
DEIMOS IMAGING: CURRENT MEDIUM AND HIGH RESOLUTION SATELLITES FOR AGRICULTURE AND ENVIRONMENTAL MAPPING AND MONITORING

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ABSTRACT: Deimos Imaging has played a key role in the design, implementation and operational consolidation of highly relevant services in precision agriculture in different parts of the world. DEIMOS-1 has demonstrated large-scale coverage capacity since 2011 by providing the US Department of Agriculture (USDA) with the satellite imagery to retrieve in-season crop statistics and crop monitoring for the 48 contiguous states. This is done in cooperation with its twin satellite UK-DMC2, owned by Airbus.

Apart from USDA, major precision agriculture services in the world use Deimos Imaging as data source. The main contribution is the continuous optimization in the provision of DEIMOS-1 and UK-DMC2 data to empower the precision agriculture users at different stages: (i) Planning; (ii) in-season; and (iii) yield.

During the planning stage, the data provided by Deimos Imaging is being used in:

- The definition of uniform management zones and yield potential based on the analysis of the historical performance of the crops
- Planning of soil sample
- The definition of maps for variable rate of seeding and fertilizer

During the in-season frequent monitoring, the data is being used in:

- Prescriptions for variable rates: fertilizer and plant protection products (pesticides, herbicides, etc.) In function of the growth anomalies
- Prescriptions for irrigation support systems.

After harvesting, yield values are compared to the management zones maps and yield potential maps. Satellite archive record is reanalyzed for a better understanding of crop performance and for readjusting the management zones for the next season.

This presentation we will cover the results of various campaigns in agriculture, carried out with DEIMOS-1 and UK-DMC2 since 2011. Finally, Deimos Imaging will introduce “UrtheDaily”, a new constellation of satellites for a worldwide daily monitoring of entire landmass of Earth.

1. INTRODUCTION

Deimos Imaging, a subsidiary of UrtheCast Corp., is a private Spanish company specialized in the operation and commercial exploitation of EO Systems, and in the development, generation and delivery of remote sensing products and services. Deimos Imaging operates and does the commercial exploitation of DEIMOS-1, DEIMOS-2, Theia and Iris EO systems. DEIMOS-1 (22-m) multispectral data and DEIMOS-2 (75-cm pan-sharpened with a 12km-wide swath) are both in a sun-synchronous orbit which provide a high revisit time acquiring at 10:30 LTAN every day worldwide.

These two satellites are supplemented by two cameras on board of the ISS. Theia provides medium resolution (5-m) multispectral data; and Iris is an agile pointing platform that captures 1-m full-color videos. The ISS has a nominal orbit altitude of 350km with a nominal inclination orbit is 51.6°. The orbit is not sun synchronous and precesses relative to the sun at a rate of roughly 6° per day. Therefore, repeat imaging of a given point on the earth will be at different times of the day on both ascending and descending passes through each 60-62 day cycle. The advantage of this is that a point can be imaged with a wide range of look and sun angles in a pattern that repeats about 6 times per year.

Deimos Imaging provides a 24/7 commercial service from their three facilities in Spain and through their own network of ground stations in Canada, Sweden and Norway. All the ground segment software, from mission planning to image processing, has been co-developed in-house, allowing a unique capacity to customize the service to best suite all customer needs.

Deimos Imaging provides high-quality services to clients worldwide, not only from the current portfolio of their sensors in orbit but also from the satellites of other partners like the PanGeo Alliance, and value-added applications in a wide range of fields.

2. DEIMOS IMAGING'S EO SENSOR SYSTEMS

2.1. Deimos-1

DEIMOS-1, launched in 2009, is the first Spanish EO satellite, which produces multispectral optical data with 22m GSD at an altitude of 660 km. With a mass of 100 kg, a nadir-pointing platform and 8GB on-board data storage capacity, Deimos-1 is able to provide data in 3 spectral bands (R,G,NIR) similar to Landsat to assure continuity with existing tools and harmonization with historical data. Also, the synthetic blue band can be generated for natural-color imagery.

