CONTRIBUTION OF THE INDIAN IRS PROGRAM TO THE EUROPEAN DATA REQUIREMENTS THROUGH EUROMAP

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ABSTRACT

The IRS program includes a series of EO satellites operating in the optical domain at various resolution levels ranging from MR through HR to VHR. Euromap has, in close cooperation with the German Aerospace Center (DLR), a long-standing tradition in receiving, processing and exclusively distributing data from these systems into Europe.

The technical set up of the above mentioned cooperation and the sensor characteristics of commercial IRS systems which are currently being used by various GMES and other European activities will be presented. Experiences derived from past and ongoing project activities will be discussed including an appraisal of the possible future role of upcoming IRS EO satellites for European data requirements.

1. INTRODUCTION

India's space activities started during the early 1960's with investigations of the upper atmosphere and ionosphere [1]. In 1969, the Indian Space Research Organisation (ISRO) was formed, and the first indigenous Indian satellite Aryabhata was launched from the Volgograd launch station in 1975 [2]. In 1988, the Indian Remote Sensing (IRS) satellite system was commissioned with the launch of IRS-1A [3]. ISRO has successfully operationalised the Polar Satellite Launch Vehicle (PSLV), the Geostationary Satellite Launch Vehicle (GSLV), the Indian National Satellites (INSAT) for communication services, and the Indian Remote Sensing (IRS) satellites for management of natural resources [1].

The IRS satellite system is one of the largest constellations of remote sensing satellites in operation in the world today. The IRS programme, commissioned with the launch of IRS-1A in 1988, presently includes eleven satellites that continue to provide imagery in a variety of spatial resolutions from 1 m to 180 m [4].

Through several data reception agreements with Antrix, the commercial arm of ISRO, Euromap became the first and only actor in Europe to successfully receive, archive and market Indian Earth observation satellite data. Current agreements with Antrix and EOTec, an agent of Antrix, grant Euromap the right to receive and exclusively distribute data from IRS-P6 Resourcesat-1 and IRS-P5 Cartosat-1 in Europe, including Turkey, and northern Africa.

Through recent agreements with the European Space Agency (ESA), historical (IRS-1C, IRS-1D) and recent (Resourcesat-1, Cartosat-1) worldwide IRS data and related services are made available to the GMES user community. Through Euromap, the IRS program significantly contributed to activities like Image2006, Image2009 and Monitoring Agriculture with Remote Sensing (MARS).

The German Aerospace Center (DLR) is Euromap's long-term partner regarding reception and archiving activities, as well as the development of interfaces towards ESA.

2. TECHNICAL SETUP OF COOPERATION

Shortly after the foundation of Euromap in 1996, DLR and Euromap entered into a cooperation agreement. This cooperation agreement was amended to cover mission specifics regarding the reception of raw data from the Indian remote sensing missions IRS-1C, IRS-1D, IRS-P6 Resourcesat-1 and IRS-P5 Cartosat-1, to facilitate the joint development of a DEM processing chain, and to integrate the Neustrelitz IRS ground segment into ESA's Coordinated Data access System (CDS) infrastructure.

2.1. Data Reception

As Antrix's partner in Europe, Euromap is responsible for the acquisition planning, reception, archiving, processing, marketing and distribution of IRS data.

The data reception is performed through DLR's German Remote Sensing Data Center (DFD) at its multi-mission ground station in Neustrelitz, approximately 100 km north of Berlin. Besides data from several other

missions received for other clients, DFD currently receives data from IRS-P6 Resourcesat-1 and IRS-P5 Cartosat-1 for Euromap.

DFD's multi-mission ground station employs three 7.3 m X-band and several smaller antennas. The highly flexible ground station permits the fast allocation of antennas, demodulators, bit synchronisers and direct archive systems in several combinations through a programmable high-frequency matrix.

2.2. Development of DEM Products

The IMF, GAF AG and Euromap cooperate regarding the development of Digital Elevation Model (DEM) products based on IRS-P5 Cartosat-1 in flight stereo data.

The core of the DSM generation process is implemented as part of the DLR XDibias image processing system. The main processing steps are discussed in [5].

The Indian L1 Data Product Generation System (DPGS) for system corrected products, the XDibias DSM processor, as well as manual editing and quality control processes are currently integrated into Euromap's Production Management System (PMS). The PMS will control the whole production workflow.

