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Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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* *Natural Resources Institute*

** *Bradford University Remote Sensing Ltd.*

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ABSTRACT
The lack of direct access to satellite data is a major global restriction on resource management needs in developing countries. The Real-time Acquisition and Processing - Intergrated Data System (RAPIDS) is an inexpensive, PC based X-band receiver system capable of capturing data sgnals from the ERS and SPOT satellites. The design philosophy of the RAPIDS ground station seeks to meet the national and/or local needs for timely environmental data by tuning the information recipient/end user. Thus, more effective resource management can be promoted. The RAPIDS system has already been demonstrated in UK and the Netherlands. This paper presents recent experience from successful overseas demonstrations carried out in Indonesia during October and November 1998. Further demonstrations are planned on support of ESA-DUP activities in Bangladesh during the 1999 monsoon. The authors believes that reduced ground station costs and an improved, timely service to customers, especially in developing countries, will be highly advantageous for appplications development and market growth.

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Ian Downey, David Archer, Anita Perryman, Jim Williams [1]
Wim Looyen, Arjen Oostdijk, Hein Noorbergen, Albert van der Kamp [2]
Thomas Sandford, John Stephenson, Richard Stephenson [3]

[1] Natural Resources Institute (NRI),
University of Greenwich, Medway Campus, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK
Tel: +44 1634 880088, Fax: +44 1634 880066/77, Email: I.D.Downey @ gre.ac.uk

[2] National Aerospace Laboratory (NLR)
Remote Sensing Department, PO Box 153, 8300 AD Emmeloord, The Netherlands
Tel: +31 527 248247, Fax: +31 527 248210, Email: looyen @ nlr.nl

[3] Bradford University Remote Sensing (BURS) Limited,
Byril Barn, Wilsill, Nr. Pateley Bridge, Harrogate, HG3 5EA, UK
Tel: +44 1423 711211, fax: +44 1423 711933, Email: shirley @ burs.demon.co.uk

Abstract
The lack of direct access to satellite data is a major global restriction on resource management needs in developing countries. The Real-time Acquisition and Processing - Integrated Data System (RAPIDS) is an inexpensive, PC based X-band receiver system capable of capturing data signals from the ERS and SPOT satellites. The design philosophy of the RAPIDS ground station seeks to meet the national and/or local needs for timely environmental data by tuning the information supply to match the resources and responsibilities of the recipient/end user. Thus, more effective resource management can be promoted. The RAPIDS system has already been demonstrated in UK and the Netherlands. This paper presents recent experience from successful overseas demonstrations carried out in Indonesia during October and November 1998. Further demonstrations are planned in support of ESA-DUP activities in Bangladesh during the 1999 monsoon. The authors believe that reduced ground station costs, lower data costs and an improved, timely service to customers, especially in developing countries, will be highly advantageous for applications development and market growth.

Introduction

Remote sensing satellite operators and data providers currently rely on a system of large, regional ground stations for operational data acquisition and dissemination. However, this presents significant obstacles to meeting the needs for inexpensive and timely data for a very large number of potential EO users. In many previous studies problems have been observed in the access to data, especially but not limited to developing countries (EOS *et al* 1996, Westinga *et al* 1993, Swedish Space Corporation 1993). This has been the result of preferential investment directed into the space segment rather than the ground segment. Due to this bias in funding (and consequent underdevelopment) of the ground segment data distribution side, contact between users and the EO supply side has often been ineffective. This inhibits user uptake, applications development and market growth, particularly in developing countries.

What the user wants, is information, not data. However, to generate that information, users need effective and timely access to data. The single most important comparative advantage of EO is that it provides up-to-the-minute observations of an area of interest. In recent years, timely access to the data has been very poor, especially in developing countries. Affordable, local reception capabilities (such as RAPIDS) will reduce the time lag between the acquisition of data and delivery of data, enabling timeliness production of information and timely decision-making.

In addition, the great potential of SAR remote sensing has been demonstrated experimentally in recent years. Operational and potential users of EO data are therefore starting to expect delivery of reliable information through utilising and adapting this technology to complement existing operational optical techniques. Not least of these are users in developing countries where the comparative advantage of the all weather and all illumination capabilities of SAR will be of most direct benefit. In these countries introduction of new technologies must be appropriate to support effective and prudent resources management. It is also important to appreciate that there is a need for information supply to match the intervention capability of the recipient/end user, which may take time to develop and become operational.

