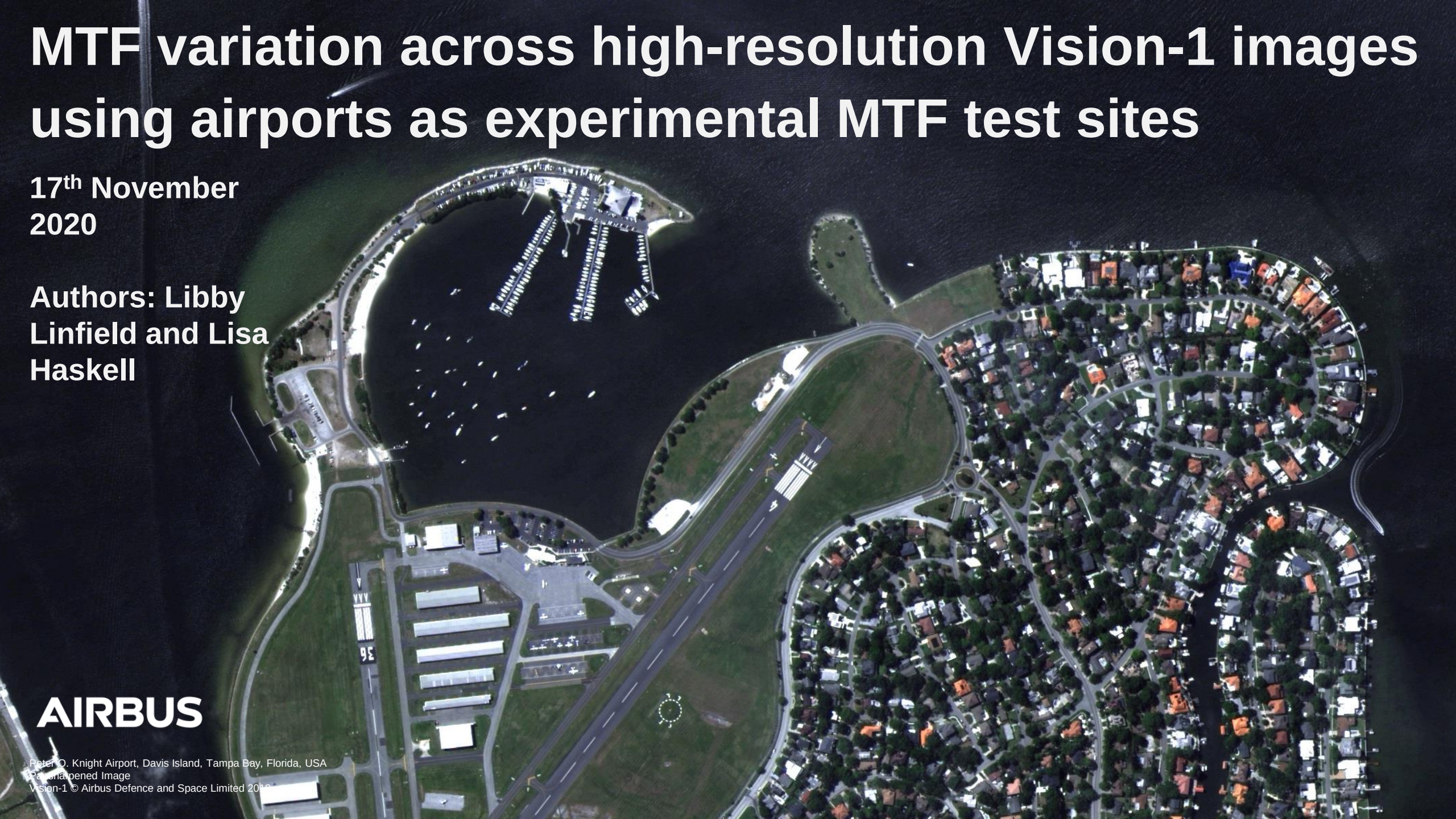
MTF variation across high-resolution Vision-1 images using airports as experimental MTF test sites

17th November 2020

Authors: Libby Linfield and Lisa Haskell



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Peter O. Knight Airport, Davis Island, Tampa Bay, Florida, USA
Pan-sharpened Image
Vision-1 © Airbus Defence and Space Limited 2019

Vision-1 – an introduction

- ✓ **First UK <1m Sovereign Asset**
- ✓ Building on historic DMC Constellation End-to-End Service **expertise**
- ✓ Additional asset **complementary to** SPOT and Pléiades

Peter O. Knight Airport, Davis Island, Tampa Bay, Florida, USA
Pansharpened Image
Vision-1 © Airbus Defence and Space Limited 2019

30 years
experience
in earth observation imagery, intelligence and defence systems

World leader
in satellite imagery

Exclusive access
to the most comprehensive EO satellite constellation commercially available

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Vision-1 Introduction

Semarang Container Terminal, Semarang, Central Java, Indonesia
Pansharpened Image
Vision-1 © Airbus Defence and Space Limited 2019

Satellite	Vision-1 (SSTL S1-4)
Launch	September 2018
Orbit	Sun-synchronous, 10:30 AM 583km altitude
Period	96.2 minutes
Spectral Bands	PAN, NIR, Red, Green, Blue
Product Resolution	Panchromatic: 0.87m Multispectral: 3.48m
Swath Width	21.6km at nadir
Off-pointing	+/- 45° (+/- 30° as standard)
Revisit	Daily to 8 days
Location Accuracy at Nadir	<500m for RAW data <12m for Orthorectified Products
Onboard Storage	550 Gb (Solid State Mass Memory)
Mission Lifetime	7+ years

Vision-1 accuracy

- Provide up-to-date and reliable geographic information for high resolution mapping projects.

- As such good sharpness in images and intrinsic quality is required

Urban

Defence

Agriculture

The Modulation Transfer Function

- MTF is a widely used parameter to assess the quality of an imaging system
- It can analytically evaluate the sharpness
- Historically we use Edge sites which enables us to obtain an accurate Edge Response Function (ESF).

- These target can be:
    1. Artificial painted targets, Eg. Salon De Provence checkerboard
    2. Natural targets, Eg. Fields, buildings, bridges

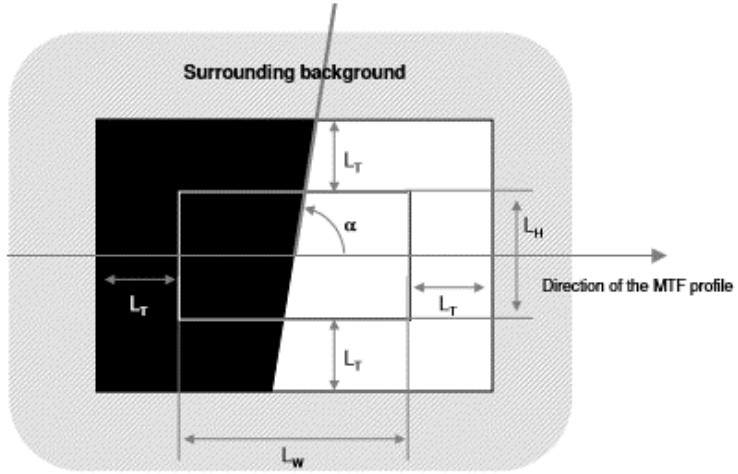
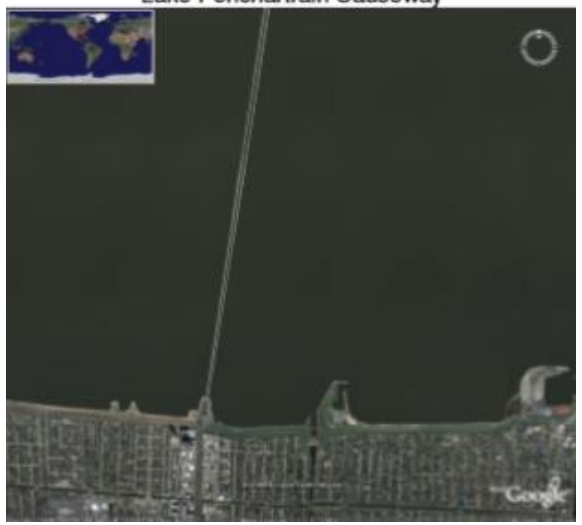


Figure 1: Schematic Edge targets.

Lake Ponchartrain Causeway



Salon de Provence checkerboard

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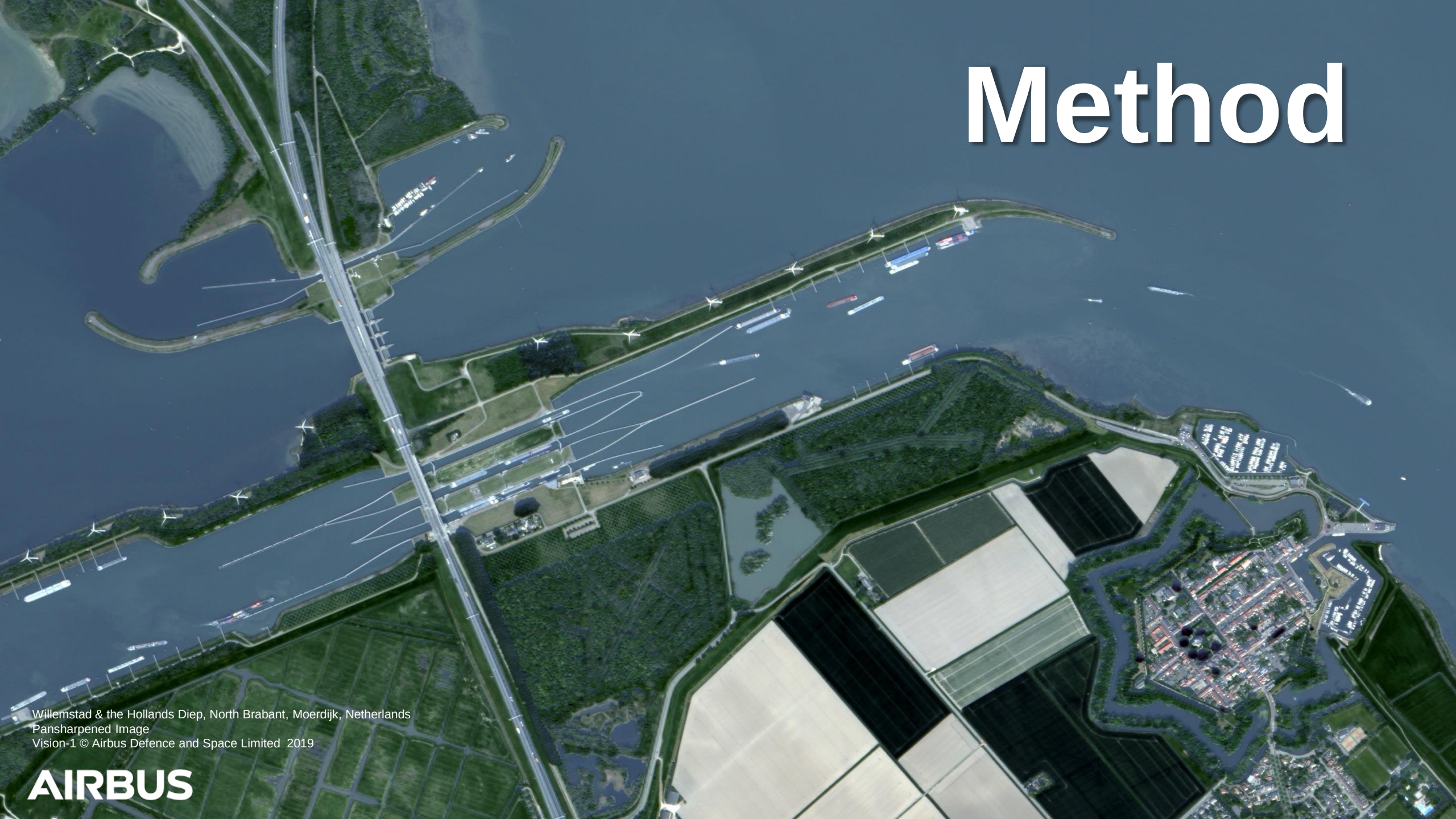
Aim of our work

- Describe a method to use **Airport runways as natural MTF sites**, utilising the edge technique.
- Assess the potential of airport to provide multiple MTF sites across an image, giving the opportunity to evaluate how the MTF varies across the field-of-view and hence across the swath of a multiple CCD satellite.
- We use multiple targets to assess the consistency of results and accuracy of the method.
- Evaluate the **most effective airport scenes** to use and test the repeatability of the method.

Method



Willemstad & the Hollands Diep, North Brabant, Moerdijk, Netherlands
Pansharpened Image
Vision-1 © Airbus Defence and Space Limited 2019

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Method based on: Crespi, M. & De Vendictis, L. 2009

Edge Detecting

- Orientation near or along scan axes
- Minimum 13 pixels
- High contrast required
- Well distributed spatially across image

Pixel Edge Locating

- Exact edge location established using DN values line by line
- **Slope** along each line calculated to determine pixel location of edge

Sub-pixel Edge Points Locating

- Estimate of the sub-pixel edge location by fitting a **cubic polynomial function**
- Location is at zero crossing location of the **second derivative** of the cubic polynomial

Edge Spread Function

- For each row, perpendicular lines to the edge are constructed and the DN values are interpolated using a cubic spine
- Average spline across all rows computed to yield a function representing the edge spread

Line Spread Function

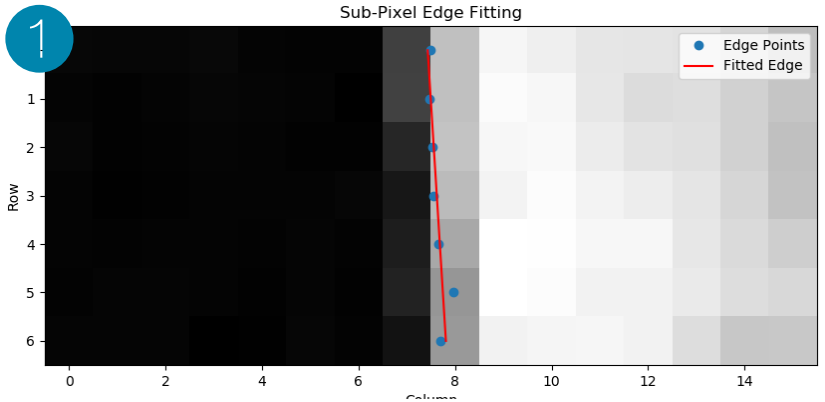
- LSF computed from ESF by a simple discrete **differentiation**
- LSF calculated again, normalised , trimmed in the interval (-5,5) pixels wrt central value

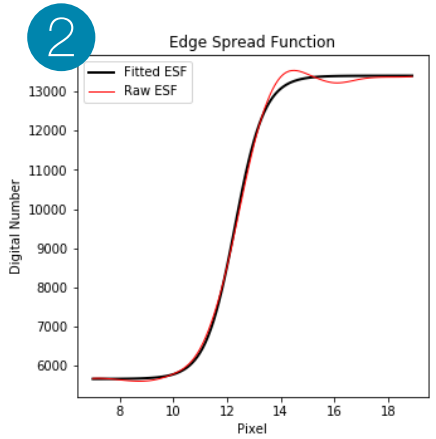
Full-Width at Half-Maximum

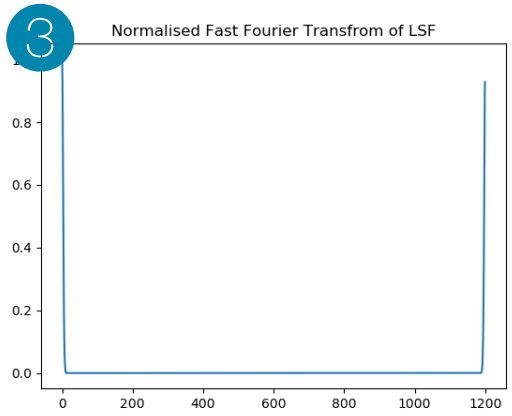
- FWHM considered the actual image resolution
- FWHM calculated by measuring distance between the starting point and ending point individuated by a linear interpolation

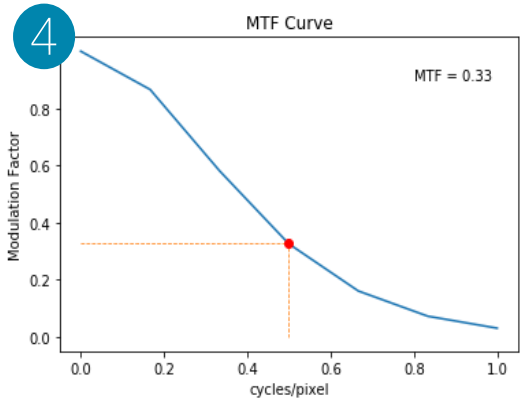
Modulation Transfer Function

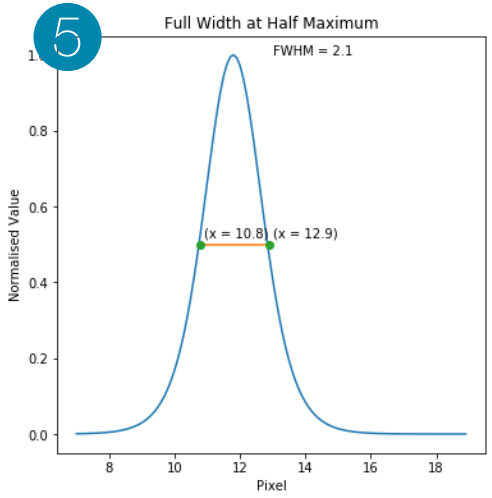
- MTF obtained by **Fourier transformation** of the LSF
- Scaled in the frequency axis to represent the MTF at the Nyquist frequency











