocean surface imagery

The main tasks of such imagery – assessment and development of ocean resources, fishery information support, ecological monitoring, natural and environmental disasters response. Satellites are operated by the countries with dashing economic activities in the oceans: the USA (**OrbView**-2/SeaWiFS), India (IRS-P3/**MOS, IRS-P4/OCM**), Korea (KompSat-1/**OSMI**), Taiwan (ROCSat-1) and China (HY-1/**COCTS** and **CZI**).

Table 3. Distribution of the direct readout ground receiving stations worldwide

Satellite	DB format	Number of stations in the world	Station average cost, $US
NOAA–POES	APT HRPT	Более 10 000 1500	3000 30 000–50 000
Terra, Aqua	MODIS	~90	300 000

The tasks of offshore zone imagery in Russia were supposed to be resolved using the "Sich-1M" radar satellite with side look (resolution 1,3-2,5 km with a swath width of 450 km) and MSU-M and MSU-ES radiometers. In 2004, the satellite was put into a wrong orbit and the plans of its further operation are not clear yet.
The low resolution data market has schemes with direct circular data transmission to the customers (Direct Broadcast – DB) in VHF-, L- and X-bands. Most of the operators enjoy a free access to meteo data in APT, HRPT and MODIS formats (under EOS program). Thanks to the combination of a free data access and direct broadcast, the market segment of "big picture" images is the most popular and democratic (Table 3). Special data of some sensors (for oceanology, vegetation studies, etc.) is payable, for example, OrbView-2/SeaWiFS, ENVISAT-1/MERIS, SPOT/Vegetation satellites data.
Further development of the low resolution data market segment depends on the increase in the information value of meteodata, therefore a transition to new digital formats (LRPT, LRD, AHRPT and so on) is expected. Production of special low resolution scanners for quick assessment of the land cover and ocean resources' parameters will be carried on.

Phone: +7 (495) 939-56-40, 246-38-53
Fax: +7 (495)-939-42-84, 246-25-93
22/5 L'va Tolstogo Street, Moscow, 119021, Russia
e-mail: info@scanex.ru
Internet: www.scanex.com