Giovanni Maria Capuano
Deep Learning-based Satellite Image Super-Resolution for Earth Observation

Tutor: Prof. Strollo   co-Tutor: Prof. Petra

Cycle: XXXVIII   Year: 2022/2023

My background

- MSc degree in **Electronic Engineering**

- Research group/laboratory: **VLSI Group**

- PhD start date: **01/11/2022**

- Scholarship type: **PNRR – DM 352**

- Partner company: **Techno System Development (TSD-Space)**

Research field of interest

- FPGA hardware acceleration for Deep Learning-based image processing on board spacecrafts

- Image processing for **Earth Observation** and Remote Sensing

- **Super-Resolution** for satellite imagery

Summary of study activities

- Ad hoc PhD courses:
  - Using Deep Learning Properly
  - How to Boost your PhD
  - Statistical Data Analysis for Science and Engineering Research
  - I Pilastri della Trasformazione Digitale
  - Scienza Moderna e Disciplina Giuridica dell'Intelligenza Artificiale

- MS courses:
  - Visione Per Sistemi Robotici (Prof. Cozzolino)
  - Embedded System (Prof. Cilardo)

- Seminars

- Conference:
  - International Astronautical Congress (IAC23), Baku (Azerbaijan)

Research activity: Overview

- **Problem:** Limit of the image spatial resolution using small satellite

When using small satellites such as nanosatellites for EO, the spatial resolution may not satisfy the desired requirements, due to the strict mass and volume constraints, that prevent the adoption of large focal length and apertures telescope
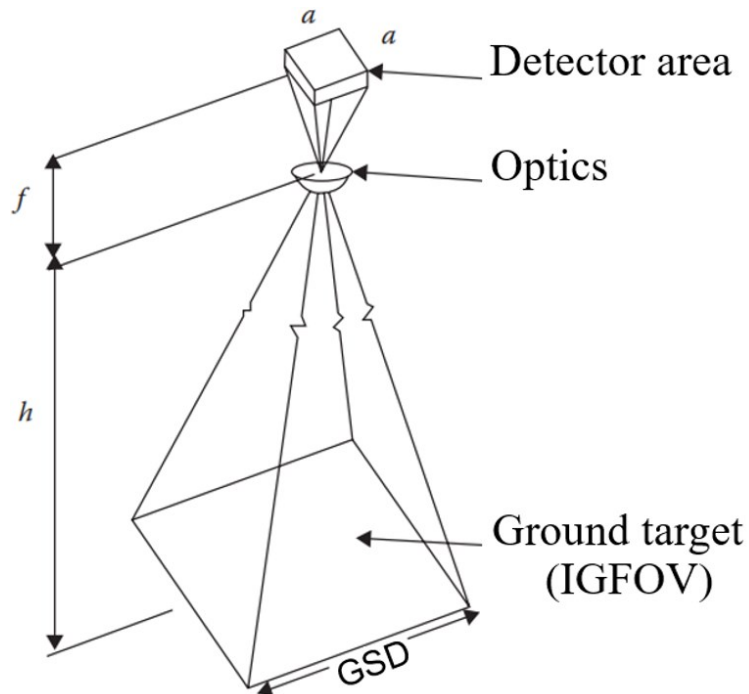

$$GSD = \frac{h \cdot pixel_{size}}{f} \quad [m];$$

Increasing Focal Length ➡ Bulky and heavier camera
(Larger aperture required to keep the optic fast enough)

Smaller Pixel Size ➡ Lower SNR
Mitigation action required (FMC and TDI)

Research activity: Overview

- **Objective:** Designing a novel Super-Resolution imaging method for the satellite image quality and spatial resolution enhancement.

