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THE POTENTIAL USE OF NEW HIGH RESOLUTION SATELLITE DATA FOR URBAN AND REGIONAL PLANNING

Gotthard Meinel, Regin Lippold, Maik Netzband
Institute of Ecological and Regional Research, Dresden, Germany

WG IV/4 - Mapping using high resolution satellite imagery

ABSTRACT

The remits of regional planning and environmental monitoring are growing steadily. Planning data and status information need to made available in ever more up-to-date form and with high spatial resolution. Given the constraints on public funding, this demand for data can only be met future using new forms of satellite sensor in outer space. The Indian IRS-1C is currently delivering data with 5-meter ground resolution, and it is expected that the American satellite image sensors Ikonos 1 and Quickbird will shortly be producing data in the 1-meter resolution range. On the basis of new colour composites, this paper assesses IRS-1C data in terms of pronouncement value, operational processing strategy, and suitability for diverse planning requirements. The conclusion arrived at is that this data is an ideal vehicle with which to up-date land-use plans, municipal survey maps, cartographic material covering urban structure types and biotopes, surface-sealing surveys, working maps for landscape planning as well as providing the basis for general data up-dating at a scale of 1:25,000. Further areas of application such as 3-D representations on the basis of digital relief models for the purposes of assessing land formations for large building ventures (wind-power installations, bridges, etc.) or the identification of biodiversity using IRS colour composites are currently being scrutinised. The research project is funded by the German Research Community (DFG).

1 NEW CHALLENGES FOR REGIONAL PLANNING

Globalisation is posing new challenges for regional planning. There is pressure to capture increasingly complex processes virtually as they happen. International competition is intensifying, leading to a situation where municipalities and regions are having to vie with one another for investment funds. The upshot is that, even in the case of projects with a significant spatial-planning dimension, the planning process is subject to tight deadlines. An example of this can be found in the companies of the microelectronics sector, who are compelled to plan and commission their extremely expensive, surface-intensive »fablines« in very short timelines. Planning is also being confronted with new tasks as a result of the demand for sustainable spatial development. This necessitates an exact analysis of the spatial impact of measures planned as well as the planning and weighting of compensatory measures.

If the causes of environmental protection and nature conservation are to be successfully pursued and the effects of spatial measures evaluated, it is essential that natural spaces be inventoried beforehand. In particular, larger spaces are only feasible if up-to-the-minute data on current spatial utilisation and its structures are available to facilitate comparison of large areas. Satellite-based remote sensing is ideally placed to remedy this shortage of topical data, especially acute in the case of environmental lead planning. Monitoring the success of measures initiated, to limit surface use for example, is made significantly easier.

The increasingly detailed nature of planning issues and the demands of information processing - comprehensive stocks of digital base data at planning and environmental agencies can now be taken as given - are causing expectations in regards to data performance (e.g. locational accuracy and data attribution) to be raised. Compelling visualisation of planning schemes has also come to be expected. This dimension is set to become more and more crucial both to political implementation and to public participation.

Whilst data processing tools have been constantly refined in the form of geoinformation systems over recent years, there are still large shortcomings in regards to methods of cost-effective, up-to-the-minute surveying of the inventoried situation. Regional planners, for instance, do not have access to wholly up-to-date cartographic material on built-up areas (planning scale 1:100,000), municipal environmental departments are short of information on biotope evolution, land surveyors departments are short of current topographical base information for the up-dating of 1:25,000-scale topographical maps and urban planners do not have up-to-the-minute actual-utilisation data (Meinel et al., 1998). New developments in the satellite image market will help overcome such deficits.

2 DEVELOPMENTS OF THE SATELLITE IMAGE MARKET

A satellite image has many advantages over an aerial photo. Foremost amongst these are its superior surface coverage and lower image distortion. The former eliminates the need for arduous processing of individual aerial images and subsequent patching together of same. Lower image distortions are a result of the smaller angular field produced when the viewing device is at a height of several hundred kilometers. This leads to a reduction in rectification work and to less serious image errors due to occlusions etc. Images can also be procured retrospectively and costs per surface unit are considerably lower. Direct digital registration of image data can likewise be regarded as a benefit, though with the aid of DPA (Digital Photogrammetry Assembly) cameras this will also

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be possible with aerial-image fly-overs in future.

