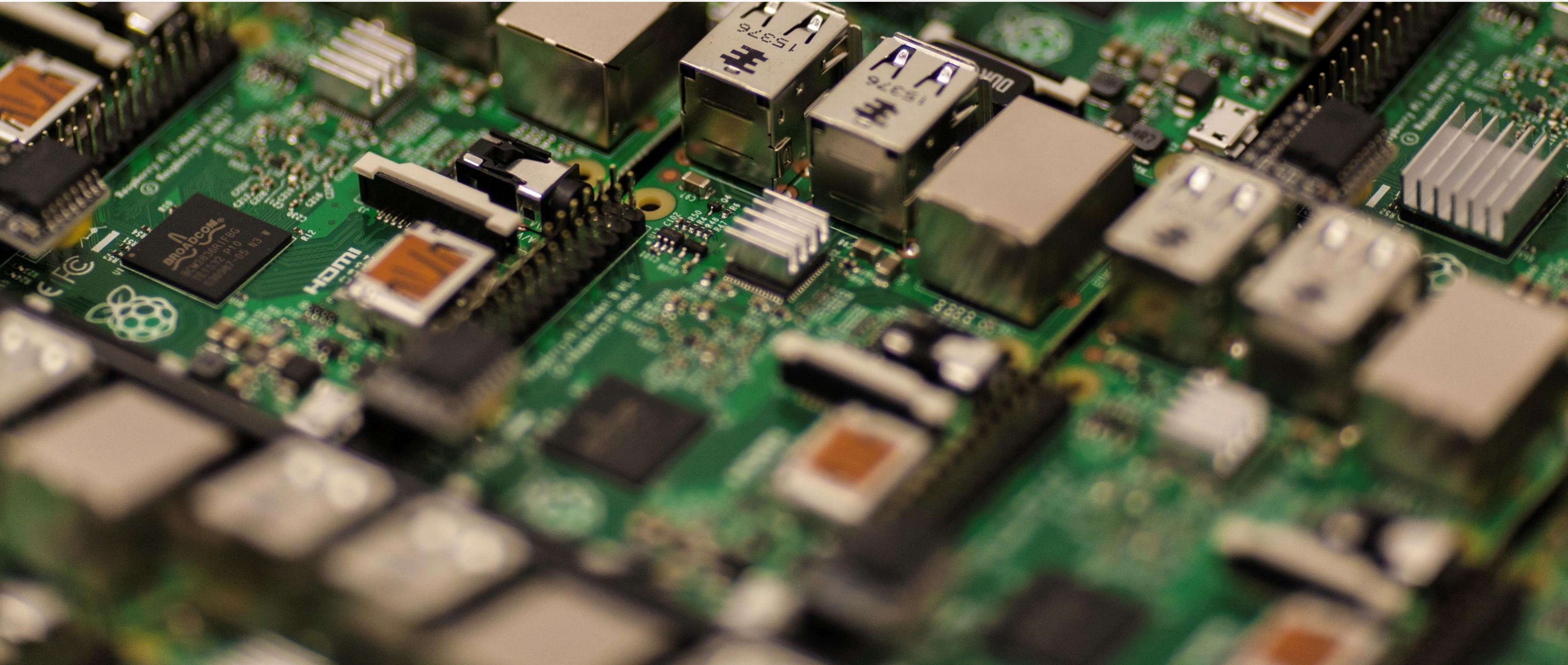
Workshop "Data Exploitation della missione PRISMA, precursore delle missioni iperspettrali nazionali"

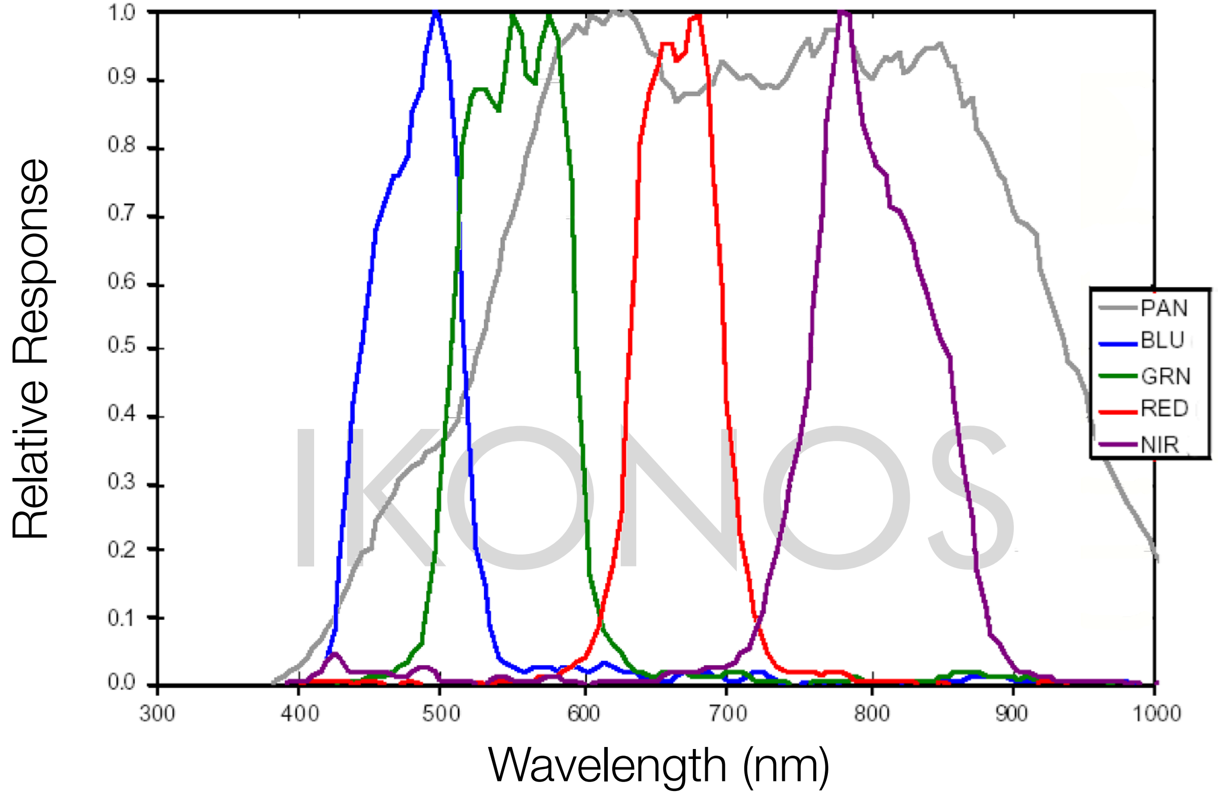
# Massimo Selva Sensori iperspettrali multi risoluzione: da pansharpening a hypersharpening