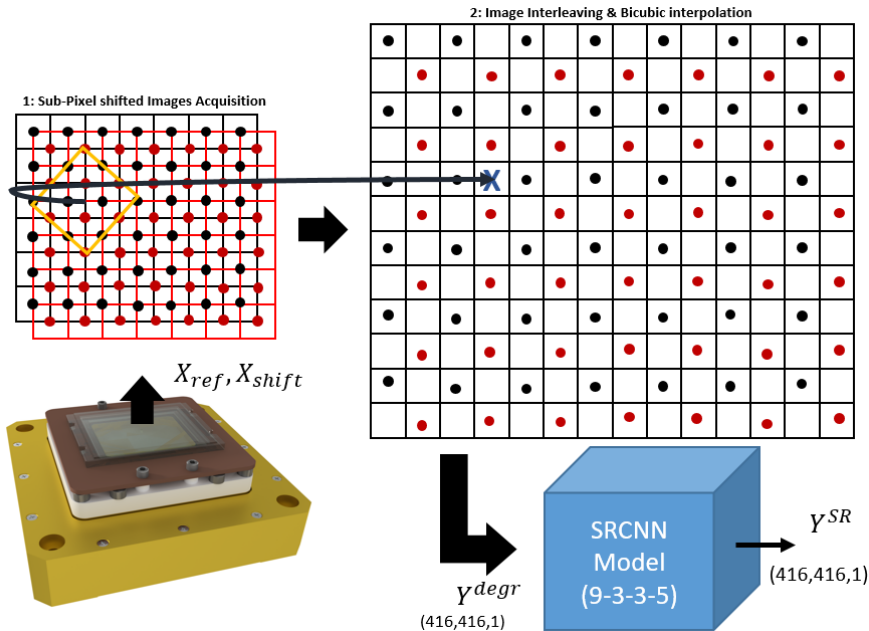- **Goal:** Recovering an HR image Y^{SR} from the LR image pair X_{ref} and X_{shift}
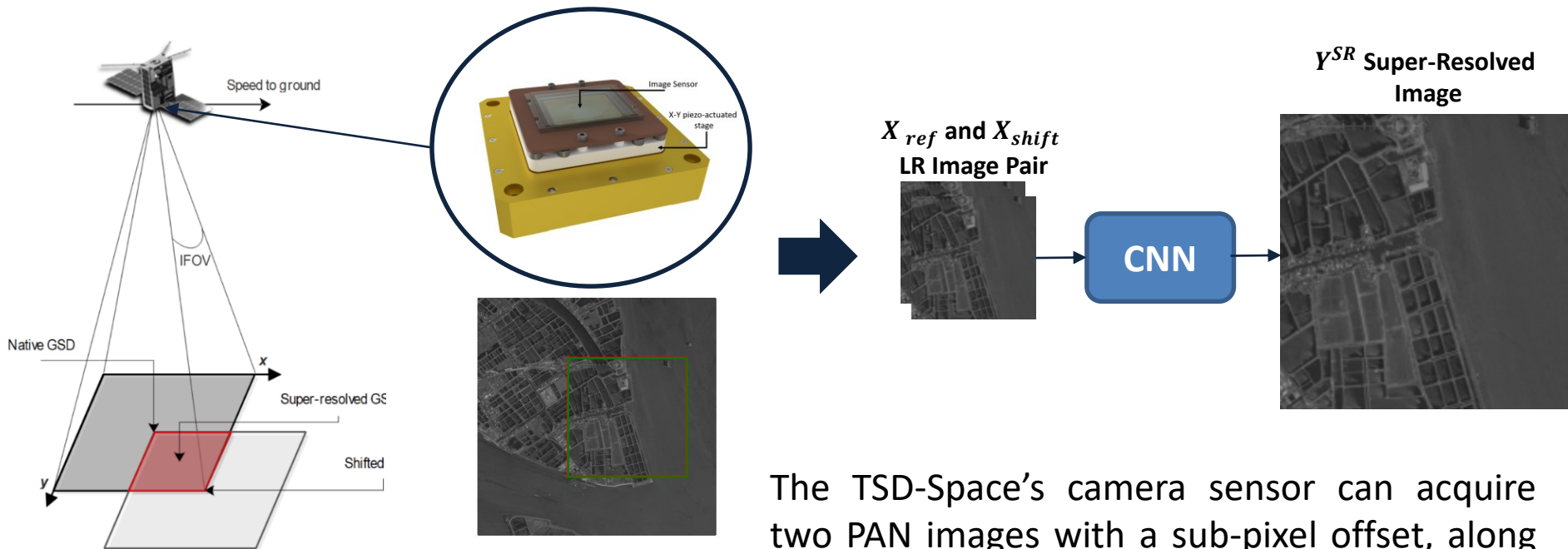
The TSD-Space's camera sensor can acquire two PAN images with a sub-pixel offset, along both row and column directions