One disadvantage of satellite image technology over an aerial photo, is the lower geometric resolution. But the new developments of the satellite image market at present, help to solve this problem (Fritz 1998). The prospects for the near future is a number of commercial high resolution satellites, open up new possibilities for urban and regional planning. New tasks will occure for satellite remote sensing. One result can be a new allocation of duties between satellite-based remote sensing and remote sensing based on aerial photographs.

Another advantage of these new systems is also to make it possible in future to markedly reduce the repetition rate of 24 days to 1 - 3 days along with lower product prices. Taken together, these are the main assumptions for an operational use of these image data in urban and regional planning.

The Indian Remote Sensing Satellite Programm has ushered in frenetic developments in satellite-based remote sensing. These Indian IRS-1C and IRS-1D data has actually been available since 1996. Data that can be searched for via the Internet has opened up radically new areas of resolution and proved, as is shown below, to be ideal for use in spatial planning. The recording system was developed specifically with terrestrial requirements in mind, satellite remote sensing being of the utmost significance especially for large countries like India, whose national cartographic recording systems are still, relatively speaking, in their infancy.

Data from the Indian IRS-1C remote sensing satellite is being assessed within the framework of a project entitled "Potential uses of the latest high resolution satellite imagery for regional planning" and funded by the German Research Community. The area under investigation is the Dresden urban region and the basis of studies, which commenced in November 1997, are one panchromatic and one multispectral (LISS III) IRS-1C scene from September 16, 1997.

3 IMAGE QUALITY AND PREPROCESSING OF IRS-1C DATA

3.1 Data search and procurement

Searching for IRS-1C data via the ISIS satellite image archive of the German Remote Sensing Data Centre (DFD) and using the search parameters Area, Sensor, and Recording Date is reasonably straightforward. Besides searches for stored image data and important recording variables (recording date, degree of cloud, covered areas, etc.), it also facilitates the display and downloading of "quicklooks" measuring 500*500 pixels. These only allow the degree of cloud and any hazy areas to be assessed, however. What cannot be verified using either a 1:1,000,000-scale representation of multispectral imagery 140*140 km in size or panchromatic imagery shown at 1:500,000 scale (70*70 km) is the presence and nature of image defects. Data procurement via Euromap GmbH was similarly straightforward. At the same time, data distribution could be further simplified in some respects, since several inquiries by phone were required when scenes were to be relocated within a strip, for example. The fact that the data of the SWIR channel are only part of the product, as long as no data shift is included, only became apparent once the data had been procured. Neither is it possible at present to mesh image data with the neighbouring strip. An improvement in the locational stability of scenes would also be desirable. The areas covered tend to vary rather greatly while still being accorded the same scene designation.

3.2 Image quality

The image quality of the IRS-1C LISS quarter-scene purchased and of the PAN sub-scene can be rated as being very good overall. That applies in particular to the inner image geometry, which facilitates high-precision rectification. Image defects in the form of blobs and faulty strips were present in the PAN scene, however. When recording extremely bright and smooth surfaces, the sensor is overset, especially when the sun is very low, and it requires quite a bit of time to reproduce correct reflection values. Defects are difficult if not impossible to remove. Whilst individual lines or points can be easily rectified by generating mean values, it is not generally possible to repair a multiline omission without visible image impairment. The area then has to be filled with data from another image set. In the case of a faulty strip approx. 10 image lines wide, the satellite image provider (Euromap GmbH) generously made part of another panchromatic scene available free of charge.

Slight banding in the orbiting direction was discernible in the panchromatic image scene (approx. 6 % intensity fluctuation at a distance of approx. 4 pixels), this being troublingly noticeable in some colour composites on very dark surfaces such as bodies of water. This may be a result of the sensor's CCD line not yet being 100 % calibrated.

3.3 Georeferencing

Panchromatic imagery was georeferenced using topographical maps of 1:25,000 scale with the multispectral image (LISS) subsequently being rectified onto the panchromatic image. This ensured a high locational accuracy between the two image products, a prerequisite for the generation of merge products. Table 1 reproduces the rectification error.

Given a mean error of 0.78 pixels, a mean accuracy of < 4 m for the PAN scene and of < 8 m for the LISS scene was achieved. The independent monitoring points confirm these findings. Very high locational accuracy is of great importance with regard to the overlaying of high-precision geodata in later processing or interpretation stages. Overlaying a georeferenced IRS image product with, in turn, an urban biotope chart (survey scale 1 : 5,000) and an ATKIS (Official Topographic-Cartographic Information System) data record (survey scale 1 : 10,000) impressively underlined the high locational accuracy and hence also the fine inner geometry of the IRS data.

