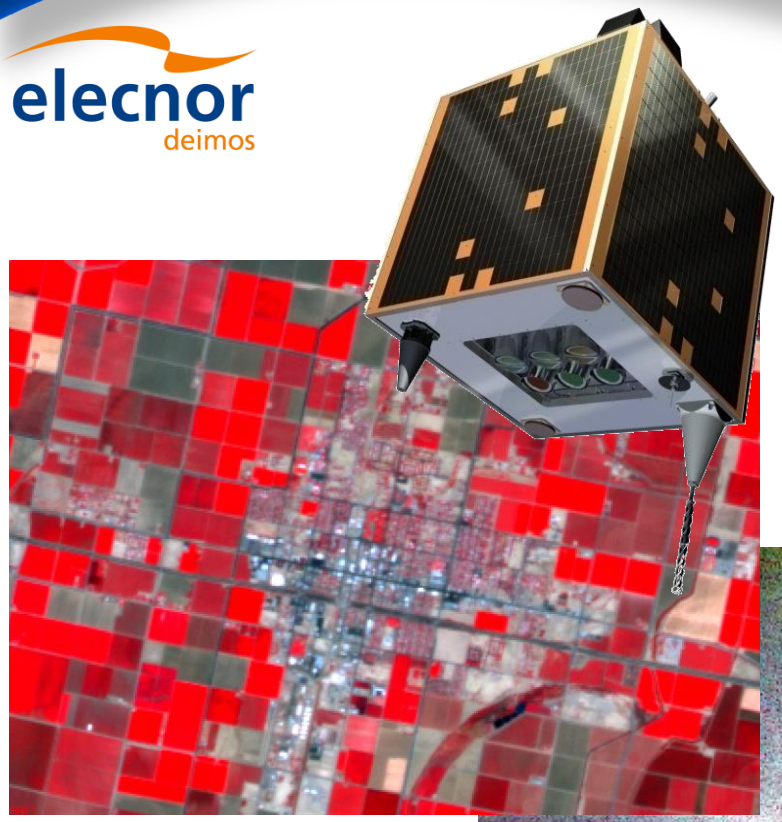
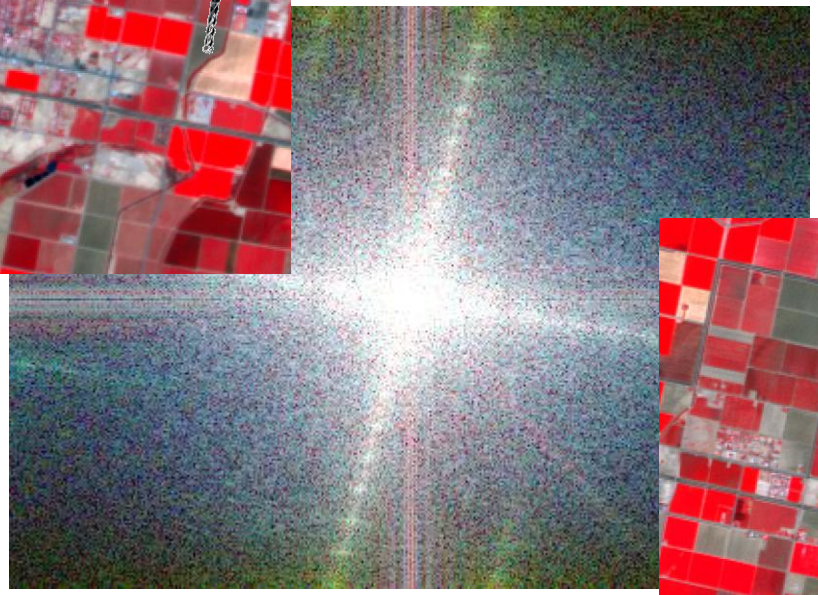
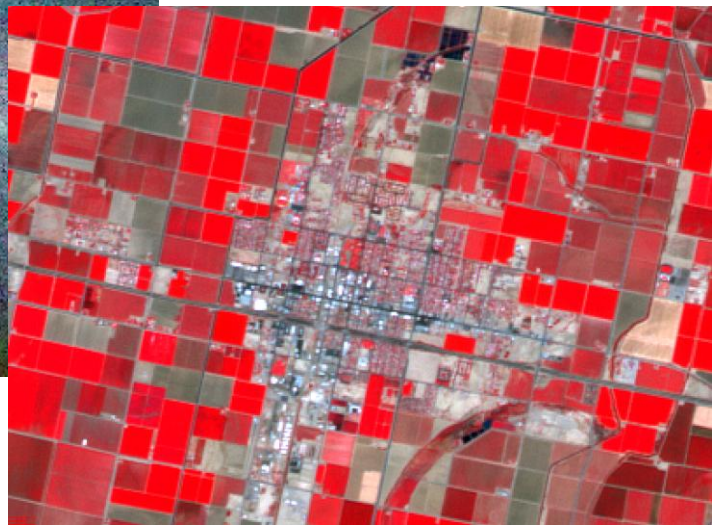
Deimos-1 - Image improvement via MTF deconvolution.







