SURREY

CHANGING THE ECONOMICS OF SPACE

Low cost, high resolution imagers in the IVOS framework

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IVOS Meeting 30 - ESA ESTEC

29th March 2018

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Summary

- Historical Introduction to affordable EO (1981-2018)
- Small Satellite capabilities (~<1m GSD)
    - For still images
    - For vidEO
- CalVal related activities:
    - MTF
        - On-ground testing
        - In orbit results
    - SNR
        - Radiometric models for design concepts
        - In orbit calibration
- Conclusion

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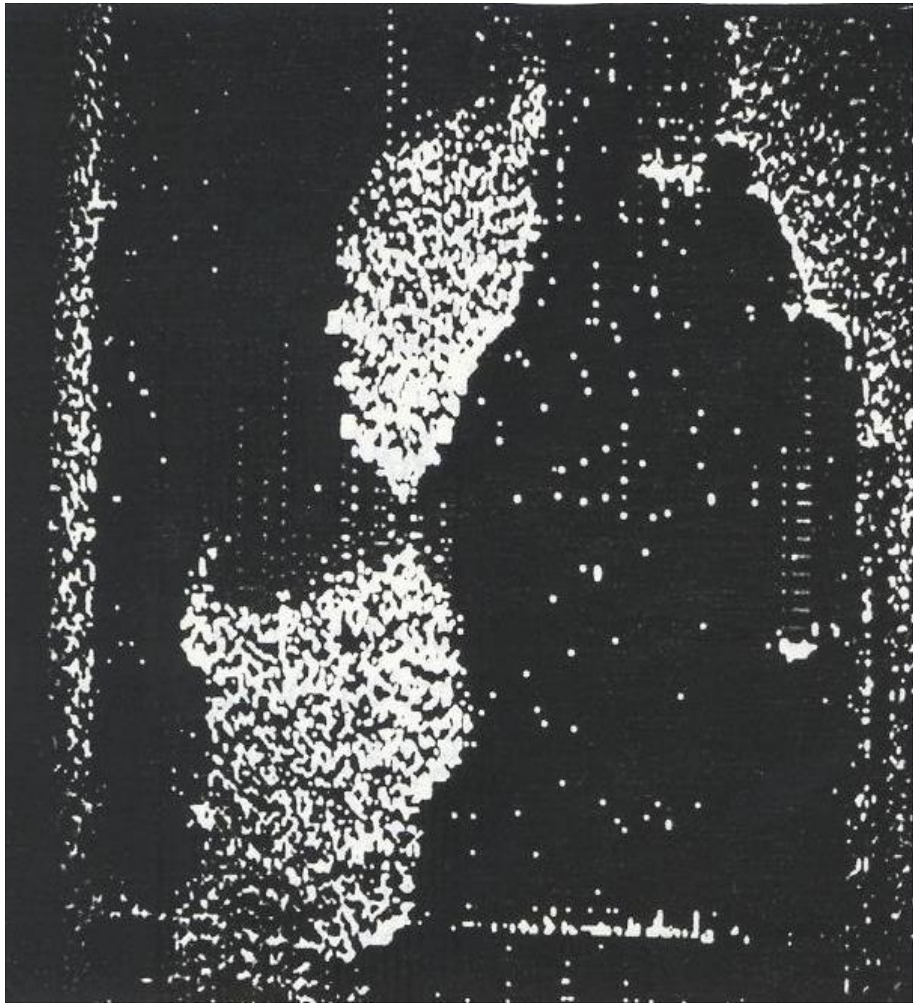
Earth Observation: From There…



- UoSAT-1Microsatellite
- Built between 1980-81
- Launched in Thor Delta rocket by NASA in October 1981
- First image of Corsica
- Carried a re-programmable on board computer and a 2D CCD array imager

To our range of Imaging Payloads

Why small ?

- To keep build and launch costs low
- To be able to meet short timescale projects
- To be able to iterate engineering solutions quicker
- It allows a constellation of more satellites to increase temporal information
- Low cost and high value EO products
    - per kg launched
    - per km^2 imaged areas
    - Per day revisits

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1m,
400kg class
1m,
50kg class

Two Different Classes of Spacecraft

- July 2015 SSTL launched two different classes of small satellites from SSTL:
  - High fidelity performance SSTL S1 spacecraft (TripleSat/DMC3)
  - High utility spacecraft designed for very low cost and rapid schedule missions: Carbonite-1
- Both classes of spacecraft provide high resolution imagery and have been fully operational for over two years
- Constelation + Carb1 were launched on PSLV from Sriharikota, India (SSO @651 km and 10:30 LTAN)
- Carbonite 2 was launched on 12 January 2018 at 505 km


Courtesy of Antrix

Sub-metric surveillance satellite
SSTL 300+

Very High resolution
Simultaneous capture of 1m (can achieve 0.7m)PAN GSD and 4m Multi Spectral GSD (NIR, R, G, B)