The satellite payload is a dual bank linear CCD push broom imager, so that banks are mounted at an angle to provide a wide imaging swath of 650 km, one of the most characteristics DEIMOS-1 features allowing the rapid coverage of large areas with 3-day average revisit time worldwide. Deimos-1 imagery has a radiometric depth (8 or 10 bits) with a geo-localization to less than 1 pixel (<22m RMSE) and cross-calibration with Landsat and DMC satellites.

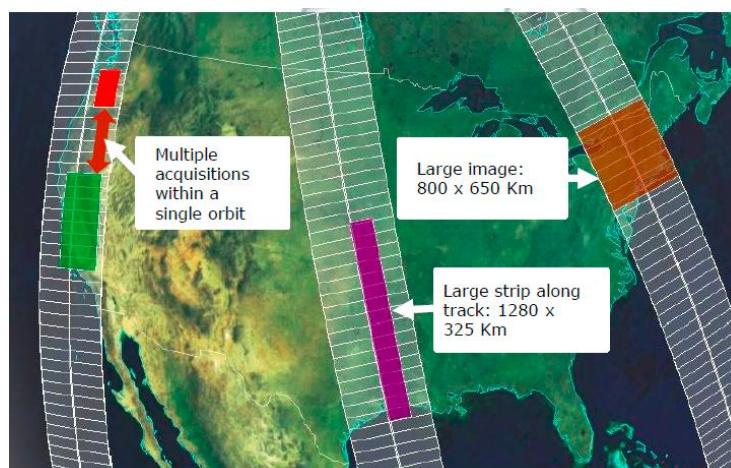


Figure 1. DEIMOS-1 Windowing Concept

Example of system capacity: Coverage of Spain using Landat-8 (16 days) and DEIMOS-1 (2 days).

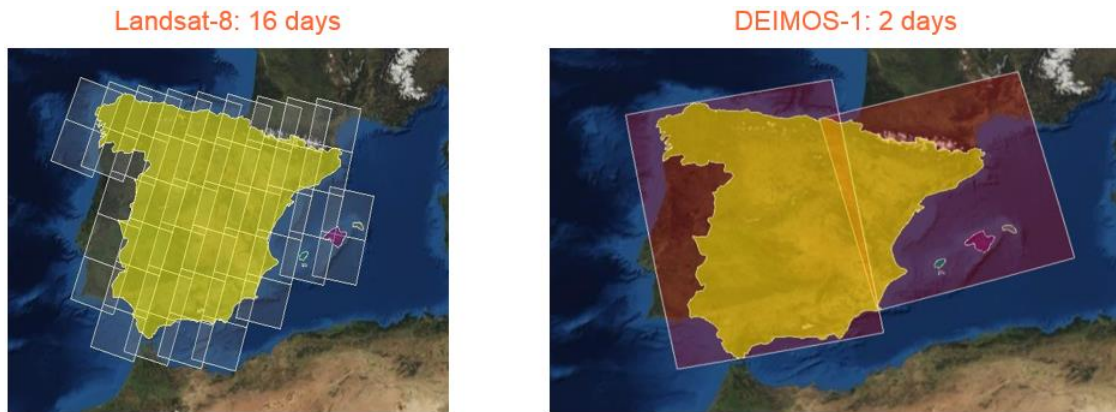


Figure 2. Example of coverage simulation – June 1 to June 16, 2013

In the case of India, because of its wide swath, Deimos-1 can get a country coverage in 3 months as shown in Figure 3:

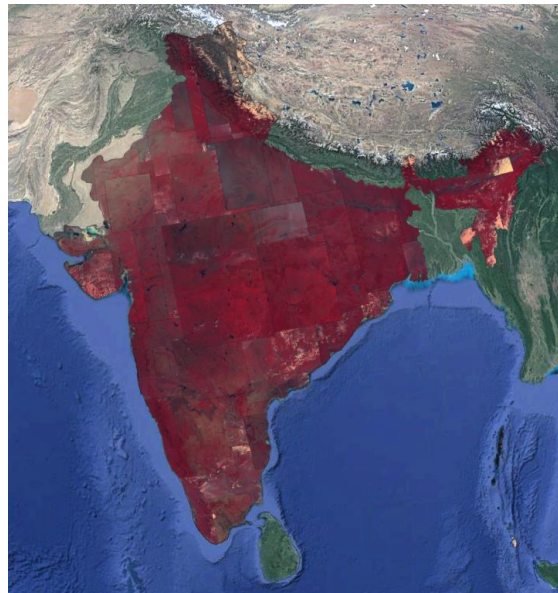


Figure 3. India full coverage with Deimos-1 imagery acquired between September and November 2016

The main applications of Deimos-1 is in the field of agriculture, forestry, disaster monitoring or large-scale change detection.