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Results

Hobsons Bay & Port Melbourne, Melbourne, Victoria, Australia
R G B Image
Vision-1 © Airbus Defence and Space Limited 2019

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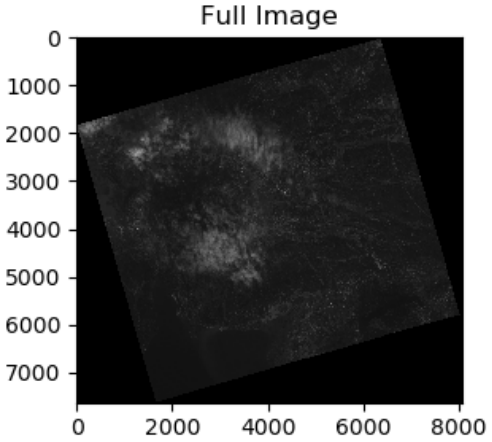
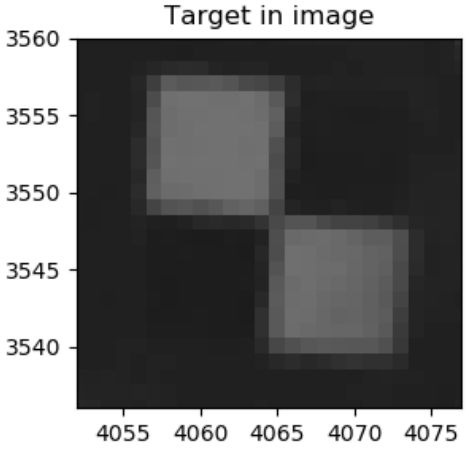
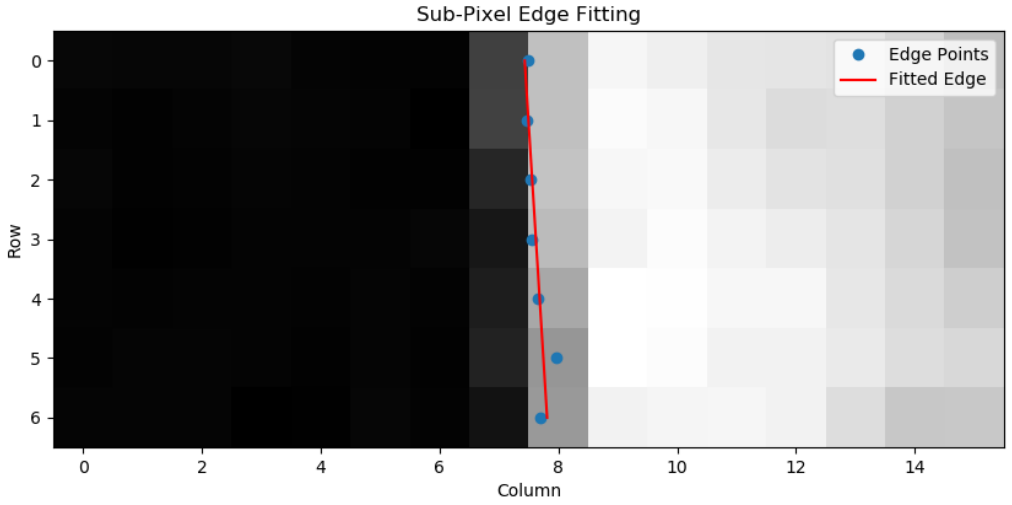
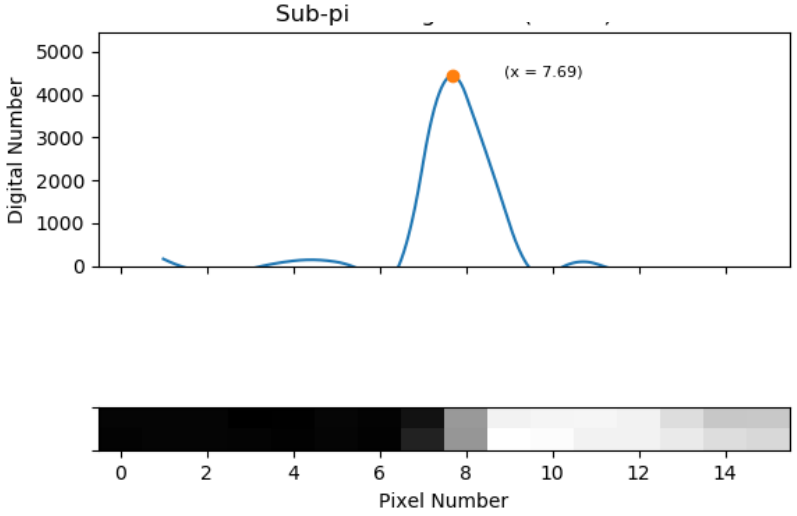
Salon de Provence – Reference measured MTF value

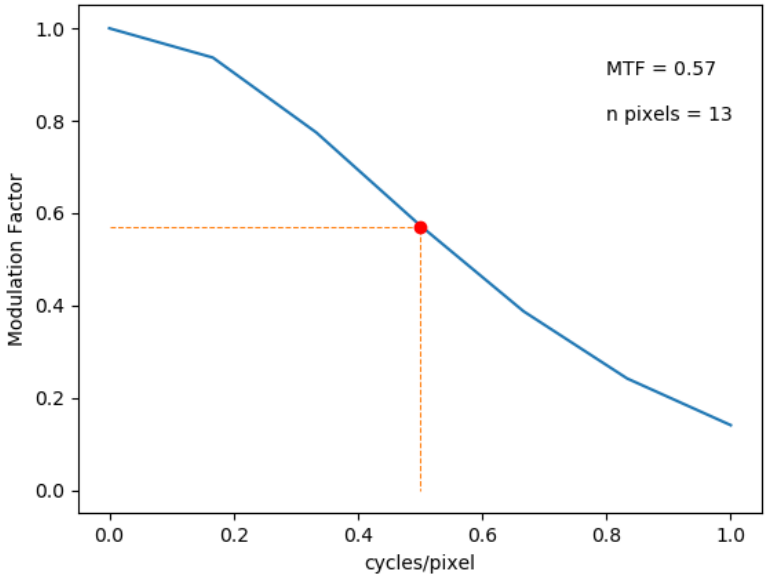
VIS1_BUN_20200211093539_ORTP_S93106_0c48





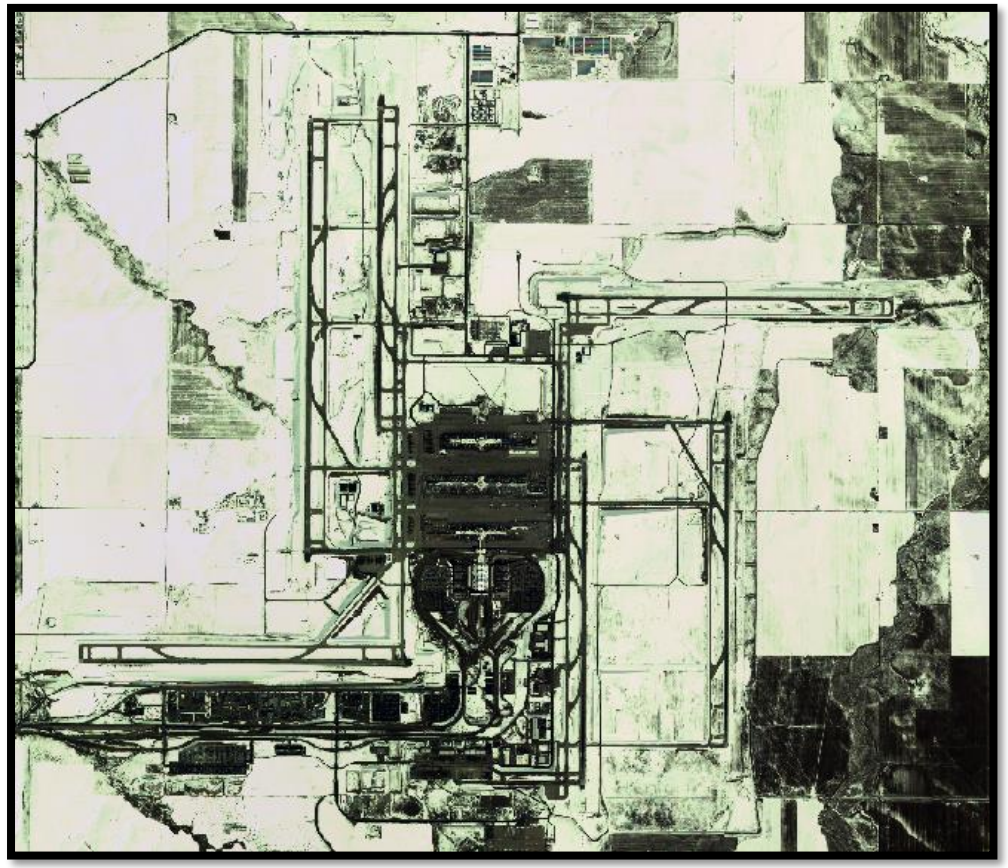






Denver Airport – target 1 (runway)

VIS1_BUN_20200221165809_ORTP_S91754_0cca



Denver Airport – target 1 (runway)

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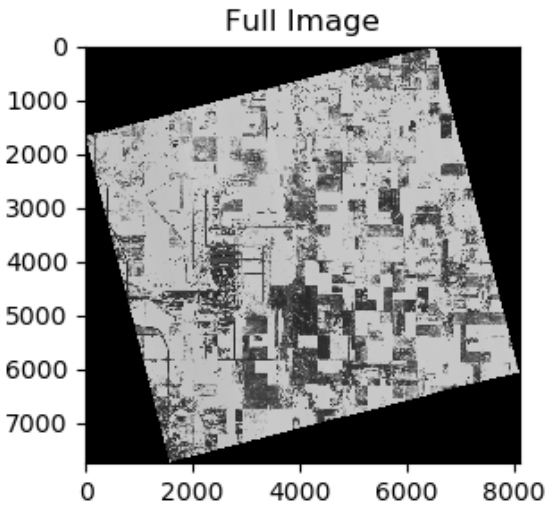

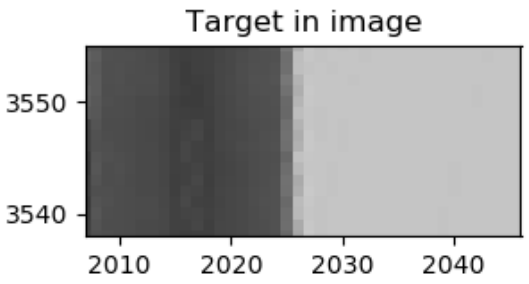

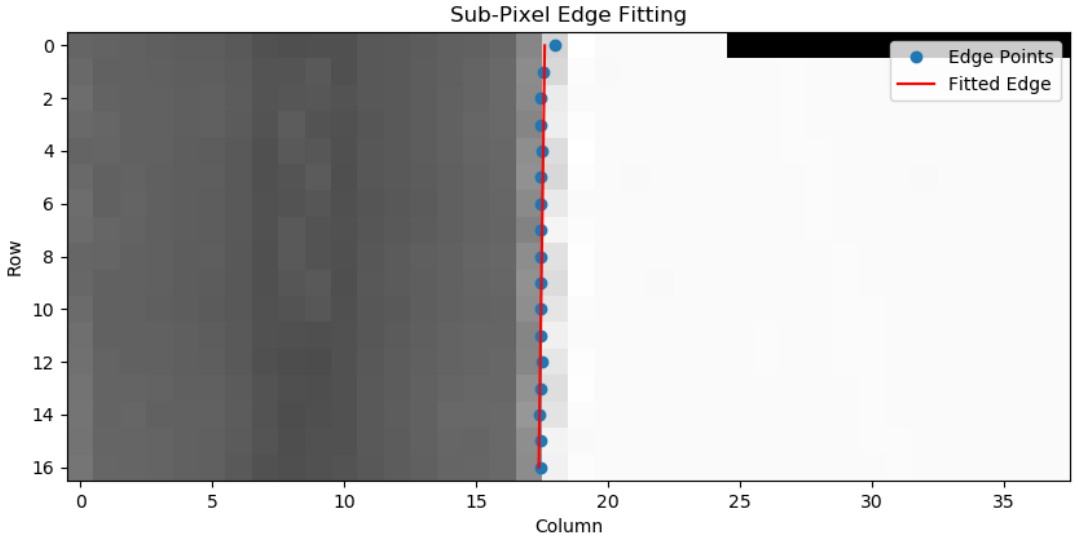

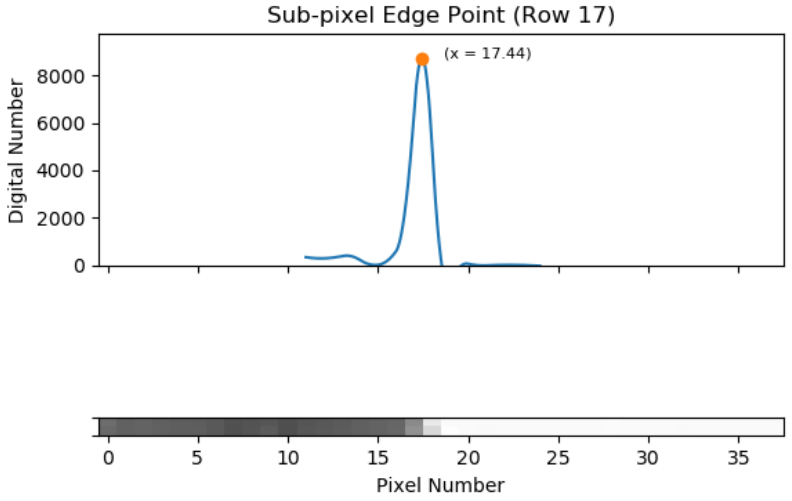

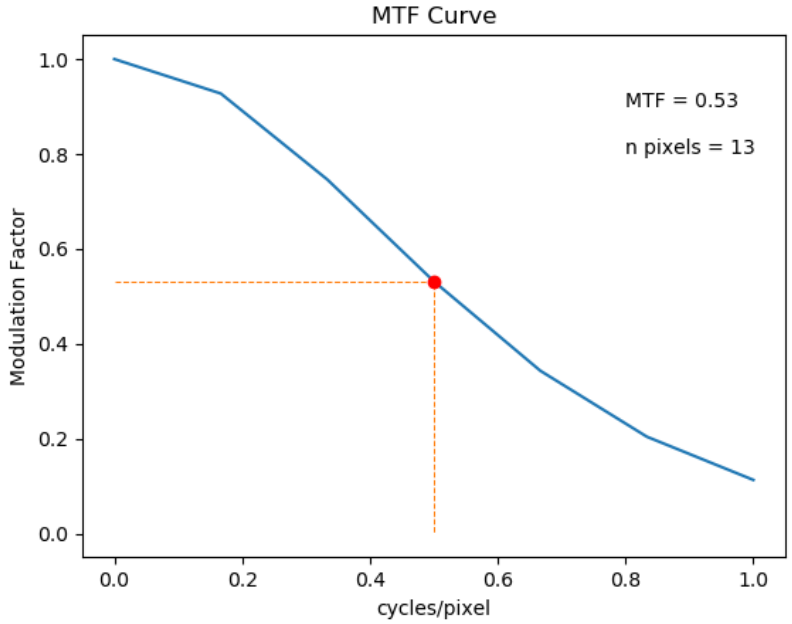

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Denver Airport – target 2 (field)

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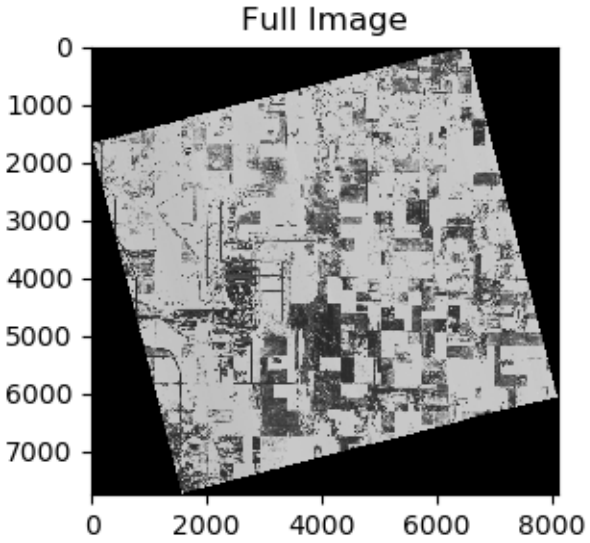