Image size
23km x 3500 km

Lifetime
7 years

Off-pointing capability
Roll and Pitch up to maximum 45 degree compound angle

Agility
Fast response mode, 30 degree roll in 40s

Compound modes
2x2 area mode, along and across track stereo modes

Geolocation accuracy
< 50m

High Storage Capacity
2 x 16GB & 2 x 256GB

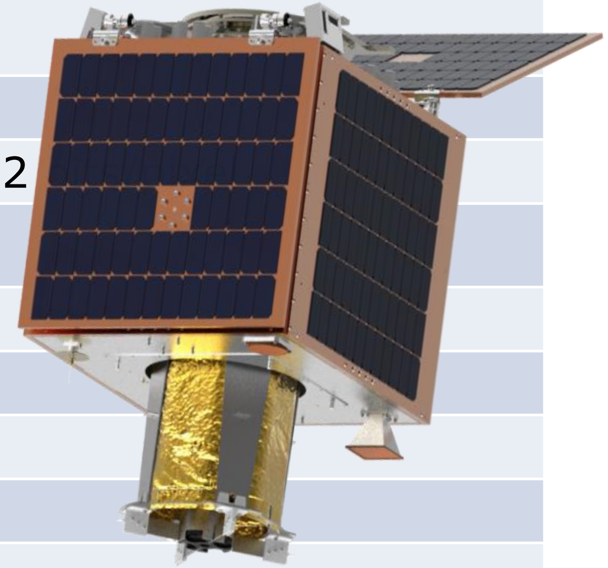
High Downlink capability and Near-Real Time Capability
500 Mbit/s downlink rate and simultaneous imaging and downloading

Complete delivery of space and ground segment
Satellite, Ground station, Mission Planning, Image post Processing, Launch services

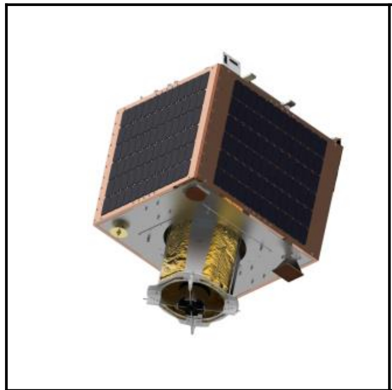
Extensive heritage
NigeriaSat-2 & DMC3 constellation

SSTL-50 Precision – Colour HD Video

Specification	
Spectral Bands	HD Video: PAN or colour, Still: Red, Green, Blue, NIR
GSD	HD video: 1 m, Still imagery: 0.7 m, Both modes from the same payload
Swath	Video mode in 2.5xk2k HD format, Still image mode 17 km swath
Field of Regard	+/- 40^{o} , Equivalent to 750 km on the ground
SNR	All bands > 100:1
Data Products	Radiometrically and geometrically calibrated, 12
Compression Ratio	Lossless up to 2.5:1, Lossy at higher ratios
Mass	150kg dependent on configuration
Redundancy	Dual redundant systems
Reference Orbit	500km, SSO, 10.30am LTAN
Data Storage	Up to 1 Tbyte
Downlink	80-500 Mbits per second
Design life	5 years+
Revisit	2 times daily above lower latitudes for 5 satellite constellation
Data capacity	640 – 960 image scenes per day (17x17km) 185,000 to 280,000km^2 per day