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JACIE 2013
12th Annual Civil Commercial Imagery Evaluation Workshop
St. Louis, MO - April 16-18, 2013

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elecnor deimos

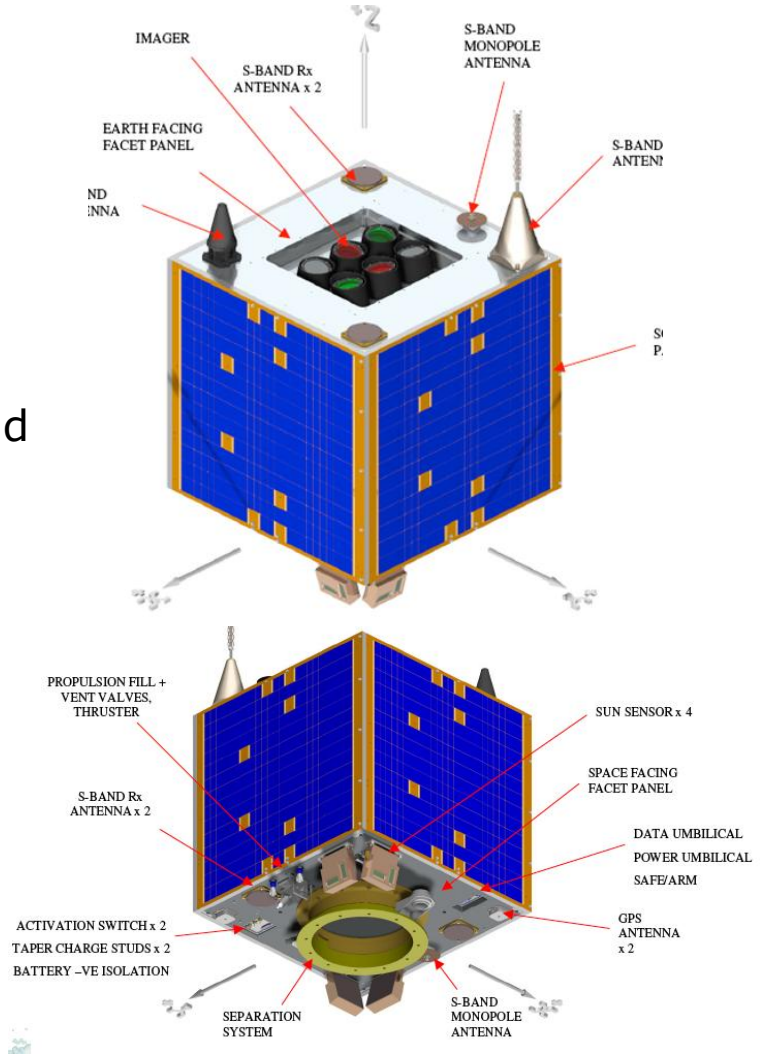
1 The DEIMOS-1 Earth Observation System

DEIMOS-1 EO System

- Fully owned and operated by **ELECNOR DEIMOS IMAGING**
- Subsidiary of **ELECNOR**, one of the largest industrial private groups in Spain
- Member of the **Disaster Monitoring Constellation** (DMC)
- Launched in July 2009, operational since March 2010
- Sun-Synchronous orbit at 650 km
- Lifetime: 5 years nominal, >7 years expected