Roma, Sede ASI, 1 - 3 Marzo 2017

# Hardware: **INSTRUMENTS**



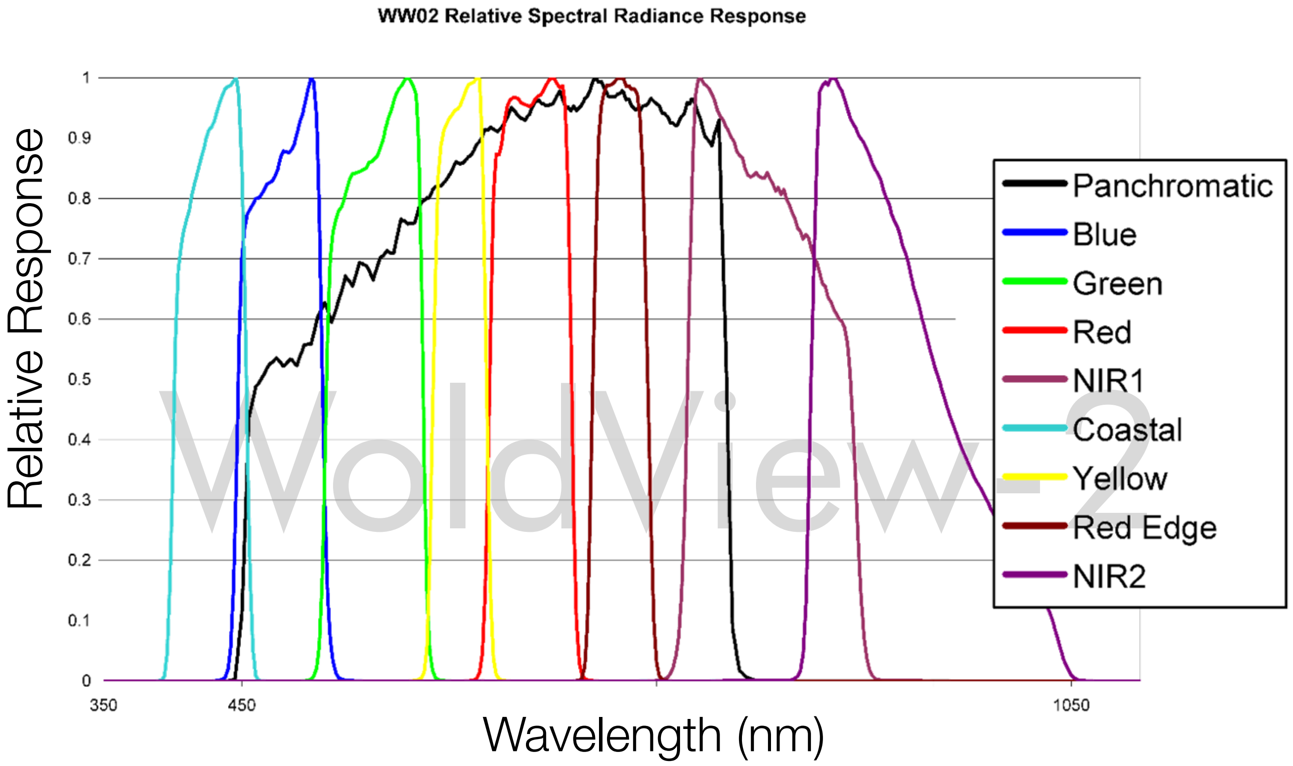
# 1999




Multispectral 4m

Panchromatic 1m

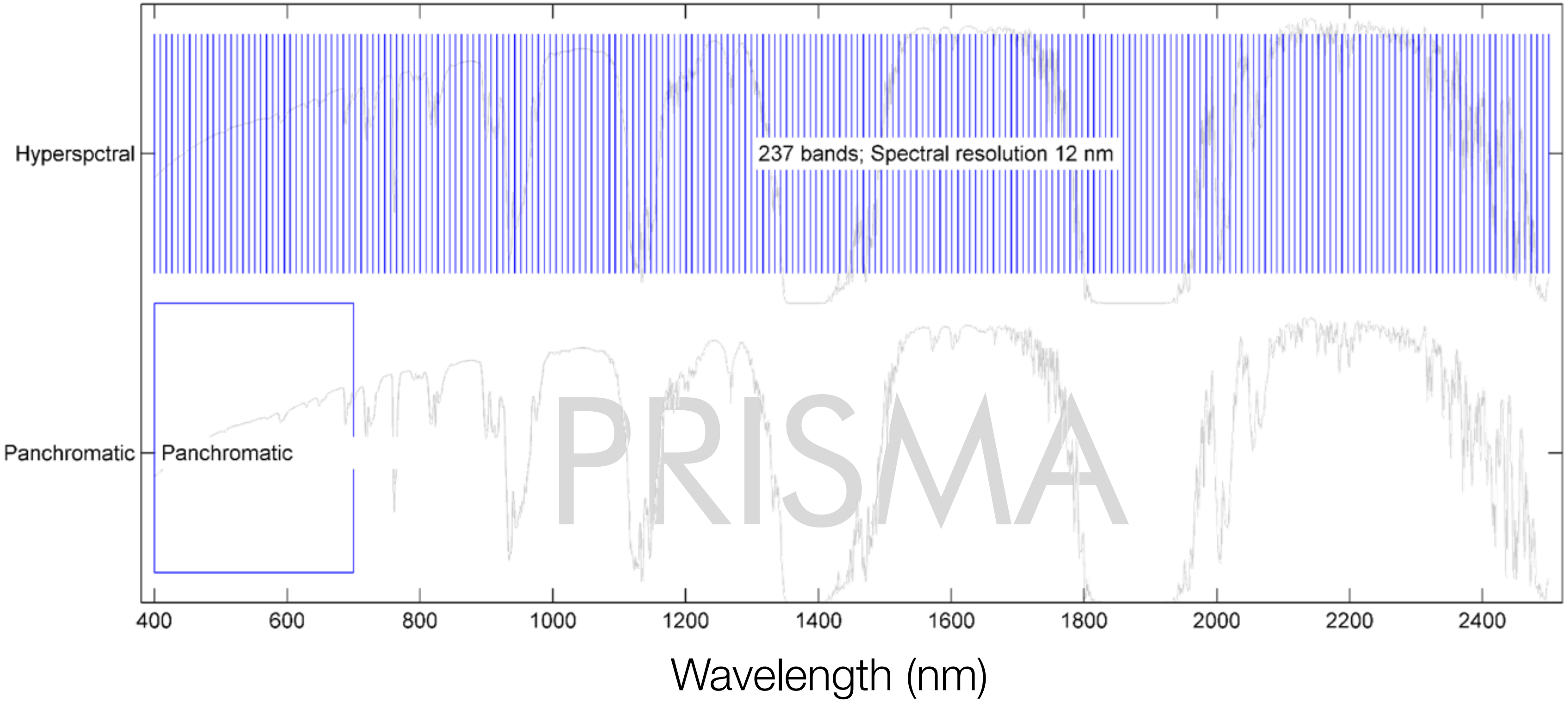
# 2009




Multispectral 1.85m

Panchromatic 0.46 m

# In Progress




Hyperspectral 30 m

Panchromatic 5 m

# Software: PANSHARPENING

Pan-sharpening is the process of enhancing the spatial resolution of a low resolution (LR) multispectral/hyperspectral image, by extracting the spatial details from a single high resolution Pan image. The spatial details are inserted into the LR image by means of a suitable injection model. The goal is to produce an high resolution multispectral/hyperspectral image at the Pan spatial resolution.

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## PANSHARPENING

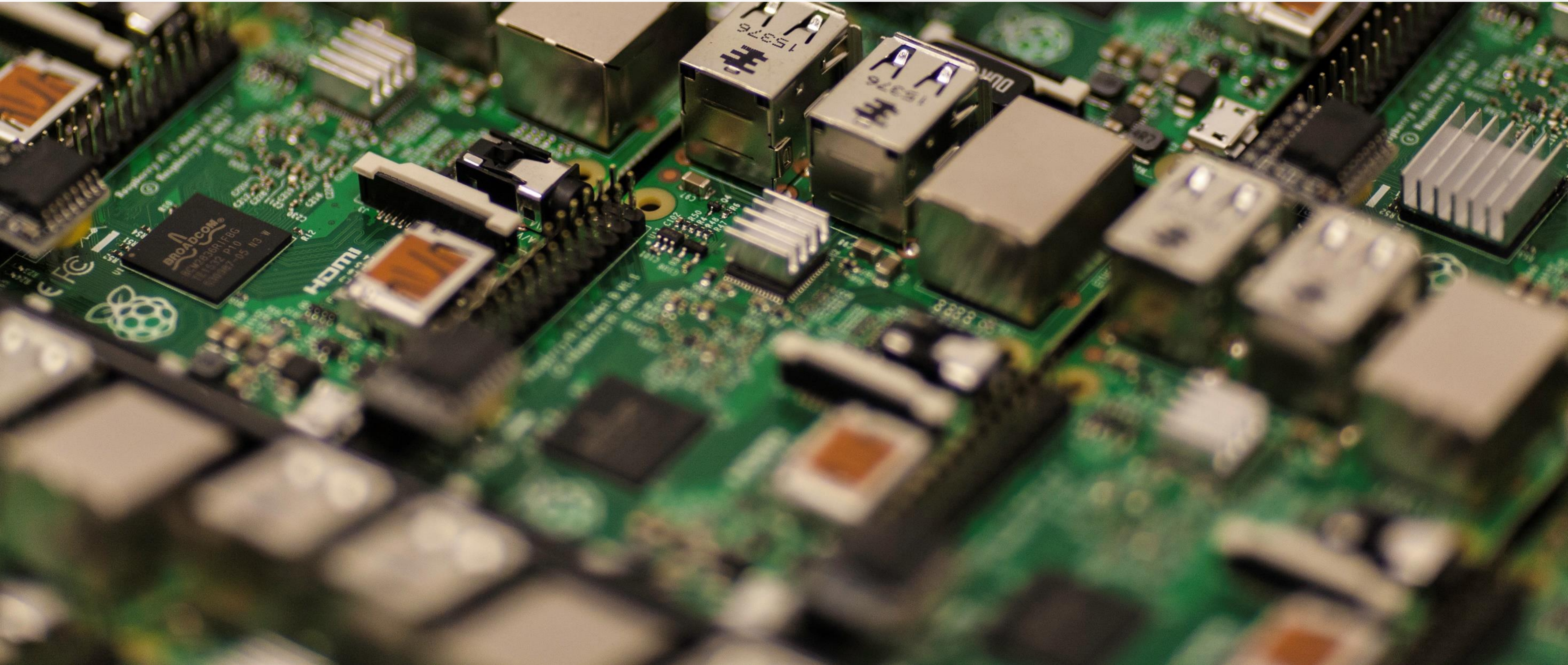
Detail from a single spatial high resolution image (Panchromatic)