The main role of GAF AG is to provide the user perspective during product definition and to perform the accuracy evaluation of the developed products.

A test using 21 single scenes scattered across Europe, processed without block adjustment, confirmed a horizontal accuracy CE90 of 7.7 m and a vertical accuracy LE90 of 5.1 m relative to available GPS tracks. Results of further tests are presented in [6].

2.3. IRS and GMES Space Component Data Access

In the frame of the Global Monitoring for Environment and Security (GMES) Space Component Data Access (GSC-DA) project, DLR and Euromap formed a consortium under the leadership of Euromap to integrate the IRS ground segment into the GSC-DA infrastructure and to make IRS data therewith accessible to the GMES user community.

The development of interfaces towards the ESA Coordinated Data access System (CDS) is performed in cooperation with the DFD. One of DFD's major tasks is the migration of the IRS catalogue service and its interfacing with the CDS Core Infrastructure (CDS-CI).

DLR's Institute for Remote Sensing Methodology (IMF) in Oberpfaffenhofen is the partner with respect to the orthorectification of IRS data. An XDibias-based ortho processing system, established in the frame of the Image2006 project [7, p. 19] and operated by the IMF in Oberpfaffenhofen, was integrated into the Euromap Production Management System (PMS). The PMS and ortho processing system were successfully used to orthorectify large amounts of Resourcesat-1 LISS-III data for the European wall-to-wall coverage 2009 [DAP-S_V1.0_S2_P_001] and AWiFS data for the Europe land cover of forests [DAP-S_V1.0_S2-S3_P_004].

3. CONTRIBUTION OF THE IRS PROGRAM TO EUROPEAN DATA REQUIREMENTS

Through framework contracts with the Joint Research Center (JRC) of the European Union, Euromap contributed IRS data to several EU projects. LISS-III data were continuously supplied to the EU's agricultural subsidy control programs since 1997.

The European Space Agency (ESA) and Euromap signed a GMES Space Component Data Access (GSC-DA) agreement in May 2009. Through this agreement European and world-wide IRS data are accessible to the GMES user community. The agreement covers optical remote sensing data from the current IRS-P6 Resourcesat-1 and IRS-P5 Cartosat-1 missions, as well as historical data from IRS-1C and IRS-1D.

3.1. Historical Data

Optical remote sensing data from the missions IRS-1C and IRS-1D were acquired through the Neustrelitz ground station between June 1996 and September 2005. Both missions were identical in construction and carried the payload indicated in Table 1 and further detailed in [8] and [9]. As a result of a systematic acquisition strategy, the Euromap archive contains multiple complete coverages of Europe from all sensors.

Table 1: IRS-1C and IRS-1D payload characteristics

Sensor	Bands	Resolution [m]	Swath [km]	Quantisation [bits]
PAN	pan	5.8	70	6
LISS-III	green red NIR SWIR	23 23 23 70	140	7
WiFS	red NIR	188	810	7

3.2. Data from Current IRS Missions

The series of optical EO missions within the IRS program was continued with the launch of IRS-P6 Resourcesat-1 in October 2003. Data from its improved payloads were acquired by Euromap since 2004. The cameras main characteristics are provided in Table 2 and [10]. Most interesting is the fixed-track Advanced Wide Field Sensor (AWiFS) with its combination of 56 m resolution at nadir and a repetition rate of 5 days at the equator.

Table 2: IRS-P6 Resourcesat-1 payload characteristics

Sensor	Bands	Resolution [m]	Swath [km]	Quantisation [bits]
LISS-IV Mono mode	red	5.8	70	7
LISS-IV MX mode	green red NIR	5.8	23.9	7
LISS-III	green red NIR SWIR	23	140	7
AWiFS	green red NIR SWIR	56 (nadir) … 70 (edge)	740	10

With IRS-P5 Cartosat-1, launched in May 2005, an in-flight stereo mission was added to the fleet. The cameras main characteristics are provided in Table 3 and [11].