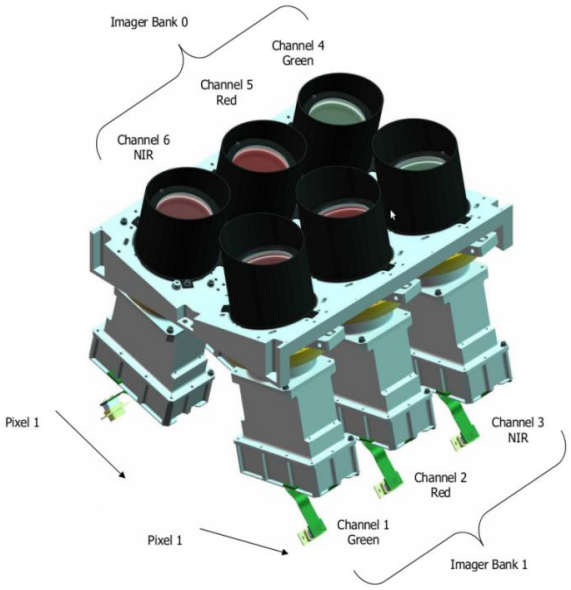
DEIMOS-1 EO System

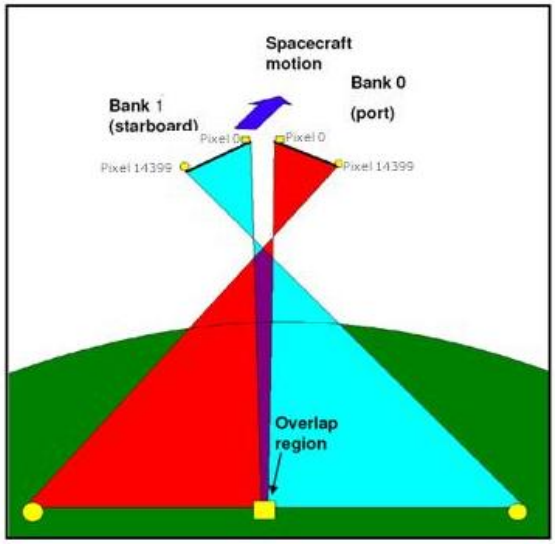
- Built by SSTL (UK)
- Mass: 100 Kg
- Nadir-pointing platform
- 8-Gb on-board solid state recorder
- X-band antenna for data transmission
- S-band antenna for telemetry & telecommand

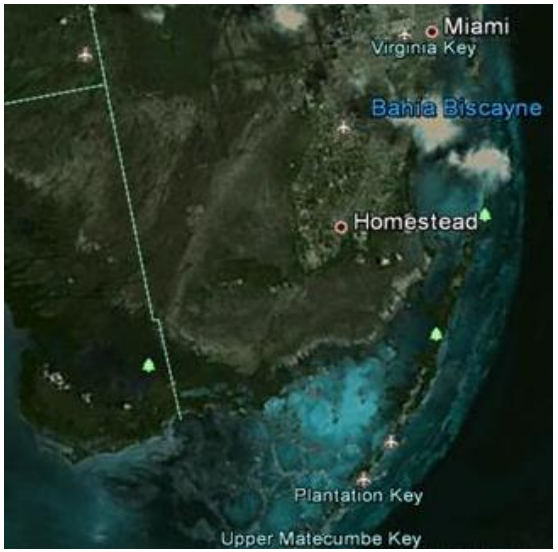


DEIMOS-1 EO System

- Dual-bank pushbroom CCD, 3 cameras per bank
- Spatial resolution of **22m** GSD at 10 bits
- The wide **>620-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
- Synthetic blue band can be generated for natural-color imagery





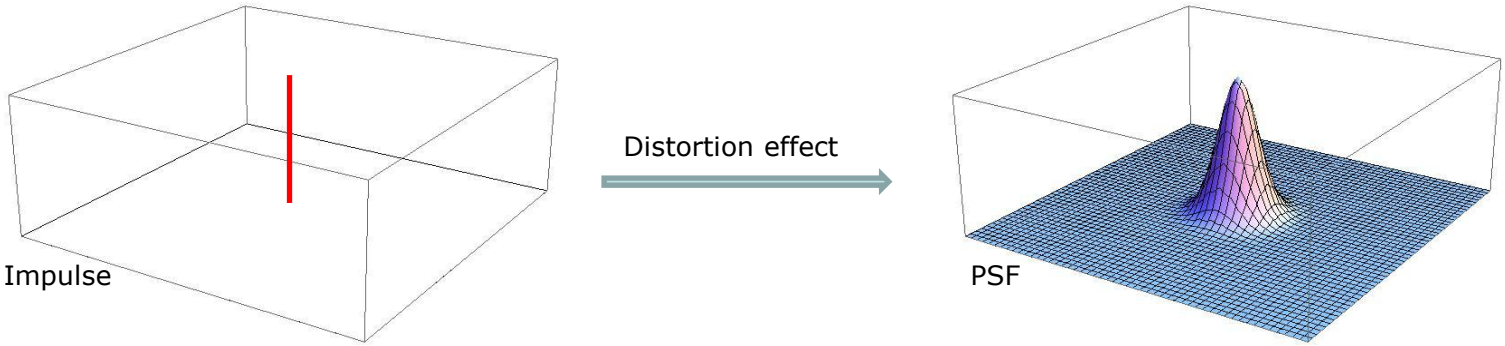


2 Theory overview

Spatial domain

As any signal processing system, there is always a **distortion** between the signal and the measurement. Causes:

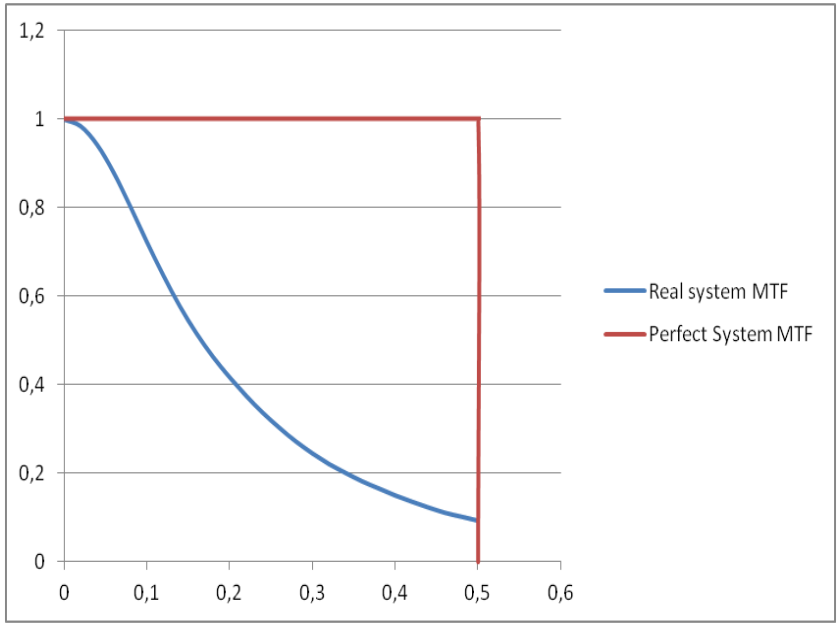
- Satellite motion
- Electronics
- Atmosphere
- Optical system
- Viewing geometry