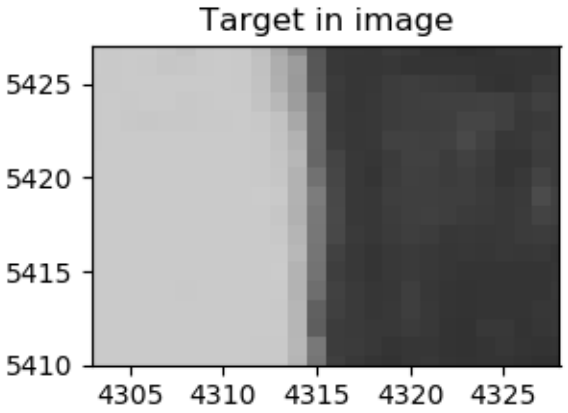

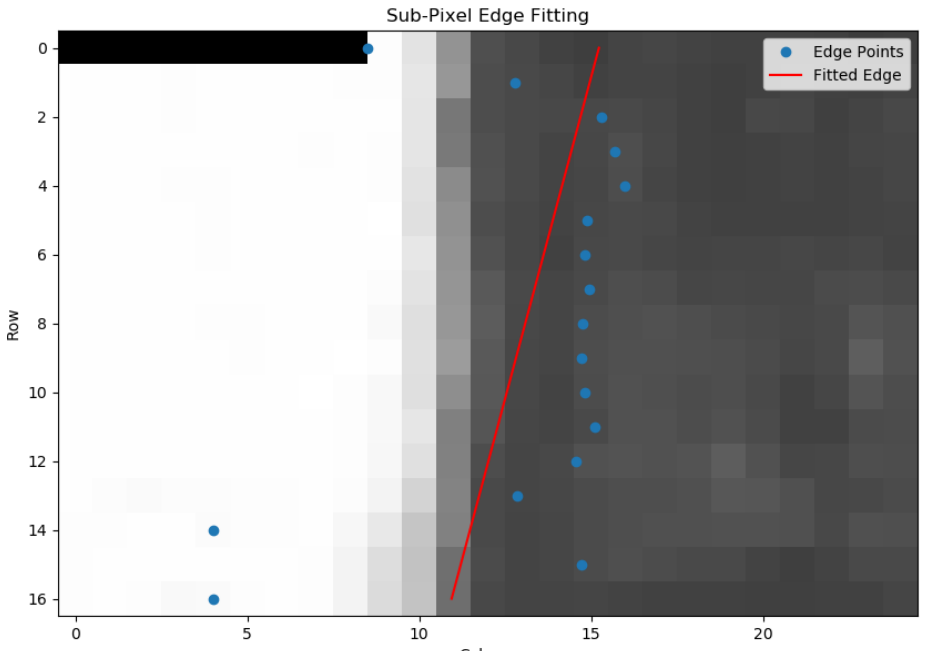

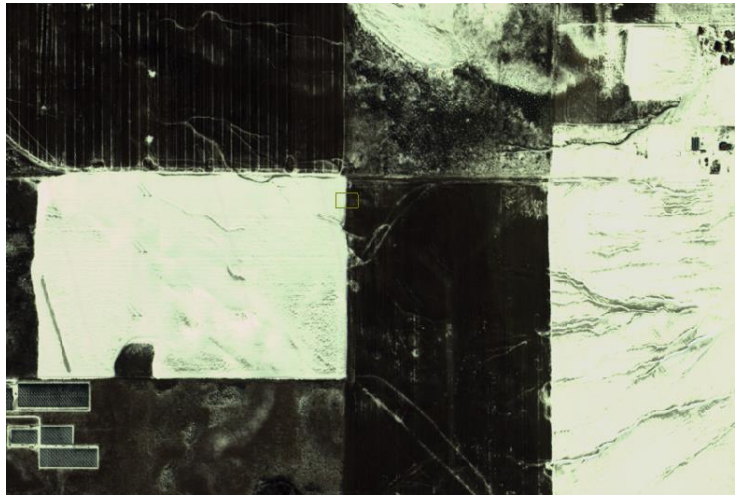

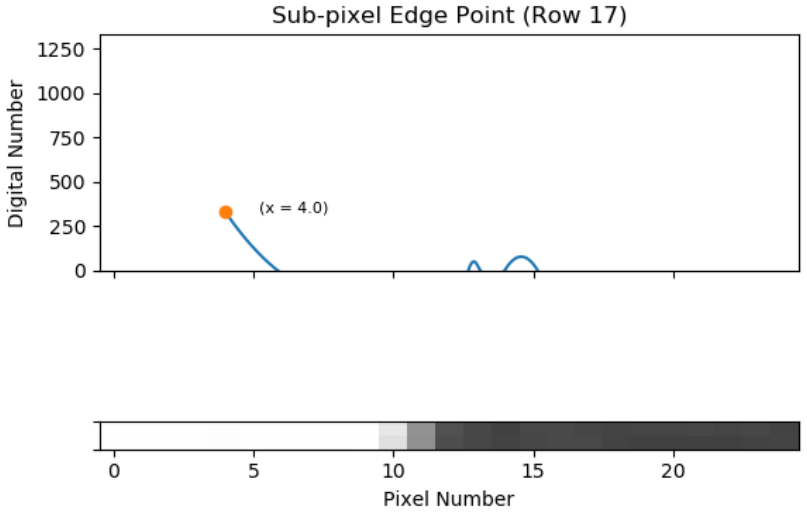

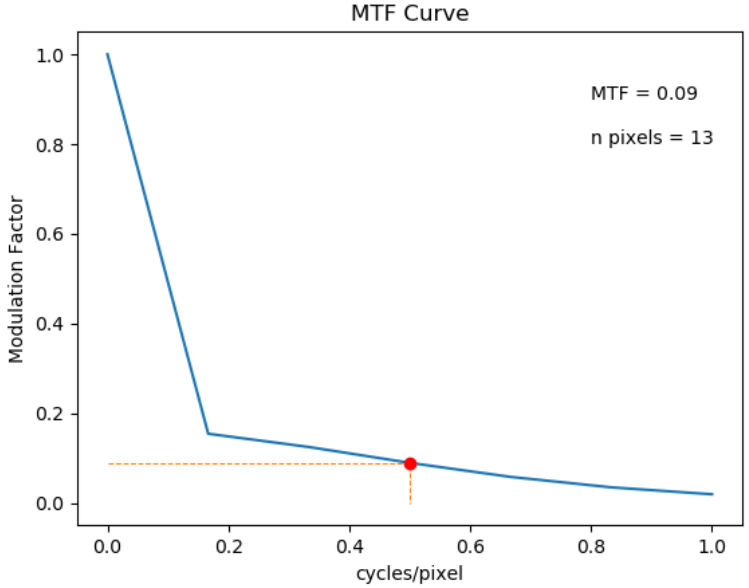

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Denver Airport – target 3 (runway 2)

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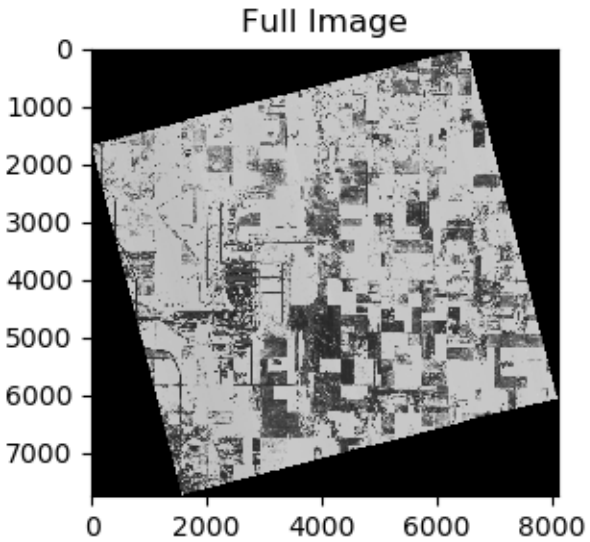

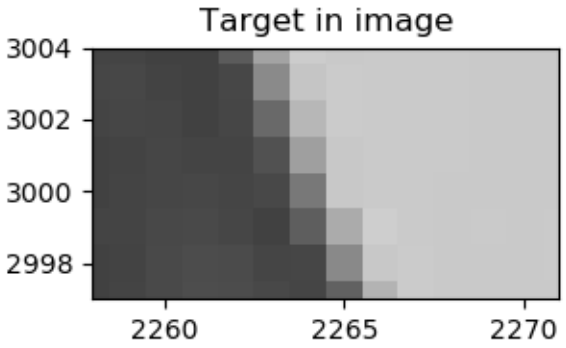

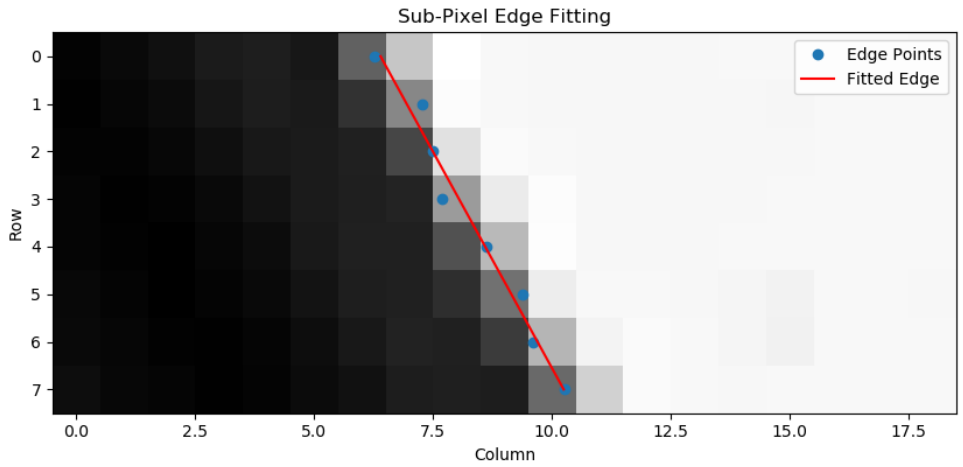

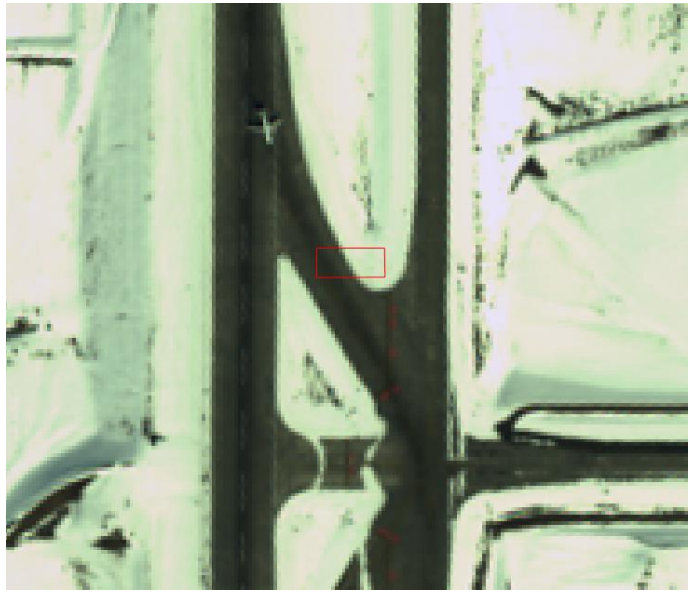

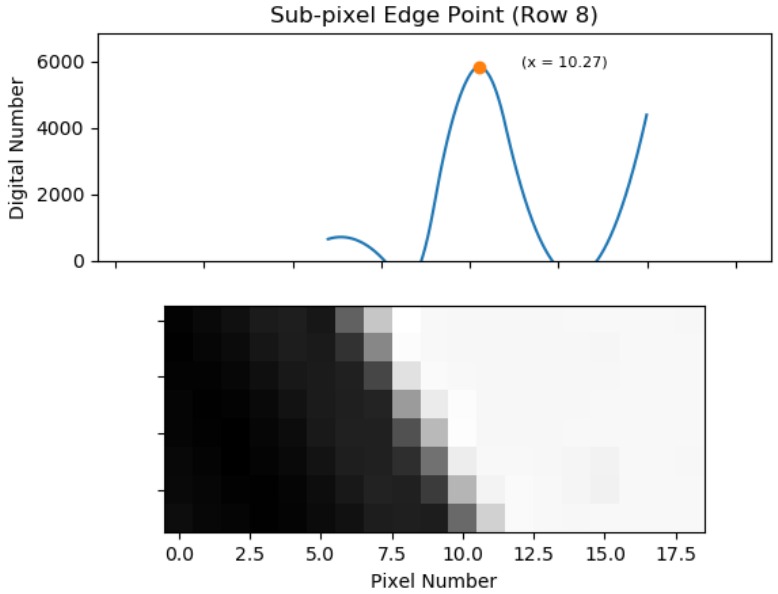

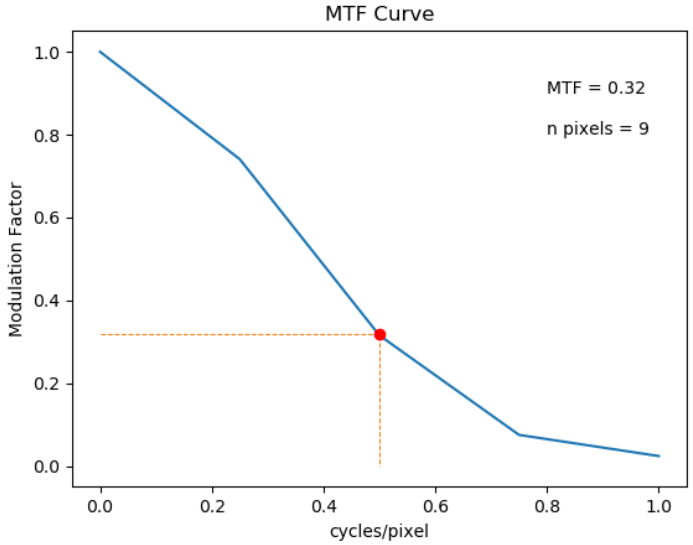

Atlanta Airport – target 2

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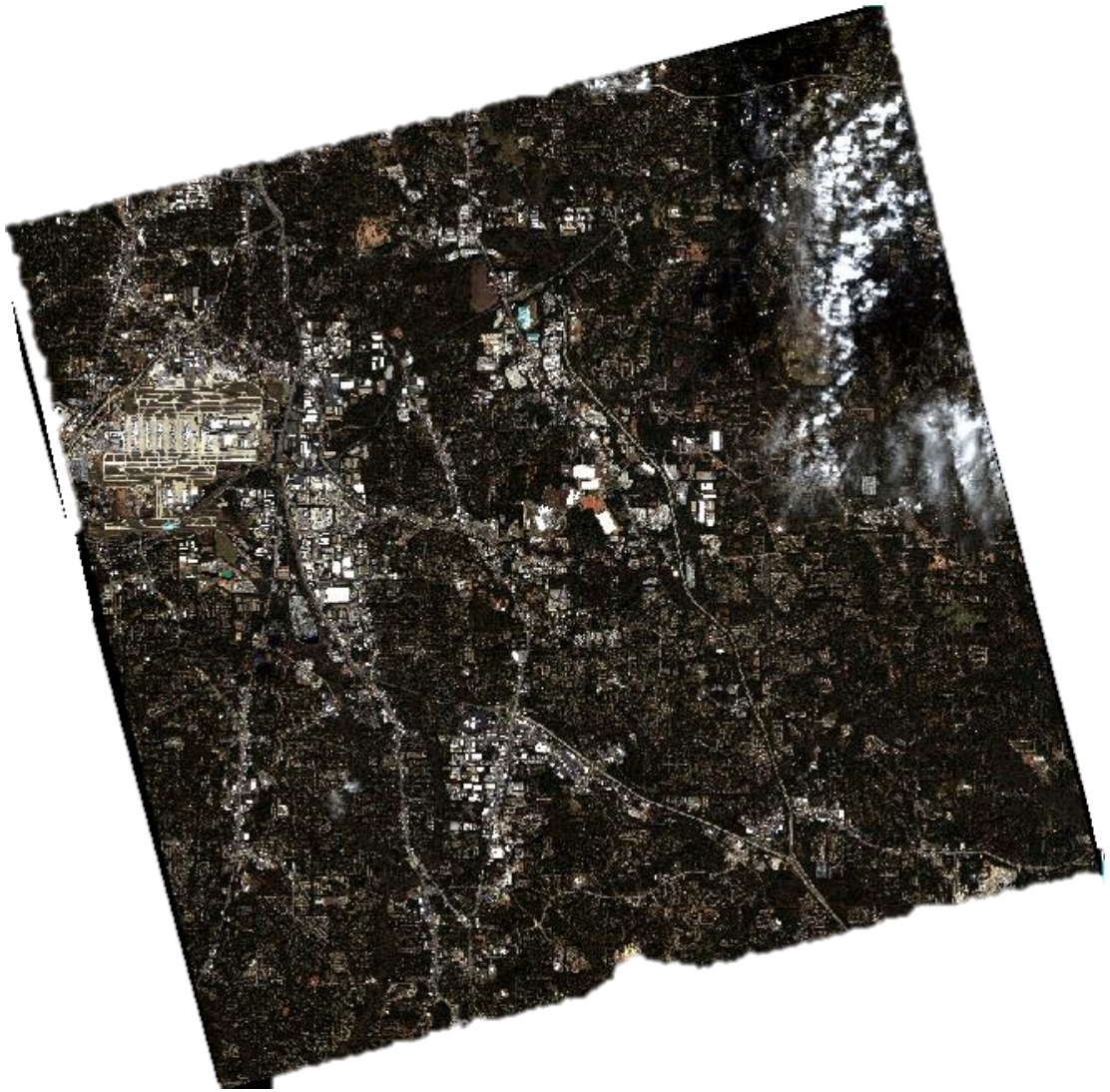

