Deimos-1
Absolute Calibration and Data Validation

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The Deimos-1 E2E EO System

Calibration
  - Relative calibration
  - Absolute calibration
  - Cross-calibration

Data Validation
The Deimos-1 E2E EO System
**DEIMOS Imaging** is the company devoted to Earth Observation within the DEIMOS Group, the technological branch of **ELECNOR**, one of the largest industrial corporations in Spain.

DEIMOS-1 is part of the DMC, but **DEIMOS Imaging** is the owner and operator of the **DEIMOS-1 satellite**, and markets its images and value-added products worldwide.
End-to-End EO System

**Space Segment**

- DEIMOS-1 Multispectral Satellite
- High spatial resolution (20 m)
- Very large swath (640 Km)
- High revisit capacity

**Ground Segment**

- Ground segment antennas in Valladolid (Spain) and Svalbard (Norway)

**User Segment**

(Data Processing and applications)
- **Combination of high spatial and temporal resolution**
- Spatial resolution of **22m**
- The wide **640-km swath** allows to have a high frequency of observation of any given point on Earth
- **Three bands (R,G,NIR)** similar to Landsat to assure continuity with existing tools and harmonization with historical data
- Radiometric resolution dynamically optimized on-board to 8 or **10 bits**

![Deimos-1 (22m)](image1)

![Landsat 7 ETM+ (30m)](image2)

![Wavelength (nm)](image3)
The **2-station ground segment** is a key asset of the DEIMOS-1 system

- Svalbard (Norway) allows to **download data at each orbit**
- Boecillo (Spain) allows **4 further contacts each day**
- Weekly data volume: 120Gb
- DEIMOS premises in Boecillo have a complete control centre integrated with a user segment
  - Mission Planning
  - Flight Operations
  - Telecommand
  - Telemetry
  - Processing
  - Archive
- **Advanced mission planning system**, developed in-house, allows optimization of large coverage campaigns
- DEIMOS-1 **wide swath** (640 km) combined with **data download at each orbit** assures a high revisit frequency for any given point on Earth

- 2-3 images per day over the US (~1 million sqkm per day)

- **Complete coverage of the US every 2 weeks**
Example of system capacity: **monthly cloud-free (>90%) coverage of Spain**
Example of system capacity: **monthly coverage of Afghanistan**
Example of system capacity: **almost complete cloud-free coverage of South-east Asia in 2010** (ESA TROPFOREST project)
DEIMOS Imaging provides **DEIMOS-1 images** to ESA, institutional customers and added value EO companies.

In addition, DEIMOS Imaging provides final EO **value added products and services** in the following domains:

- Agriculture
- Fire Monitoring
- Environment
- Insurance
- Forestry
- Maritime Surveillance
- Disaster Monitoring
Contents of DEIMOS-1 **online image catalog** (>3000 images)

[www.deimos-imaging.com](http://www.deimos-imaging.com)
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Deimos-1 Calibration
The Deimos-1 Payload

- 2 banks, 3 cameras per bank
- 3 bands (NIR, R, G Landsat equivalent)
- 22 m GSD
- 320-km swath per bank
- SLIM6 pushbroom CCD
- ~ 14,400 detectors per camera
- Radiometric resolution: 8 or 10 bits
- Each detector is considered a radiometer and has to be characterized
Calibration Strategy

- On-board measurement of noise parameters and on-ground de-noising

- **Dynamic Calibration**: on-board control of gain parameters (rescaling from 14 to 8 or 10 bits) as a function of the type of the target, to optimize the radiometric resolution of the data

- **Absolute and relative calibration pre-launch, and complete post-launch calibration campaigns (periodically updated)**:
  - Sensor relative calibration / detectors equalization
  - **Absolute calibration** (annually on Tüz Gülü, CEOS-endorsed, with ground team)
  - **Cross-calibration with other DMC platforms** (annually on Dome-C, CEOS-endorsed)
  - **Cross-calibration with the “gold standard” Landsat 7** (annually on Libya, CEOS-endorsed and Dome-C)
  - **Tracking of cross-calibration with Landsat 7** (monthly in Spain and Libya)
  - Analyses of cross-calibration with other platforms: SPOT-5, Formosat-2

- **Combination of DMCii constellation calibration and DEIMOS activities**
- Post-launch commissioning campaign
- Assess background signal for each detector and estimate noise
- Full-swath images over the Pacific, at night, avoiding natural and artificial light sources (dark frame)

- The background signal is different for each detector, due to pixel-to-pixel variation in sensitivity
- The signal is also sensitive to a number of imaging parameters, which shall be optimized and fixed

(Source: Dr. S. Mackin, DMCii)
Two effects are visible, in addition to the difference in response for each detector:

- **Vignetting**: Intrinsic to the camera. Compensated by calibration coefficients
- **Asymmetry**: The snow has a significant BRDF effect, and the ground is viewed under a changing solar angle across-track

**Asses the signal over a bright target**

**With a ~300-km swath per bank a large and uniform area is required**

**CEOS Landnet site Dome-C (Antarctica) is chosen**

**Yearly calibration campaign**

A very uniform white surface: Deimos-1 image over Dome-C

(Source: Dr. S. Mackin, DMCii)
To minimise the BRDF effect, we **turn the platform in yaw** so that the CCD is perpendicular to the Principal Plane. This manoeuvre has to be parametrized ad-hoc for each Dome-C capture.

In the image above, we can see the nominal swath footprint in comparison with a dual bank image captured using the described technique.
The asymmetry disappears on the right graph, which comes from a Dome-C image taken with the platform properly yawed. The left one was generated using an image captured with the platform in its nominal orientation.

Once the effect of the BRDF is removed, we can characterize each detector with a gain and a bias, equalize their response, and consider the full array of detectors as a single one.