Information Flow to Support Decision Making

There is a pressing need for the timely and efficient flow of information (from data supply through to decision support) for effective, more informed decision making. At each stage of this decision support chain, timely and efficient access to useful and relevant information is the key to making more informed decisions. Transforming the data into useful information depends on the accessibility and availability of data in a timely way for the areas of greatest (local) relevance. This process needs to be more open to control by the user because, in any operational context, there is a heavy reliance on that information being available to support decision making at various levels whenever it is needed (Figure 1).

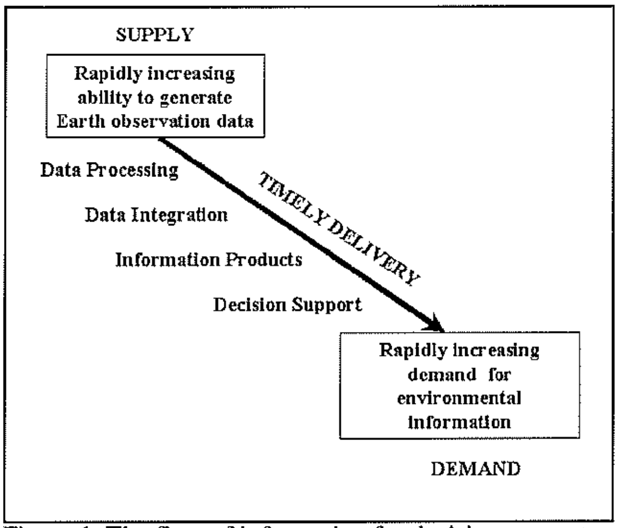

Figure 1. The flow of information for decision support.

Therefore, the data need to arrive where they are required so that they can be integrated into the day-to-day activities of institutions, line agencies, ministries, NGOs, private sector enterprise, etc. However, in many countries, especially in the developing world, this may not always be the case. Furthermore, once the information is produced, it might not then be transferred in a timely manner to users who require that information as part of their day to day monitoring, decision making and intervention activities.

Under current circumstances access to data, especially when the area covered by EO data crosses national borders, is often hindered by a mixture of technical factors, economic factors and political factors.

Technical factors relate to:
- Cloud problems [Optical satellites cannot see through the clouds]
- Interpretation of SAR data is perceived as being difficult
- Training and education are lacking

Economic factors relate to:
- Prices of data are too high
- Ground station access fees are too high
- Copyright and royalties

Political/Institutional factors relate to:
- Security issues
- National prestige
- Autonomy

It is in these areas that most work is now required in order to ensure efficient flows of data to support effective information extraction and applications development. This is especially with regard to regional operating ground stations. It is virtually impossible to obtain timely data from these stations unless you are a user in the same country. The Centre for Remote Imaging, Sensing and Processing (CRISP) ground station in Singapore is a notable exception in this respect.

Addressing these issues is a necessary and vital step towards realising the true potential of (public and private) remote sensing investments to date. Growth in demand, the variety of satellite data available and increases in the number of applications mean that greater flexibility in data access is therefore necessary to improve the supply side. It follows that, to facilitate exploitation of this important environmental information, increased consideration of direct broadcast and a lower level of control of data distribution is required (Harris, 1997).

RAPIDS Philosophy
The design philosophy of the RAPIDS PC-based ground station is to meet national and/or local needs for timely environmental data. In most countries, a large number of resource managers, planners and decision makers would benefit from timely information on their environment, if it were available promptly (on demand), reliably and as inexpensively as possible (Williams and Rosenberg 1993). The needs of these local areas/users can be met without defaulting to horizon-to-horizon systems. Thus the resulting ground segment can be scaled down to support operations within only a local area footprint. This means the station can be inexpensive, easy to transport, install and maintain.

RAPIDS Design
The principal design requirement is, therefore, a system to capture moderate amounts of data regularly for local areas. This requires the system to maximise control during overhead passes where the rate of change in satellite position is highest. A cone of acquisition of ± 45° enables capture of small unit volumes of data of local interest which meet the real-time needs of customers and users within a radius of about 1000 km. The system also has to be robust enough to minimise the effect of wind forces during tracking, and to be simple to maintain and operate. Standard PCs were selected as the platforms for management, tracking, capturing and processing of data. This is because of their increasing performance/cost advantage and their widespread

availability and use (compared to UNIX workstations) in developing countries. This makes for easier local maintenance and cost-effective integration with existing capacity. Full technical details are found in other papers Downey *et al* (1997) and Stephenson *et al* (1997).