High Resolution Panchromatic

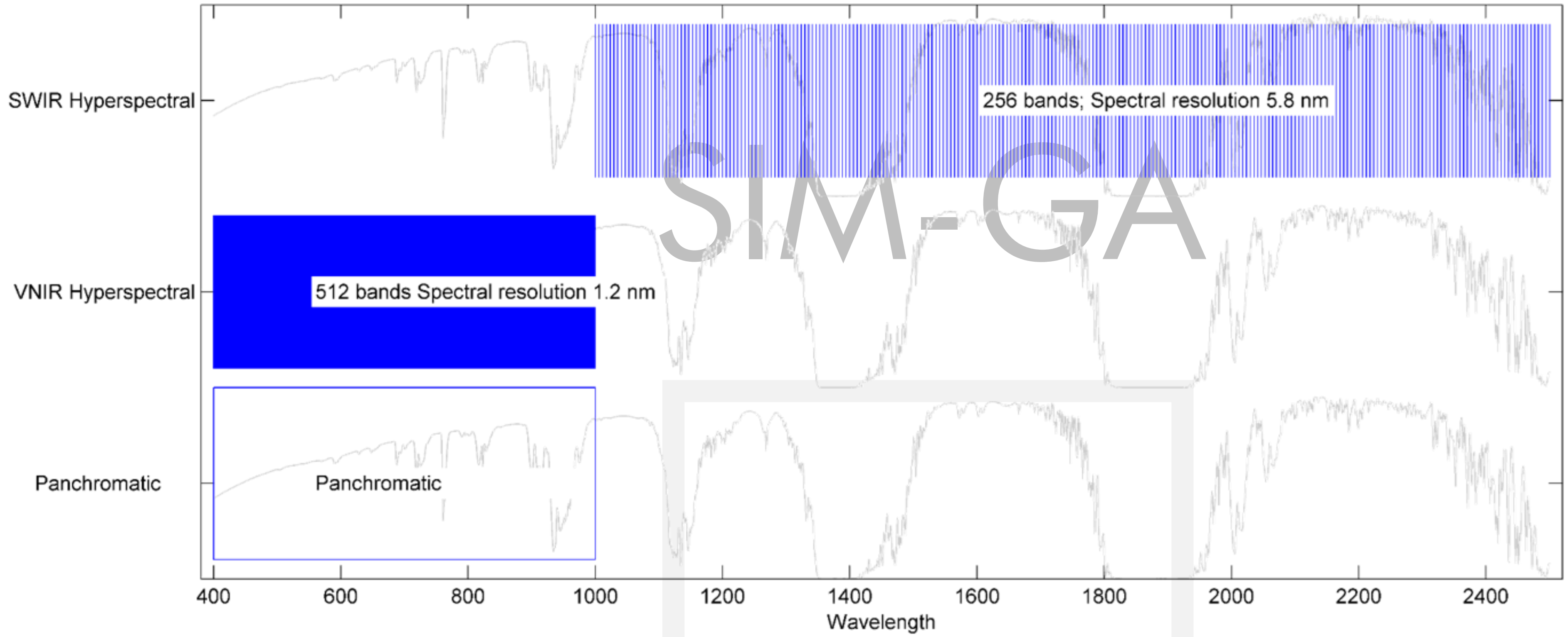
Low Resolution Multispectral/Hyperspectral

High Resolution Multispectral/Hyperspectral

# Hardware: **INSTRUMENTS**



# In Progress




Hyperspectral SWIR 1.5m

Hyperspectral VNIR 0.5m

Panchromatic 0.17 m

# Software: **HYPERSHARPENING**

Hypersharpening is the natural evolution of pansharpening. This new paradigm is applied when a multispectral/hyperspectral data is the source of detail. The hypersharpening methods can choose/synthesize a different band as source of the high spatial frequencies for each multispectral/hyperspectral band that has to be fused.

Hypersharpening is the natural evolution of pansharpening. This new paradigm can be applied when a multispectral/hyperspectral data is the source of detail. The hypersharpening methods can choose/synthesize a different band as source of the high spatial frequencies for each multispectral/hyperspectral band that has to be fused.

# HYPERSHARPENING

Detail from a high spatial resolution multispectral/hyperspectral data

HAVE A LOOK AT HYPERSHARPENING

PANSHARPENING

HYPERSHARPENING

The Pansharpening MRA methods employ digital spatial filters to extract high frequency information, by the sensor MTF in the reduction step. The injected details are the differences between Pan (P) image and the suitable its expanded LP version. The details is weighted by global or local coefficients $g_k$ before to be added to the interpolated low spatial **hs** bands.

$$\hat{hs}_k = \tilde{hs}_{k_{exp}} + g_k \left( P - \tilde{P}_{k_{exp}} \right) \quad k = 1 \ldots N$$

$$g_k = \frac{cov(\tilde{P}_{k_{exp}}, \tilde{hs}_{k_{exp}})}{var(\tilde{P}_{k_{exp}})}$$

KEY-POINT

HYPERSHARPENING

$$\hat{hs}_k = \tilde{hs}_{k_{exp}} + g_k \left( P - \tilde{P}_{k_{exp}} \right) \quad k = 1 \ldots N$$

# P IS REPLACED BY $X_k$

$$\hat{hs}_k = \tilde{hs}_{k_{exp}} + g_k \left( X_k - \tilde{X}_{k_{exp}} \right) \quad k = 1 \ldots N$$

# WHAT IS $X_k$ ?

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$X_k$ is obtained by processing the high spatial hyperspectral **HS** ($HS_h$ h=1 … M).

$X_k$ can be different for each band of **hs.**

# HOW IS $X_k$ OBTAINED ?

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$X_k$ can be obtained by two different approaches:

the first is called selected band and the second is called synthesized band

1

# SELECTED BAND

Each $hs_k$ band is enhanced by using as $X_k$ the $HS_h$ band that at spatial resolution of **hs** has the highest correlation coefficient with $hs_k$.

2

# SYNTHESIZED BAND

Each $hs_k$ band is enhanced by using as $X_k$ a new band that is synthesized starting from the hyperspectral HS.

2

At the low spatial resolution, the following minimization is processed:

$$\|\tilde{hs}_{k_{exp}} - \tilde{X}_{k_{exp}}\|$$

$$\tilde{X}_{k_{exp}} = \sum_{h=1}^{M} w_{k_h} \cdot \tilde{HS}_{h_{exp}} + b_k$$

2

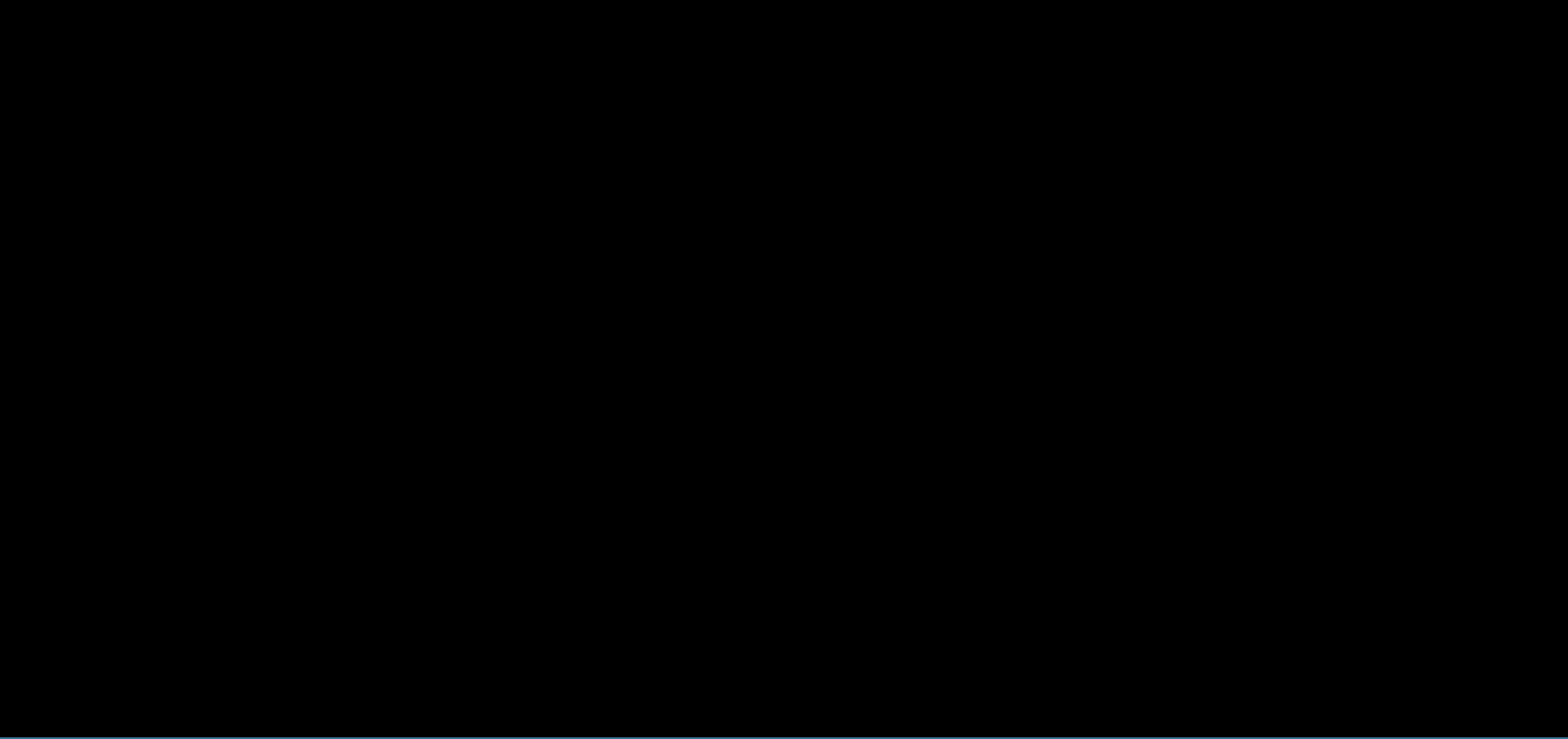
$X_k$ is synthesized by using the weights previously processed:

