

# **Growth and development of the DMC; New developments in the international constellation build a sustainable EO system.**

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## **ABSTRACT**

Two enhanced 20 metre class satellites, UK DMC-2 and Deimos-1, with 650 km swath will be launched in December 2008 to join the Disaster Monitoring Constellation (DMC). The huge increase in imaging capacity and improved resolution open up new areas of application for DMC satellite imagery.

The DMC is a unique demonstration of the value of international cooperation in space in achieving a sustainable and affordable Earth Observation system. Through the synergy of multiple spacecraft coordinated in sun synchronous orbit, the whole DMC satellite constellation is able to achieve more than any individual satellite. Each DMC Consortium Member owns and operates its own national DMC satellite. Members benefit by gaining the support of other DMC satellites and ground stations for specific national programmes, as well as gaining income from international sales of DMC data. Coordination and management of international imaging campaigns is provided by DMC International Imaging Ltd (DMCii), which markets and licences data on behalf of the DMC Consortium.

This paper presents the advances in imaging capability and the achievements of the DMC since the first satellite launched in 2002. It also reviews the development of new applications benefiting from the daily revisit and wide area imaging capability of the DMC, as well as the contribution made to global disaster monitoring through DMC Membership of the International Charter.

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## **History of Success**

The first satellite of the Disaster Monitoring Constellation was launched for Algeria in 2002 on board a Cosmos launcher from Plesetsk, Russia.

The other members of the DMC Consortium, UK, Nigeria, Turkey and China awaited their own launch date as their DMC satellites were built at Surrey Satellite Technology Ltd, in Guildford, UK.

The next three satellites, UK-DMC, NigeriaSat-1 and BilSat, joined AlSat-1 in orbit on 27 September 2003.

The most recent launch is the enhanced Beijing-1 satellite in 2005, carrying not only the standard 650km wide swath 32-metre multispectral imagers, but also a 4-metre panchromatic imager with high onboard imaging capacity and X-band downlink. This satellite marked the next step forward in evolution of the constellation.



**Figure 1; Turkey, Nigeria and UK DMC satellites ready for launch, September 2003**

Now in 2008 two new satellites will be launched into the constellation, and in 2009 two more are scheduled. The constellation is growing, providing data continuity to its members, new opportunities to new members, and a rapidly expanding new resource for Earth Observation that enables new applications to be developed based on the daily revisit capability and wide area coverage of the constellation.

The DMC concept arose from the recommendations of the United Nations UniSpace-III conference in 1998, which recommended that space agencies should seek ways of coordinating activities in space to better monitor natural disasters, and provide information for disaster relief response planning.

SSTL worked to build a coordinated constellation that could achieve the goal of daily repeat imaging anywhere in the world. To do this it had to convince a group of international clients to each purchase a DMC satellite and to agree to work together in a phased orbit. The credibility of the programme was greatly enhanced by the support from the British National Space Centre which awarded a MOSAIC grant that enabled SSTL to build a UK satellite.

The DMC Members each own and operate their own satellite via their own groundstation for their national requirements. However they all agree to work together for disaster response free of charge, and to share information and resources for mutual benefit. Thus the inconvenience of downtime for maintenance of a groundstation is avoided by the ability to use other compatible DMC groundstations. Similarly the DMC Members will work together to provide imaging resources if there is an urgent need in one Member's Area of Interest, such as the monitoring of locust swarms across North Africa.

## Achievements

The DMC set out to establish a new practical operational constellation to deliver daily repeat imaging for disasters, and to provide benefits of cooperation in space to international Consortium members. In addition this is part of SSTL's mission to "change the economics of space"; the whole constellation in orbit cost circa \$50 million (£25m). This means that a presence in space becomes affordable for new entrants, such as Nigeria and Algeria. Coupled with know how and technology training (KHTT) this provides a first step towards building capacity in the country and capability in orbit.

### Daily repeat imaging

To achieve daily revisit the constellation was designed with a 650m wide swath imaging system with a 32metre resolution similar to Landsat and using the same core spectral bands for close compatibility. By placing four satellites into the same orbit, and equally phased, the swaths overlap and daily revisit imaging becomes feasible. The DMC has

proved the benefits of this both in disaster response and in bringing new capabilities to the commercial market.

## Funding

Various models of funding the central organisation were explored, and the DMC Consortium eventually decided to do this through sales of imagery from the DMC satellites when not in use over Members' national territory.

Over 4 years DMCii has established a reliable constellation service and, as well as funding central constellation coordination, is able to return significant data licence royalties to Members.

## Commercial success

The DMC Consortium agreed to establish a central coordinating company, DMC International Imaging Ltd (DMCii) to handle disaster response and other constellation issues including calibration.

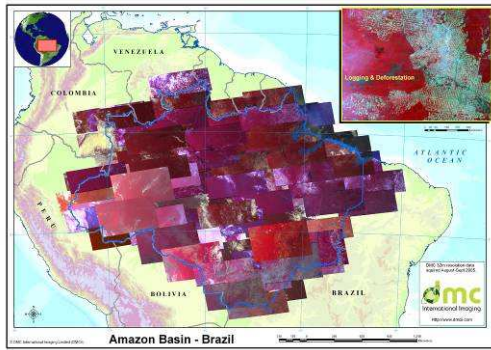
The advent of daily repeat imaging capability stimulated considerable interest in the market for new applications.