RAPIDS Implementation

The ground station consists of four major subsystems:

- Orbit Planning
- Satellite Tracking
- Data Capture (ERS SAR, ERS LBR, SPOT HRV)
- Data Processing (ERS SAR, SPOT Pan, SPOT XS)

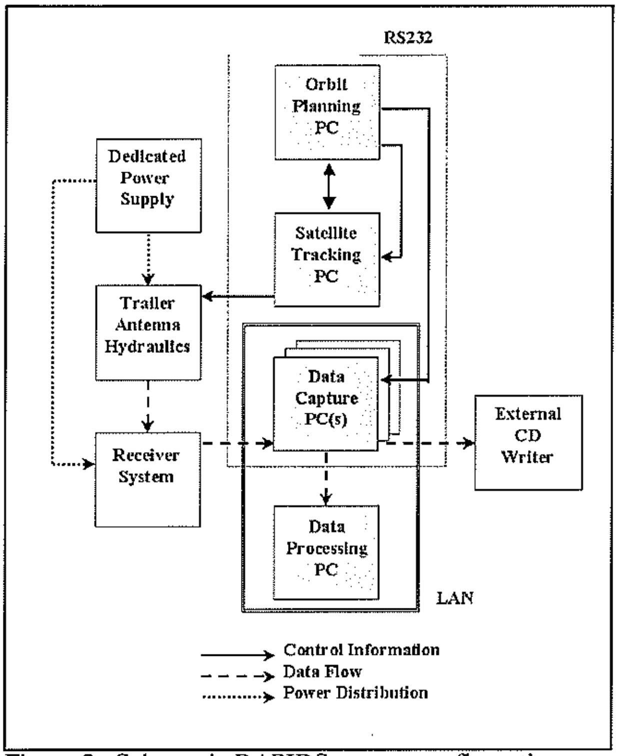

Figure 2. Schematic RAPIDS system configuration.

The subsystems are currently configured in such a way that separate PCs are utilised for specific functions (Figure 2). All the PC's are connected to each other by fast Ethernet or RS232 links.

Current capability includes ERS, SPOT, and (until very recently) JERS-1 which has ceased operating. Other satellites can potentially be accessed (i.e. Indian, Japanese, Landsat, EOS etc.). Future plans include researching capabilities for ENVISAT and Radarsat.

Orbit Planning

The orbit planning PC is used to send timing information to both the tracking computer and the data receiver. These, in turn, control and monitor the whole tracking and reception process via RS232 links for logging system operation and generating post-capture diagnostic reports.

Satellite Tracking

The tracking PC receives information from the orbit planning PC and is used to set up the tracking receiver, to process the patch aerial signals and to generate signals to drive the aerial. The tracking part of the receiver is a dedicated to lock onto beacon signals and provide patch signal information. This enables the system to fully 'auto-track' satellites during overpass.

The antenna set-up consists of a 2.7 metre dish that can be tilted over a range of +60° to -30° in two perpendicular directions (Figure 3). The dish is moved and controlled by hydraulic drive rams. This set-up allows data capture within a circular area of approximately 1000 km diameter, depending on the site. A set of four patch aerials (each with its own low noise amplifier) for the 2.2 GHz tracking system is mounted at the centre of the dish. An 8 GHz data reception LNA is positioned in the same focal plane as the patch aerials.