Comparison of S1 and Carbonite



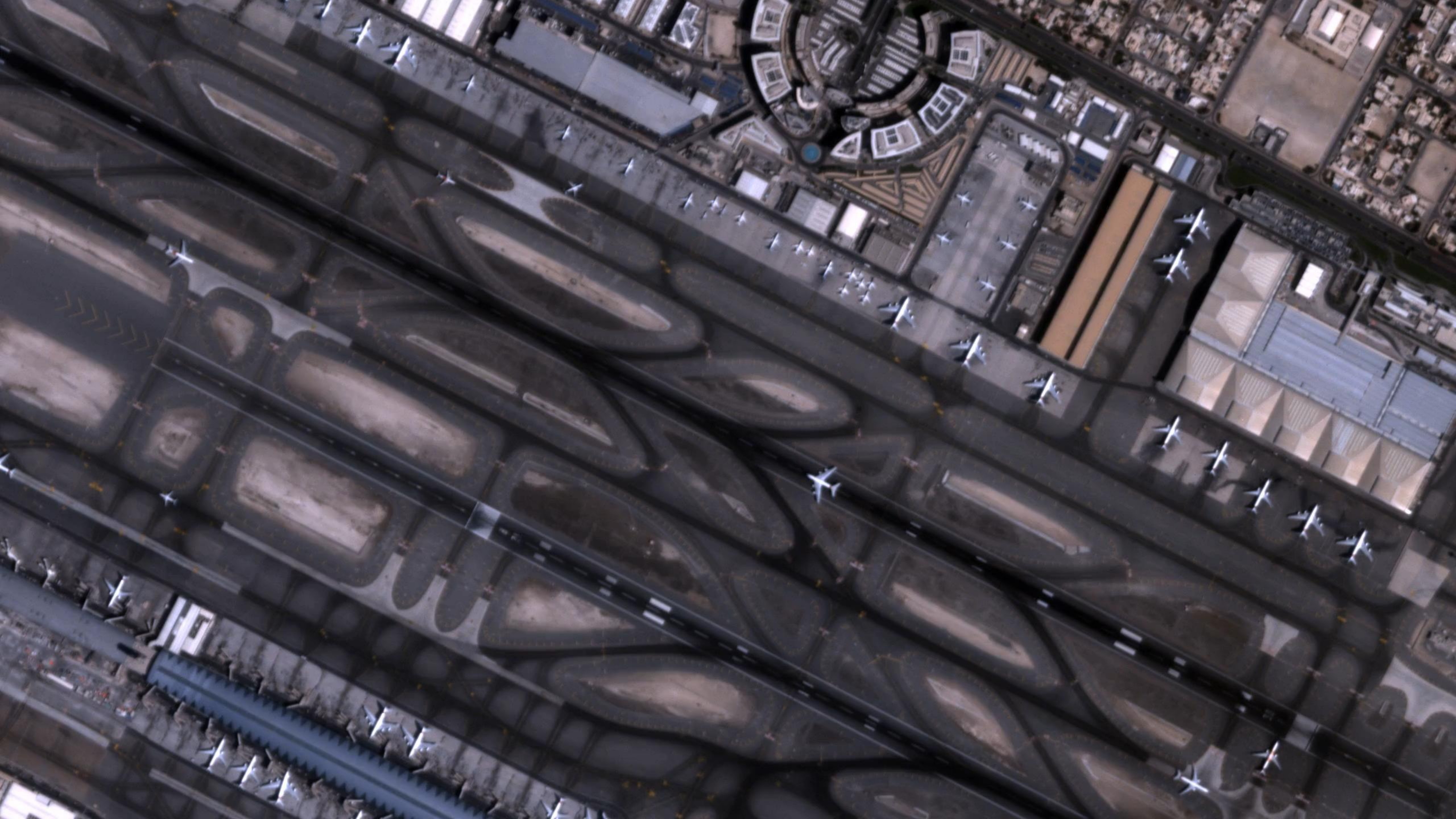
Spacecraft	Carbonite-1	S1
Design Lifetime	1 year	7 years
Mass	86 kg	447 kg
Envelope	0.6 × 0.7 × 0.9 m	3 x 1.35 x 0.65 m
Payload Data Storage		
Storage Volume	16 GBytes	554 GBytes
Imager Overview		
GSD	1.5 m Colour imagery and video	1 m PAN 4 m Multispectral
Swath	~5 km	22.5 km
Payload Data Downlink		
Frequency Band	X-Band	X-band
Data Rate	80 Mbits/s	500 Mbits/s
Schedule		
KO-FRR	8 months	24 months

SSTL S1

- DMC3 uses the SSTL S1 platform based on the tried and tested basic layout of the SSTL-300 (as on NigeriaSat-2), adding a new high resolution payload and more advanced avionics.
- SSTL S1 spacecraft is fully redundant and designed for triple-launch configuration on most popular small launcher fairings

Carbonite-1

- Carbonite-1 platform is similar in size to the heritage SSTL-100 platform
- Utilizes single string (except for receivers) architecture based on reliable heritage equipment
- Carbonite Series also allows video imaging



Examples of Carbonite use

Total number of satellites	Number of orbital planes	Lat 20° revisits	Lat 50° revisits	Maximum video duration (min)	Average video duration (min)	Comments
12	3	0-2 per day	2-3 per day	2.5	2	
24	3	3-5 per day	4-6 per day	4.6	3.3	Optimised for 30 minute intervals between videos
36	3	Daily	Daily	25	15	
36	4	2 per day	Daily	19	5	
72	3	>1 per day	>1 per day	52	35	
135	3	1-2 per day	1-3 per day	96	50	
163	9	Multiple per day	Multiple per day	264		Special case. Orbit precesses after one month and video duration is reduced