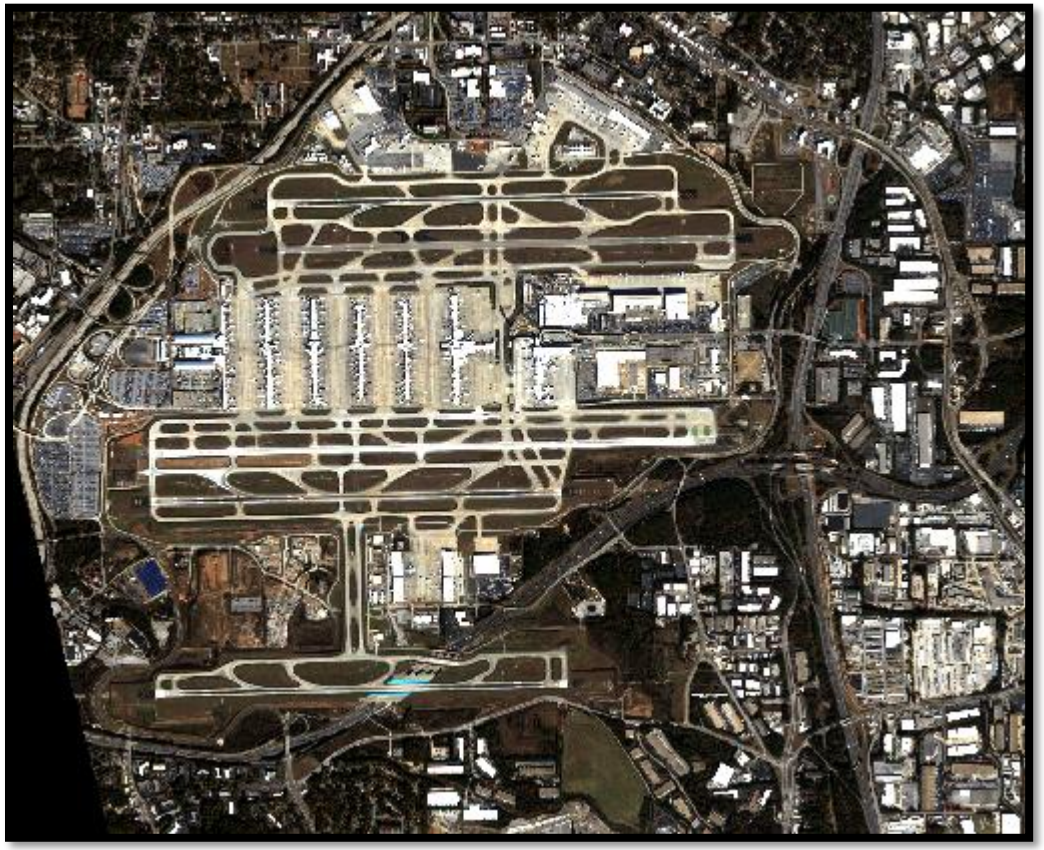

Atlanta Airport – target 1

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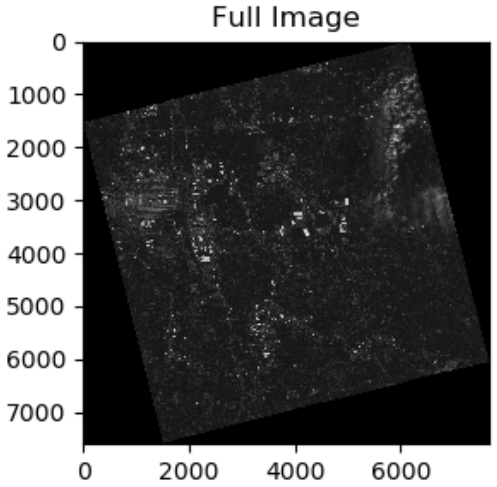

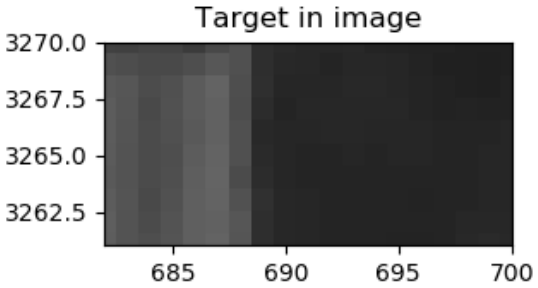

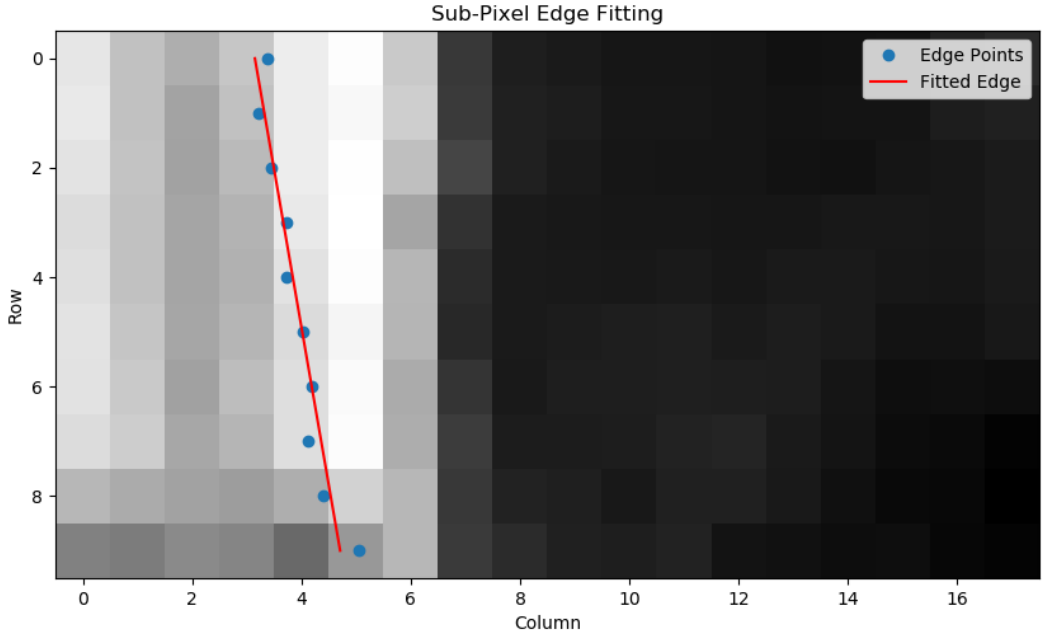

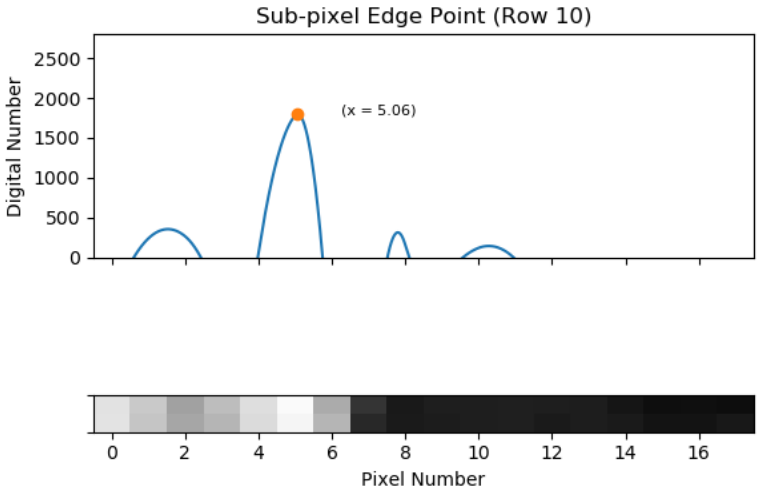

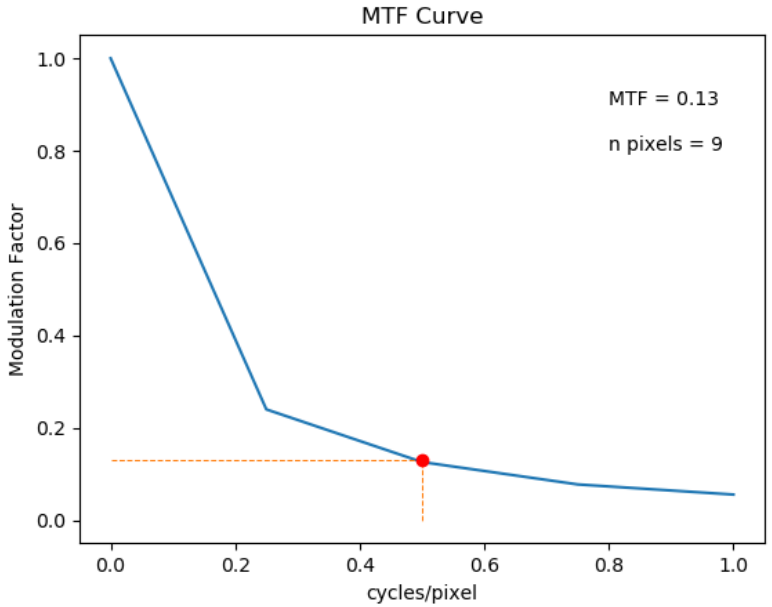

Atlanta Airport – target 2

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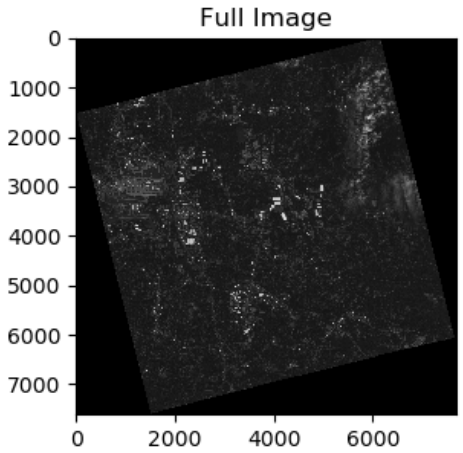
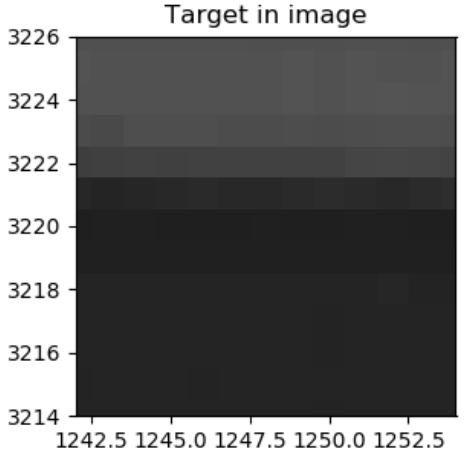
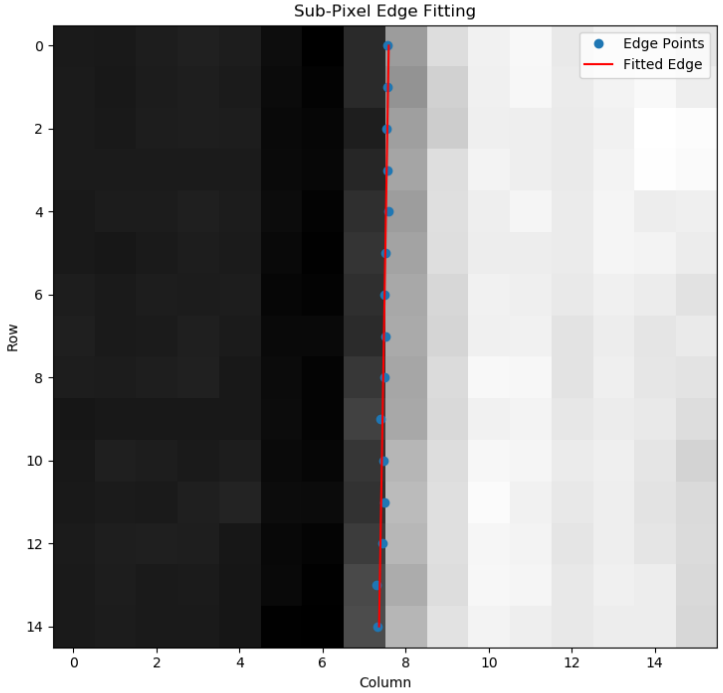
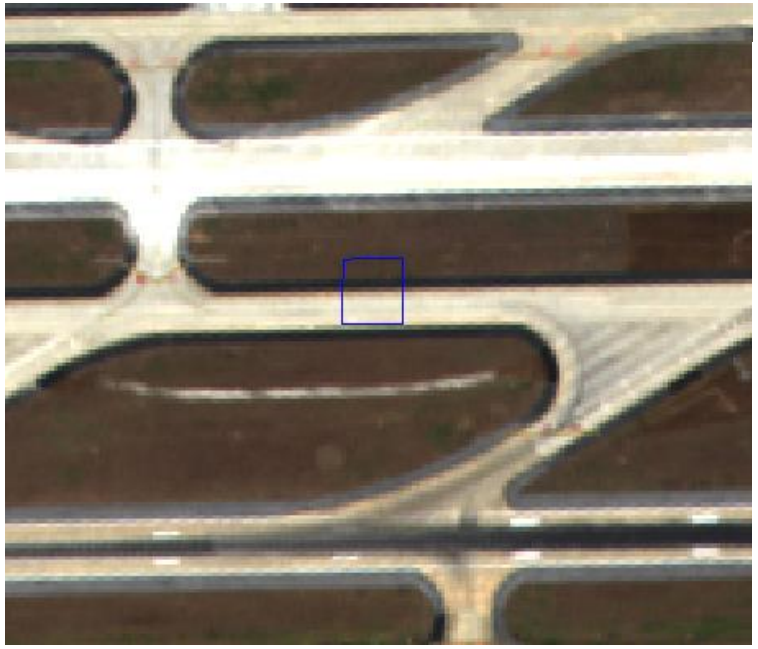
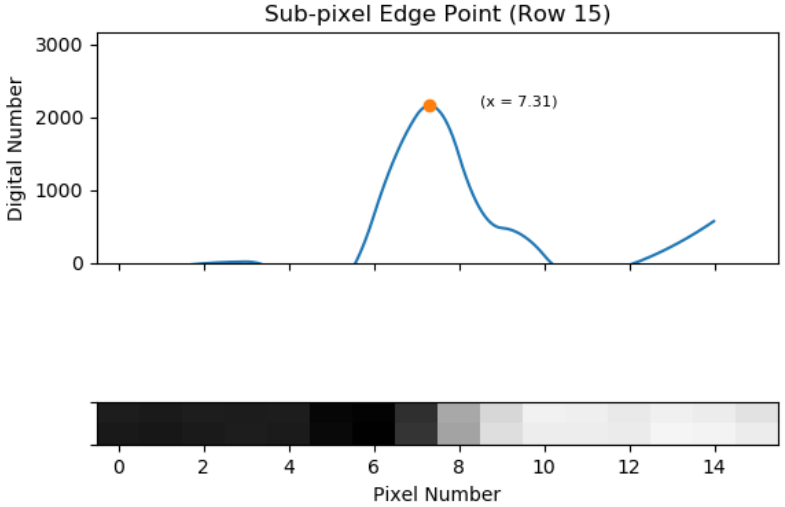
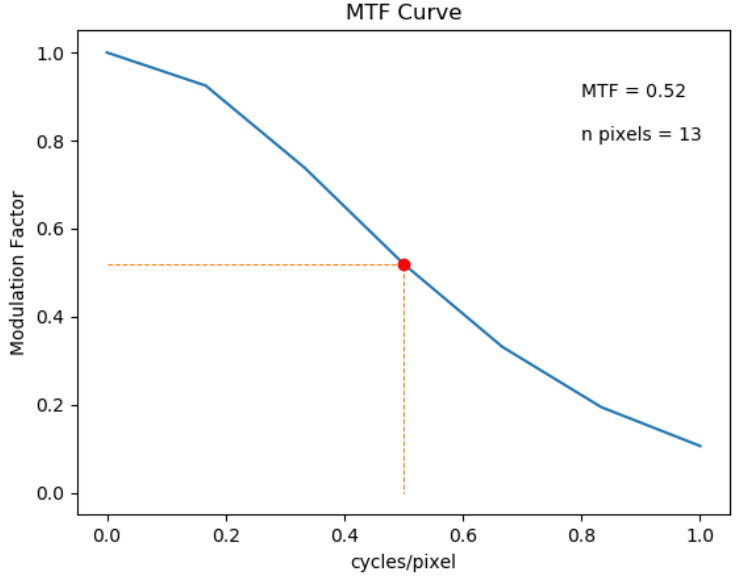