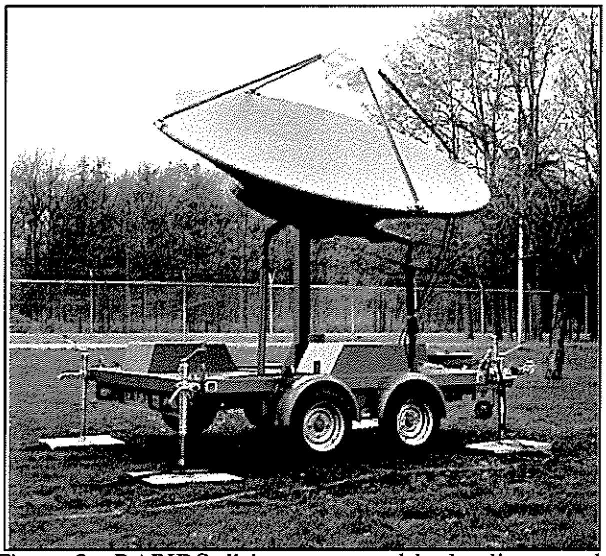

Figure 3. RAPIDS dish antenna and hydraulic control system deployed at NLR, The Netherlands.

Data Capture

The data capture PC is used to set up, control and monitor the data receiver system. The data receiver system is a general purpose programmable X-band receiver, operating in the range 8 to 8.4 GHz. There are separate data demodulators for SAR and optical data signals. Currently the capture capacity includes ERS SAR and SPOT Panchromatic and XS data. Technically it is already possible to capture data from the IRS satellites although but this has yet to be tested.

Data rates that can be captured vary from 6 Mbits sec^{-1} to 150 Mbits sec^{-1}. It is possible to capture these data rates by addressing large volumes of electronic RAM in the capture PC. At present, this PC uses 512 Mbytes of RAM, which is fast approaching the status of being a standard off-the-shelf PC configuration. Whilst writing the data into RAM, the data are also transferred immediately to the hard disk. Thus, although the speed of capture is faster than the speed of writing to disk, significantly more than 512 Mbytes of data can be acquired. Because satellite data rates vary, the total amount of data captured is different for different satellites. Up to 650 Mbytes of ERS data (equivalent to c. 50 seconds of transmission) and up to 900 Mbytes of SPOT data (c. 160 seconds) can be acquired.

Data Processing
A RAPIDS User Interface has been developed to enable the user to process the data in an easy manner. The design philosophy is based on the assumption that users want a simple, easy-to-handle, easy-to-understand software tool enabling them to transform raw radar and optical data into an image to assess the information content. Data processing and the generation of output products take place on a fourth PC.

QSAR - SAR Processing
The raw CEOS formatted ERS SAR data is synchronised and processed using QSAR, a basic SAR processor. The raw ERS SAR data is first frame and line synchronised and then converted to the CEOS-SAR format. QSAR generates "quick-look images" (64m resolution) and can optionally produce higher quality products (e.g. intensity, phase and SLC outputs). The software currently processes a standard ERS scene equivalent (c. 375 Mbytes of raw ERS data) in approximately 1 hour on a Pentium 300, with 256 Mbytes of RAM.

The default parameters process data in a 64m pixel spacing Windows bitmap (with options for 32m and 16m outputs), for which it is not necessary to have (expensive) image processing software. Alternative options are to process the data into 32 bit intensity and/or phase data. These options are designed for applications where higher precision processing is required.

Currently, dedicated QSAR processors are under development for determining the extent of flooded areas in rice areas (FloodSAR: a collaboration between Synoptics, NLR and EGIS) and for determining the agricultural information in ERS data (AgriSAR: a collaboration between Synoptics and NLR).

QOPT - Optical Data Processing
In developing QOPT, the same philosophy was followed as with QSAR. The software performs frame and line synchronisation and initial processing of acquired raw SPOT data. Both HRV-XS and HRV-PAN data can be acquired and processed. The processed data can be viewed within minutes of overpass using a customised viewer. This enables XS or PAN images to be assessed quickly before further downstream processing.

Basic SPOT output products are level 0 data (raw data; no corrections) and level 1 data (radiometrically corrected data). The latter is to be improved using the calibration coefficients as provided by SPOT Image. There is currently no pre-processing to level 1A (removal of systematic distortion effects due to Earth curvature, rotation, etc.) but it is planned to introduce these in the near future. Output is presented in Windows bitmap (.bmp) format, which makes it possible to display the output in standard graphics packages included on most PCs.

Operational Experience
The satellite tracking and acquisition capability is well developed and is a routine operation. Field trials have been carried out in the UK and the Netherlands. Data from the ERS and SPOT satellites have been successfully acquired, and processed into useful images.

Results to date show that, although the functionality of QSAR and QOPT is currently limited to generating basic products, the outputs already satisfy many customers who need rapid data availability and accessibility. For these users, a vast amount of useful information can already be obtained from visual inspection.