MTF

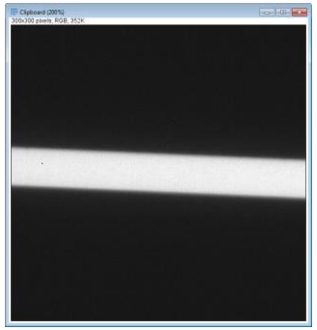
Two different systems

On-ground and In-Orbit

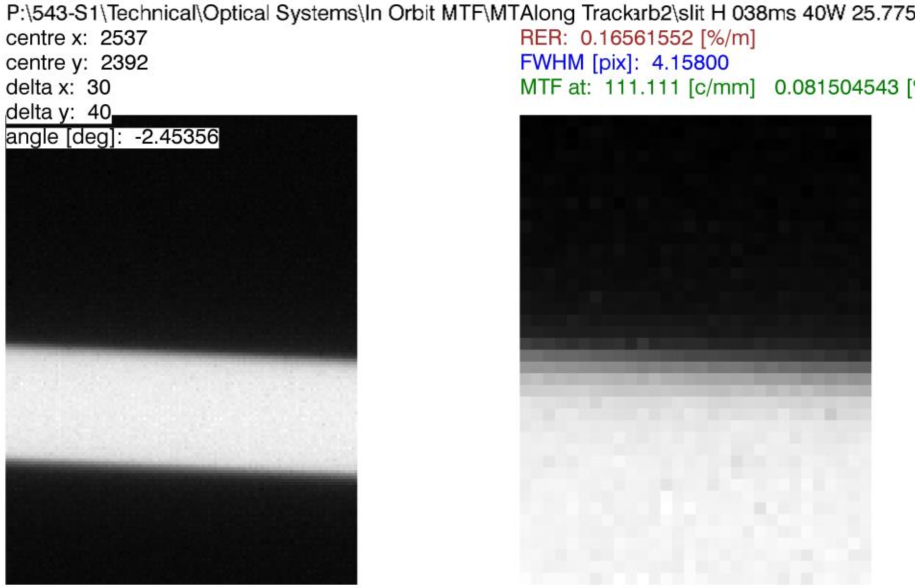
MTF targets - Baotou, China

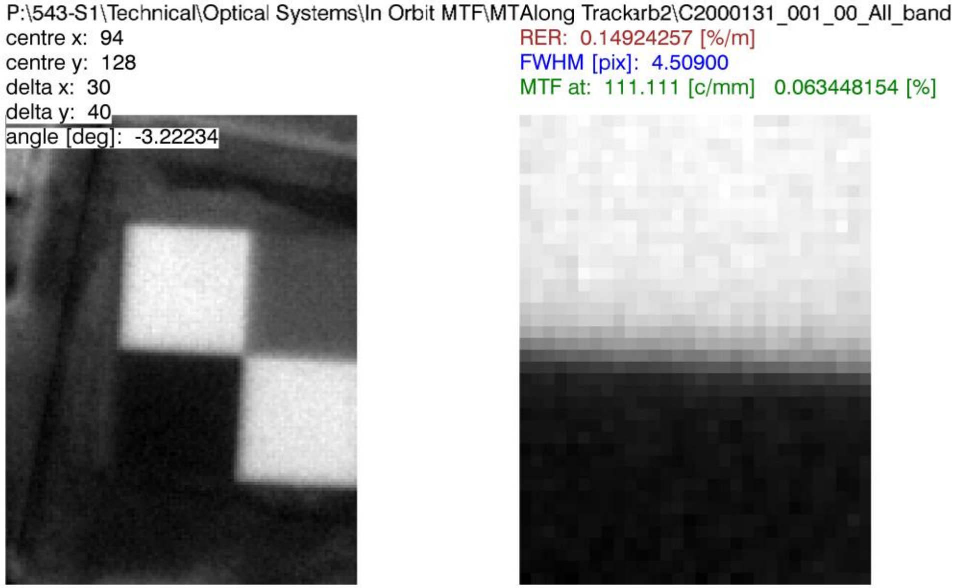
On ground vs In-Orbit (1)