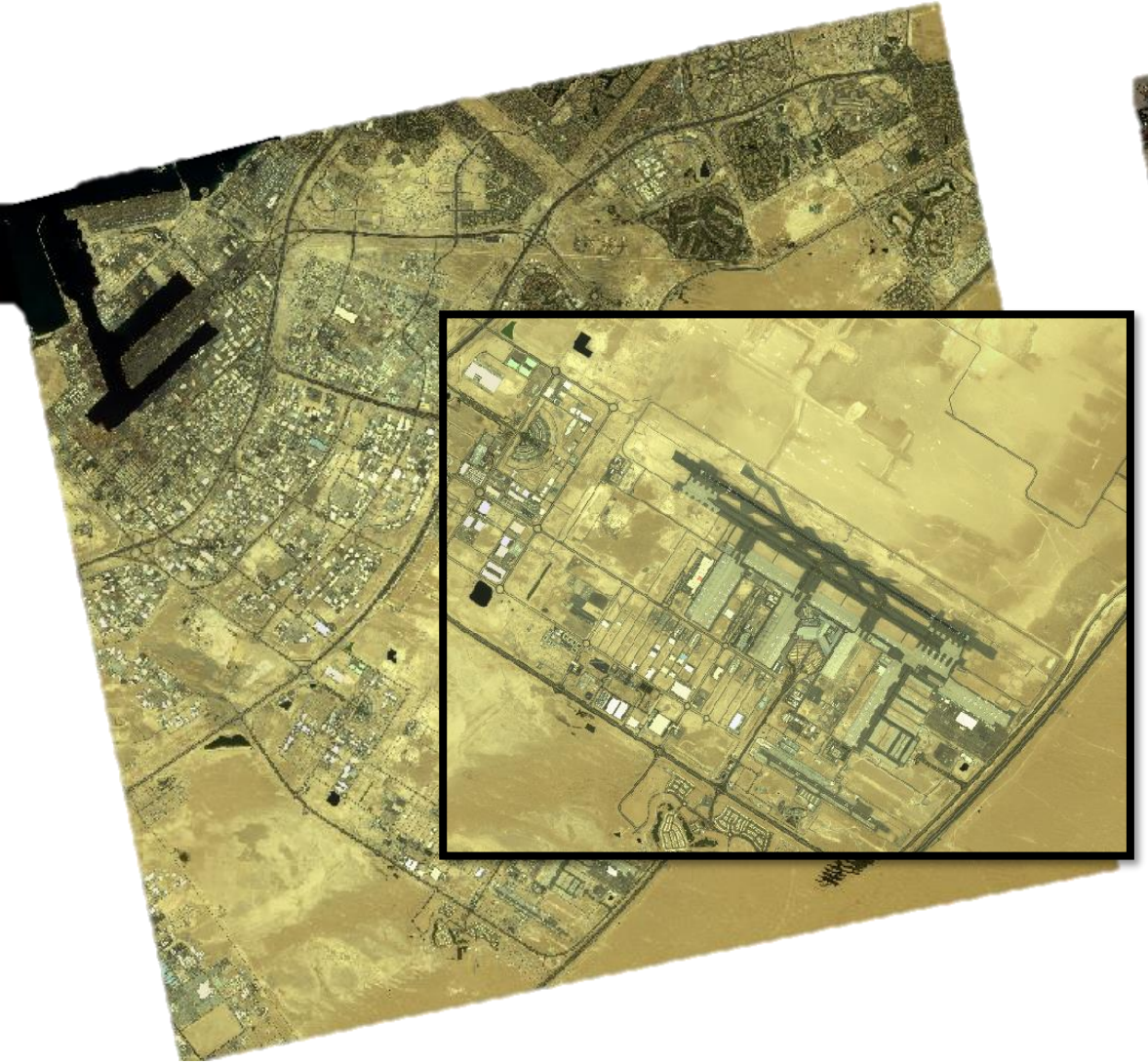


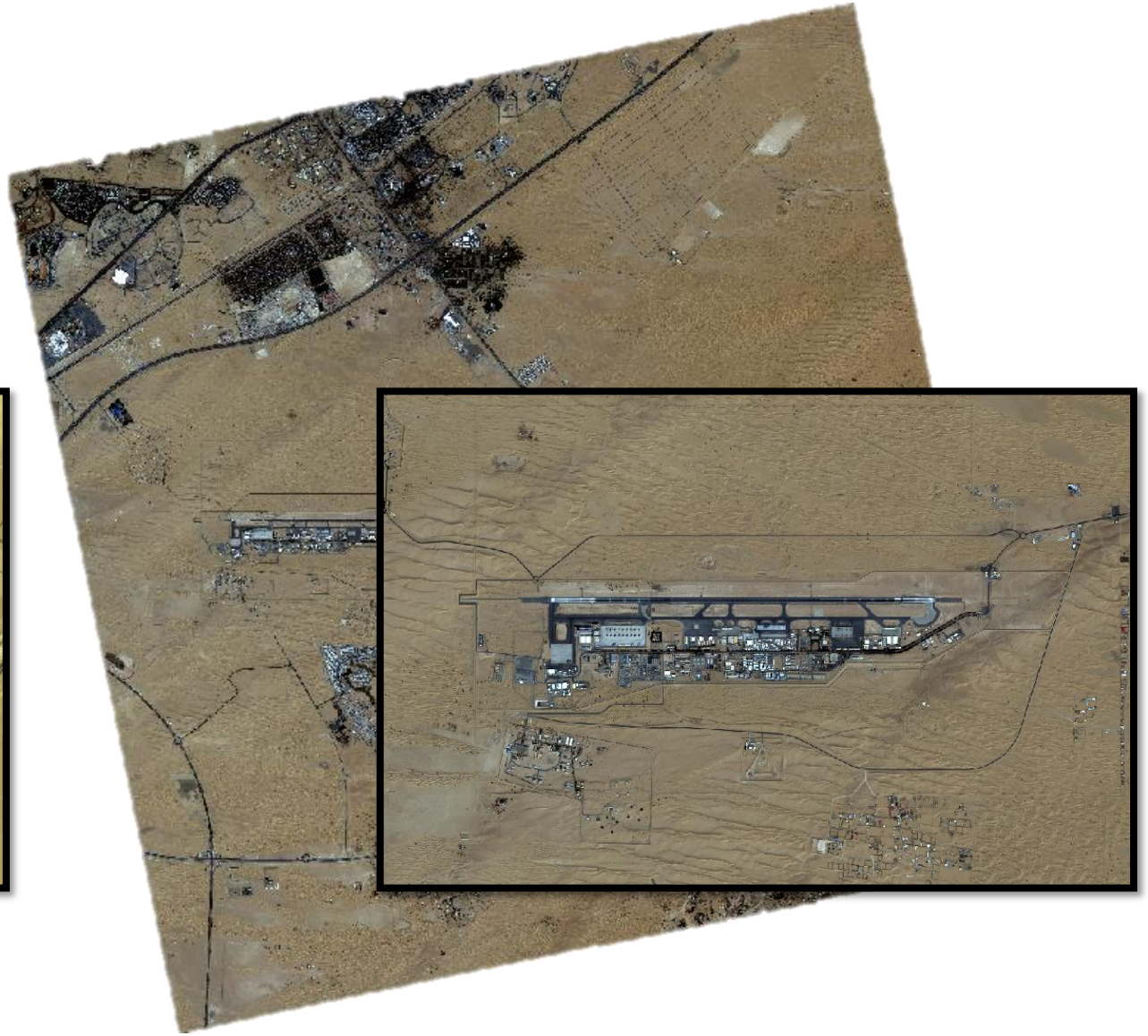






Dubai Airports





Dubai Maktoum International Airport – target 1

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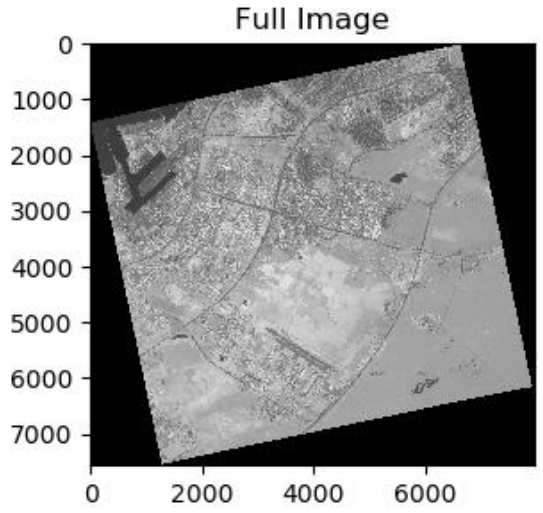
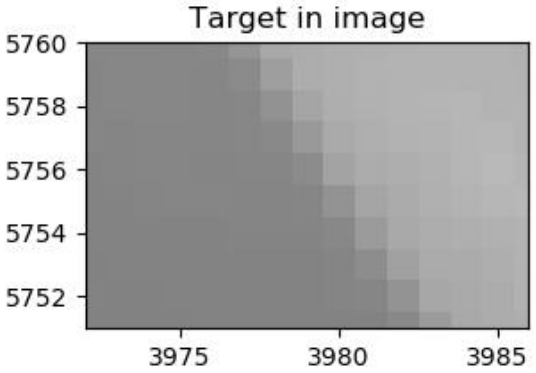
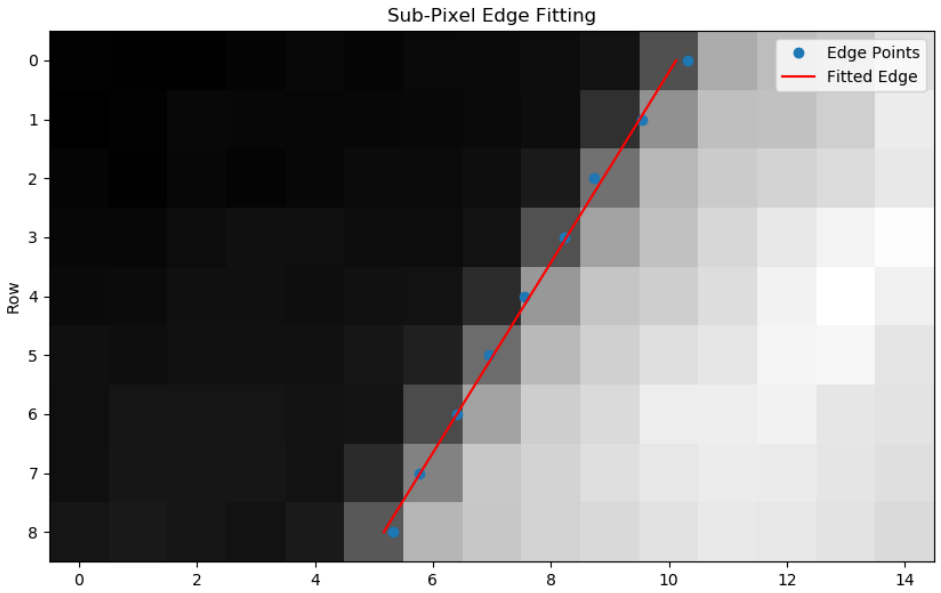
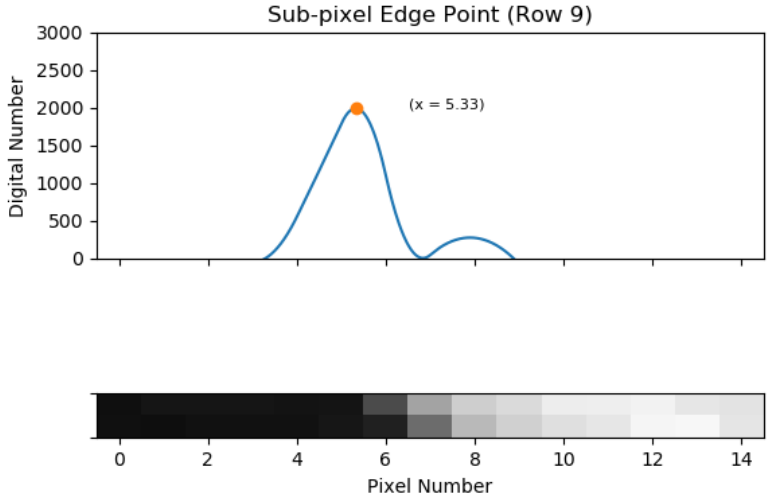
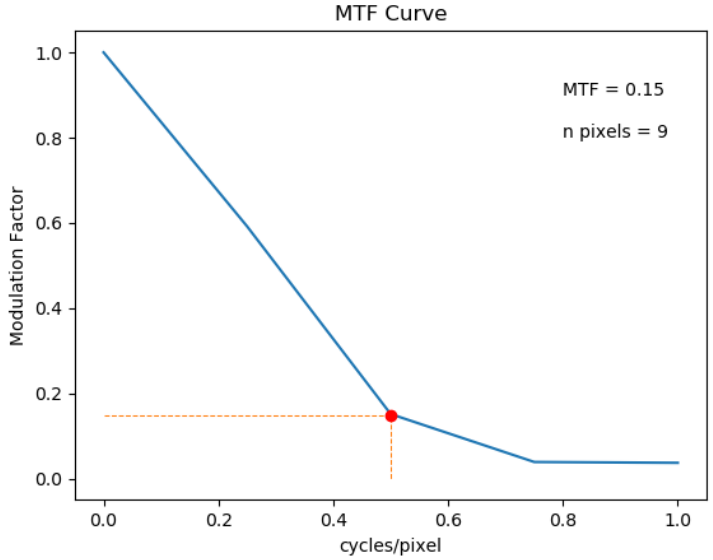




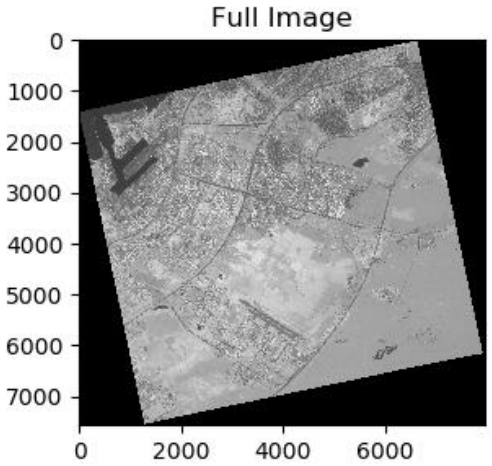


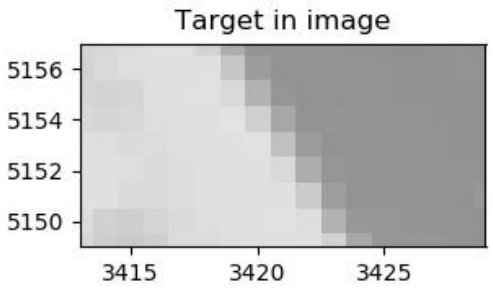


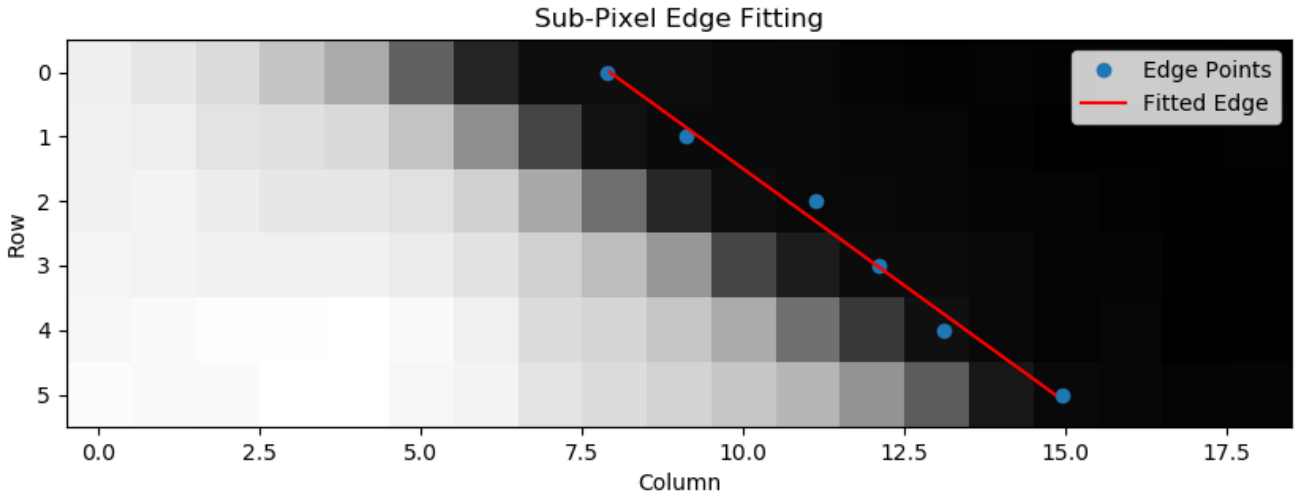


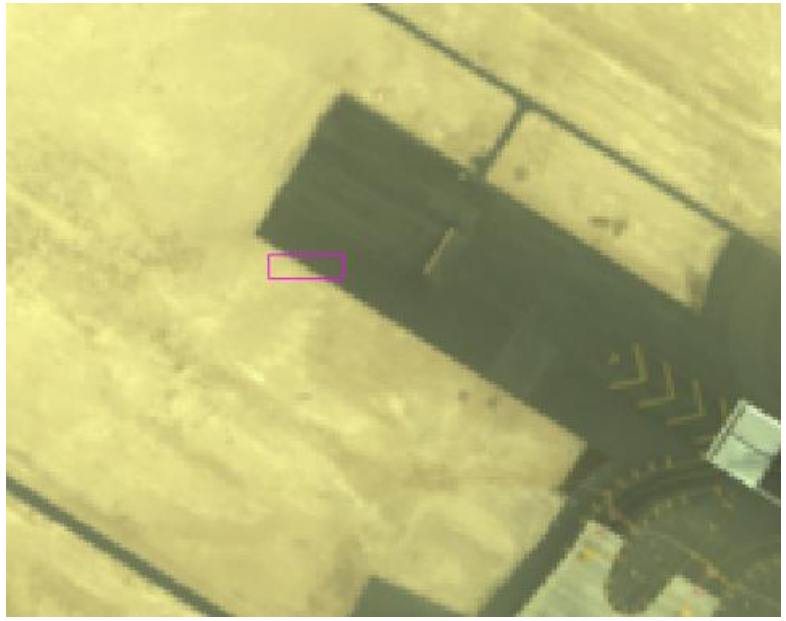
Dubai Maktoum International Airport – target 2