For an extra charge, the data distributor Euromap is now offering georeferenced data with a locational accuracy of 5 m for panchromatic and 15 - 20 m for multispectral imagery.

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Table 1: Rectification error of IRS-1C data

		IRS-1C PAN full scene	IRS-1C LISSIII quarter scene
Recording date		16.09.97	16.09.97
Scene size		70 * 70 km	70 * 70 km
Rectification base		topographical maps scaled 25,000	georeferenced PAN scene
Number of pass/monitoring points		160 / 21	95 / 35
Pass point accuracy	$RMSE_X$	0.45 pixels / 2.6 m	0.20 pixels / 4.6 m
	$RMSE_y$	0.64 pixels / 3.2 m	0.26 pixels / 6.0 m
	$RMSE_{total}$	0.78 pixels / 3.9 m	0.33 pixels / 7.6 m
Monitoring point accuracy	$RMSE_X$	0.49 pixels / 2.5 m	0.12 pixels / 2.8 m
	$RMSE_y$	0.45 pixels / 2.3 m	0.14 pixels / 3.2 m
	$RMSE_{total}$	0.67 pixels / 3.4 m	0.18 pixels / 4.1 m

3.4 Atmospheric adjustment

Given the ever improving resolution of satellite imagery, atmospheric adjustment will assume great significance in future. Change detection methods and the application of absolute spectral signatures for land-use classifications both necessitate atmospheric adjustment. There are now very high-performance program packages with good operational attributes available which can also be deployed in mountainous terrain, being capable of compensating for relief-related lighting discrepancies (Richter 1997). Atmospheric adjustment of data was effected in the research project using the ATCOR3 program and having recourse to a relief model (grid width 25 m, altitude accuracy approx. 15 m in mountains). (This section was covered by R. Richter [DLR], to whom many thanks!) By converting intensity values into relative reflection values, the atmosphere and lighting-adjusted image products become far easier to interpret and classify, shady slopes being better illuminated for example. Whereas the intensity values of the visual green and red channels are reduced by atmospheric adjustment, those in the near-infrared channel are raised in the middle and more effectively differentiated. Following atmospheric adjustment in NIR, surface waters for instance have reflection values of 0 % whilst lush vegetation produces a 60 %-plus reading.

3.5 Merging IRS-1C PAN and LISS

The image fusion pixel by pixel (merging) has the objective of producing the image products best suited to a given task of interpretation. Spatial resolution and colour rendition play a decisive part in this. High spatial resolution can be achieved without sacrificing the colour information required for surface evaluation by combining high-resolution panchromatic images with multispectral data records. Important colour composites are the real-colour and the infrared representations (the latter particularly so for assessments of vegetation).

Intensity-Hue-Saturation transformation (IHS), principal component transformation (PC), and procedures originated by Brovey (B) were tested for their capacity to produce colour composites. The best visual results were yielded by the PC process. The results of these three methods were unconvincing in regards to both their sharpness of detail (incomplete imaging of high-resolution panchromatic information) and their colour fidelity (incomplete retention of multispectral information). The reason for this is the low correlation between the panchromatic and the infrared channel of the IRS data. The different spectral sensitivity curves of the channels do not take this into account (Pellemans et. al 1993). So it will be necessary to check other merge methods. The best way is through the separation of merge methods; merge for display and merge to maintain radiometric integrity. Thus, the implementation of merge methods will be checked, which preserves the radiometric characteristics of the original multispectral data.

3.6 Image classification

Multispectral pixel-based classification is basically possible with the 3-band IRS-1C LISS data but reaches its limits in the very heterogeneous urban areas with high frequent changes of land-use. At present there are no automatic and operational methods dedicated to urban settlement detection, but only adaptations from other application fields (like forestal or agricultural monitoring). In addition no attention is given to the morphology and spatial pattern of the detected objects/surfaces in conventional classification methods even if the spatial pattern is a key dimension of human settlement analysis and planning. For these reasons it is necessary to develop new methods and concepts involving morphological and textural analysis.

The development of a hierarchical classification scheme is in progress combining spectral and textural analysis methods. For the IRS-1C merge product, a multispectral classification is performed to separate large-area land-use classes, mostly in the urban fringe, e.g. water, forestries and agricultural areas, carvings, etc. Areas covered by vegetation can be separated in an exact manner using the vegetation index NDVI (ratio of visible red and near infrared). Concerning the essential settlement areas a classification of urban structure types (see also Tab. 2 for class division and characteristics) under utilization of their morphological and textural characteristics is aspired.