Table 3: IRS-P5 Cartosat-1 payload characteristics

Sensor	Tilt along track [°]	Resolution [m]	Swath [km]	Quantisation [bits]
PAN-Fore	+26	2.5	30	10
PAN-Aft	-5	2.2	27	10

3.3. Upcoming IRS EO Missions

The next mission to be added to the fleet of IRS EO missions is Resourcesat-2, whose launch is currently scheduled for the third quarter of 2010. Compared to its predecessor Resourcesat-1, Resourcesat-2 will have two major improvements. The LISS-III camera will work with 10 bit quantisation like the AWiFS, and the swath of the LISS-IV camera in the multispectral MX mode will be 70 km. The major payload characteristics are indicated in Table 4. LISS-IV will have an off-nadir viewing capability of ±26°, leading to a revisit capability of 5 d at the equator. The repetition rate of LISS-III will be 24 d and that of AWiFS will be 5 d at the equator.

With its combination of three multispectral cameras of different spatial and timely resolutions, Resourcesat-2 will be a valuable tool for all kinds of monitoring applications and assure data continuity until 2015.

A Resourcesat-3 mission is already in an early planning stage and has to be confirmed by the Indian government.

Table 4: Resourcesat-2 payload characteristics

Sensor	Bands	Resolution [m]	Swath [km]	Quantisation [bits]
LISS-IV Mono mode	red	5.8	70.3	7
LISS-IV MX mode	green red NIR	5.8	70.3	7
LISS-III	green red NIR SWIR	23	141	10
AWiFS	green red NIR SWIR	56 (nadir) … 70 (edge)	740	10

Planned for 2011 is the launch of the radar imaging satellite RISAT-1, which follows the launch of RISAT-2 in April 2009. RISAT-1 will have a multi-frequency synthetic aperture radar (SAR), capable of operating in Scansar Mode, Strip Map Mode and Interferometry Mode.

A technology development initiative has been initiated for Cartosat-3A and Cartosat-3B. Each will simultaneously provide data with a spatial resolution of 0.5 m in panchromatic and 2 m in multispectral mode with 10 bit radiometry over a swath of 15 km. Cartosat-3A, planned to be launched in 2013, has been submitted for government approval.

A follow-up for the Cartosat-1 in-flight stereo mission is currently under discussion.

ISRO also plans to launch two hyperspectral imaging satellites in 2013 and 2014. The GEO-HR-Imaging Satellite will have about 210 spectral bands in the VNIR and SWIR with resolutions of 320 m and 192 m respectively. In planning stage is also a Hyperspectral Imager Satellite with 50 m spatial resolution and a swath of 30 km for 64 bands in the VNIR and 64 bands in the SWIR portion of the electromagnetic spectrum.

4. APPLICATIONS AND PROJECT EXPIRIENCES

4.1. GMES Fast Track Land Service Image2006

Through a consortium with Spot Image as the prime contractor, Euromap provided a large amount of IRS-P6 Resourcesat-1 LISS-III data for the two multispectral coverages of the Image2006 project in the frame of the GMES Fast Track Land Service.

The quick look mosaics in Figure 1 and Figure 2 show the LISS-III pre-selections of the 2005 and 2006 data according to the selection criteria plus some 2007 gap fillers.

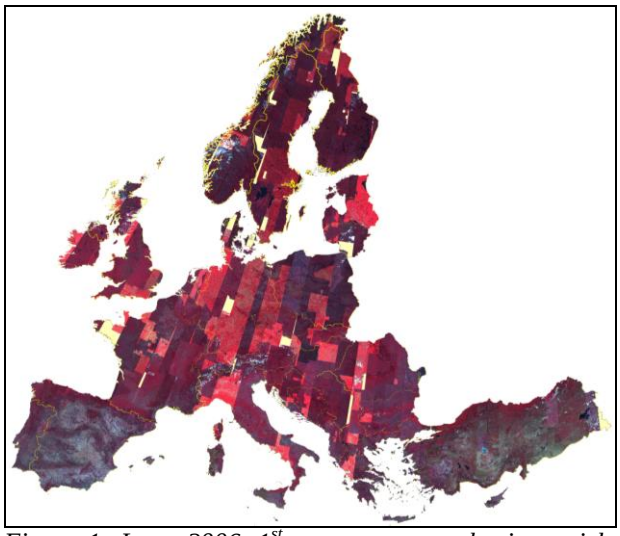

Figure 1: Image2006, 1st coverage pre-selection quick look mosaic

Figure 2: Image2006, 2nd coverage pre-selection quick look mosaic

The LISS-III pre-selections and corresponding SPOT 4 and SPOT 5 pre-selections and later the gap fillers were merged by the prime contractor to compile the final data selection. The merge process considered factors like the acquisition date with respect to the acquisition window and the sensors scene size.