First amongst these has been precision agriculture which has demanding requirements for wide area imaging at key stages in the growing season. DMCii developed close working relationships with its customers to respond effectively to their needs. Over the last five years the main areas imaged have been in Europe and North America, and the imagery enables the service provider to derive information for each field. The farmers are then advised on the variable application of fertiliser, successfully increasing yields and reducing fertiliser costs.



Figure 2; Precision agriculture application

Other applications include forest monitoring, with the largest project being the regular imaging of the entire Amazon Basin for Brazil.



**Figure 3; DMC coverage - Amazon Basin**

The wide area imaging dramatically reduces the amount of image processing required and achieves a view of the area within a very short time window. For example the Amazon Basin is imaged in less than 60 days with just 130 images.

The growth in demand for Earth Observation, and changes in the availability of other sensors, means that DMC imagery is in increasing demand. For example in 2007 DMCii supplied the European Global Monitoring for Environment & Security (GMES) programme with the first full low-cloud imagery of 38 countries in Europe, within the time window specified by each country.



**Figure 4; DMC coverage 2007 - Europe 38**

DMC imagery is also available as a Landsat replacement service through a framework contract with the US Geological Survey (USGS).

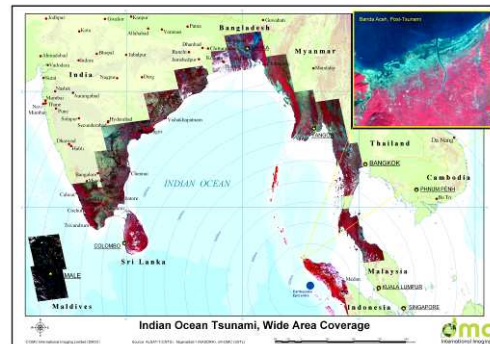
## Lessons learned

The extraordinary project to bring many nations together to create a working constellation in space has been a huge success. New satellites with enhanced capabilities are being added as the first ones reach the end of life, and new members are joining.

The process has of course raised many issues, problems and difficulties which have been overcome, resulting in some important lessons. Some of these are discussed here.

## Disaster response

In the early stages, DMCii responded to news items. The Indian Ocean Tsunami was an example of this when DMCii's Operations manager heard the news whilst at home on his Christmas holiday but was able to rapidly acquire superb imagery of the key disaster areas, and then extend the imaging campaign to cover the entire perimeter of the Indian Ocean. However it turned out to be difficult to find the right organisations to which to deliver the data. Initial liaisons were through membership of the EC RESPOND programme which was developing techniques to deliver rapid mapping services to crisis centres.



**Figure 5; DMC coverage -Tsunami damage**

Subsequently the DMC joined the International Charter: Space & Major Disasters which has proved to be an effective liaison.

## The International Charter

Like the DMC, the Charter also arose out of the recommendations of UniSpace-III. The European Space Agency (ESA) and the French Space Agency (CNES) and others agreed to coordinate, on a best efforts basis, the respective spacecraft under their control.

Since 2000 the Charter has grown in membership, and in 2007 the DMC joined, bringing the benefits of its coordinated constellation.

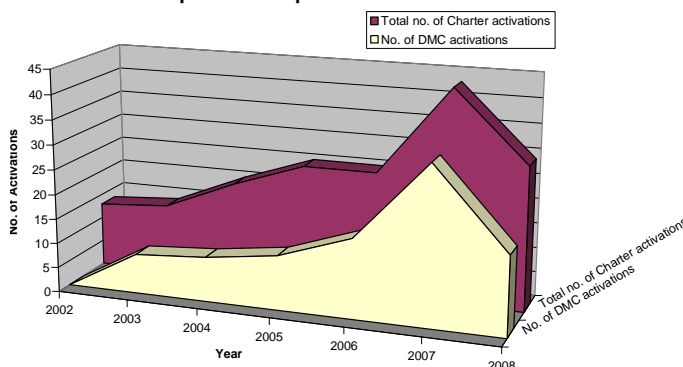
The wide range of sensor types available through the Charter provides a versatile response to different types of disaster. The ability to monitor wide area flooding with DMC's medium resolution optical sensors is complemented by synthetic aperture radar (SAR) which is not hampered by cloud. Additional spectral bands can be useful for monitoring fire or volcanoes, and very high resolution enables the infrastructure damage from earthquakes to be better characterised.



For the DMC the key advantage is the established process with a single central telephone number taking requests for assistance, and passing these to an Emergency On Call Officer (ECO). There is then an established procedure to acquire and deliver imagery to a Project manager who is responsible for deriving information maps and getting these to the coordinating disaster response by on the ground.

DMCii carries out 24/7 ECO duty on a one week in six rota, coordinating appropriate satellite response from the Charter satellites as

**DMC Disaster responses compared with Charter Activations**



well as those from the DMC. Over the last two years DMCii has been used in more than 60% of disaster activations, programming more than 300 images.