Overseas field trials are important components in proving the system for operational use in the tropics and elsewhere. Development of the RAPIDS programme includes a number of demonstration projects overseas. These include deployments in Indonesia and Bangladesh. The most recent results have been obtained from applications demonstration activities in Indonesia during October and November 1998.

Europe
A RAPIDS system has been installed at NLR Noordoostpolder, the Netherlands, since November 1997. An identical system is currently installed at NRI in Chatham, Kent, UK. Both of these systems have been demonstrated to a wide audience of interested organisations. At the same time the system has been used routinely in support of specific operations. The day-to-day experience of the NLR operators indicates that a minimum of manual intervention is required. In general, one to two hours are required to plan, acquire, process and archive optical data and between two and three hours to plan, acquire, process and archive SAR data. Of this time approximately 85% is processing time.

Indonesia
A RAPIDS station has been installed, demonstrated and operated at the Pekayon facilities of Lembaga Penerbangan dan Antariksa Nasional (LAPAN), near Jakarta, Indonesia. LAPAN is the Indonesian National Institute of Aeronautics and Space, responsible for the

acquisition, processing and distribution of satellite data in Indonesia.

The objectives of the demonstrations were to show the capabilities of RAPIDS in tropical conditions and to promote greater awareness and appreciation of the practicality and usefulness of near real time data delivery in support of real management decisions. In particular the data acquired during the demonstrations will be used to:

- support assessment of forest areas in Southern Sumatra (with respect to forest fire damage and deforestation) in support of the EU Forest Sector Support Programme and the Netherlands Tropenbos/ Ministry of Forestry research project.
- determine the bathymetry in Banka Strait in support of the joint Indonesian/Netherlands SIMBA project.
- assess the coastal zone in Banten bay in support of the Royal Netherlands Academy of Sciences Global Change project and in support of the Aerospace Programme on Education, Research and Training Programme (APERT).
- assess the usefulness of data captured by RAPIDS for providing timely estimates of rice extent and production estimates in support of the SARI (Satellite Application for Rice in Indonesia).

Shipping from the Netherlands, customs clearance and installation at Pekayon were completed in two weeks. Data acquisitions were operating successfully within two days of installation. Local users were trained in data capture and processing and have become proficient enough to operate the station reliably and with confidence in a matter of days. Figure 4 shows the RAPIDS area of satellite coverage visible from this location for both ascending and descending passes.

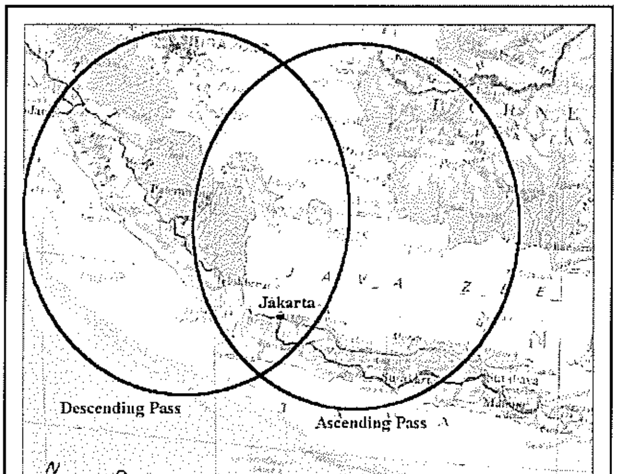

Figure 4. Region of ERS satellite image coverage visible to RAPIDS from Jakarta.

The primary acquisition requirements were for ERS SAR data. Some SPOT data were also been acquired for demonstration purposes by kind courtesy of SPOT Image.

Results
Routine data acquisitions were made, both from descending and ascending passes, during the demonstration period. All the ERS and SPOT data captured were archived on CD-R media.

Figures 5 to 9 show typical output image products from data acquired and processed by RAPIDS during the field demonstration in Indonesia.

Figure 5. First RAPIDS acquisition of ERS at LAPAN, Jakarta, Indonesia. ERS-2 SAR image of Tanjong Putting, Kalimantan, 27/11/98 (© ESA 1998).