$$X_k = \sum_{h=1}^{M} w_{k_h} \cdot HS_h + b_k$$

2

Indeed, in place of HS can be used a new hyperspectral sequence that is derived from HS but with less bands than HS

# HYPERSHARPENING APPLIED TO SIM-GA DATA



Original Pan is preliminary reduced to VNIR scale (0.5 m).

Pan Degraded

0.5 m GSD

256 SWIR Bands

1.5 m GSD

512 VNIR Bands

0.5 m GSD

PANSHARPENING

HYPERSHARPENING

Pan Degraded
0.5 m GSD

256 SWIR Bands
1.5 m GSD

512 VNIR Bands
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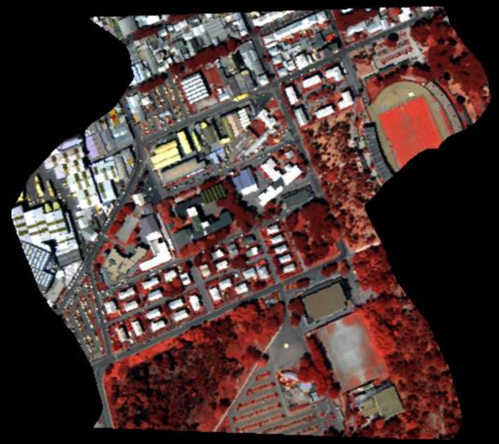
PANSHARPENING

HYPERSHARPENING

256 SWIR Bands
0.5 m GSD

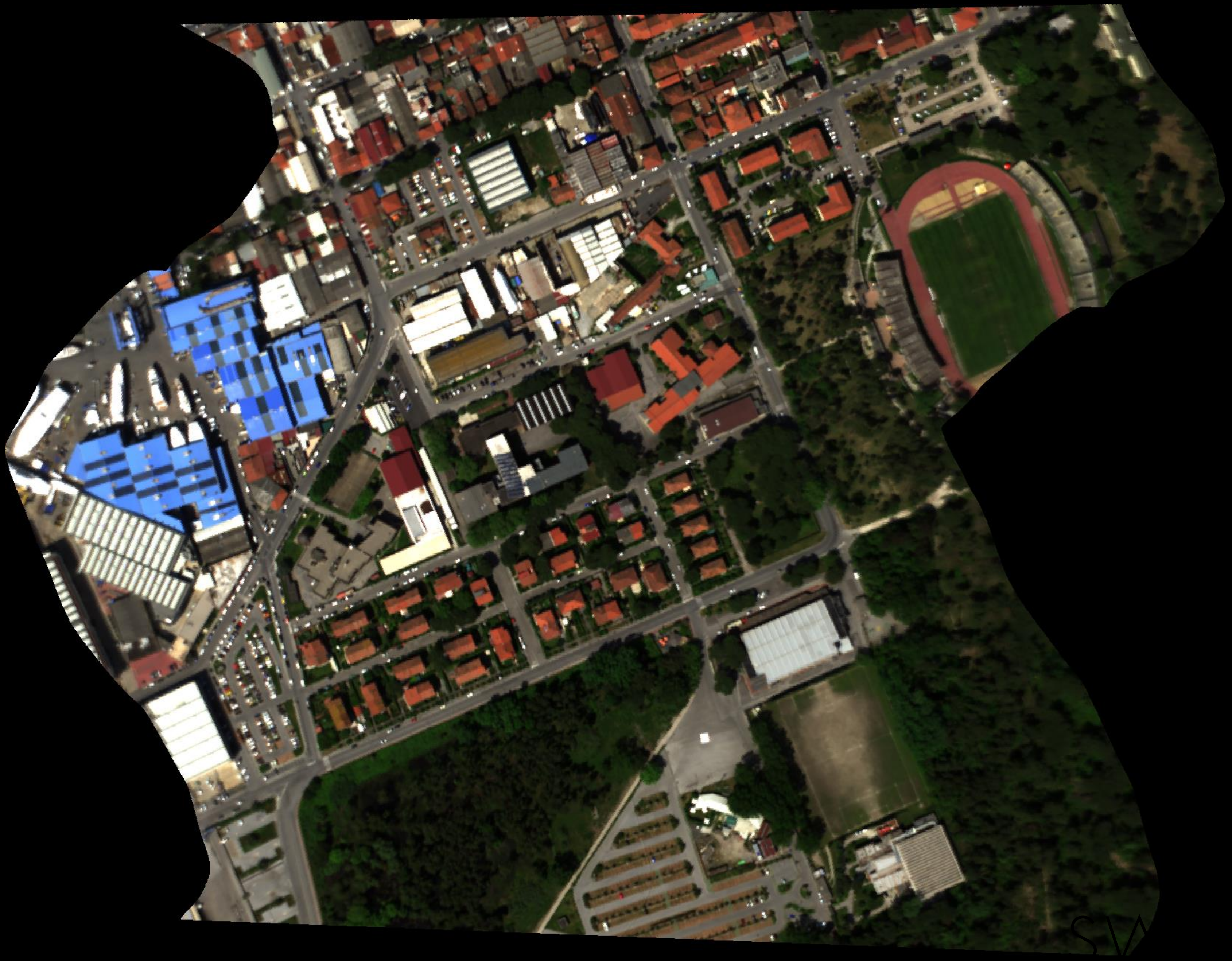
256 SWIR Bands
0.5 m GSD

# DATA
# S E T



SWIR

1.5 m



VNIR

0.5 m

Pan

0.5 m

# Experimentation at the lower scale

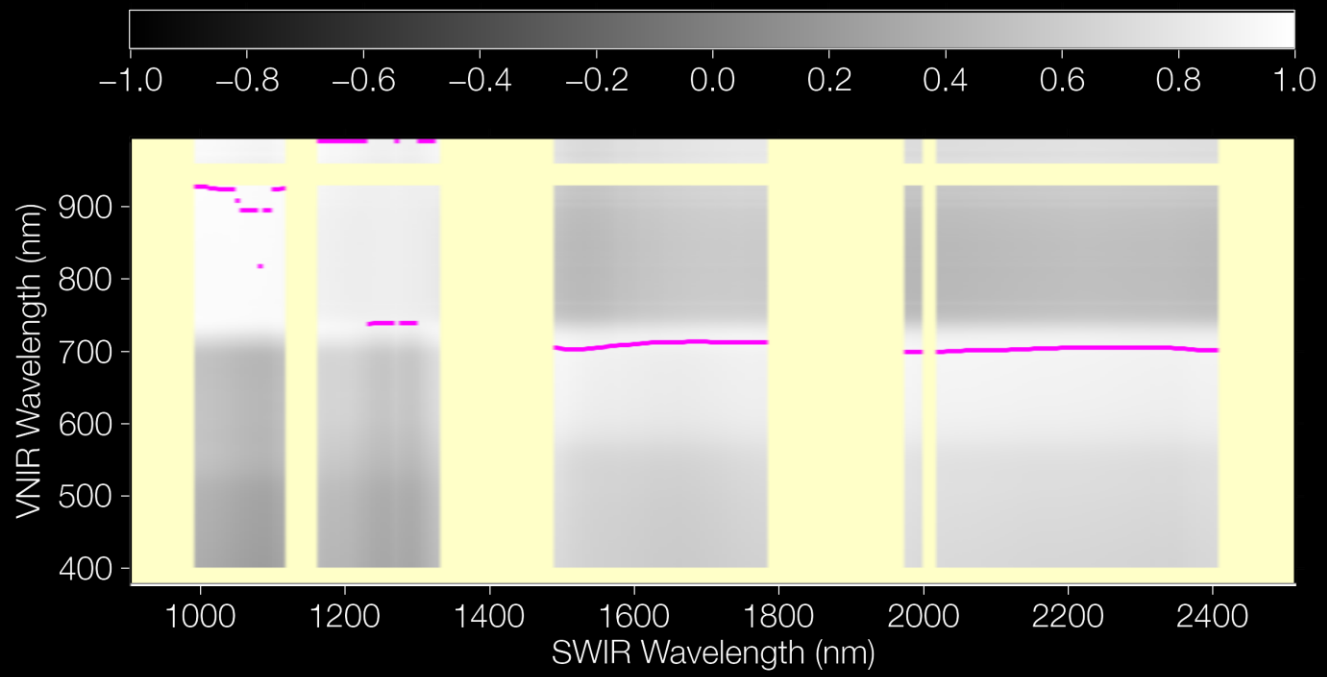
(from 4.5 m to 1.5 m)