3.7 Overlaying IRS data with other geodata

An overlay with geographical base data, data from the Official Topographic-Cartographic Information System (ATKIS) for instance, can facilitate the creation of digital or analogue cartographic bases that are ideal for visual interpretation. The superimposition of vectoral data records is also necessary for the assessment of segregated surface units or even for their up-dating. Visually estimating the dimensions of structural utilisation within a construction block, for example, is eminently

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(Image data: © ANTRIX, SIE, Euromap Neustrelitz)

Scale
500 0 500 Meters

Fig. 1: IRS PAN overlayed with the urban construction blocks

feasible by superimposing the construction-block boundaries. Furthermore, the vector data records can themselves be up-dated by means of image interpretation (e.g. up-dating of land-use planning, regional planning, ATKIS, biotope mapping). So it is possible to simply actualize the settlement layer of a regional plan, for instance (see chapter 4.1). The updating of the actual land use of preparatory land use plans (F-Plans) is likewise possible as well as the determination of the principal classes of urban biotop mapping.

In addition to visualisation there is a high potential of GIS-analytical operations of geographical base data in combination with IRS data. One example is the automatic calculation of the vegetation and of the surface sealing inside urban construction blocks obtained by fusion of the construction blocks with appropriate classified image data. Fig. 1 shows an example of panchromatic IRS data overlaid with the urban construction blocks in a small scale.

4 USES AND AREAS OF APPLICATION OF IRS-1C IMAGE DATA

4.1 Regional planning

Regional planning is rapidly gaining in status in Germany. It has the task of providing a link between land-use planning (preparatory) by municipalities and the land development plan. Where the past is concerned, a lack of information on current land use, in particular disclosures regarding built-up areas, is cited. Land use is still surveyed on the basis of topographical maps and ground inspections. With its planning scale of 1:100,000 regional planning regards IRS colour composites as a very good planning foundation. As described in chapter 3.7 the demarcation of settlement areas is definitely identifiable both by visual interpretation (fig. 2) or automatic extraction (Steinnocher 1997). Land-use classification using IRS colour composites or through interpretation of an image composite would be of enormous benefit here. Another area of application could be the evaluation of effects on landscape appearance caused by larger construction projects. In these cases the 3-D-visualization of IRS-colour-composites fused with digital elevation models are expected to offer useful information.

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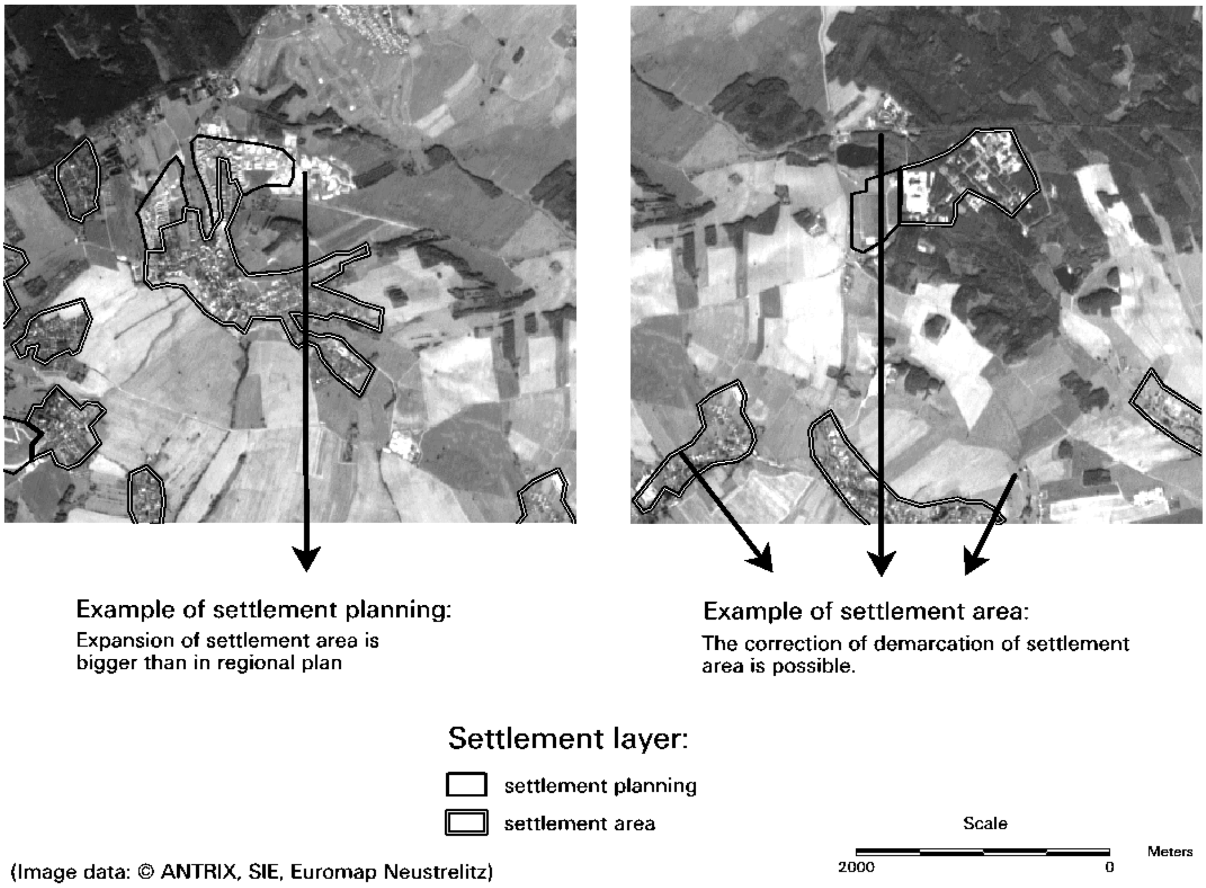