4.2. European wall-to-wall Coverage 2009

Through the GSC-DA agreement, ESA ordered two IRS-P6 Resourcesat-1 LISS-III coverages of 38 countries for the European wall-to-wall Coverage 2009. As a successor to Image2006, this dataset is also referred to as Image2009.

The quick look mosaics in Figure 3 and Figure 4 show the 2008 and 2009 LISS-III data selected, ortho rectified and already delivered, as well as some proposed gap fillers.

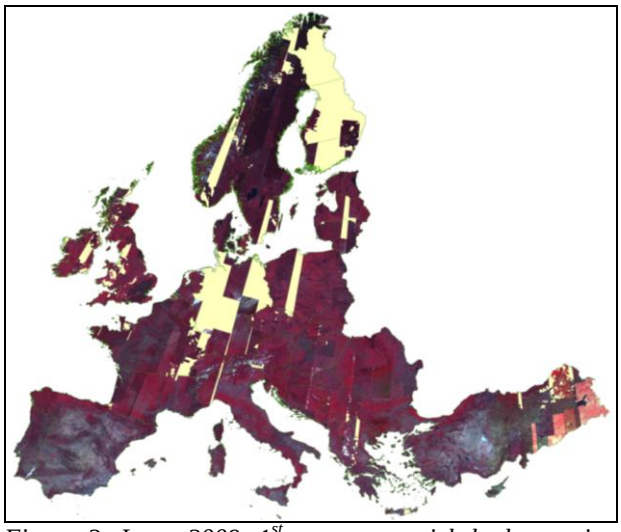

Figure 3: Image2009, 1st coverage quick look mosaic, as of 15-Jun 2010

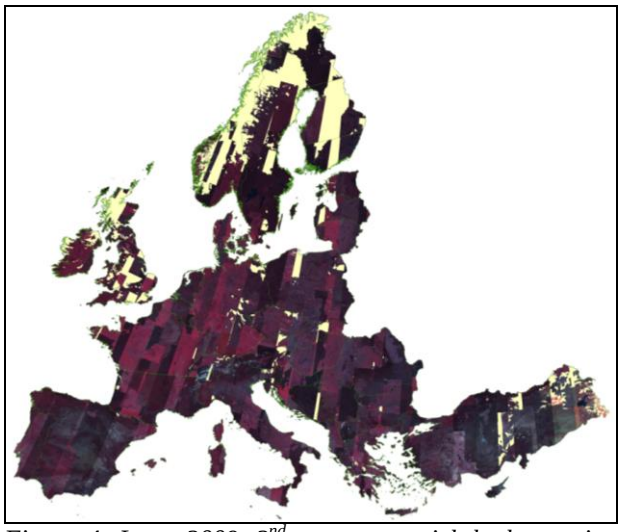

Figure 4: Image2009, 2nd coverage quick look mosaic, as of 15-June 2010

It has to be noticed that the state of the 2nd coverage shown in Figure 4 depends on the state of the 1st coverage, as an off-period of at least six weeks was requested between acquisitions in both coverages. As a result, potentially suitable scenes for the 2nd coverage cannot be selected, produced and delivered before a final decision on the scenes in the 1st coverage, including gap fillers.

In early 2010, this requirement was relaxed to four weeks. The repeat cycle of the fixed-track Resourcesat-1 LISS-III is 24 days. An off-period of six weeks (42 d) corresponds to 1.75 cycles, and an off-period of four weeks (28 d) corresponds to 1.17 cycles. Therefore both the six and four-weeks off-periods require two cycles. Nevertheless, the four-week off-period may have some advantages when data from different acquisition years have to be considered.

The reduction of the off-period to one cycle or 24 days would permit to consider all acquisitions within the reference year. This would allow the consideration of two additional cycles per year, which corresponds to an increase of 15% as calculated in Eq. 1.

$$15\% \approx \frac{2\,\text{cycle/y}}{\left(\frac{365\,\text{d/y}}{24\,\text{d/cycle}}\right) - 2\,\text{cycle/y}} * 100\% \qquad (1)$$

In the praxis relevant case that acquisitions during winter or spring do not pass the sun elevation threshold or do not meet the snow-free criterion, even more than 15% would be gained.