Carb2 On Ground



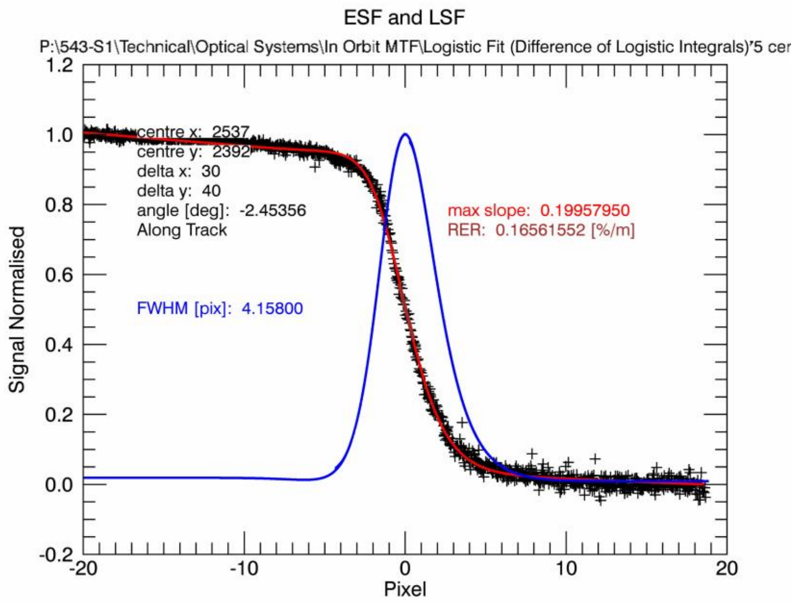
Carb2 in Orbit

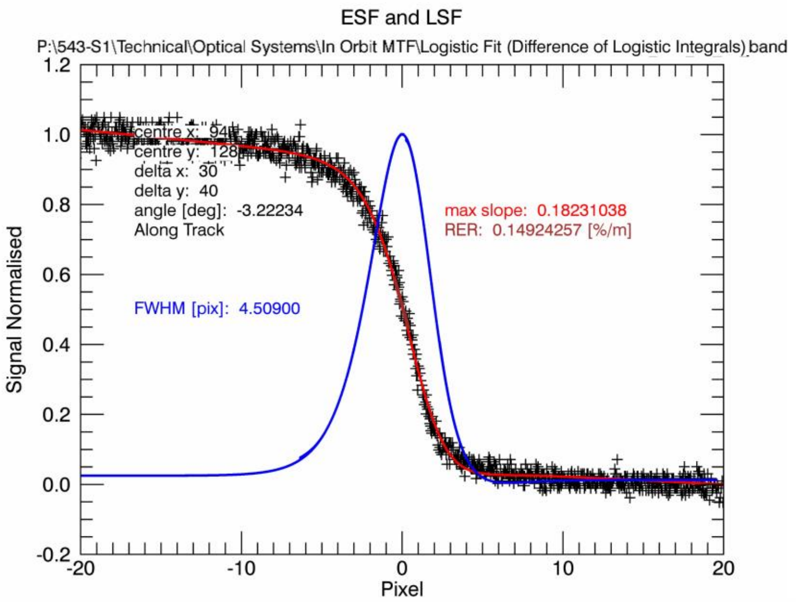


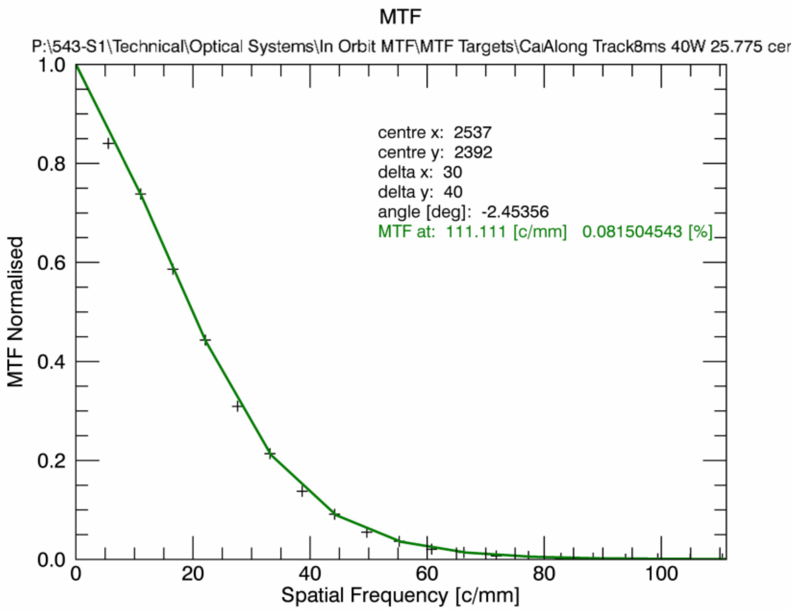


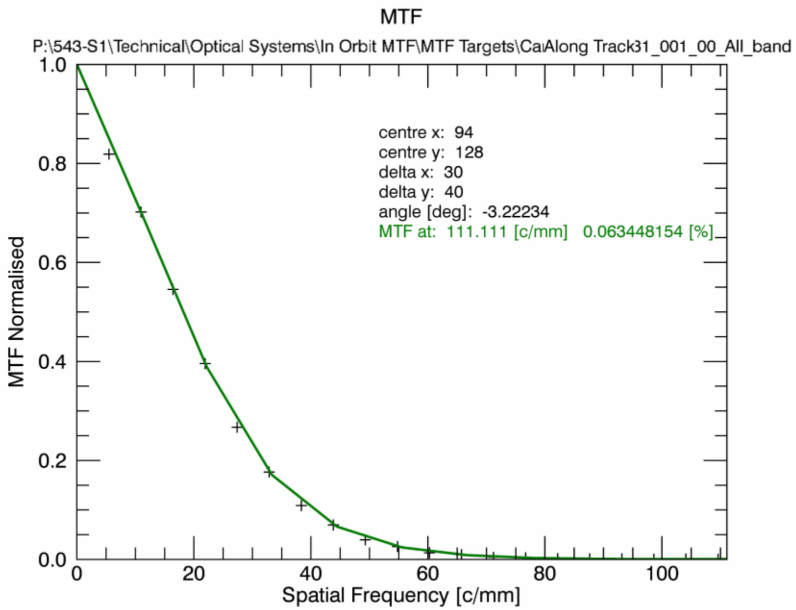
On ground vs In-Orbit (2)

- Ground-based measurements (left) are in good agreement with in-orbit estimates (right)