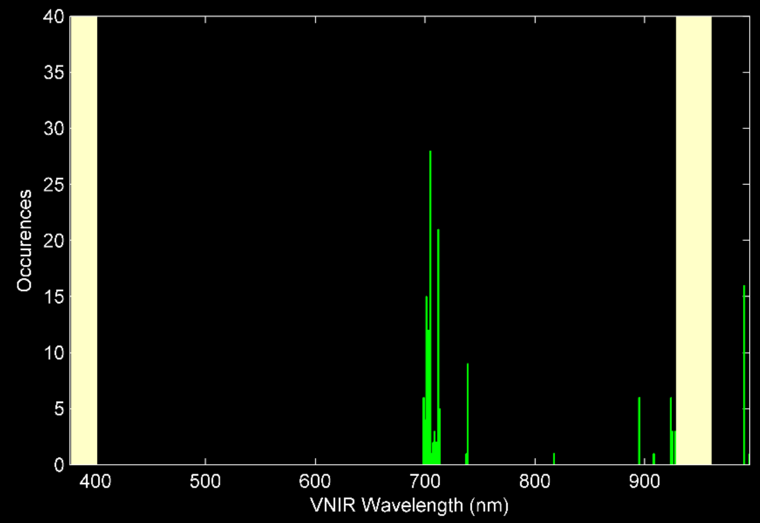
## Experimentation at the lower scale

(from 4.5 m to 1.5 m)

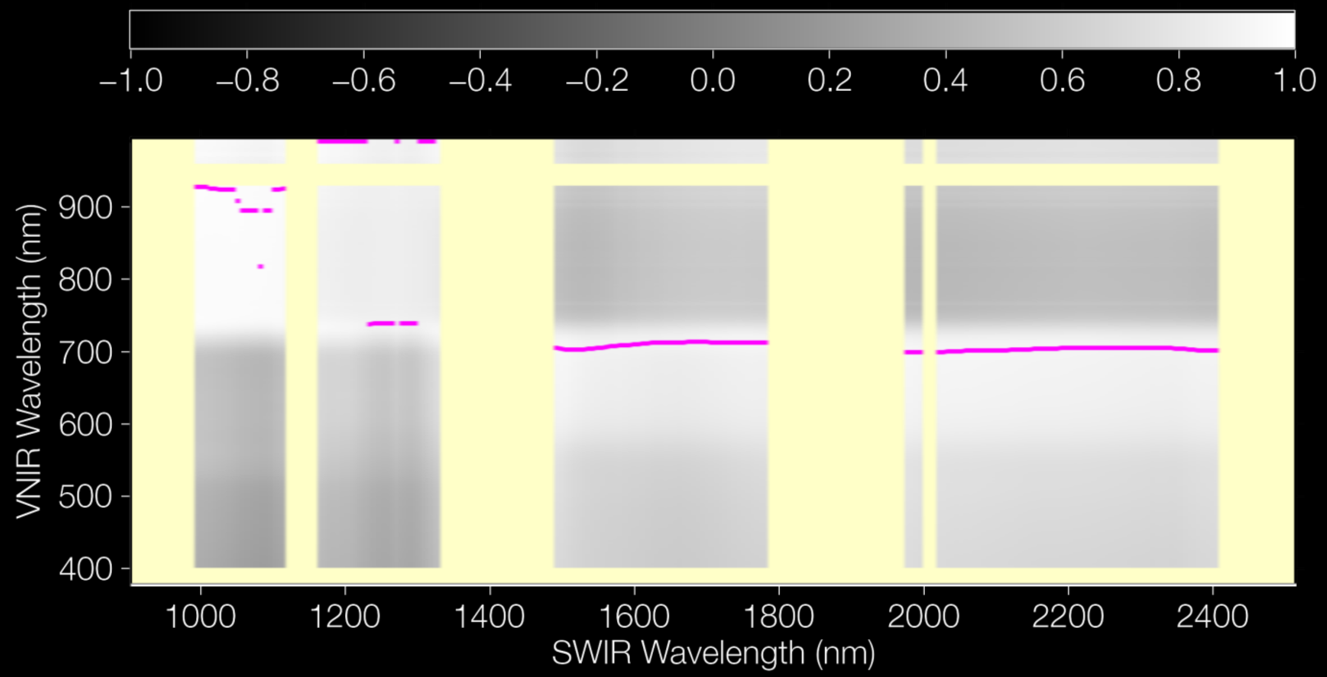
To numerically assess the fused images

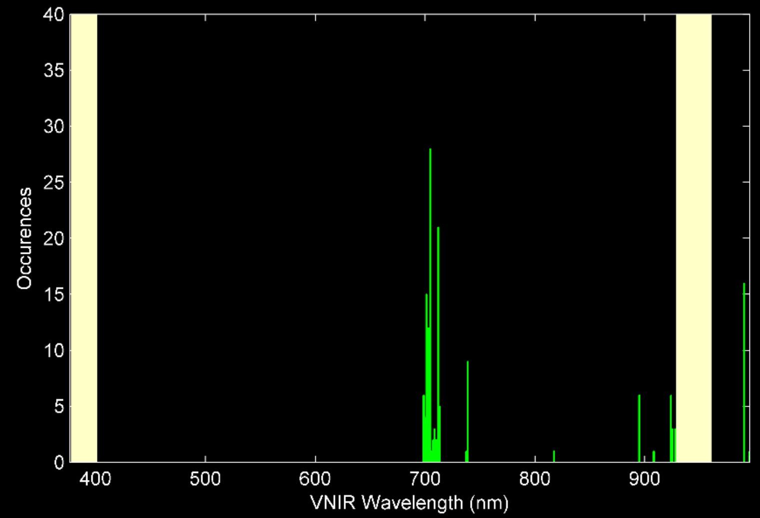
# Hypersharpening Selected Band: Which bands are chosen ?