Though being aware of the underlying user requirement to capture different phenological stages of the biosphere, it may still be better to have partially shorter off-periods than ending up with no data.

A comparison of the extended windows for the 1st coverage of some neighbouring countries (e.g. Portugal (45 d) and Spain (120 d), of Latvia (60 d) and Estonia (90 d), of Ireland (90 d) and the UK (180 d)) leads to the question whether precisely defined windows are sensible. See [12, pp. 62-63].

Figure 5 shows the achieved cloud-free coverages in percent per country calculated from the delivered data acquired in 2008 and 2009.

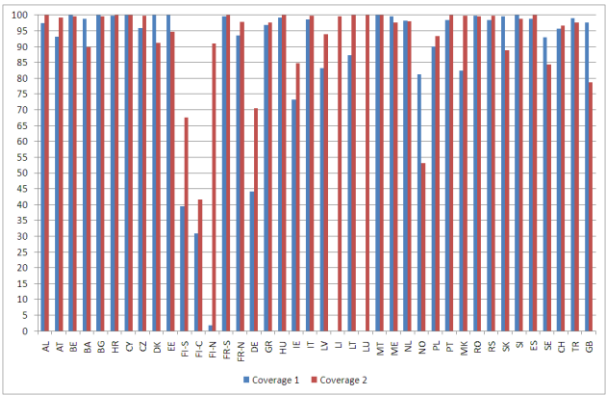

Figure 5: Image2009, area covered in % with data from 2008 and 2009

Considering the area of all countries together, a cloud-free coverage of 87.5 % for the 1st coverage and 90.1 % for the 2nd coverage was achieved with data from 2008 and 2009. The contribution made by acquisitions from different years is shown in Table 5.

Table 5: Image2009, area covered cloud-free

Priority	Acquisition Year	1st Coverage [%]	2nd Coverage [%]
1	2009	44.50	64.71
2	2008	43.04	25.38
Total		**87.54**	**90.09**

A gap-filling exercise during 2010 aims at reducing the gaps as far as possible.

4.3. Europe Land Cover of Forests

The potential of the Resourcesat-1 AWiFS sensor to provide MR multi-temporal coverages with high frequencies was utilized by Geoland-2 through the GSC-DA agreement for the Europe-land-cover-of-forests data set.

Figure 6 and Figure 7 show quick look mosaics of the AWiFS time series delivered for the Munich-Verona transect. The 2005 time series with three acquisitions in Figure 6 was acquired in just two months. Thanks to its enormous swath and its 5 d repetition rate at the equator, the AWiFS sensor has the potential to provide high-frequency multispectral time series over entire Europe.