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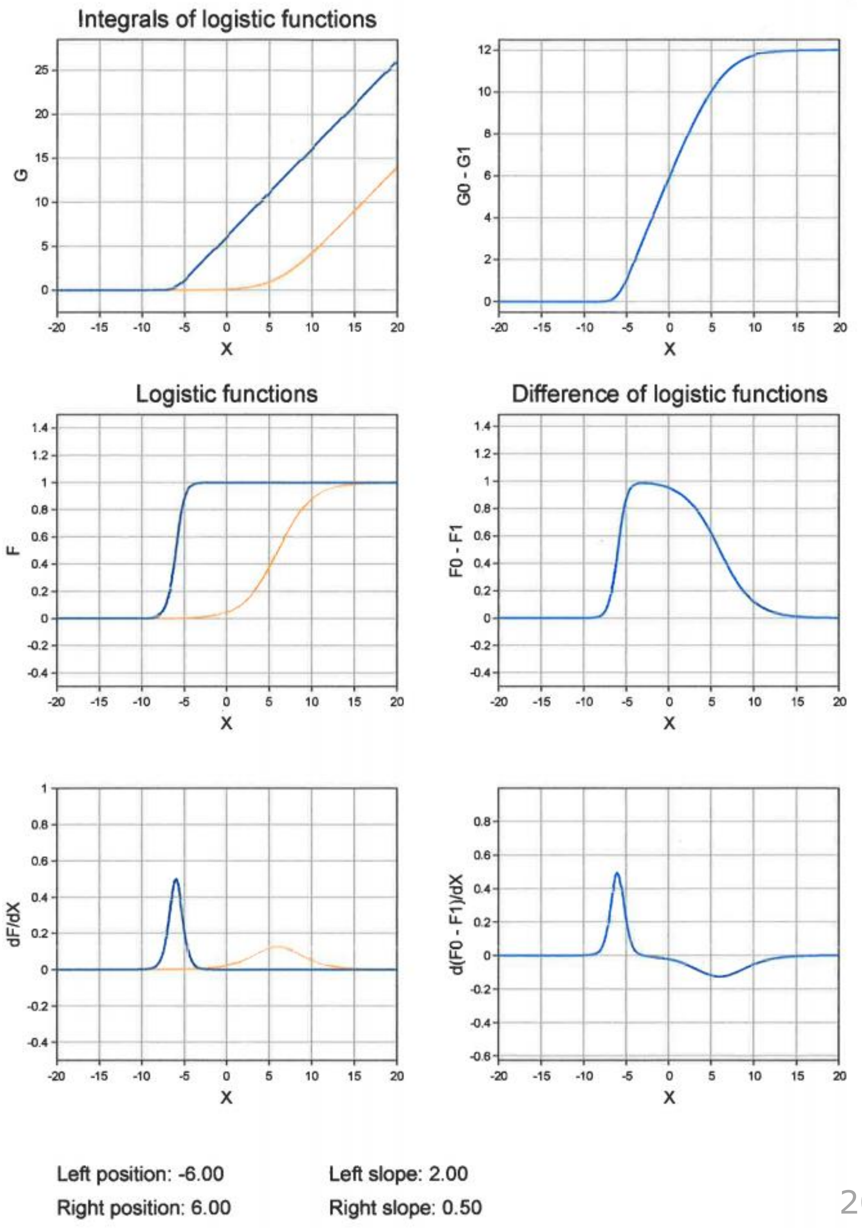
Logistic Functions

- Logistic functions can be used as an approximation to the Edge Spread Function
- Two logistics can be used for non-symmetrical shapes
- The difference of two logistic integrals with different parameters allows a closer representation to the ESF and LSF
- It allows an analytical function to obtain MTF



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Radiometry

Models and Measurements

On-ground and In-Orbit

Radiometric calibration

- MODTRAN 5.3 used to predict TOA Radiances for a given EO mission; a radiometric instrument model is derived and used at 10nm sampling.
- Spectral bands are very close or equal to Landsat 8
- Typically, a characterisation is performed on-ground, sometimes with traceability (NPL spectroradiometer, integrating sphere)
- Calibration is aimed to typically ~5-7% error
- Small satellites can benefit from expanding infrastructure, algorithms and calculated uncertainty budgets
- Need to use as many calibration sites as possible (RadCalNet) for rapid commissioning due to limited observations and use it for Verification purposes (customer requirements)
- Typically PICS sites have been used (Libya-4)