2.2. Theia (MRC)

Theia, UrtheCast's Medium-Resolution Camera (MRC), captures strips of 5-m resolution and 4-channel multispectral imagery (R,G,B,NIR) with a swath width of 50 km. The system located in the ISS has a fixed nadir viewing and is on continuously, imaging both day and night, acquiring roughly 29 Mkm²/day.

2.3. Deimos-2

DEIMOS-2, launched in June 2014, is a very-high resolution (75cm pan-sharpened) multispectral optical satellite with a 12-km swath. The spacecraft design is based on an agile platform for fast and precise off-nadir imaging (up to 30° over nominal scenarios and up to 45° in emergency cases), and it carries a push-broom very-high resolution camera with 5 spectral channels (1 panchromatic, 4 multispectral). The agility of the sensor allows for acquisition in single-pass stereo imaging mode. The whole end-to-end DEIMOS-2 system has been designed to provide a cost-effective and highly responsive service to cope with the increasing need of fast access to very-high resolution imagery.

2.4. Iris

Iris, UrtheCast's High-Resolution Camera (HRC), is mounted on an agile pointing platform that allows for the tracking of targeted Areas of Interest. Iris captures 1-m full-color videos with a duration of up to 60 seconds.

3. MULTITEMPORAL COVERAGES

3.1. US Crop Season Monitoring Campaign

One of the key advantages of DEIMOS-1 is merging short revisit times and high spatial resolution. The system is optimized to generate frequent coverages over very large areas, such as countries or continents. This capacity provides a short latency for new opportunities which mitigates cloud risk coverage.

DEIMOS IMAGING has been the satellite imagery provider for the US Department of Agriculture (USDA) campaigns for the monitoring of crop seasons between 2011 and 2015 in the frame of the contracts awarded to and led by Airbus Defense and Space delivering one coverage of Contiguous United States (CONUS) every 15 days. The provision of Deimos-1 data has been complemented with data from its twin DMCii satellite UK-DMC2 (around 65% of all delivered data is from Deimos-1, with 35% from UK-DMC2). The data has been acquired from April to October with 90% cloud-free coverage and with daily acquisitions. In addition, the imagery has been delivered and orthorectified in most of the cases in less than 24 hours from acquisition and orthorectified with <1 pixel GSD accuracy. The consistent service provided is shown thanks to the provision of more than 1 Million Km2 cloud-free data delivered every day for 6 months every year. The final USDA products are 30-m Cropland Data Layers with 9 billion pixel.



Figure 4. Simulation of complete coverage of CONUS in a fortnightly period with DEIMOS-1

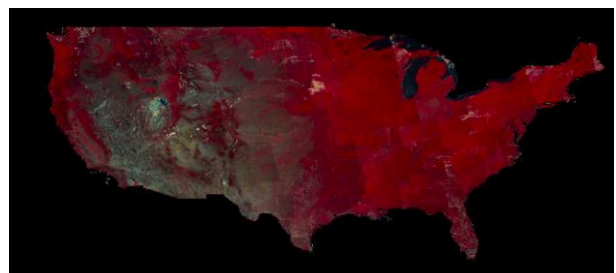


Figure 5. DEIMOS-1 coverage of CONUS in 2 weeks (16-30 June 2012)

In the Figure 6, it can be seen the result of the fortnightly delivery carried out, showing 23 bi-weekly coverages of the US during the two crop seasons. By default, an average of 12 bi-weekly coverages has been delivered in every crop season between 2011 and 2015.