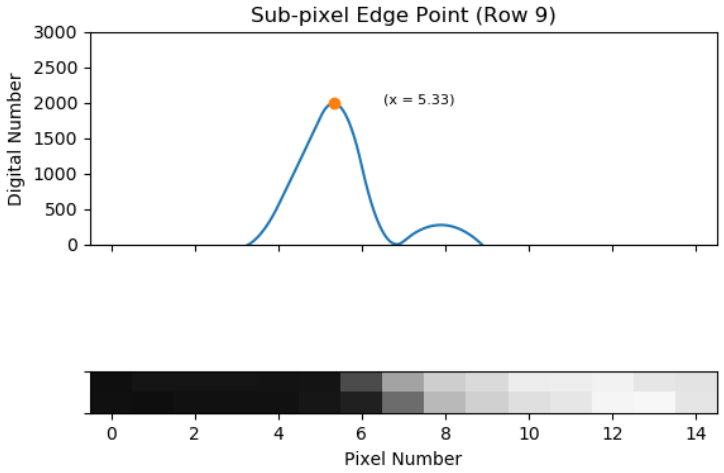
VIS1_BUN_20200729063350_ORTP_S96789_154a

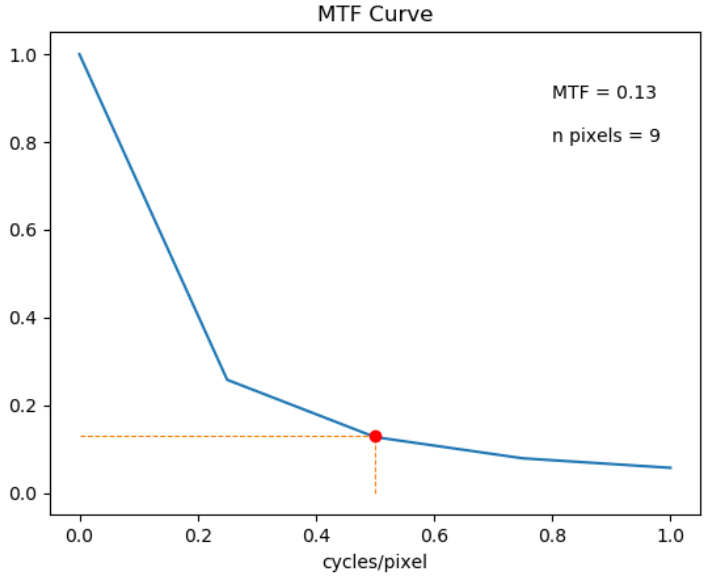






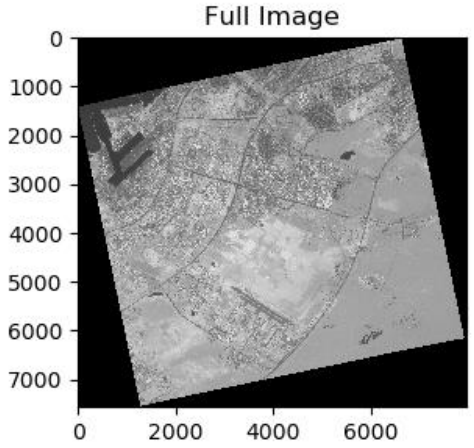


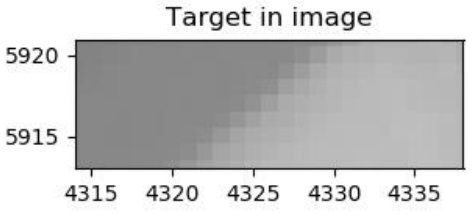


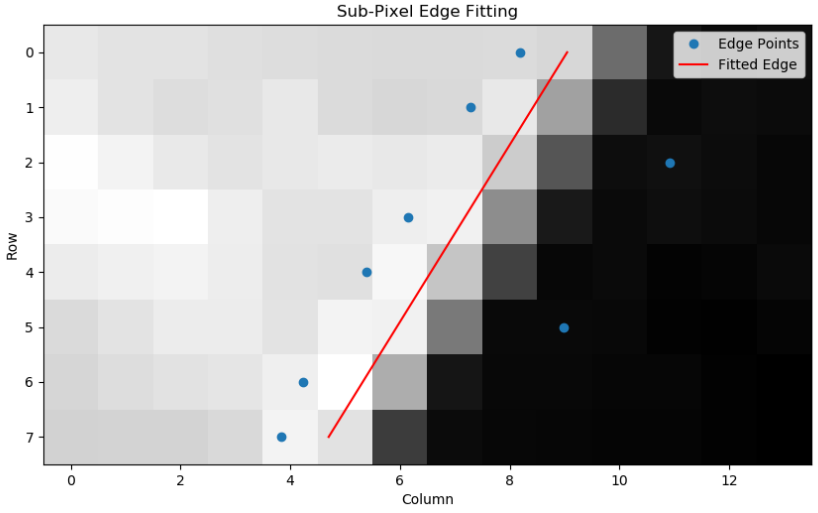


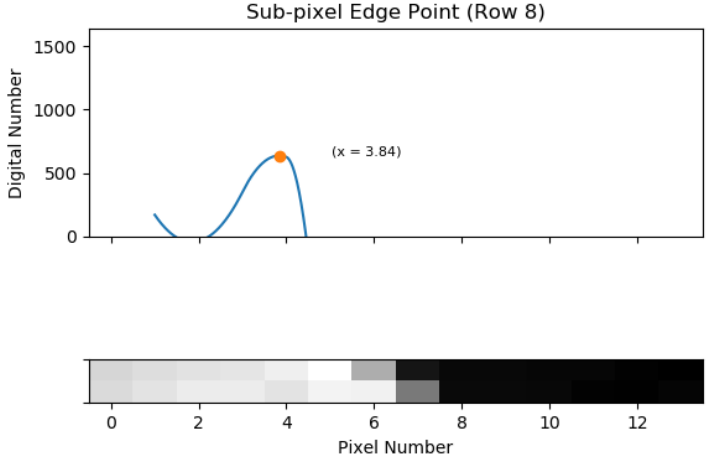
Dubai Maktoum International Airport – target 3

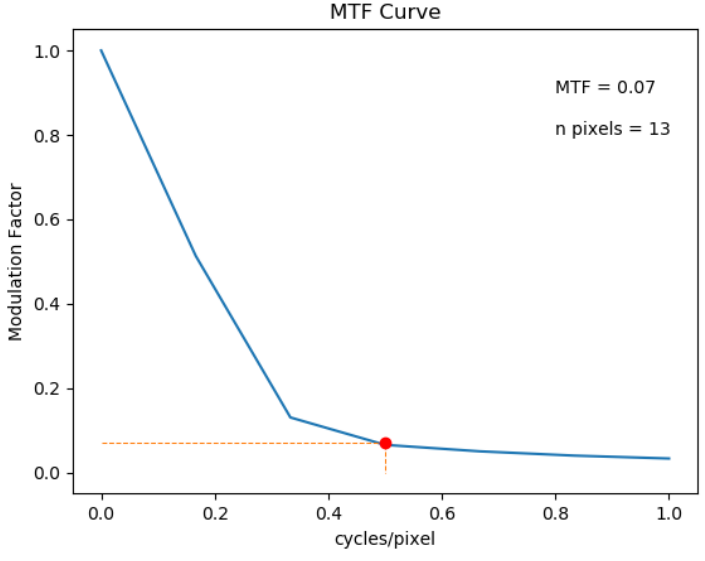
VIS1_BUN_20200729063350_ORTP_S96789_154a





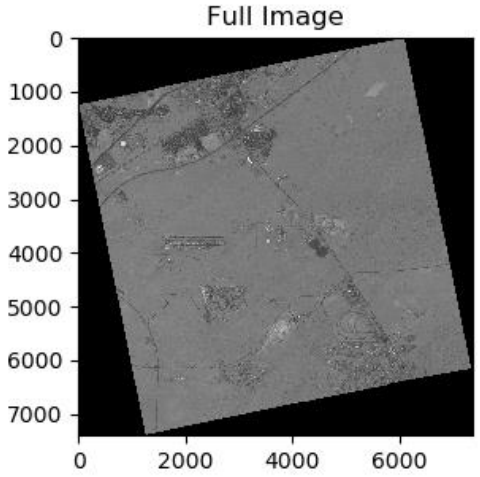


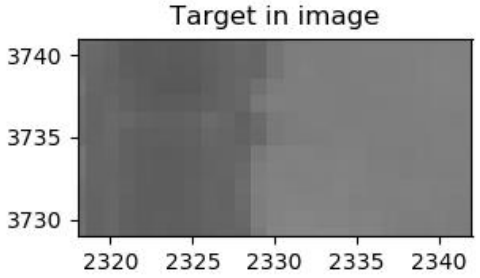


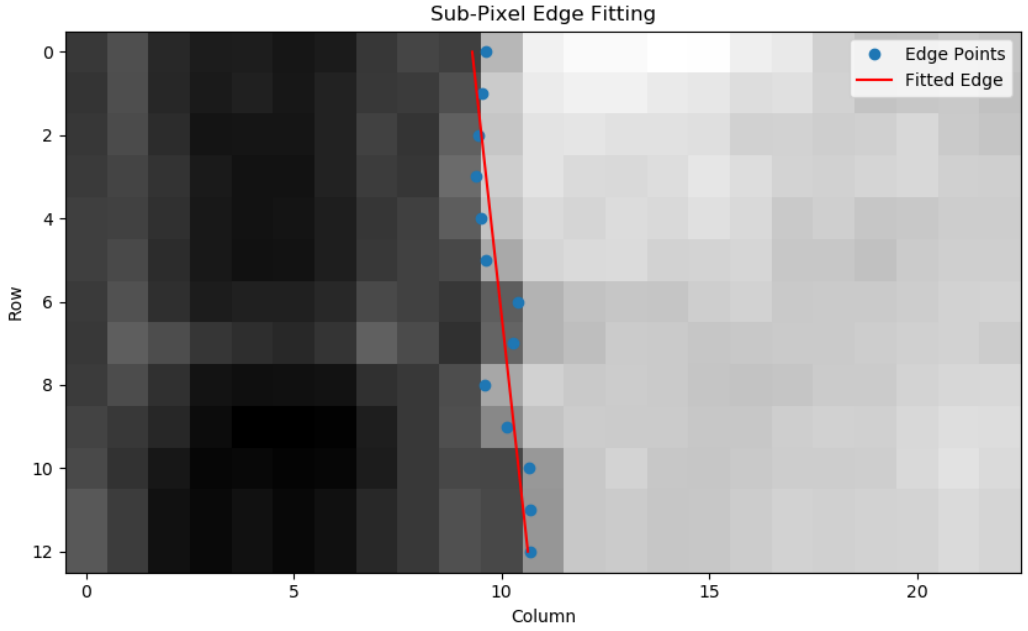


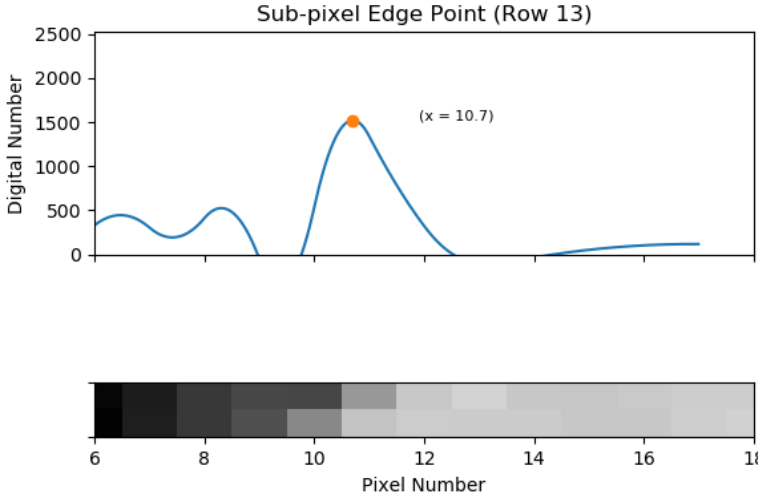
Minhad Airbase Dubai – target 1

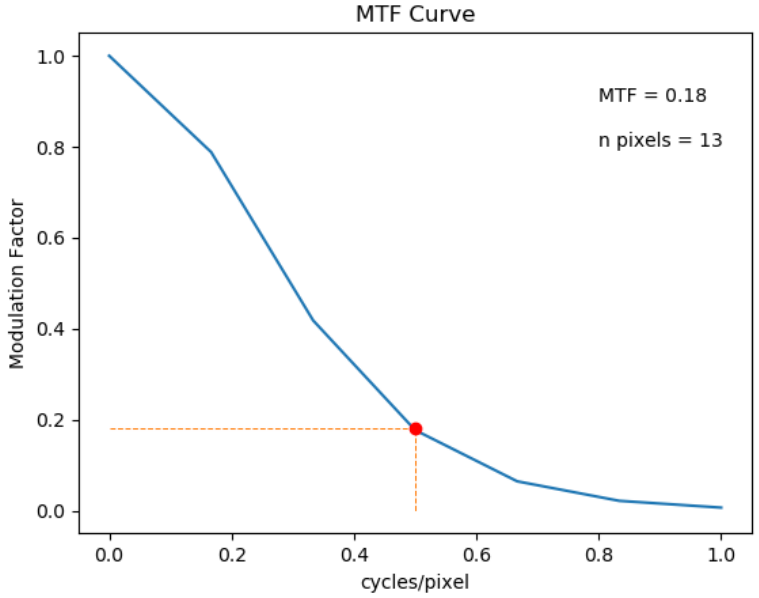
VIS1_BUN_20191020063208_ORTP_S87246_0728











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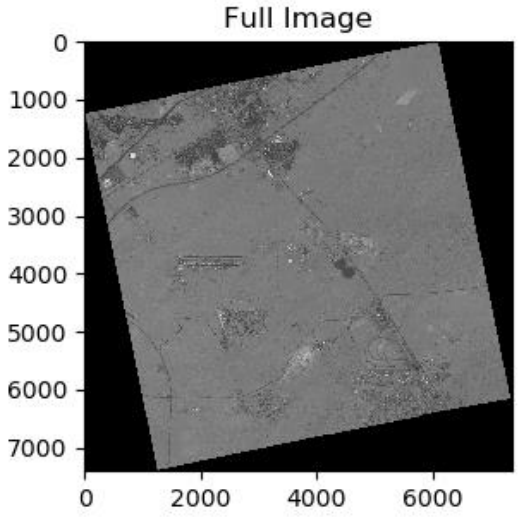
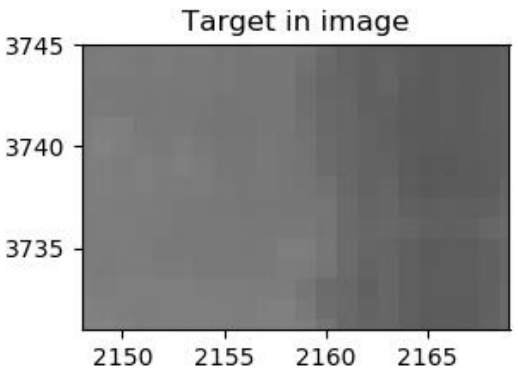
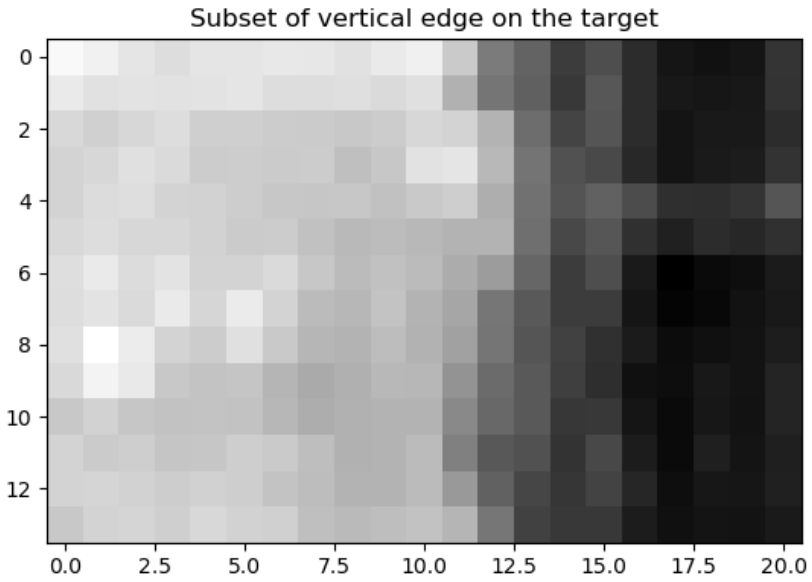
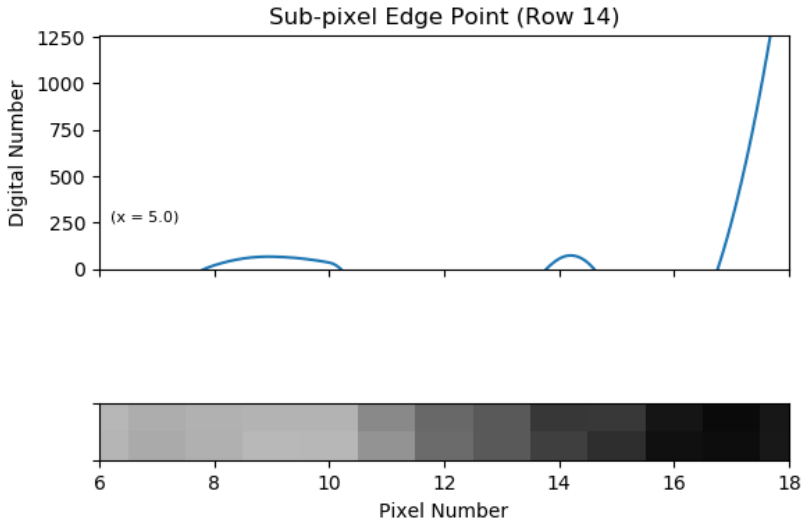
Minhad Airbase Dubai –target 2