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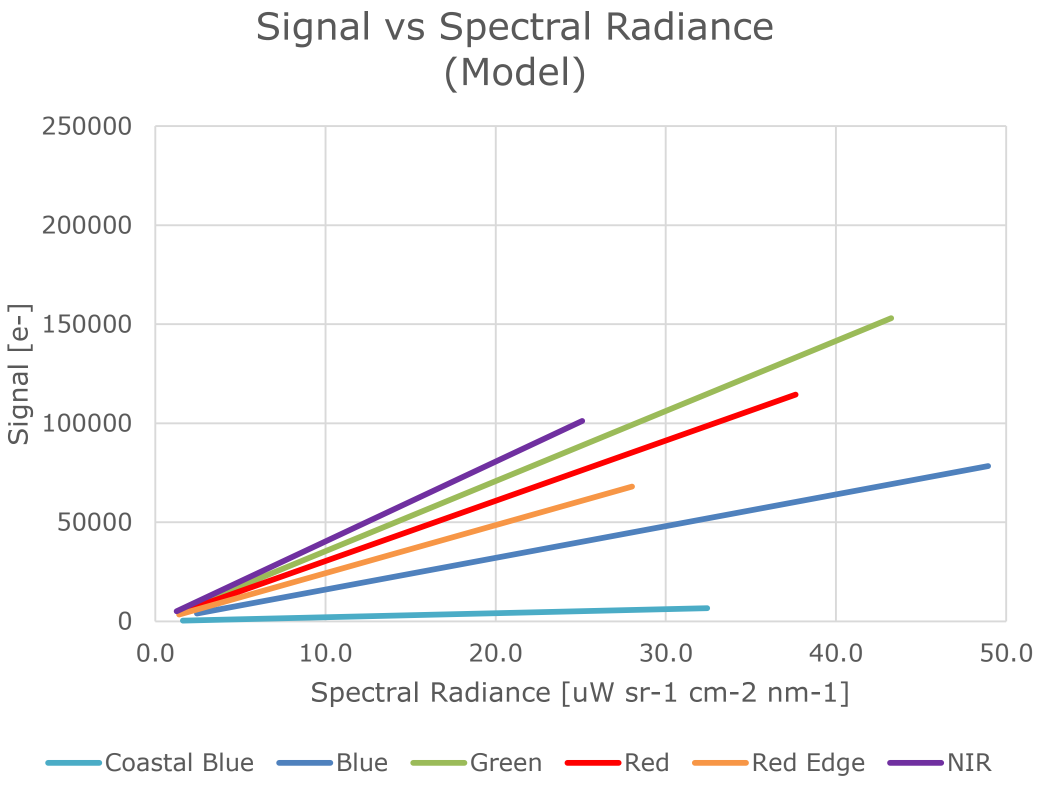
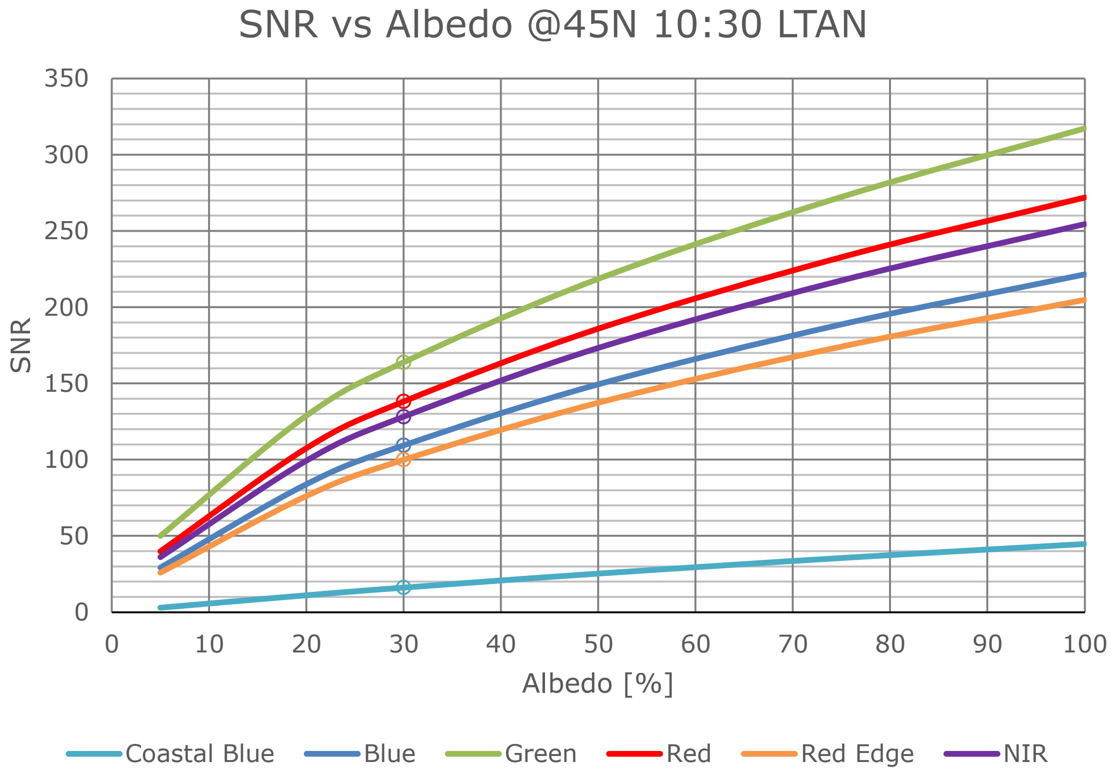
Radiometry for SNR