Result: The image of a signal can be interpreted as the convolution of the signal and the PSF.

Frequency domain

Spatial performance characterized in the frequency domain: MTF

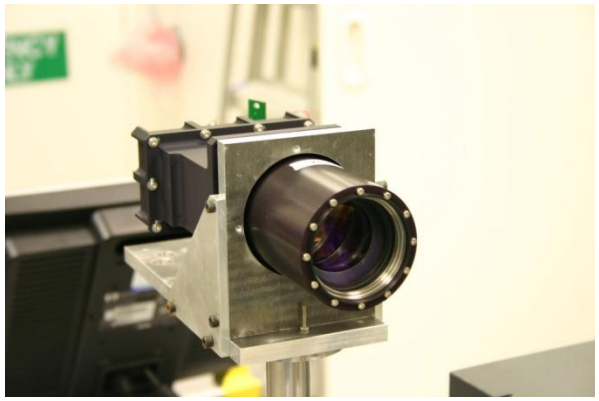


- High MTF@Nyquist in a real system
  - Good response at high frequencies
  - Possible artifacts

3 Targets considered

Constraints to MTF estimation

- The Deimos-1 MTF was measured pre-launch
- Due to launch vibrations, sensor degradation and other factors, it is necessary to measure it in flight
- Proper targets shall be selected on-ground to perform the estimation
- Constraints to in-flight MTF estimation in Deimos-1:
  - GSD
  - Wide swath
  - Integration time
  - Atmospherical & ground effects

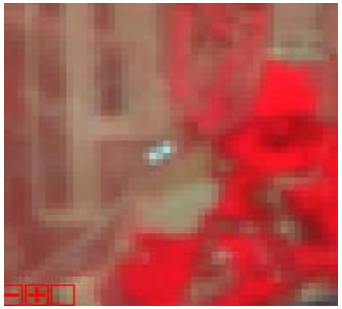


Targets considered

- Point source (Light source)
  - PSF undersampled
- Pulse target (Bridges)
  - Not a true pulse
- Artificial calibration targets
  - Too small

Bronx Whitestone Bridge, New York City, U.S.
Width: 26 m

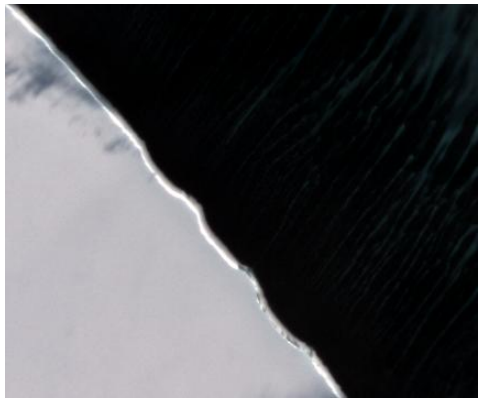
Salon de Provence checkerboard (France)



Deimos-1 image

Targets considered

- Natural edge targets: Ross ice shelf.



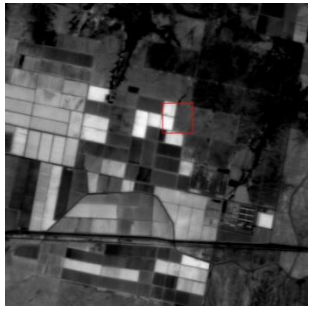
- Sunglint-like effects in the border caused by snow or ice BRDF and the slope

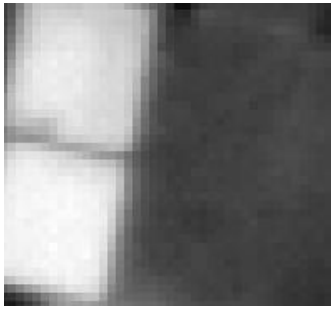
- Area under a cloud shadow: Diffuse illumination. The border is still not sharp