Fig. 2: Actualization and monitoring of sttlement areas in regional planning using IRS PAN data

4.2 Urban planning

Intensive and profound discussions with urban planners with regard to the deployment of IRS-1C imagery yielded the following areas of application:

- up-dating of the preparatory land use plan (F-Plan) by incorporating actual land use (through on-screen digitalisation of the F-Plan on the basis of underlaid IRS data)
- actual land-use mapping
- surface sealing cartography (classification on the basis of the NDVI vegetation index or else visual assessment within construction blocks in 5 classes)
- base data procurement for newly incorporated lands
- overview of land potential and land-use conflicts

In order to validate the potential use of the satellite image data it is primarily planned to actualize the preparatory land use plan on the basis of an IRS colour composite.

A written survey of over 500 institutions in Germany was initiated in March 1998 as a means of acquiring spatially comprehensive and statistically very safe pronouncements on demand for remote sensing data and on advanced IT equipment levels at spatial planning departments and environmental agencies. Its findings were not available when this paper went to press.

4.3 Environmental planning

Wide-ranging discussions with municipal surveyors on the suitability of IRS colour composites led to the following conclusions: a system of urban mapping by structure type has an important part to play in urban ecology, since structure types point up significant ecological features of lands. For one thing, they can be used to estimate the degree of surface sealing. Urban structure types can be extrapolated with excellent clarity using a 1:25,000 scale image. For the city of Dresden a structure type mapping using the IRS-1C colour composite and a digital block construction map is carried out, under consideration of the following classification scheme (Tab. 2):

The following assessments are made by urban environmental protection authorities: An appraisal of urban greenery is eminently feasible. The vitality of roadside vegetation can be determined, and parklands cleanly subdivided into meadows and woodlands. The principal classes of urban biotope mapping can be very effectively determined in the IRS colour composite, whilst subclasses are only recognisable in individual instances. This stress the value of the data for the up-dating of biotope mapping, for instance, to significantly reduce the extent of fieldwork. The issue of relief models was addressed repeatedly, these being crucial to the identification of erosion hazards, assessing flood risks, as well as to the mapping of urban climate.

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Tab. 2: Classification scheme of urban structure types

Principal structure type	Structure type	Classification characterists
built-up areas	high-densely built-up areas	mistaken identity with densely built-up areas (in spots)
	densely built-up areas	mistaken identity with terrace houses (in spots)
	terrace housing	mistaken identity with densely built-up areas (in spots)
	one-family housing	characteristical rough texture
	large-scale commercial areas	features: large coherent areas, suburban location
green areas	parks and green spaces	single and groups of trees with characteristical signatures ures
	forests	characteristical spectral signatures
	cemeteries	mid-fine texture, in spots mistaken identity with allotments
	allotments	fine texture, in spots mistaken identity with cemeteries
	sport facilities	characteristical area outlines
agricultural areas	pasture land	large coherent areas, characteristical spectral signatures
	arable land	large coherent areas, in spots mistaken identity with pasture land
traffic areas	streets, squares	in spots covered by buildings, not necessary for block construction classification
	railway areas	characteristical area outlines
water		clear, no problems
carvings		in spots mistaken identity with construction sites
construction sites		characteristical spectral signatures and area outlines