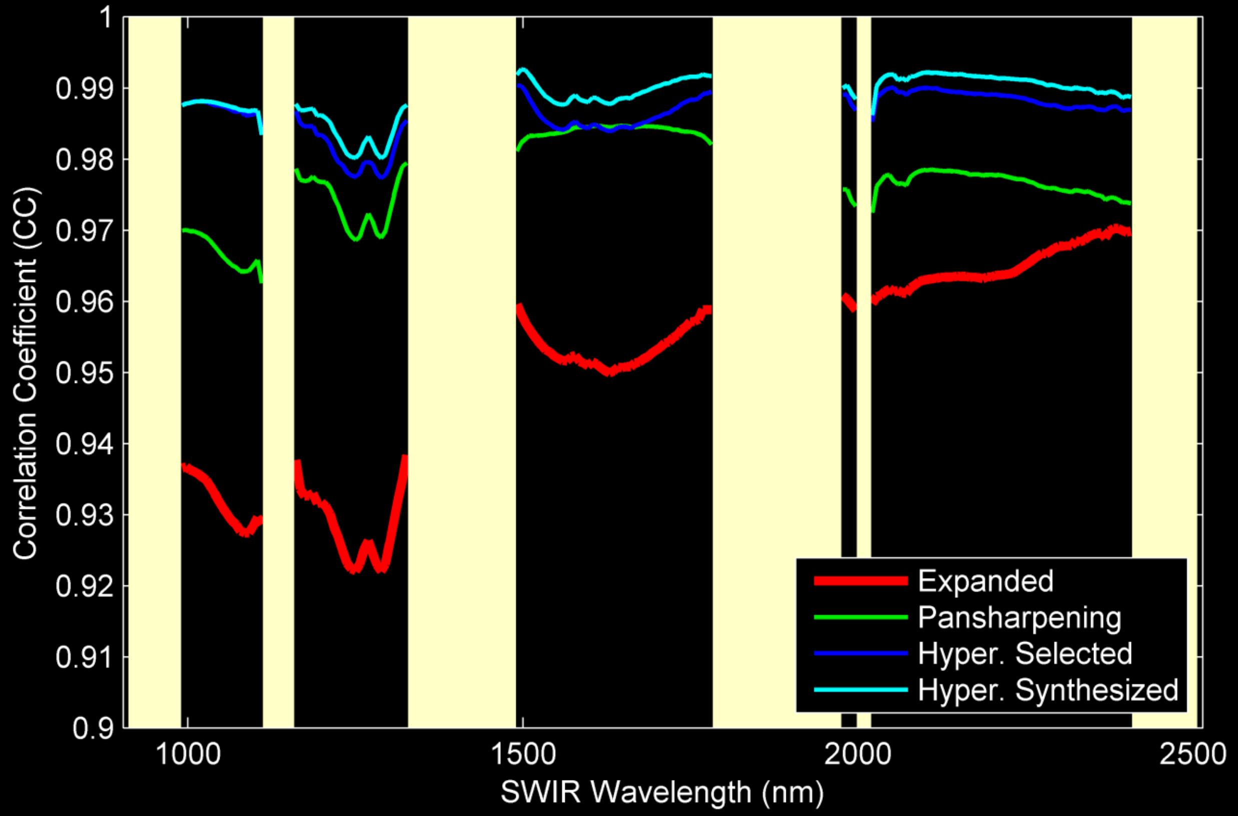



# Hypersharpening Selected Band: Which bands are chosen ?

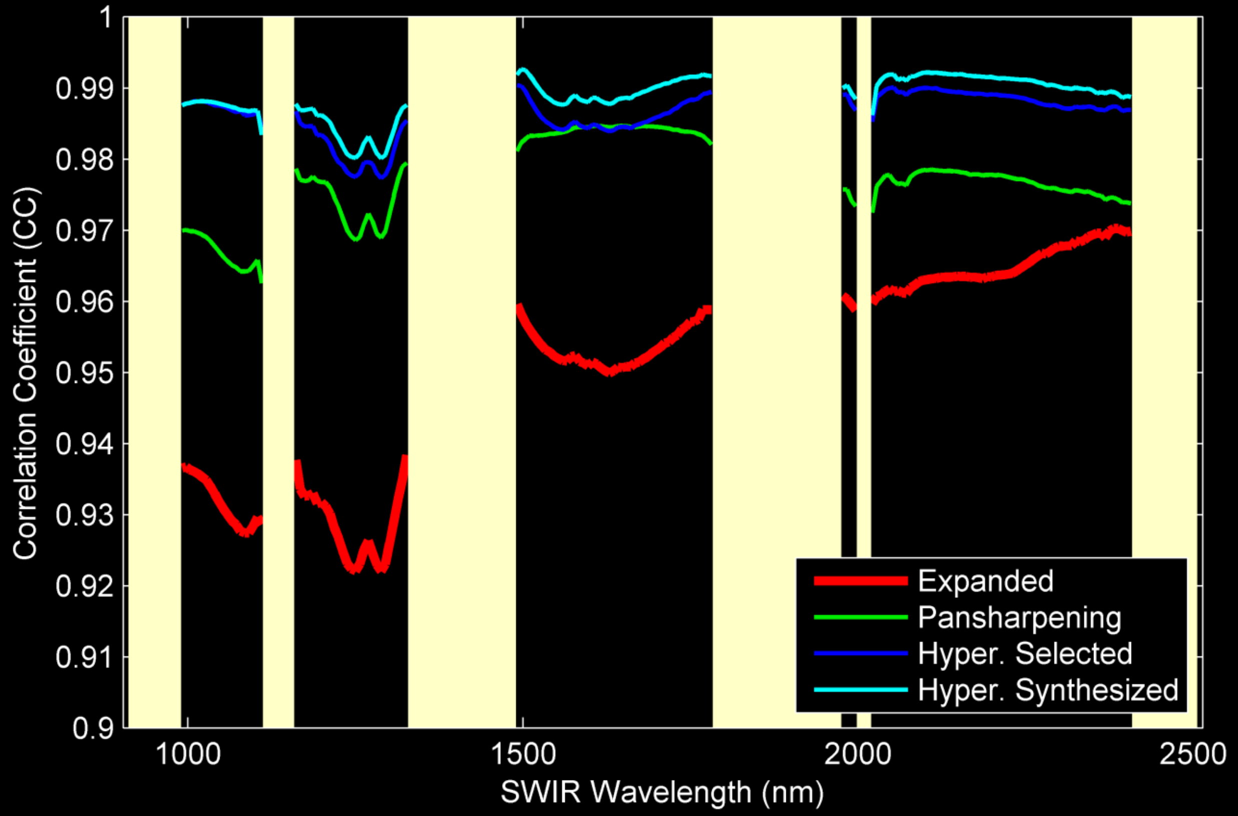



Only a small number of bands of VNIR hyperspectral are chosen



Correlation Coefficient (CC)
SWIR Wavelength (nm)
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
1000
1500
2000
2500
Expanded
Pansharpening
Hyper. Selected
Hyper. Synthesized




The assumptions done are consistent

| | Expanded Image | Pansharpening | Hypersharpening Selected Band | Hypersharpening Synthesized Band |
|---|---|---|---|---|
| SAM | 1.98 | 2.18 | 1.69 | 1.49 |
| ERGAS | 6.74 | 4.95 | 3.71 | 3.32 |

| | Expanded Image | Pansharpening | Hypersharpening Selected Band | Hypersharpening Synthesized Band |
|---|---|---|---|---|
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|---|---|---|---|---|
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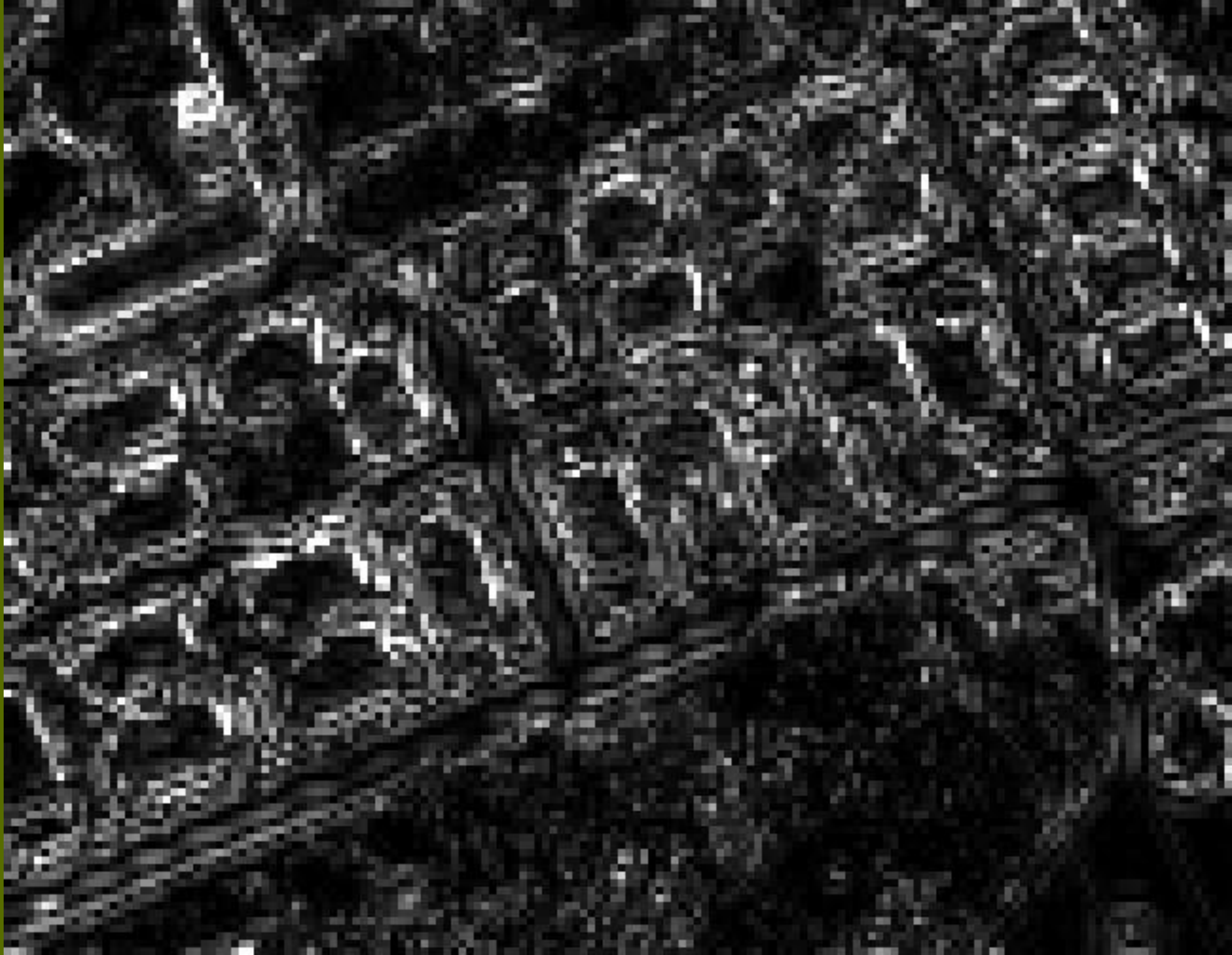
SAM MAP