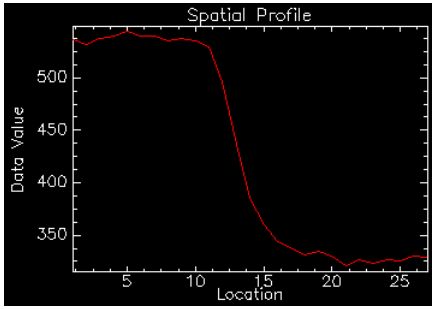
Targets considered

- Field transitions

NIR

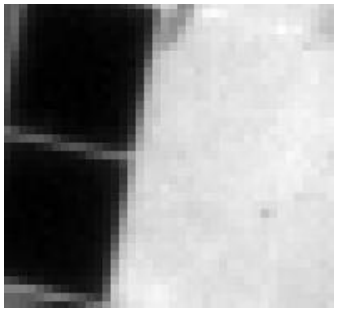


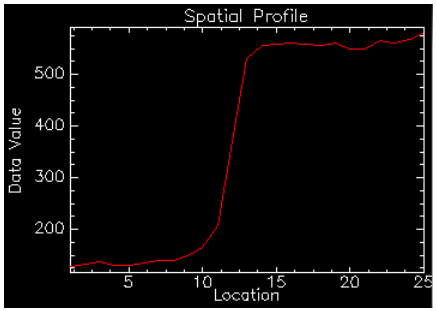




Contrast
~ 40%

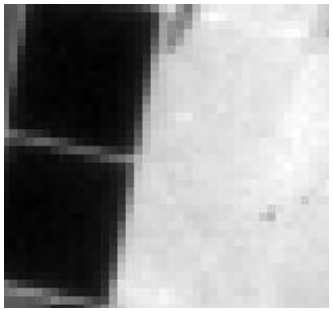
Red

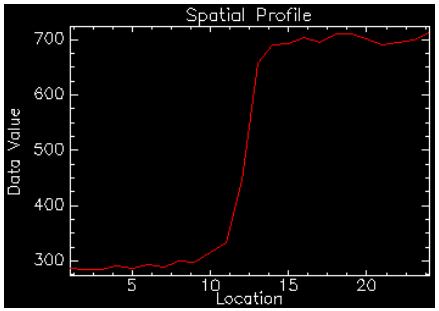




Contrast
~ 76%

Green





Contrast
~ 59%

Targets considered

- We find the **field transitions** more suitable for Deimos-1 MTF estimation

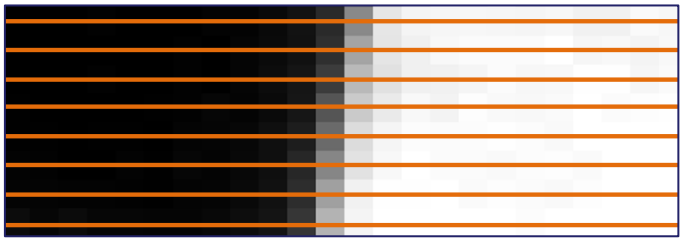
- Advantages:
  - Large number of targets
  - The borders are sharp
  - The contrast is high enough to perform a representative estimation

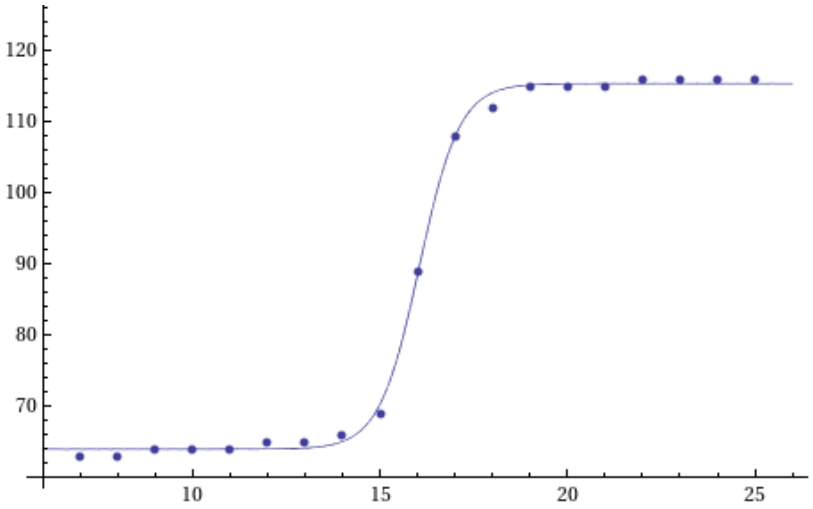
- Disadvantage:
  - The areas neighbouring the edge are not uniform