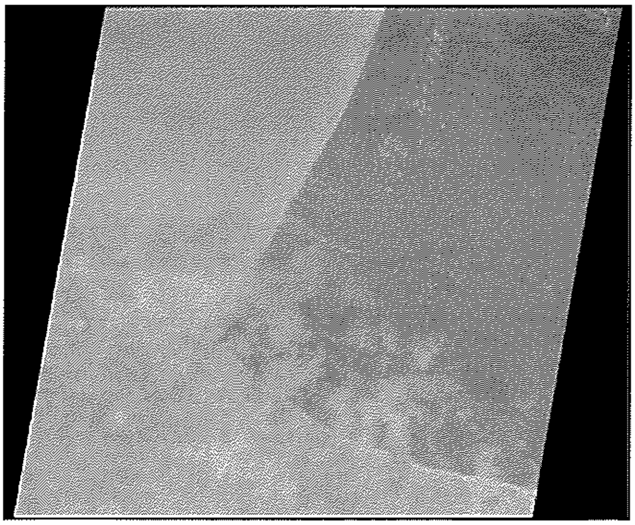

Figure 6. First RAPIDS acquisition of SPOT at LAPAN, Jakarta, Indonesia. SPOT-1 XS (20 m resolution) image of Tanjong Putting, Kalimantan, 28/11/98 (© SPOT Image 1998).

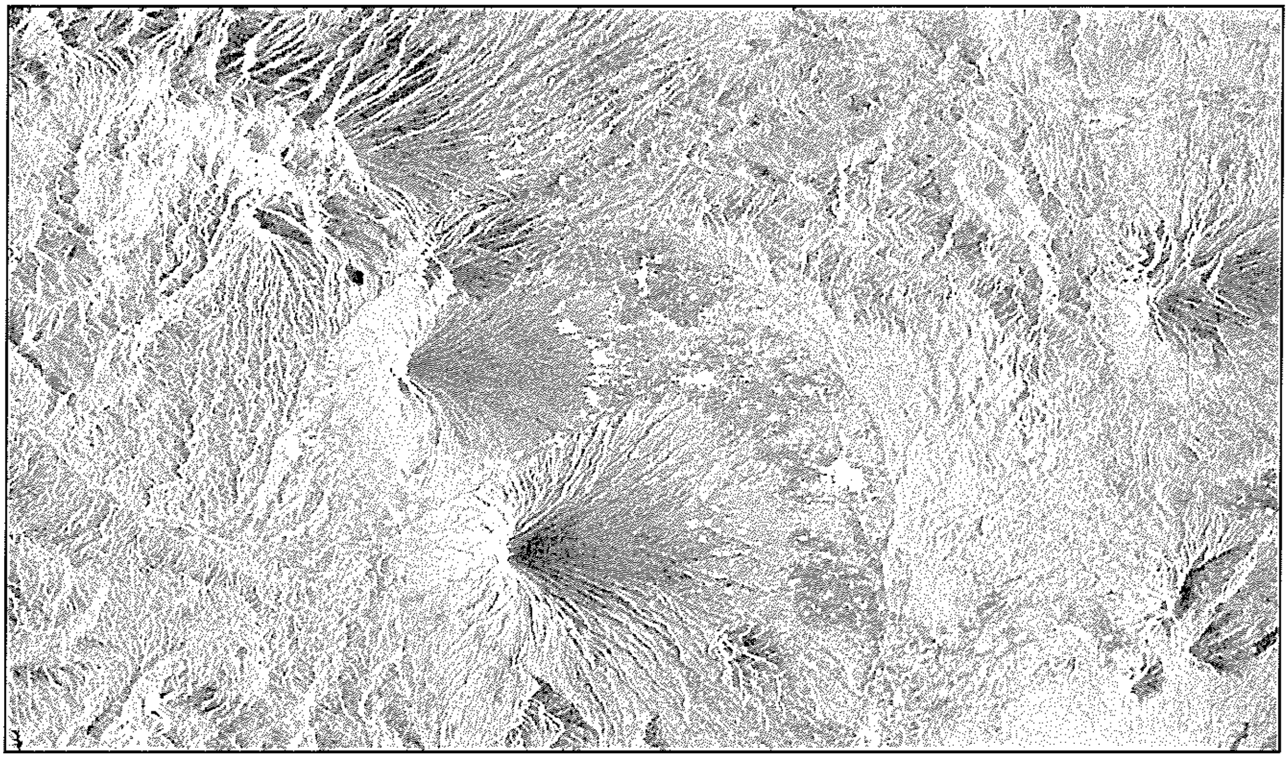

Figure 7. ERS-2 image of Central Java, 2/11/98 acquired and processed to 64 metre resolution product using the RAPIDS system installed at LAPAN, Jakarta, Indonesia. © ESA 1998