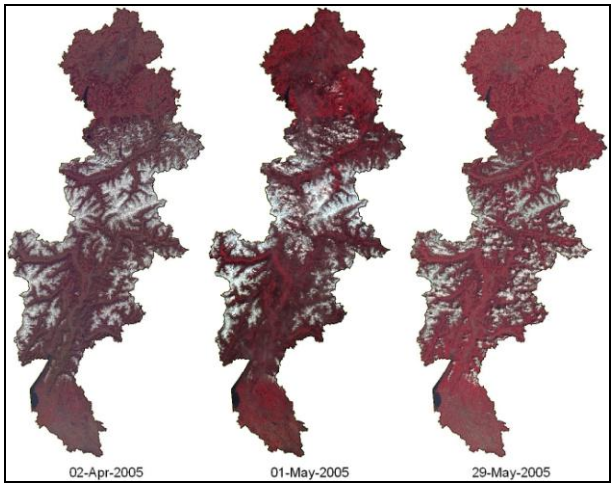

Figure 6: Transect Munich-Verona, 2005 time series quick look mosaics

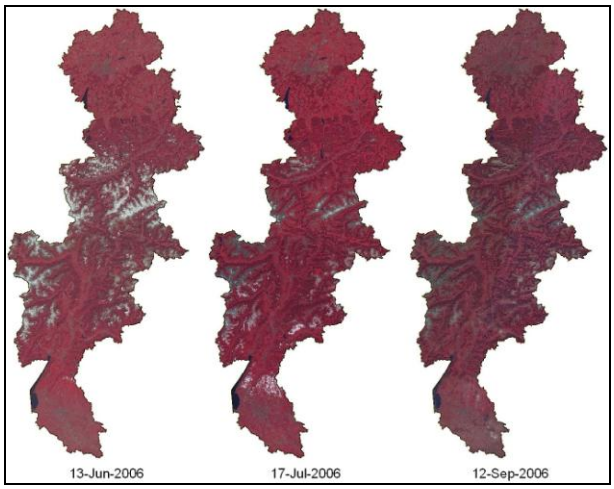

Figure 7: Transect Munich-Verona, 2006 time series quick look mosaics

5. CONCLUSIONS

With the IRS program, ISRO has established one of the world's leading EO programs. Through Euromap, the exclusive supplier of data from several IRS missions in Europe, the IRS program has significantly contributed to GMES and other European activities. Considering the upcoming IRS EO missions, the IRS program has the potential to continue being a significant data source satisfying European data needs.

Whereas Image2000 products were primarily derived from Landsat 7 Enhanced Thematic Mapper ETM+ imagery [13], Landsat data were primarily replaced by Resourcesat-1 LISS-III data for Image2006 and Image2009.

Due to a fixed off-period between the two coverages of Image2009, at least 15% of acquisitions could not be considered. In order to possibly improve results for similar projects, an investigation of the effect the combination of fixed time windows and off-periods with fixed-track sensors and the phonological development, which does not follow political borders or the calendar, may have on the resulting coverages is proposed.

6. REFERENCES

1. ISRO web site (2010). Online at http://www.isro.org/scripts/Aboutus.aspx, (as of 9 June 2010).
2. ISRO web site (2010). Online at http://www.isro.org/scripts/milestones.aspx (as of 9 June 2010).
3. ISRO web site (2010). Online at http://www.isro.org/satellites/earthobservationsatellites.aspx, (as of 9 June 2010).
4. ISRO web site (2010). Online at http://www.isro.org/scripts/currentprogrammein.aspx#IRS (as of 9 June 2010)
5. d'Angelo, P., Lehner, M., Krauss, T., Hoja, D. and Reinartz, P. (2008). Towards Automated DEM Generation from High Resolution Stereo Satellite Images. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, International Society for Photogrammetry and Remote Sensing, XXXVII (B4) , pp 1137-1342. ISPRS Conference 2008, 2008-07-03 - 2008-07-11, Peking (China). ISSN 1682-1750 http://www.isprs.org/proceedings/XXXVII/congress/4_pdf/199.pdf
6. d'Angelo, P., Reinartz, P., Carl, S. and Barner, F. (2010). Automatic Generation of High Quality DSM Based on IRS-P5 Cartosat-1 Stereo Data. *ESA Living Planet Symposium, Bergen 28-Jun to 02-Jul-2010, Special Publication SP-686*
7. Müller, R., Krauß, T., Lehner, M., Rönnbäck, G., Karsson, A. (2008). *GMES Fast Track Land Service 2006-2008, Orthorectification of SPOT and IRS-P6 Products, Final Report*, Issue 1.0, 2008-05-12. http://earth.esa.int/pub/ESA_DOC/Image2006-v1_01.pdf
8. National Remote Sensing Agency, Hyderabad (1995). *IRS-1C Data Users Handbook*, Issue 1.0, September 1995, http://www.euromap.de/pdf/1C_data_user_handbook.pdf
9. National Remote Sensing Agency, Hyderabad (1997). *IRS-1D Data Users Handbook*, December 1997, http://www.euromap.de/pdf/1D_data_user_handbook.pdf
10. National Remote Sensing Agency, Hyderabad (2003). *IRS-P6 Data User's Handbook*, October 2003, http://www.euromap.de/download/P6_data_user_handbook.pdf
11. National Remote Sensing Agency, Hyderabad (2006). *CARTOSAT-1 Data User's Handbook*, September 2006, http://www.euromap.de/download/P5_data_user_handbook.pdf
12. European Space Agency (2008). *GMES Space Component – Data Access Portfolio Specifications Document (DAP/S) V1.0*, Issue 1.0, 2008-05-27.
13. European Commission, Joint Research Centre, Institute for Environment and Sustainability. *Image2000 – the Spatial Reference for Europe*. Online at http://image2000.jrc.ec.europa.eu/index_ie.cfm/page/image2000_overview (as of 11 June 2010)