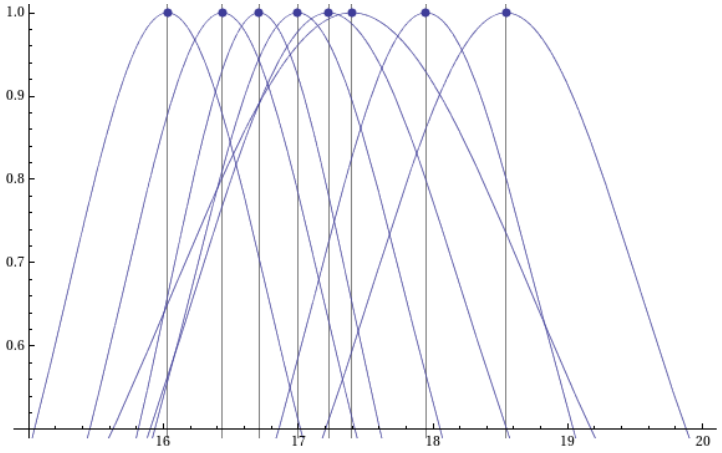
4 MTF estimation

MTF estimation

- MTF estimation was performed using the **slanted edge methodology**
- Source data was raw data after PRNU correction
- Fixed integration time for all captures to avoid the motion blur to affect the characterization
- Viewing geometry was taken into account

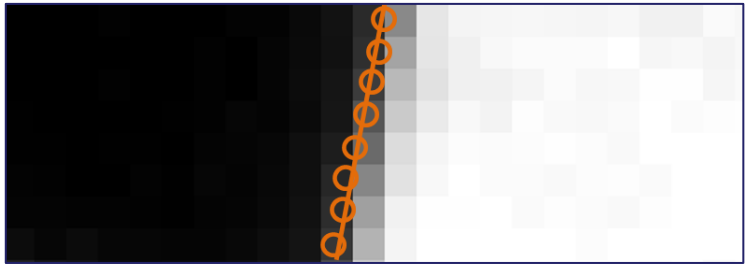


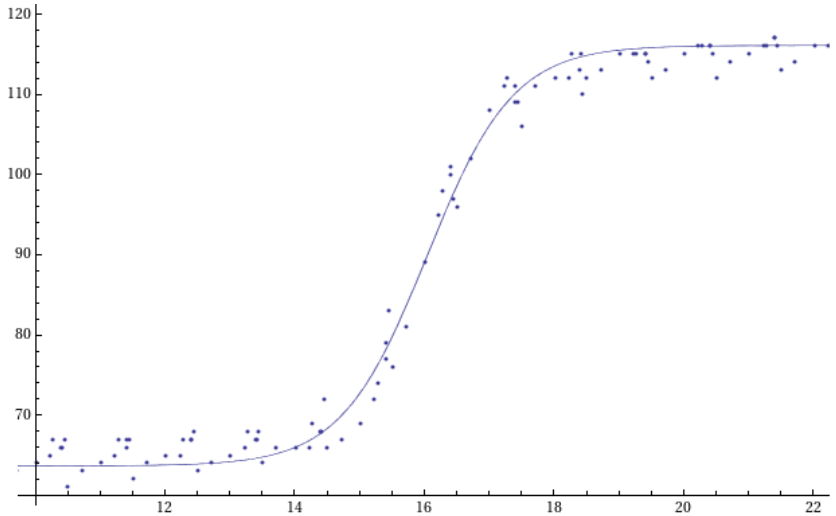




MTF estimation

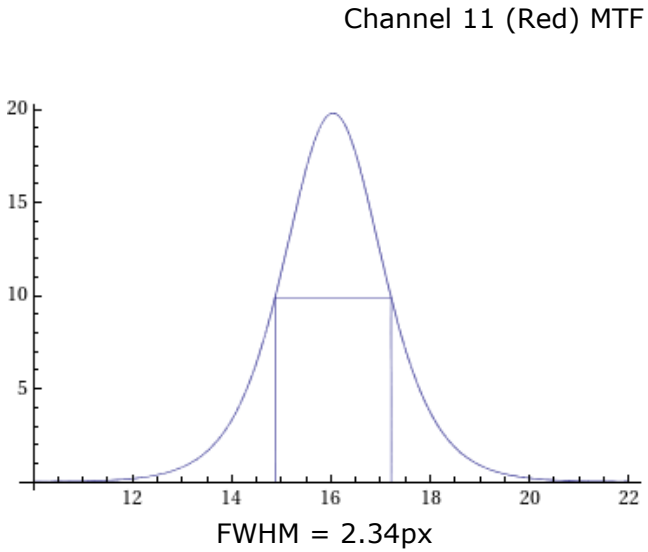
- We assume that the edge is straight, so a least square fit is performed on the edge locations
- The profiles are shifted in order to the maximum slope to match the fit