4.4 Surveying

The setting-up of the first stage of ATKIS at a scale of 1 : 25,000 (survey scale 1 : 10,000) in Germany has nearly been concluded. The survey departments' study group (AdV) is currently elaborating procedures for up-dating the digital data inventory. The up-dating of ATKIS vector data is to be effected by means of on-screen digitalisation on underlaid ortho aerial images at a scale of 1 : 10,000. Presupposing the need for a resolution at 1 : 10,000 scale, a necessary ground resolution of approx. 2 m is arrived at. Accordingly, the IRS-1C data would be unsuitable for up-dating the ATKIS data inventory.

In-house studies, however, suggest that, given accurate rectification, it is possible to achieve good delimitation of lands with IRS-1C data - a precondition for object formation - and also the locational accuracy of 3 - 5 m required by ATKIS. An problem is the discernibility of narrow linear features such as tracks, especially where these covered by vegetation.

Whereas the ATKIS survey is conducted by land surveying departments, urban surveying departments obviously need to elaborate larger scales. Nevertheless, it is usual to publish a digital survey map on a scale of 1:25,000. An IRS colour composite represents an excellent basis for the up-dating of this map.

4.5 Landscape planning

IRS-1C colour composites form a good basis for generating up-to-date cartographical foundations to underpin visual interpretation and further mapping functions relating to landscape planning. By overlaying colour composites with existing geoinformation, the planner is able to acquire visual information in the first instance that extends beyond what is contained in the existing data. A panchromatic IRS image with road, track and waterway networks (ATKIS linear objects) superimposed serves as an excellent survey chart for terrain mapping work. As a result, construction developments not yet recorded in ATKIS can be rapidly identified for example. Some utilisation types such as green areas with a large proportion of free-standing timber can be more effectively appraised even at this early stage, thus reducing the need for field studies and enabling those surveys that are necessary to be conducted in a more targeted manner. IRS data make for a far more finely structured interpretation than ATKIS, this being of particular value for landscape planning and ecology. Good interpretation of large trees and their state of health is possible, for instance, and shrubbery along tracks can be discerned along with crop boundaries and field alterations.

5 CONCLUSION AND OUTLOOK

IRS-1C data constitute superb tools for the spheres of regional planning, urban planning, environmental protection, agricultural monitoring, forestry and telecommunications planning. The area of application for this data could be considerably extended, in the authors' opinion, if the data was suitably refined and data distribution further improved, an opinion arrived at after numerous conversations with would-be data users who again and again showed great interest in the data but who expressed unfamiliarity with data procurement and evaluation routines and rated them as being anything but straightforward. It must also be assumed that the application potential of the data is far from having been fully tapped. With science having "given a lead" on conceivable applications, it is now imperative that the new data be got across to the end-user and that its usefulness be further scrutinised in direct relationship with day-to-day tasks of planning and environmental agencies and the like.

The following wishes are expressed by would-be image users:

- flexibility of area purchasable (option of only purchasing area of direct interest and not full or quarter scenes)
- rectification with high accuracy

- image composites in natural colours and colour infrared representations
- digital terrain models (DTM)
- monitoring on a range of issues

Besides a tighter definition of areas of application, of particular importance for the future would appear to be the question of how data is to be integrated into the basic data inventories of the various departments. Though it has been a painfully slow process, it can now be taken as a given that, in Germany, the planning and environmental agencies are increasingly being fitted out with leading-edge information and communications technology. Digital geographical base data in the form of topographical information (ATKIS), administrative geometrical data (e.g. municipal block map), and specialist data (biotope mapping, urban structure types, etc.) are increasingly available and, in conjunction with the dissemination of geoinformation systems, provide an ideal spring-board for the deployment of high-resolution remote sensing data in the period ahead.

It only remains to be seen who will be best placed to process the data in the most suitable fashion - the satellite image distributor, a service provider, or the end-user. Of course, the answer will be very strongly influenced by the nature of specific applications and the degree of data refinement required. The most sensible approach would appear to involve preprocessing by the satellite image distributor (geocoding, image merging), classifications and across-the-board interpretations by the service provider, and integration of data including evaluation in conjunction with the entire data inventory by the end-user.

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