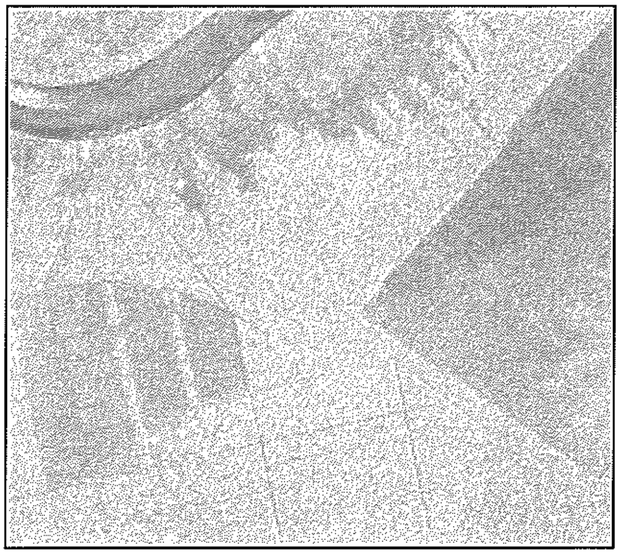

Figure 8. ERS-2 image of forested areas in Sumatra, 20/11/98 acquired and processed to 12.5 metre resolution product using the RAPIDS system installed at LAPAN, Jakarta, Indonesia. © ESA 1998

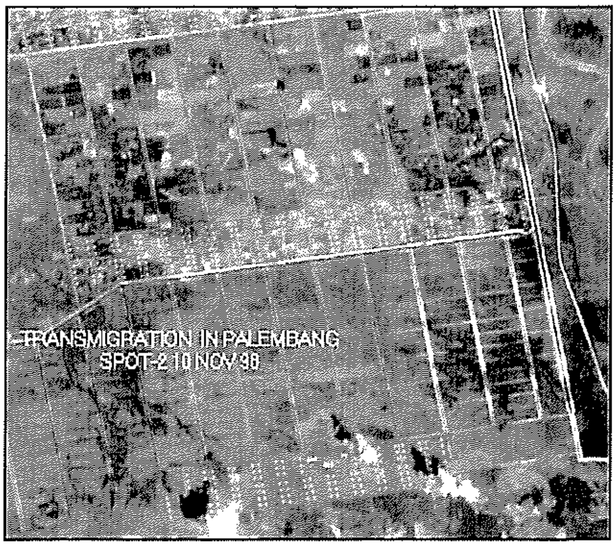

Figure 9. SPOT-2 Panchromatic (10m resolution image) of a transmigration area near Palembang, Sumatra acquired on 10/11/98 and processed using the RAPIDS system installed at LAPAN, Jakarta, Indonesia. © SPOT Image 1998

Typical data volumes (per overpass) that have been acquired during this demonstration are given in Table 1 below.

Mission	Data Volume (Mbytes)	No. Scenes Equivalent
ERS-2 SAR	654	3.5
SPOT HRV (XS)	905	15
SPOT-HRV (PAN)	905	15

Table 1. Typical data volumes acquired by RAPIDS during deployment in Indonesia.

It was noted that, despite the perception that images of this region are almost 100% cloud affected, the SPOT data collected contains a lot of cloud free image parts. The usefulness of these can be rapidly assessed for resource monitoring purposes in the local context.

Combined with the excellent coverage by the SPOT-1 and SPOT-2 satellites (which almost guarantees virtually daily acquisitions) of parts of Indonesia, an unexpectedly high proportion of useful optical data of the region was captured. No SPOT-4 data were captured, although the satellite was tracked routinely.

Bangladesh
Further field trials are planned in Southeast Asia during the monsoon season of 1999. A RAPIDS ground station will be stationed in Dhaka, Bangladesh at the Environmental Geographic Information Service (EGIS), to perform flood monitoring and mapping. This will be in support of an ESA Data User Programme (DUP) project to investigate rice cultivation and flood mapping using ERS data of seasonally flooded areas. There are also proposals under development to enable acquisition of SPOT data during the monsoon.