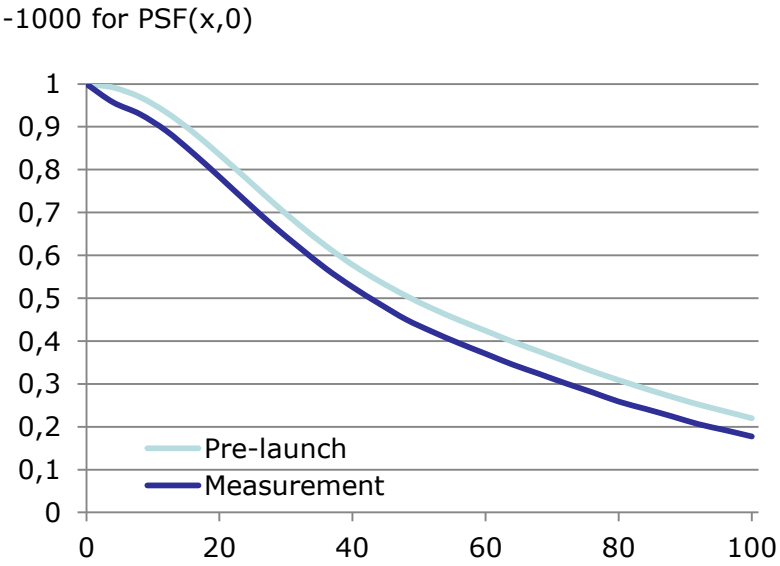




- And adjusted again to a parametric function
- We keep the parametric model to reduce noise inherent to this methodology

- The function was then discretized by 0.05 pixel steps to obtain the **super-sampled** ESFx, differentiated and normalized to get LSFx





- Repeating the procedure along the track will provide the LSFy.
- After normalization, we build the PSF as PSF(x,y) = LSFx(x,0) x LSFy(0,y)

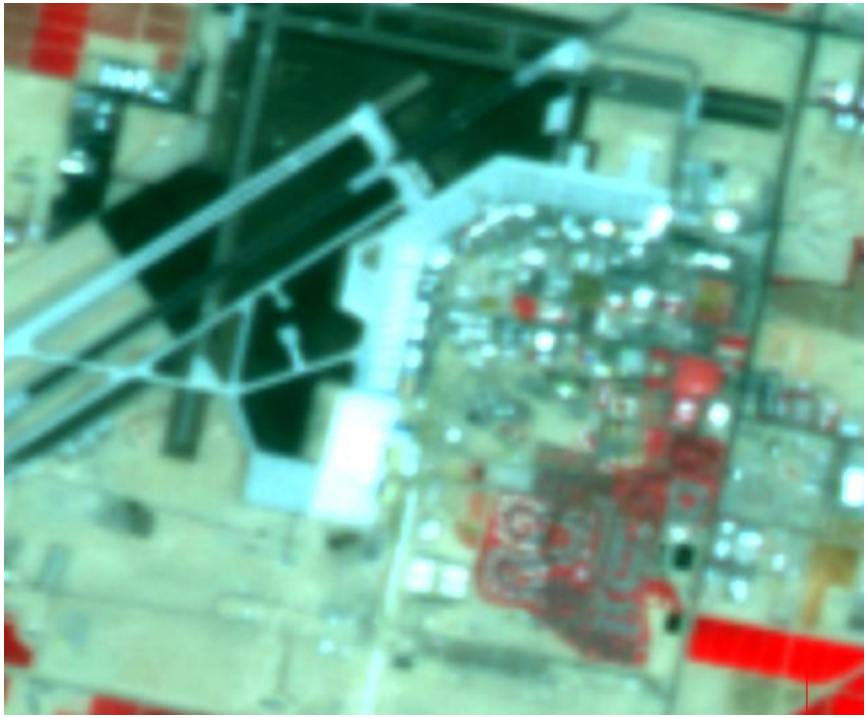
5 MTF correction

MTF correction

- Several deconvolution methods were evaluated
  - Adaptative algorithms
  - Iterative algorithms
  - Direct deconvolution
  - Wiener deconvolution
- The non-iterative **Wiener deconvolution** method was chosen
  - Assumptions:
    - White additive noise, so it is a constant
    - SNR is linear with the signal and has not dependence with the frequency
    - Formulation: $$\hat{W}(u,v) = \frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + \frac{1}{SNR}}$$
- Finally, we can correct the image using $$\hat{I}(u,v) = O(u,v)W(u,v)$$
- And restore it to the spatial domain using the inverse Fourier transform.