Expanded Image



SAM MAP

Pansharpening

SAM MAP

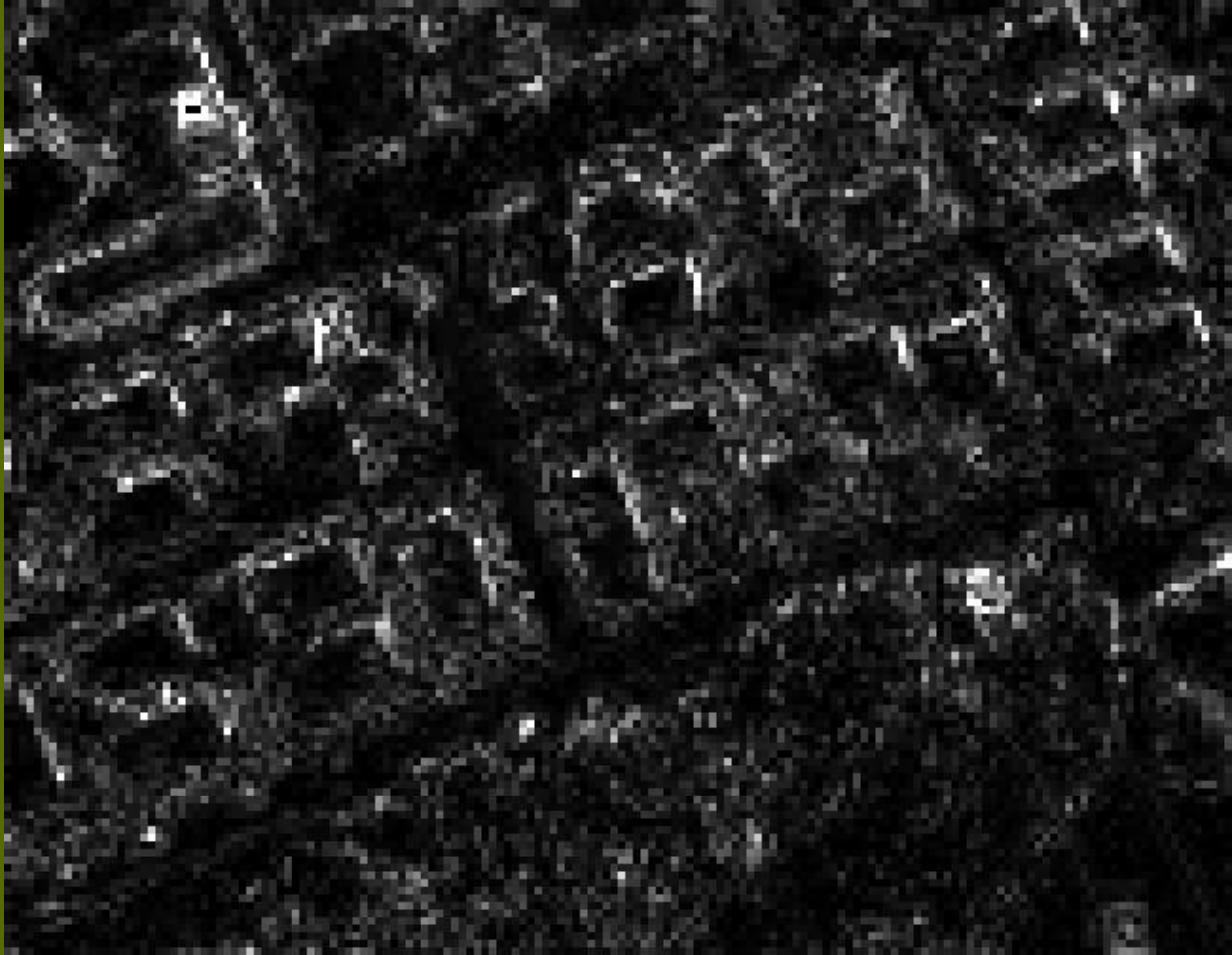
Hypersharpening

Selected Band

SAM MAP

Hypersharpening

Synthesized Band



# Experimentation at the full scale

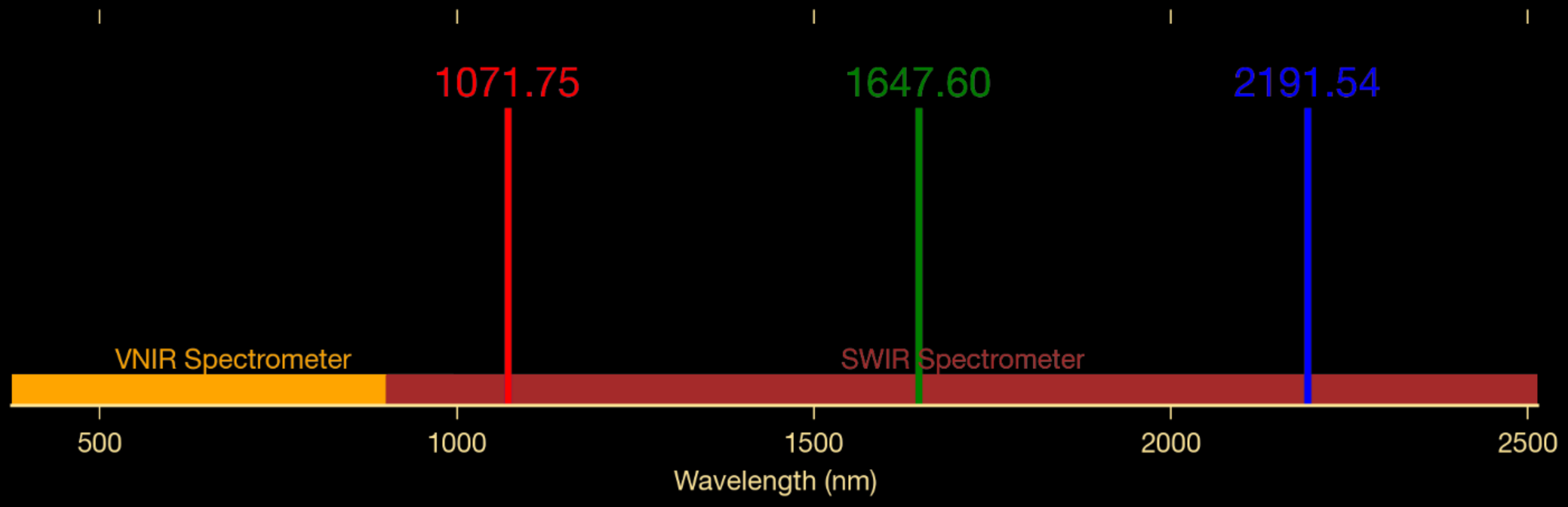
(from 1.5 m to 0.5 m)