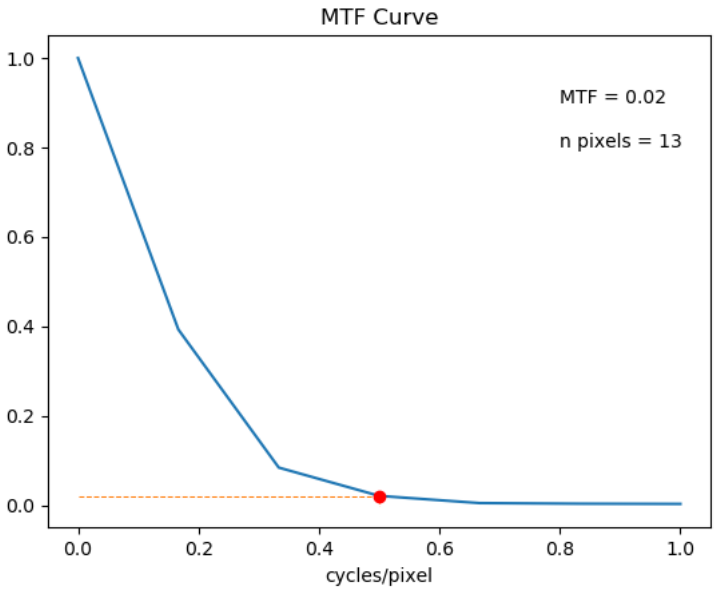
VIS1_BUN_20191020063208_ORTP_S87246_0728



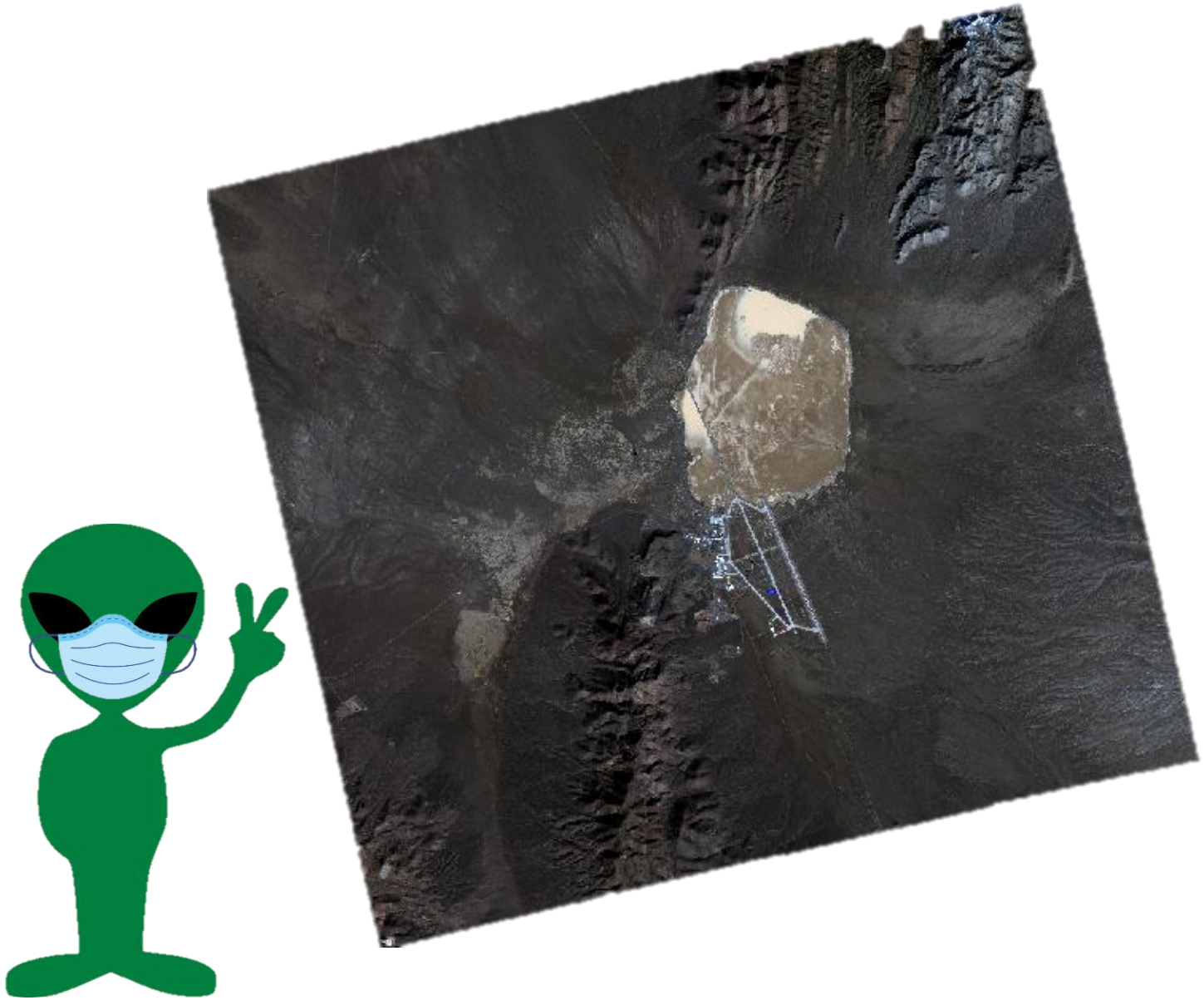






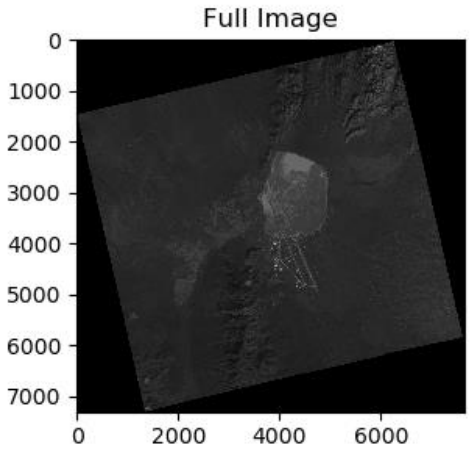


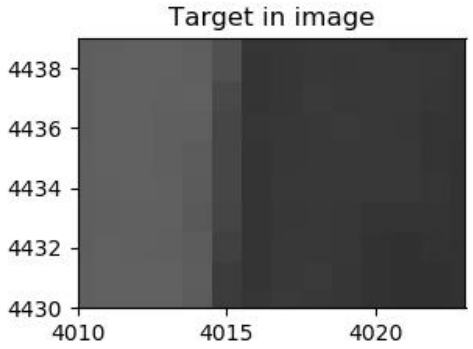
Nevada Airbase – Area 51

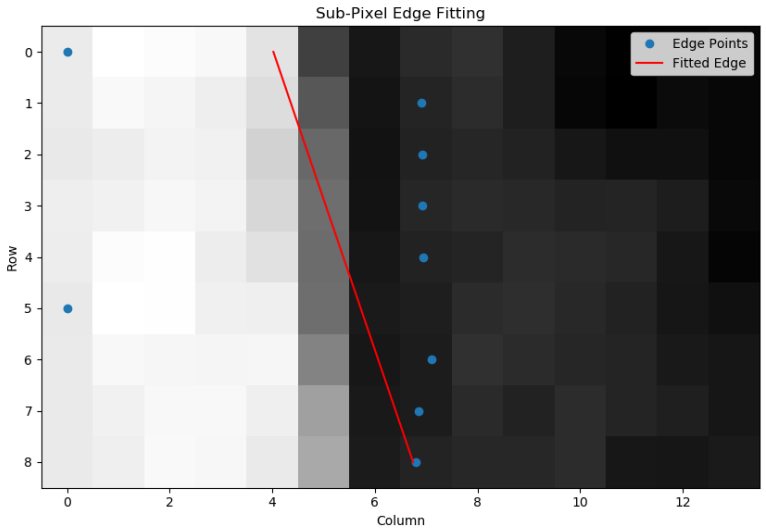


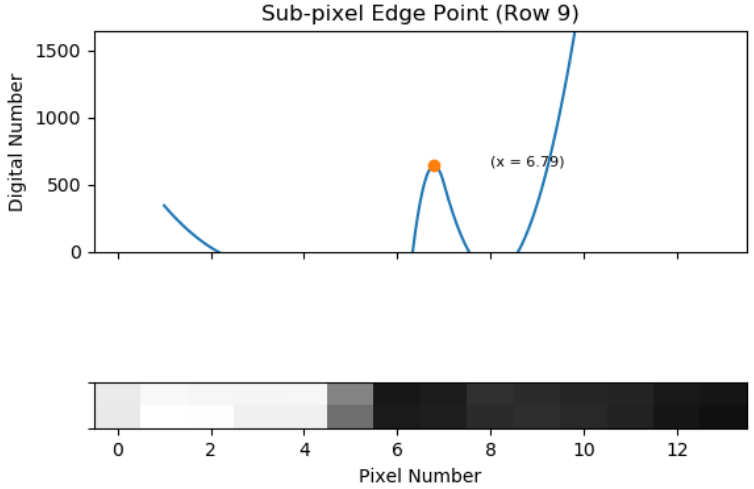
Nevada Airbase Area51– target 1

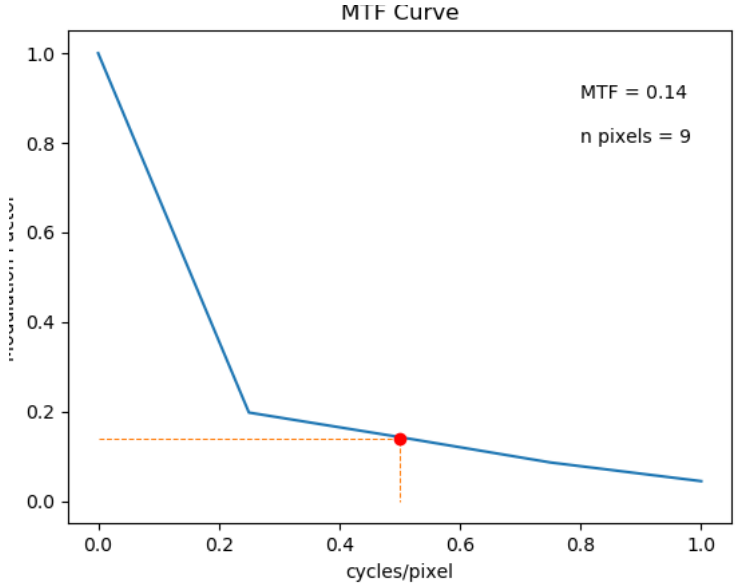
VIS1_BUN_20191123175324_ORTP_S94048_0851





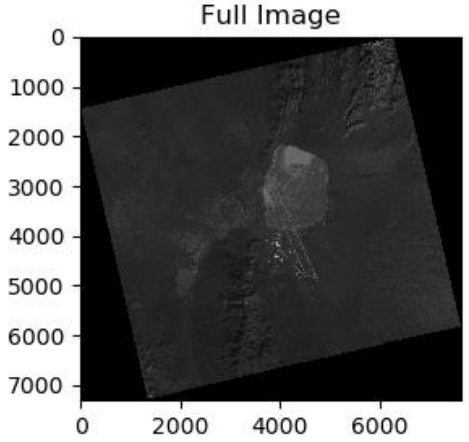


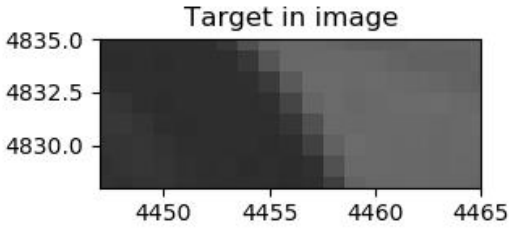


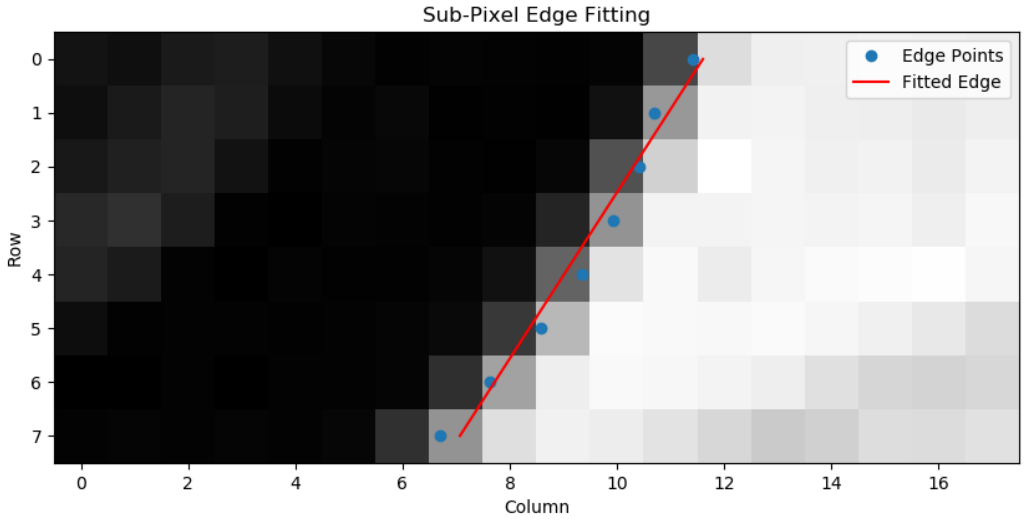


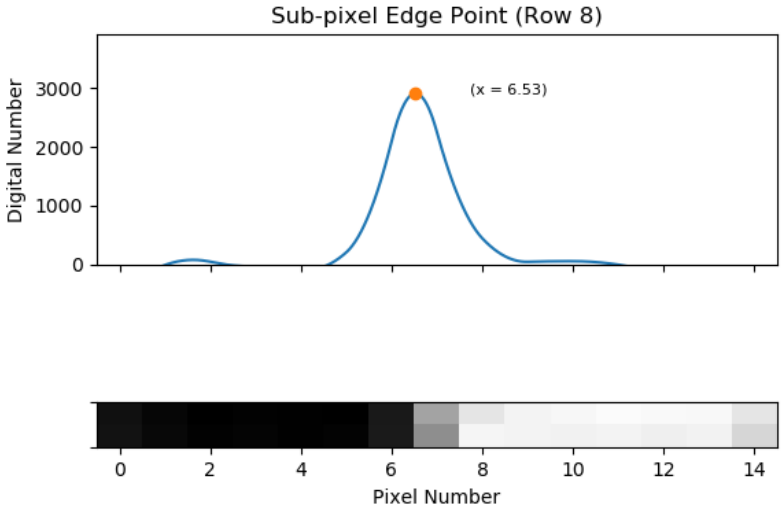
Nevada Airbase – target 2

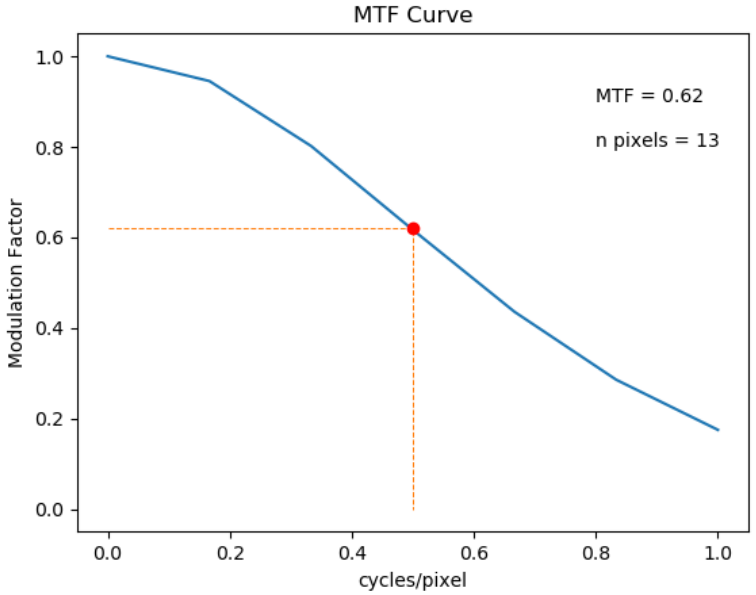
VIS1_BUN_20191123175324_ORTP_S94048_0851