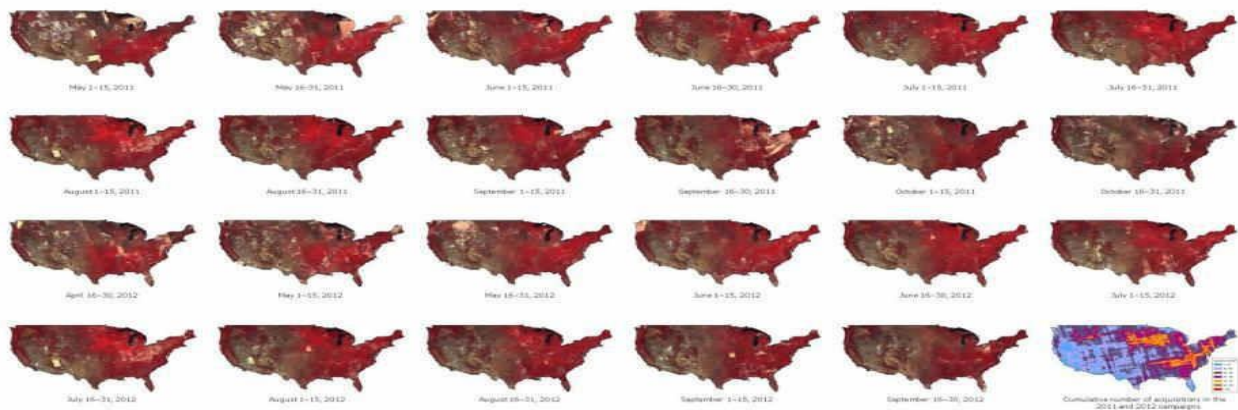


Figure 6. Bi-weekly coverage of CONUS during the crop seasons

3.2. High-frequency monitoring of crop conditions in Northern Texas in 2013

Deimos-1 has been used in precision agriculture for irrigation support systems for corn, winter wheat and sorghum crops. Specifically, Deimos-1 acquired imagery as frequent as possible over and area of interest in Northern Texas for the 6-month growing season in 2013. In coordination with its twin UK-DMC2, Deimos-1 data was acquired and manually orthorectified in less than 24 hours providing a multitemporal subpixel accuracy for seamless comparison at pixel level. For a center-pivot irrigation system support, Deimos-1 and UK-DMC2 were able to provide crop plots monitoring with cloudiness hazards minimized.

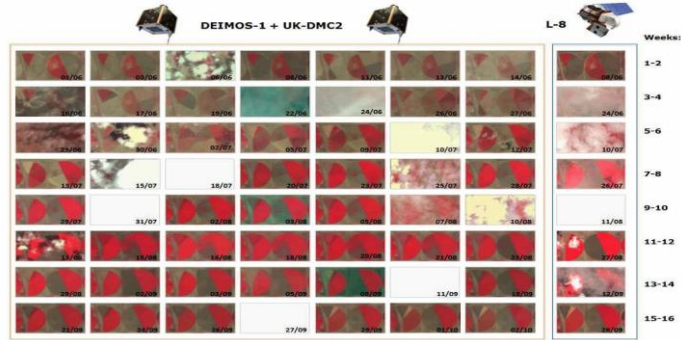


Figure 7. Deimos-1 and UK-DMC2 acquisitions over Texas in comparison with Landsat-8

The high frequency and high resolution data supplied have enabled to supply a successfully operational service for precision agriculture with a high success with the multitemporal overlay at pixel level. In the frame of this contract, Deimos-1 and UK-DMC2 have acquired 21 images in 40 days (11 cloud-free). As a comparison, only 3 images were available with Landsat-8 (all clouded).

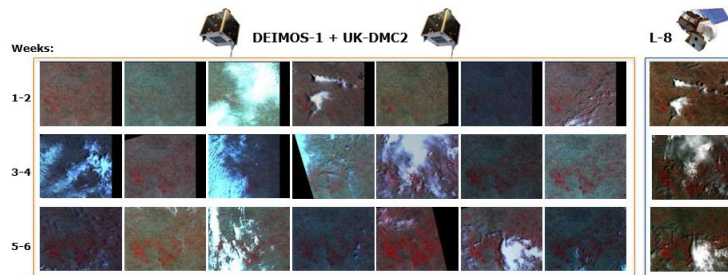


Figure 8. High-frequency coverages of Northern Texas during June-July 2013, with DEIMOS-1 & UK-DMC2

In this campaign, the use of Deimos-1 gave the opportunity to analyze vegetation evolution derived of the high-frequency monitoring for a proper NDVI evolution study.