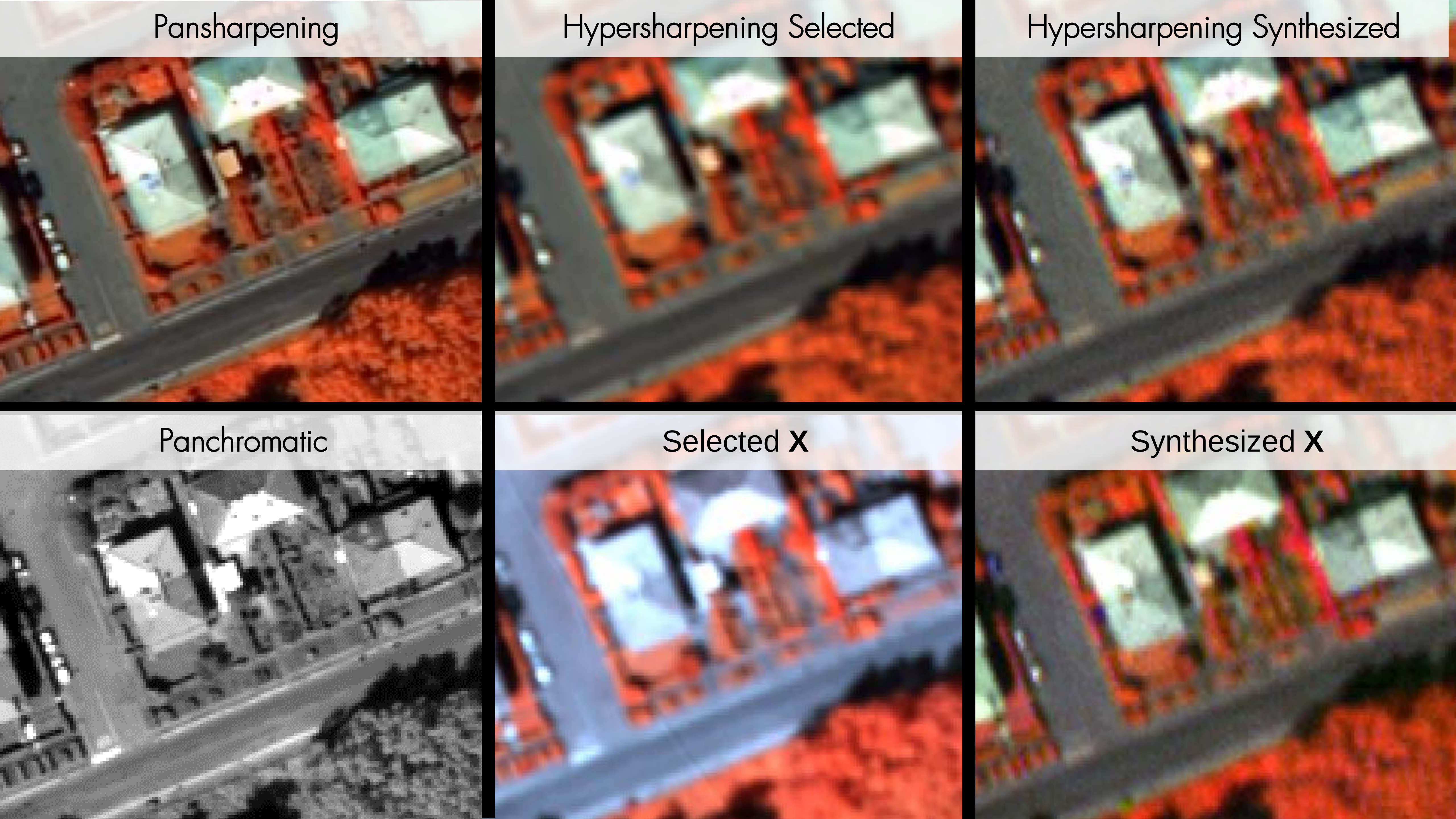
## Experimentation at the full scale

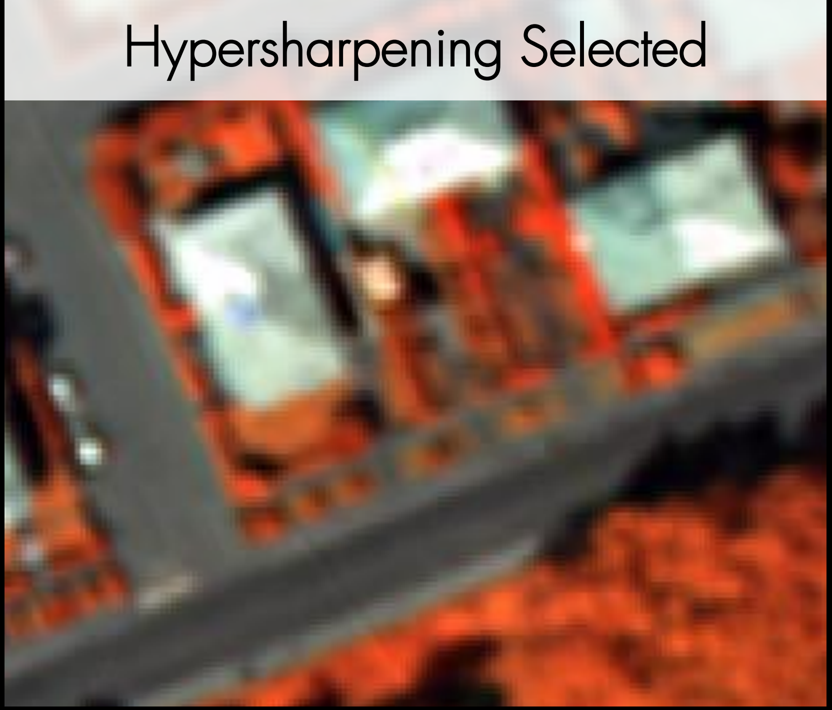
(from 1.5 m to 0.5 m)

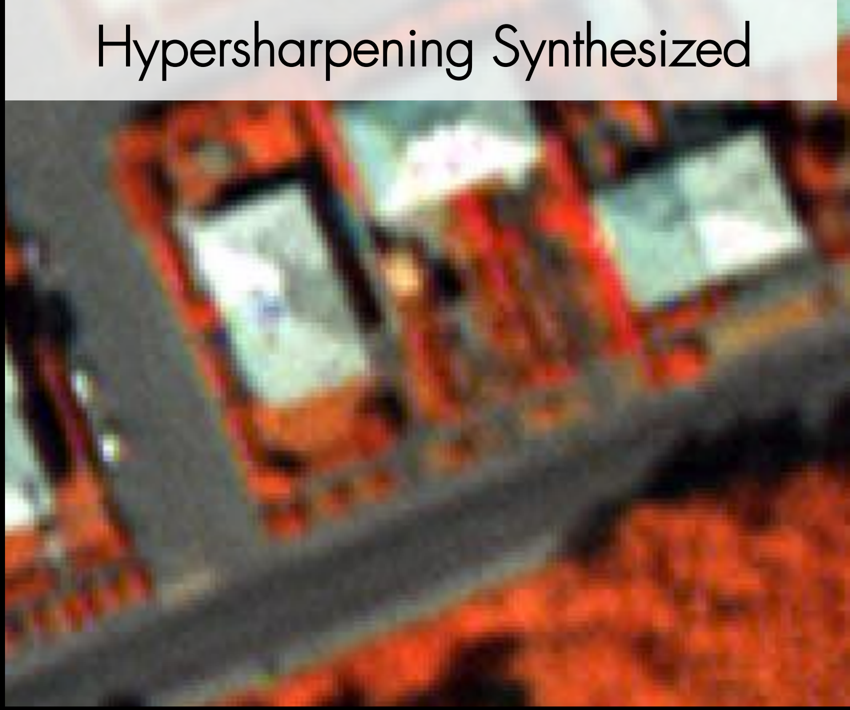
To visually assess the fused images

# RGB visualization

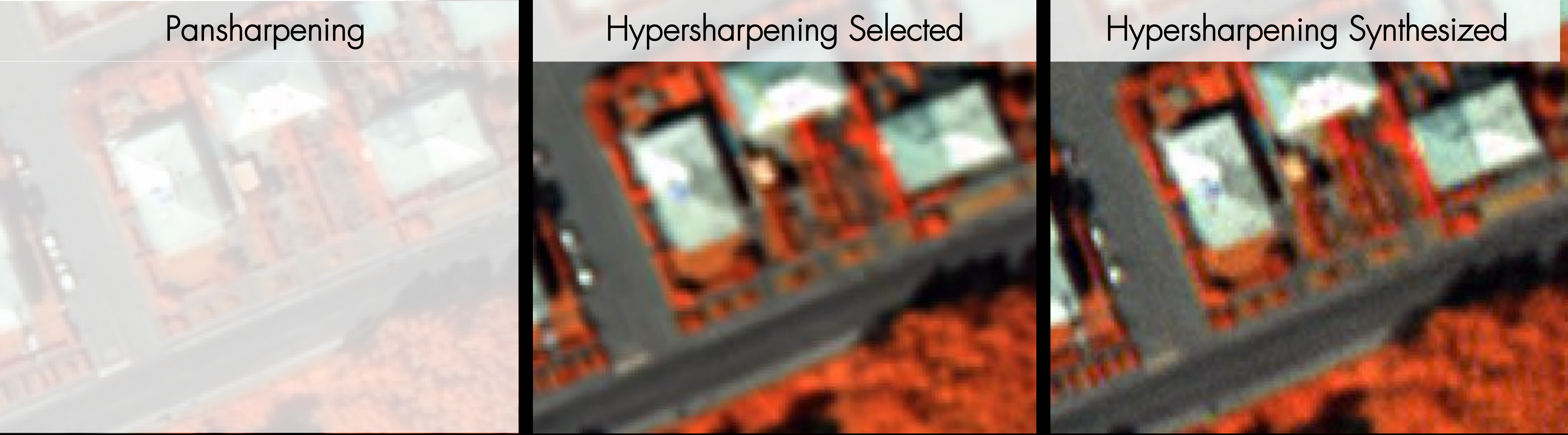



Pansharpening
Hypersharpening Selected
Hypersharpening Synthesized
Panchromatic
Selected **X**
Synthesized **X**






Pansharpening is more detailed due to MTF differences between VNIR and reduced Panchromatic.




Hypersharpening Synthesized Band is sharper even though is a little bit noisy

# CONCLUSIONS

1

The hypersharpening paradigm is rewarding. The synthesized variant provides the best results especially for the spectral quality.

2

The MTF characteristics of the different sensors are critical factors in the choice between hypersharpening and pansharpening.

3

Hypersharpening paradigm can be adopted to fuse data acquired by different hyperspectral instruments.

# Thank You