The DUP project is being implemented by Synoptics BV and NLR (supported by NRI and BURS) as a parallel, reinforcing, activity linked to an existing long term Netherlands programme of support to the Bangladeshi Environment and GIS Support Project for Water Sector Planning (EGIS) in Dhaka. The ultimate objective of EGIS is to provide useful environmental information operationally, and on an independent basis, by the end of the (4 year) Netherlands programme there. The EGIS centre has a well equipped infrastructure with qualified employees.

The DUP project includes 6 months in-country ERS data acquisition, processing and associated training activities. There is definite in-country user demand, a well developed application need and a strong need for low-cost direct reception as the only mechanism to enable ERS uptake in Bangladesh.

Discussion
A great many applications using high resolution optical and SAR data have already been developed to support environmental monitoring and decision making around the world. Easier access to less expensive high resolution data would lead to an explosive growth in its utilisation by developing countries.

There is a clear environmental and commercial need to stimulate high resolution data markets and product uptake in both the developed and developing world. An EU funded study (EOS *et al,* 1996) on the constraints and opportunities of Earth Observation in developing countries identified the lack of more direct access to satellite data as a major global restriction on resource management needs in these countries.

The authors believe that reduced ground station operational costs, lower data (capital and running) costs, together with an improved, timely service to customers, especially in developing countries, will remove this obstacle and will be highly advantageous for applications development and market growth. So much so, that access to remote sensing data will become increasingly open to many potential users that would otherwise not be aware of, or inclined to utilise Earth Observation products and information.

However, institutional issues need very careful consideration. The authors have significant previous experience with direct reception of (low resolution meteorological) satellite data and its implementation in-country. This experience shows that remote sensing applications that improve already on-going activities, are more likely to start well, and be sustained, than applications in totally new domains. Once potential customers get used to seeing such products on a regular basis, ideas and interests develop to diversify the use of the data for other purposes. It is anticipated that this will be the case in Bangladesh.

This process has to start with the real decision making needs of the many potential users and customers. Focussing remote sensing onto operational activities and needs helps to avoid institutional inertia that may arise with (for example) a self-serving, highly centralised remote sensing centre. It is also important to prepare an institution for the associated, and necessary, changes in working practice and attitude towards information use and provision. Once started, sustained operation of a satellite receiver and associated data processing routines requires a commitment to (minimal) running costs as an essential prerequisite (Williams and Rosenberg 1993).

Operational remote sensing in developing countries can thus be sustainable if applications, benefits and costs are carefully matched by the means of appropriate technology.

Conclusions

The conditions that govern access, distribution and pricing of EO data are vital to the exploitation of this important environmental information resource (Harris 1997). The Real-time Acquisition and Processing - Integrated Data System (RAPIDS) is an inexpensive, PC based X-band receiver system capable of capturing data signals from the ERS and SPOT (and potentially other) satellites.

A RAPIDS system has been installed, operated and demonstrated in recent overseas trials in Indonesia. ERS (ascending and descending) passes and SPOT passes were successfully acquired, processed and archived on a routine basis. ERS and SPOT data can be visually assessed within a few minutes of being captured. ERS data products are available within 1 hour of overpass and SPOT data products can be generated within 15 minutes.

This supports operational experience in UK and The Netherlands that the innovative RAPIDS system is optimally suited to regular reception of moderate amounts of data, to meet the real-time needs of customers and users within a radius of the order of 1000 km.

These results demonstrate that the capabilities of low cost, PC based date reception and processing can be realised in tropical conditions. This will enable a growing number of institutes and organisations in developing countries (and elsewhere) to access and utilise this technology for improved understanding and management of their natural resources.

This potential offers significant advantages for the reception, analysis and distribution of information from the predicted expansion in satellite and sensor availability. Such developments have profound implications for future EO system design, operation, market development and data policy.

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BURS designed and now manufacture the system. NRI and NLR provide processing software, applications development, project implementation and technical support. QSAR is developed by NLR. QOPT is developed through collaboration between NLR and T. Sandford of Paradise Green Technical Services Ltd.

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