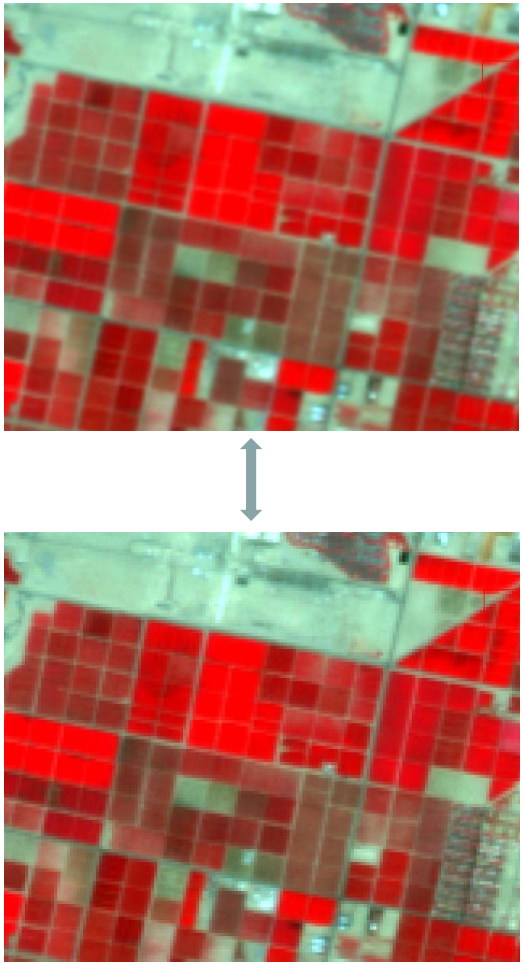
6 Results

- Image enhancement

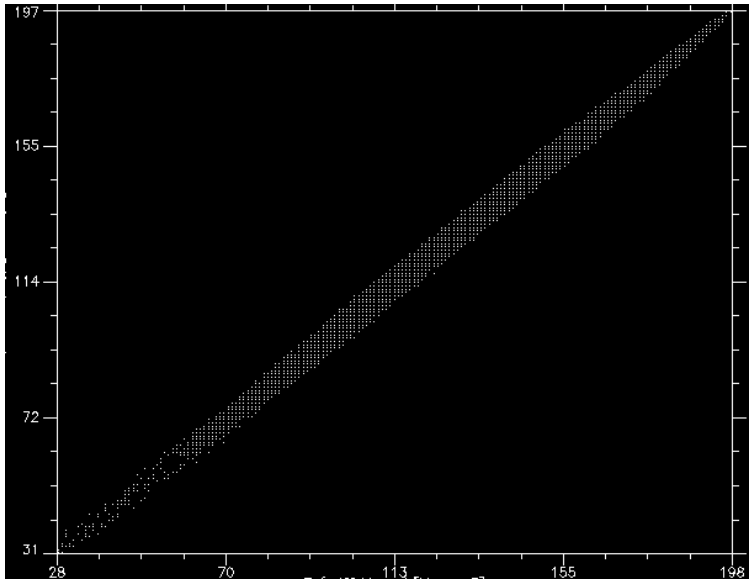


- Image enhancement

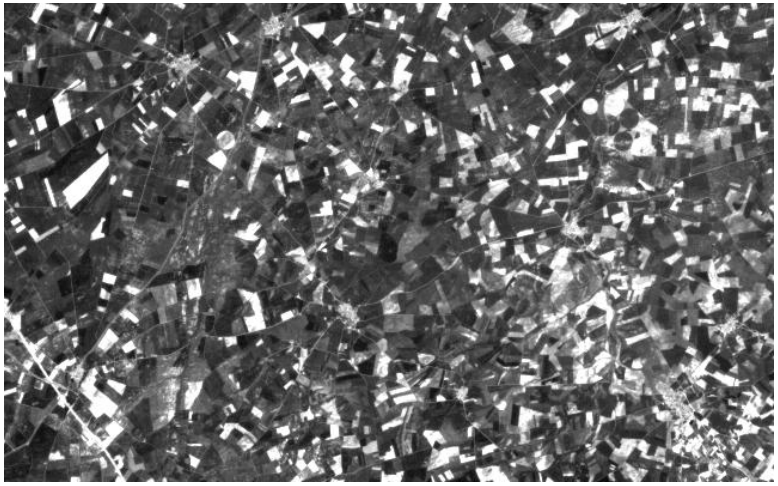
- Radiometric consistence

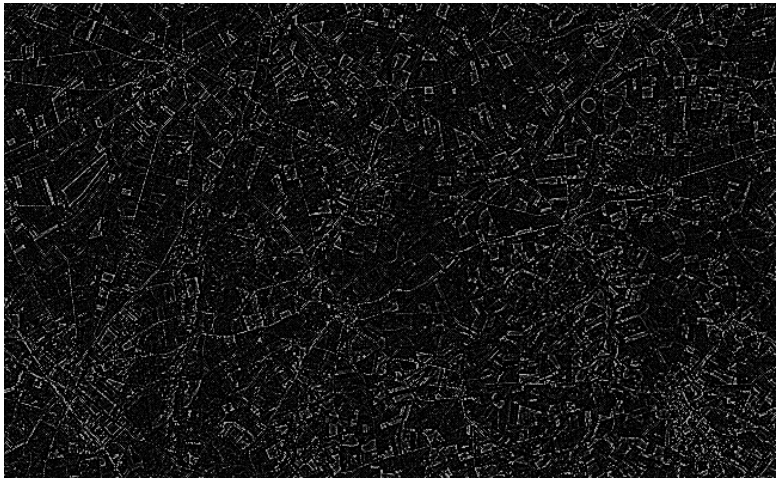


	NIR	Red	Green
Mean error	0.96%	1.97%	2.00%
Stddev error	2.19	3.57	3.76



- Radiometric consistence
  - Effect similar to deblur filter using high-pass
    - Uniform areas keep stable
    - Variation in non uniform areas





Thank you!

Questions?

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