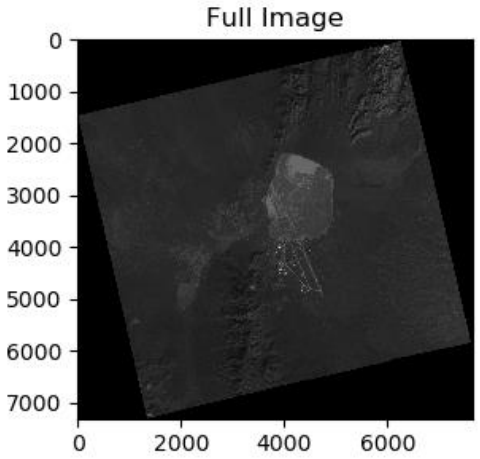


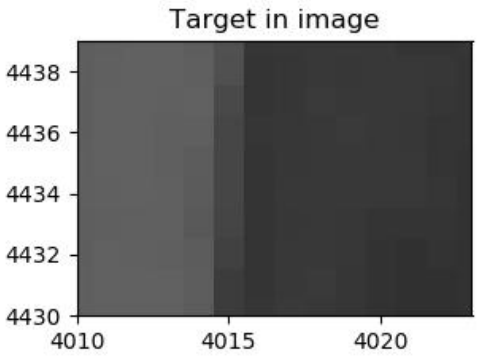


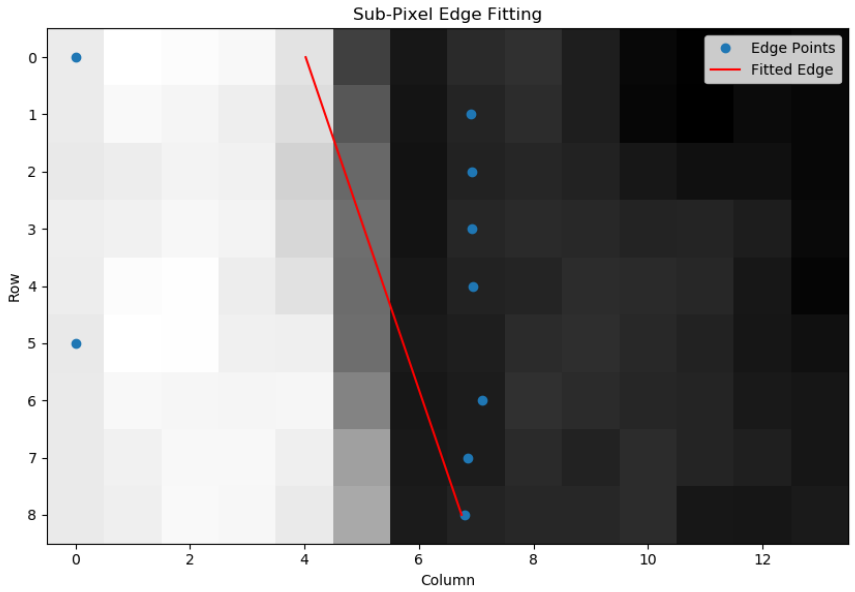


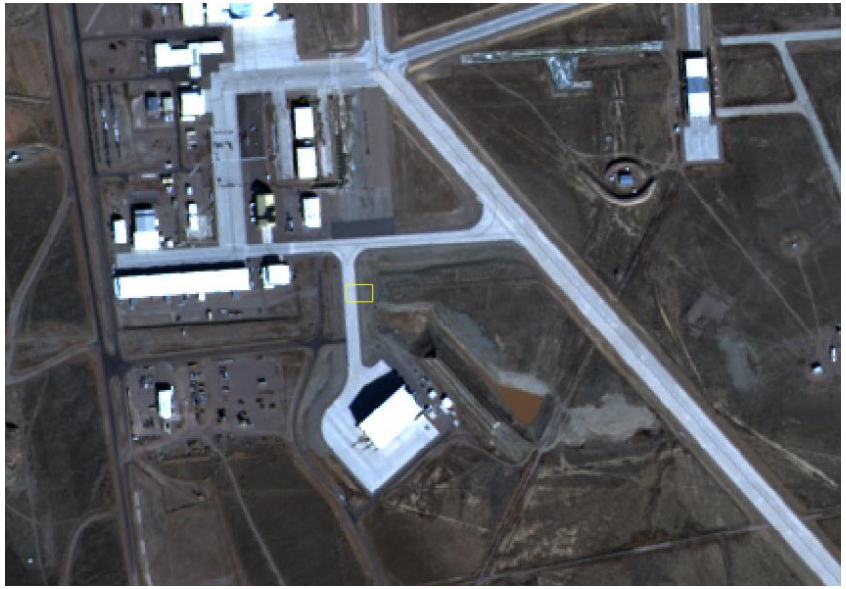
Nevada Airbase – target 3

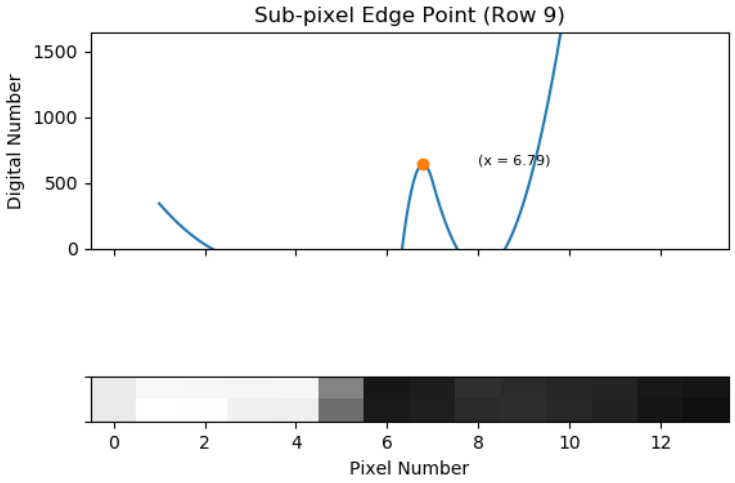
VIS1_BUN_20191123175324_ORTP_S94048_0851

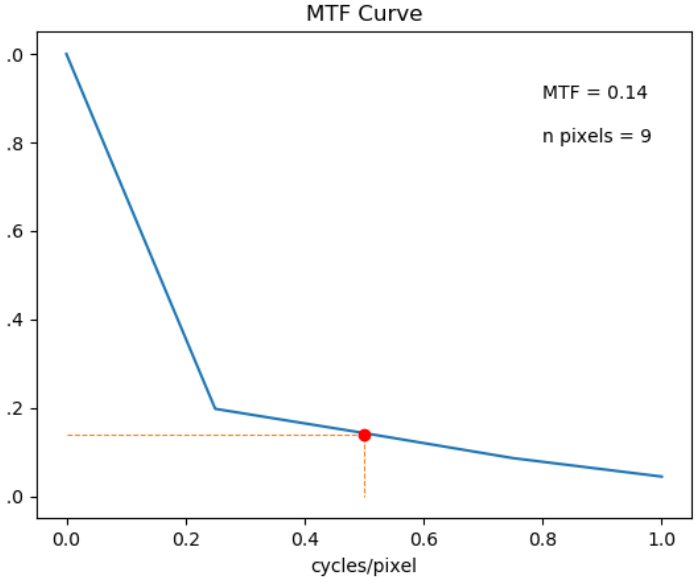












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Conclusions

Hamilton, Novato, California, USA (includes the Hamelton Wetlands)
Pansharpened Image
Vision-1 © Airbus Defence and Space Limited 2019

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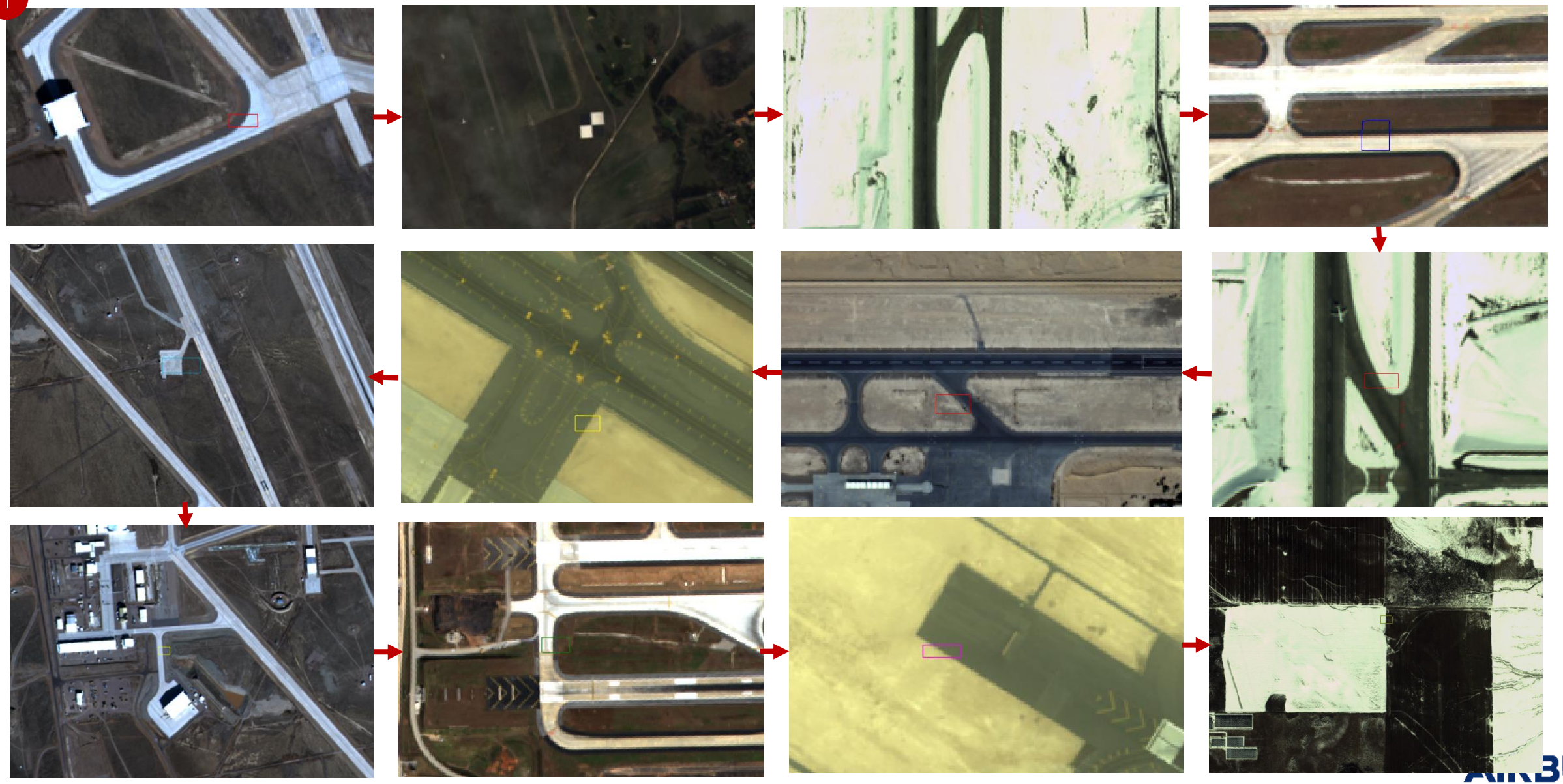
Sites in order of decreasing measured MTF

1



Results Overview

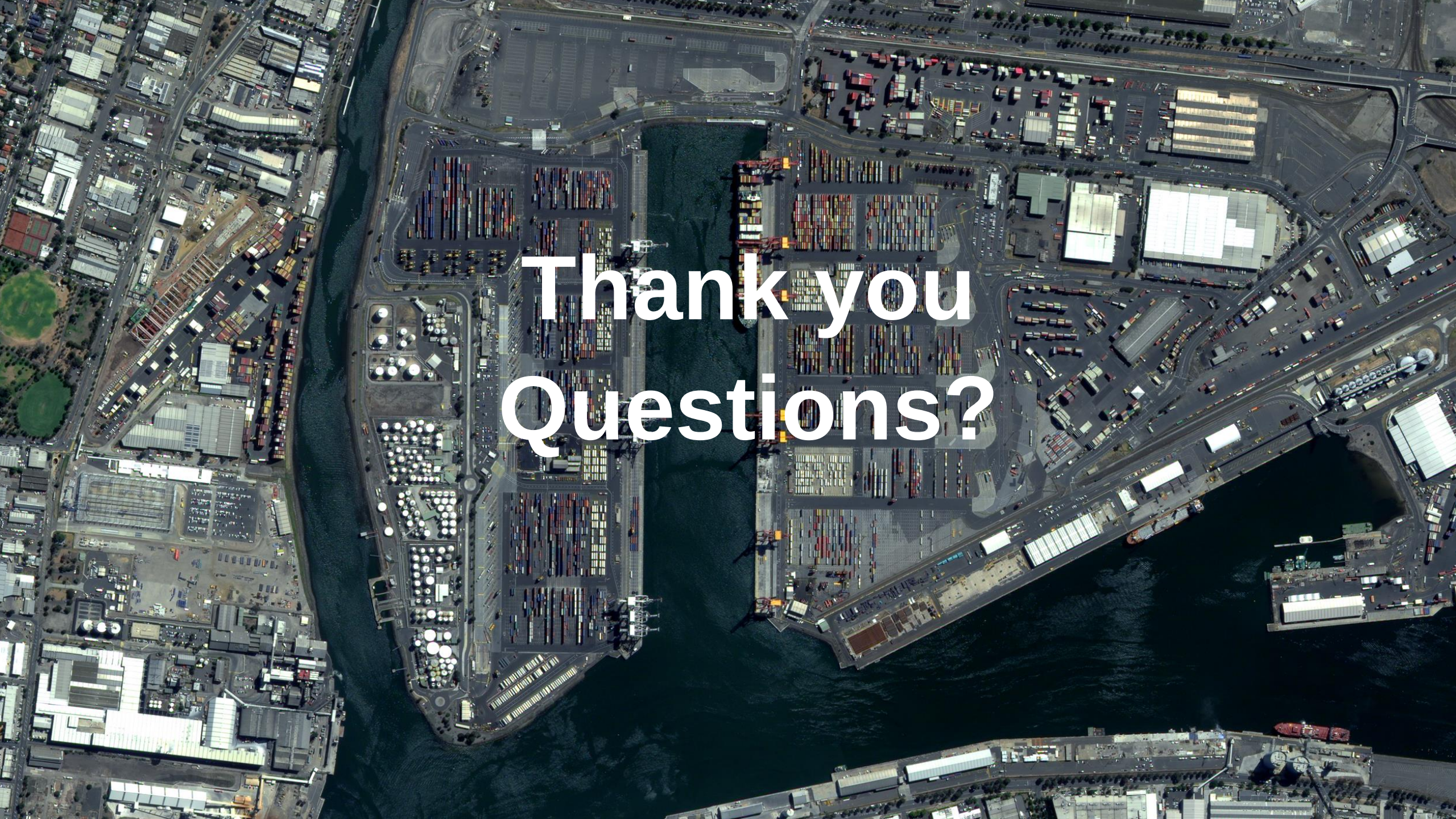
Image Location	Terrain Type	MTF Value
Salon de Provence	Artificial MTF site	0.57
Denver Airport	Runway and snow	0.53
	Black/white snow	0.09
	Runway with snow	0.32
Atlanta Airport	Runway and grass	0.13
	Runway with dark edge and grass	0.52
Dubai Al Maktoum Int Airport	Runway and sand	0.13
	Runway and sand	0.15
	Two sections of runway	0.07
Minhad Airbase, Dubai	Runway and sand	0.18
	Runway and sand	0.02
Area 51 (Nevada Airbase)	Runway with bare terrain	0.14
	Runway with dark edge and terrain	0.62
	Runway with bare terrain	0.14

Conclusions

- **Airports can provide multiple potetnial MTF sites giving results** comparable to artificial sites.
- Very useful for satellites with a small swath and limit chances to acquire a site.
- Not all airport and AOI's are successful, regions with the **greatest contrast visually** should be selected.
- Found that airports with **dark surrounding terrain or snow** were most successful.

Future Work

- Repeat airport acquisitions for the same airports but located on different CCDs across the swath.
- Add Airport image acquisition to our scheduling, tying into our wider quality strategy for our regular MTF monitoring
- We plan to monitor the MTF on a 6 month – quarterly basis
- Expand the study to get data to perform better statistical analysis



Thank you
Questions?