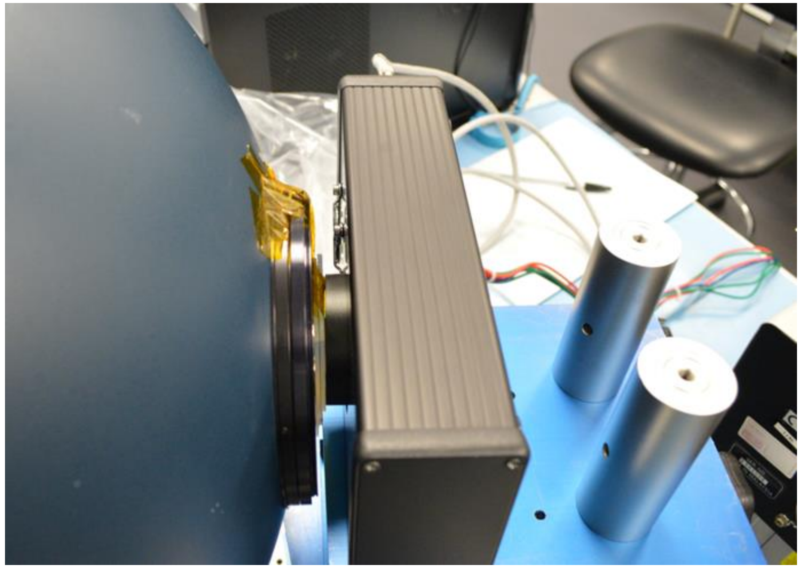
- Customer specifies viewing conditions or radiance.
- We use Modtran to obtain TOA and the instrument model to calculate SNR

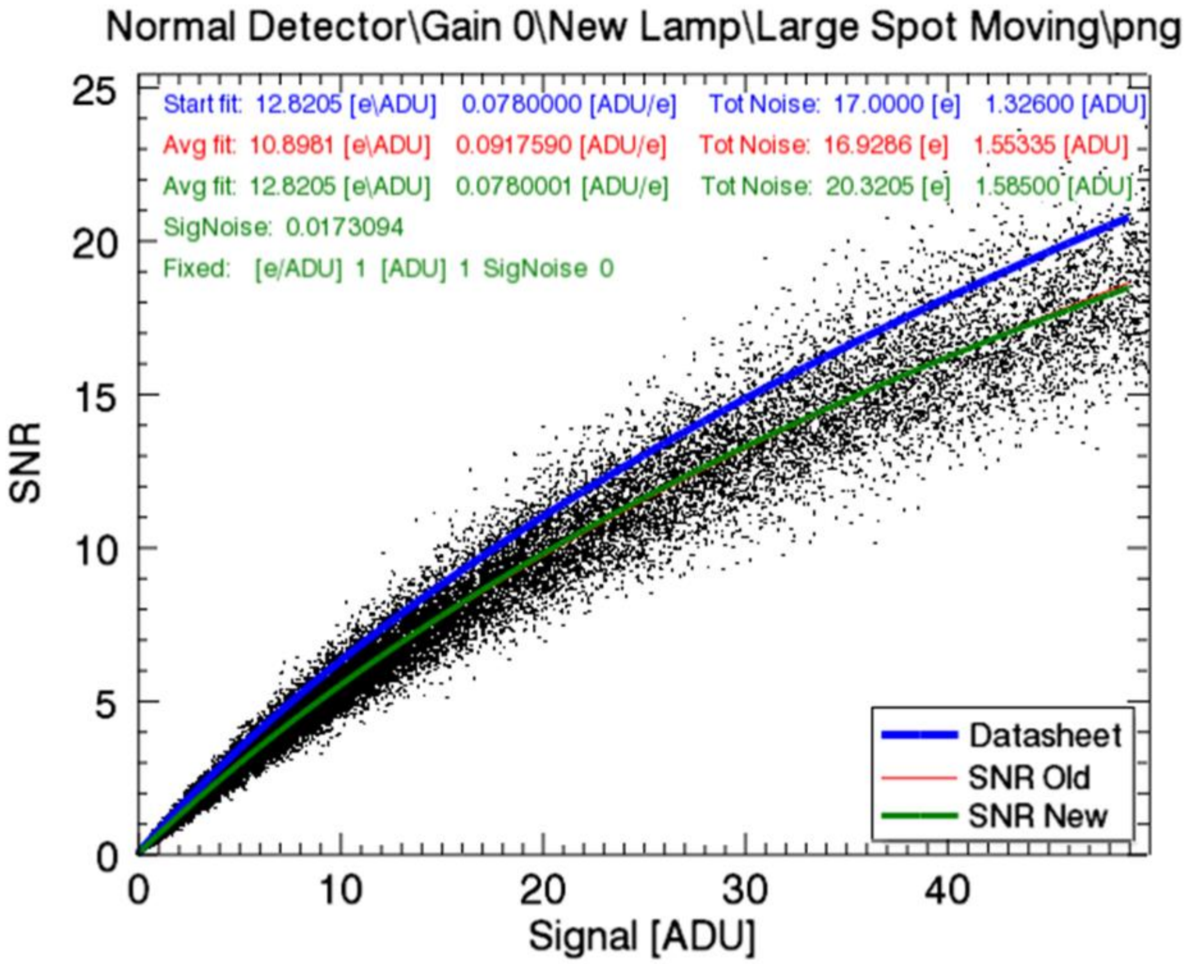




Noise measurements

- The noise assumed in the instrument model is verified by measurements
- Integrating sphere is typically used at detector level





Conclusion

- Affordable satellites are an effective solution for Earth Observation
- Performance is suitable for a range of applications
- Current CEOS IVOS WGCV PICSCAR initiatives and current work is equally important for small satellite missions
  - MTF analysis
  - SNR
- Interest to contribute and collaborate with many of the initiatives and topics discussed in this workshop

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Thank You!

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