The DMC chaired the Charter Board and the Executive Secretariat for the period October 2007 to April 2008.

### **Communication**

It was challenging to develop and maintain effective operational communication between all the DMC Members with such different nations, languages, working practices and time zones.

To facilitate communication the DMC Consortium was established, meeting twice a year to discuss policy and operational issues. The meetings, hosted in turn by each country, are the most important aspect of working together because they build trust and understanding between Members and DMCii.

Teleconferences are also held on specific issues, but it can be difficult to communicate effectively across international telephone lines and time zones.

DMCii coordinates discussions on technical issues with Members. These are handled through email or teleconference, backed up with occasional workshops.

Working groups have also been established to handle technical and commercial issues, and these make use of electronic discussion forums.

### **Commitment**

For commercial campaigns it is vital to have clear commitment from the Members before undertaking an imaging contract. There is no obligation on Members to always participate in commercial campaigns and sometimes a satellite is fully occupied with a national mission.

DMCii established formal processes to

- 1) initiate campaign feasibility studies with the members and
- 2) to secure commitment from the members to participate in campaigns.

This ensures that the resources for each commercial campaign are known before it is contracted. DMCii advises the customer of any constraints and develops and agrees a solution for their specific needs.

### **Coordination**

A DMCii Campaign Manager coordinates each contract with the participating DMC Members.

The Campaign Manager assesses all images from the various satellites as they are delivered and, depending on aggregate cloud cover over the Area of Interest, will either retarget the Member satellites or conclude the campaign.

### **Consistency**

Customers are only interested in results, and not which satellite acquired the images. With four satellites each carrying the same design of SLIM6 32 metre multispectral sensor images should be indistinguishable. The satellites are equally phased in sun synchronous orbit with LTAN 0930 so that the imaging time is consistent from image to image.

All data is processed to the orthorectified L1T product by DMCii using the calibration coefficients to ensure cross compatibility of data.

### **Cross-calibration**

Despite a common sensor design there are inevitably subtle differences between satellites in sensor response once in orbit. To overcome this DMCii carries out an annual vicarious calibration programme with acknowledged expert Prof Kurt Thome at the University of Arizona. The calibration site at Railroad Valley in the Nevada desert is now automated.

DMC satellites acquire images over the site with simultaneous ground monitoring of radiance and atmospheric variables. The absolute vicarious calibration enables images from different DMC satellites to be used effectively on the same campaign.

DMCii also coordinates monthly calibration imaging over the Antarctic DOME-C or Greenland test sites. The expertise gained in cross calibration means that DMCii leads the world in this area and heads a CEOS-ESA programme to develop trans-satellite quality control/assurance techniques.

## **New members, new sensors**

As the first DMC satellites approach end of life Members are in the process of building replacements in order to achieve data continuity.

DMCii's privately funded satellite, UK-DMC2, will be launched in 2008, followed by NigeriaSat-2 and Nigeriasat-X in 2009.

The DMC Consortium also welcomes a new Member from Spain. A private company, Deimos Imaging, has purchased a DMC satellite from SSTL, and this will launch in 2008 with UK-DMC2.

The new satellites incorporate the benefits of fast moving terrestrial technology with enhanced optical sensors, to deliver greatly enhanced performance.

UK-DMC2 and Deimos-1 both carry 22 metre sensors delivering double the pixel density whilst maintaining the 650 km wide swath. Improved power and storage technology enables the satellites to acquire and download much larger volumes of imagery every day. Together they will raise the capacity of the constellation to a level that can achieve two full coverages of the world per year, providing a level of service similar to LANDSAT.

## **A look at the future**

Low cost access to space enables cost effective constellations to be launched. Whilst the first Members of the DMC were taking the risk of pioneering a new paradigm in Earth Observation, new Members can now join an operational system with proven performance as well as established markets and applications. The DMC now includes private commercial companies as Members. The relatively cost of a DMC satellite can be justified within a commercial business plan. This trend is also demonstrated by the recent launch of RapidEye, using 5 satellites built by SSTL.

The next step is a constellation of VHR DMC satellites delivering the high temporal resolution of the first DMC generation. Nigeriasat-2 launching in 2009 will provide coordinated 2.5 metre pan and 5 metre multispectral imagery to Nigeria, and will soon be joined in orbit by others of the same design.

The DMC has grown into a sustainable system which provides real benefits for its Members and generates a synergy between the satellites which is much greater than the sum of their individual contributions. It has enabled large coordinated imaging campaigns which would never otherwise have been feasible, and has opened up new applications in agriculture which had only previously been dreamed of.

Looking ahead it is clear that international cooperation in space can deliver effective coordinated services to meet the needs of governments and commerce alike. As long as working together delivers mutual benefits, and as access to space becomes more affordable, so we should expect Earth Observation to become ever more useful.

As an operational system the DMC can provide a practical starting point for the Global Earth Observation System of Systems (GEOSS), embodying in its six years of operation, six nations, and mixture of commercial and government agencies, all the fundamental issues which must be addressed if Earth Observation is to take the next step forward.