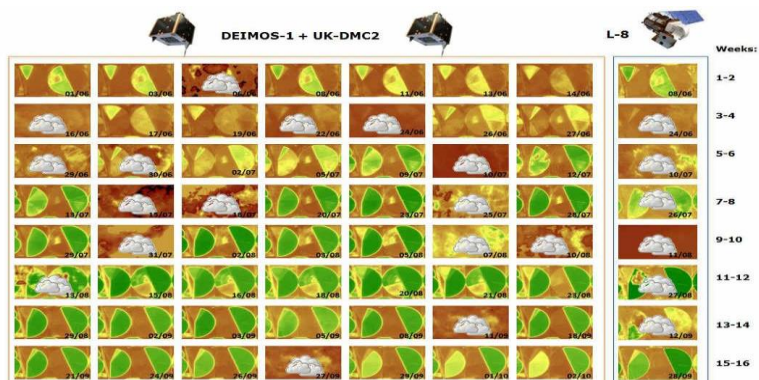


Figure 9. DEIMOS-1/UK-DMC2 data series, to the values extracted from Landsat 8 scenes

Meanwhile with Landsat 8 there is only an acquisition every two weeks, Deimos-1 and UK-DMC2 data provides a high revisit time which allows for a very detailed crop evolution analysis and reflects the variance of vegetation in two-week period.

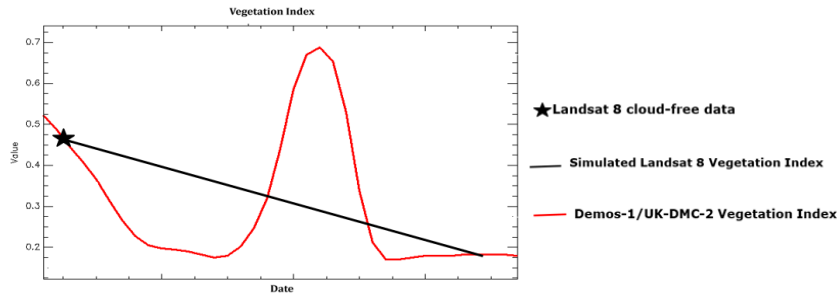


Figure 10. Differences in vegetation Index between Landsat 8 and Deimos-1/UK-DMC2

3.3. European HR2 Multitemporal Coverages

The objective of the wall-to-wall Multitemporal HR2 image acquisition has been to cover the entire Europe on a monthly basis during the 2015 vegetation period, that is, between April and October, for the continuation of previous pan-European land services and land use/land cover mapping efforts. The data from Deimos-1 and UK-DMC2 has been used for multitemporal agricultural studies and crop classification.

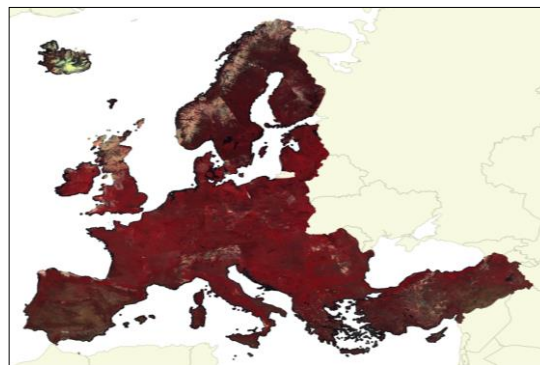


Figure 11. Europe coverage with Deimos-1 satellite

3.4. Africa: GMES Programme (ESA)

One complete coverage of Sub-Saharan Africa between 2010 and 2011 generated for the European Space Agency (ESA) in the frame of GMES Programme. Deimos-1 acquired and delivered imagery with 90% cloud free data orthorectified with <1 pixel accuracy and with a sub-pixel accuracy with RMSE average near 1/2 pixel w.r.t. Landsat GLS2000 reference dataset (see Figure 12).