Next step: Proceed with absolute calibration.
Relative Calibration

Before equalization process

After equalization process
Now we have each array equalized, it's time to make them measure radiance.

We startes with pre-launch absolute calibration parameters (launch on July 29th, 2009).

**Vicarious calibration:** Acquisition of images of Tuz Gölü (Turkey), a CEOS Landnet site, coordinated with TÜBİTAK. TÜBİTAK performed ground and atmospheric measurements and generated atmospherically-corrected TOA radiance at the time of the satellite overpasses.
TOA (Top of Atmosphere) radiance values were calculated using 6S (Second Simulation of a Satellite Signal in the Solar Spectrum) radiative transfer code.

The collected parameters for 6S were:

- Surface Reflectance
- Geometrical Conditions: Acquisition month, day, solar zenith and solar azimuth angle at acquisition time, view zenith and azimuthal angle.
- Atmospheric Model: Atmospheric Profile and Aerosol Model
- Spectral Conditions
- Target and Sensor Altitude

(Source: Tübitak)
With all linear arrays of detectors equalized, we need only a small, but very well measured, sample which spans to a few pixels to obtain the absolute calibration parameters for each band. These parameters will be extensible to the whole array.

Main output: **absolute calibration uncertainty <5% on all bands**

Deimos-1 image. 2009-08-27.
Pixel representation scale exaggerated.

The first set of post-launch absolute calibration parameters was generated on 2009-10-23
- August 2010 - CEOS Land Comparison campaign.
- Location: Tuz Gölü salt lake. Carried out by TÜBITAK.
- Sensors:

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<tr>
<th>Institution</th>
<th>Optical sensor</th>
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<td>CMA</td>
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(Source: Tübitak)
- August 2010 - CEOS Land Comparison campaign.
- Deimos-1 Image (2010-08-19)
3 Deimos-1 Validation
- Libya 4 CEOS pseudo-invariant site
- Two acquisitions per month
- Monitoring:
  - Trend
  - Landsat 7 cross-calibration
  - Other DMC platforms cross-calibration
- Outputs are used as inputs to tune the calibration parameters. So this periodic acquisition is both a calibration and a validation technique.
- The trend monitoring gives us information about the sensors degradation. If a sensible deviation is found, a new calibration campaign would be scheduled.
- Deimos-1 vs Landsat 7 cross-calibration results over Libya-4 (accuracy 1-2%)
In addition to the calibration provided by DMCii, DEIMOS Imaging routinely performs cross-calibration with Landsat-7.

Cross-calibration check with Landsat-7 over Tuz Gölü (Turkey), a CEOS Landnet site. August 2009 => Good correlation.

Cross-calibration check with Landsat-7 over La Crau (France), a CEOS Landnet site. November 2009 => Good correlation.
Satellite Constellation for Crop Monitoring: Formosat-2, Deimos-DMC and Landsat 5TM

- Evolution of NDVI of an irrigated crop (maize) estimated from Deimos-DMC, Landsat 5TM and Formosat-2, during 2010.
- Temporal evolution of NDVI from several sensors can be observed through the SPIDER WebGIS system (EU PLEIADeS Project).

Multi-sensor Constellation for obtaining temporal evolution of irrigated crops

![Graph showing NDVI values for different dates from DeimosDMC, Landsat5TM, and Formosat2](http://zeus.idfr-ab.uclm.es/publico/webais/)
Comparative analysis of CDL with Deimos-1 and Landsat-5 TM over Idaho

- Deimos-1 data can be **seamlessly used within normal procedures**
- Deimos-1 data can be **included in the normal NASS CDL process** (together with or instead of AWIFS, Landsat-5 and/or Landsat-7)
- The resulting **accuracy with Deimos-1 data is very similar** (within 1-3%) to the one obtained with **Landsat** (using all available bands)
- The improved spatial resolution allows to compensate almost completely the lack of a mid-infrared or thermal band

Courtesy MEC GeoStat Inc., USDA NASS & Astrium GEO Services. Used with permission of © owner.
Comparative analysis of NDVI with Deimos-1 and Spot-5 (rice fields)

- In search of the **optimal imagery resolution**, matching to management scale
- SPOT-5 sees more in-field detail: needed for fields with contour variability
- BOTH sensors identify patterns of NDVI variability well
- Much larger swath on DEIMOS-1 assures higher revisit frequency and lower costs
- For most applications, **DEIMOS-1 data is a very cost-effective solution**

Courtesy Astrium GEO Services. Used with permission of © owner.
Conclusions
Conclusions

- DEIMOS Imaging has been successfully operating DEIMOS-1 since July 2009

- DEIMOS-1 has an unmatched coverage capacity at 22-m resolution, thanks to:
  - Wide sensor swath (640 km)
  - 2-station ground segment that guarantees 20 data download slots per day
  - Advanced mission planning system that allows acquisitions optimization

- Calibration (both absolute and relative to Landsat) is considered top priority for DEIMOS-1

- DEIMOS-1 data is constantly calibrated according to CEOS guidelines and validated w.r.t. Landsat

- Results of absolute calibration are within 5% accuracy, and relative calibration with Landsat is within 1-2%

- DEIMOS-1 data can be seamlessly included in the nominal NASS CDL process, with a resulting accuracy very similar (within few %) to Landsat.
• DEIMOS Imaging EO system will be upgraded in 2013 with a new satellite
• DEIMOS-2 will be a small multispectral optical satellite with very high resolution (1m)
• It will be designed, integrated and tested in Spain, in new DEIMOS premises currently under construction
• The combined use of DEIMOS-1 (20 m) and DEIMOS-2 (1 m) will provide a wide range of capabilities for the generation of products in all optical imagery market segments
Thank you!

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