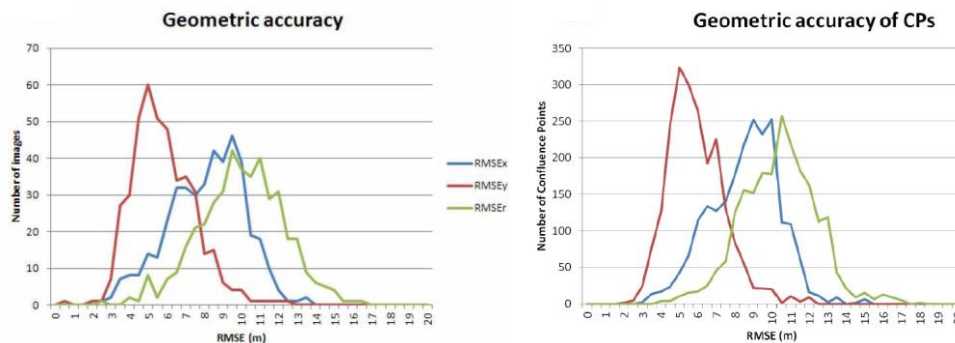


Figure 12. Low geometric error in Deimos-1 ortho imagery delivered

Also, Deimos-1 collects a cloud-free african continent coverage every year.

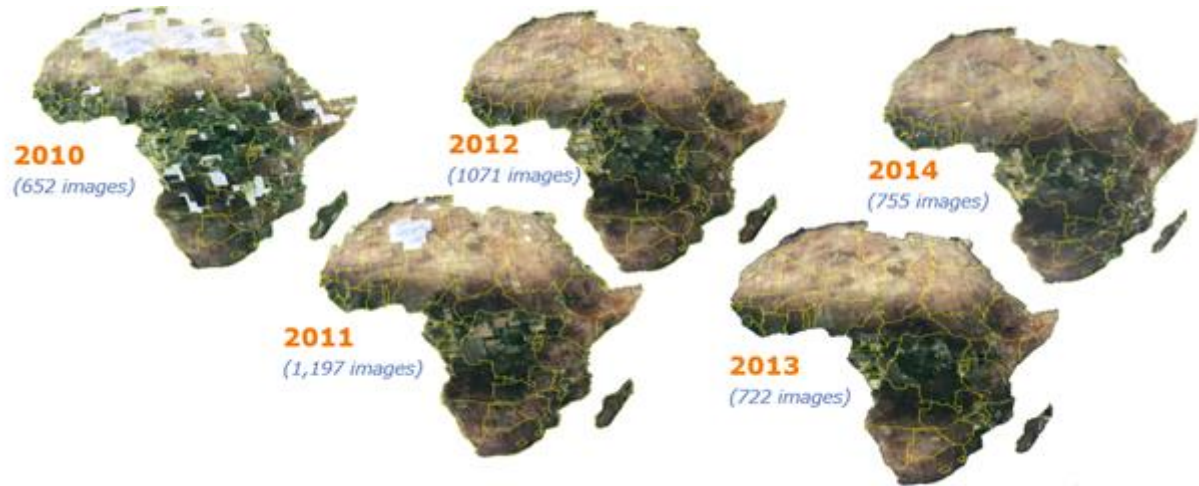


Figure 13. Yearly Africa coverage with Deimos-1

4. URTHEDAILY CONSTELLATION: CONTINUITY AND UPGRADE OF THE SYSTEM

UrtheDaily™ Constellation concept consists of eight additional electro-optical satellites equiphased in a sun synchronous orbit and designed to provide coverage of the Earth's entire landmasses (around 140 Mkm²) in six-band multi-spectral imagery at 5m GSD every single day.

Imaging over land at nadir pointing with a 360-km swath in an altitude of 660 km, UrtheDaily will acquire tens of terabytes on a daily basis which will be processed, analyzed and distributed immediately after collection. Dedicated ground stations will continuously collect the data and feed it into the UrthePlatform, the user-friendly UrtheCast's cloud-computing infrastructure and via APIs, all based on the UrthePlatform. Data archives will be managed and made accessible at various levels of abstraction. This constellation is the market-driven progression of Deimos-1 and Theia sensors and it is estimated to be fully operational by the 2018 growing season.

The system is being optimized for agricultural, forestry and change-detection applications and is expected to enable powerful data mining and global intelligence capabilities. It will revolutionize global monitoring with high-quality, high-revisit imagery, and daily global coverage.

UrtheDaily will deliver reliable, global daily stream of high quality and scientifically accurate ortho-rectified imagery with a high geometric accuracy. It will be key for any value-added products.