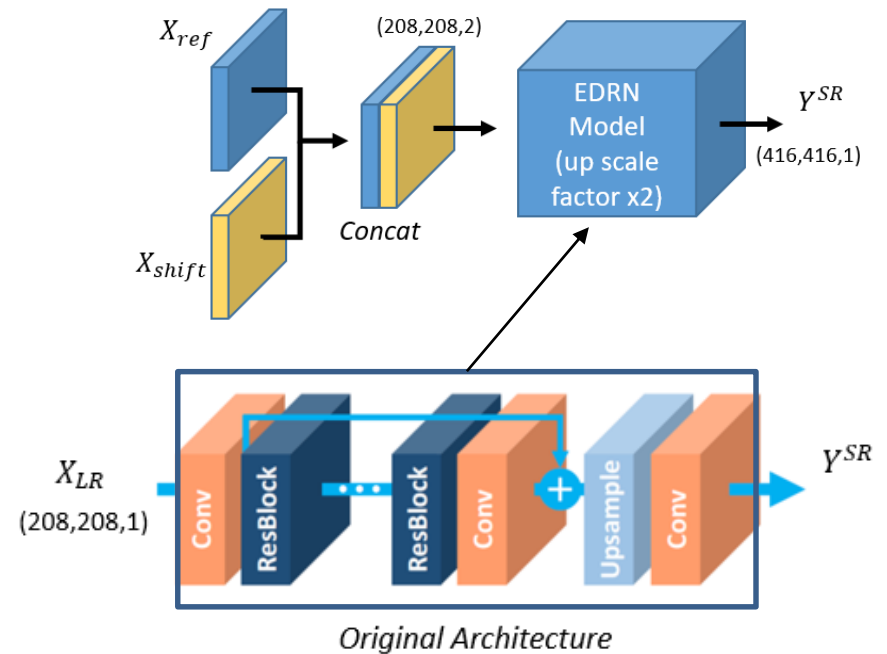
Research activity: Overview

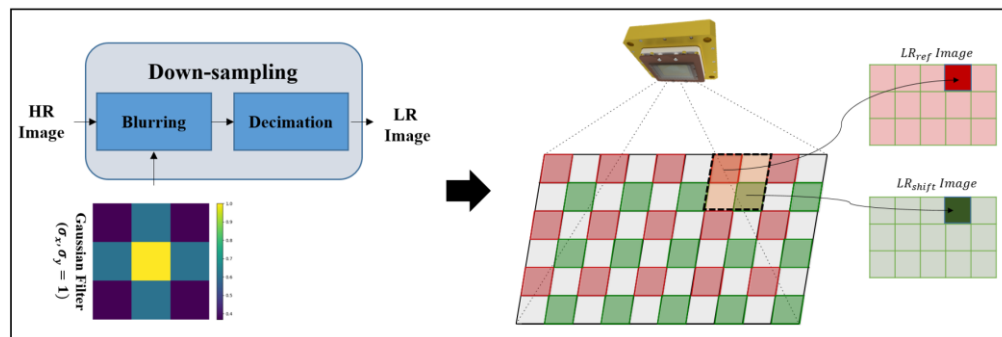- **Methodology - Networks:** Modifying the original architecture of commonly used NN models designed for the SISR
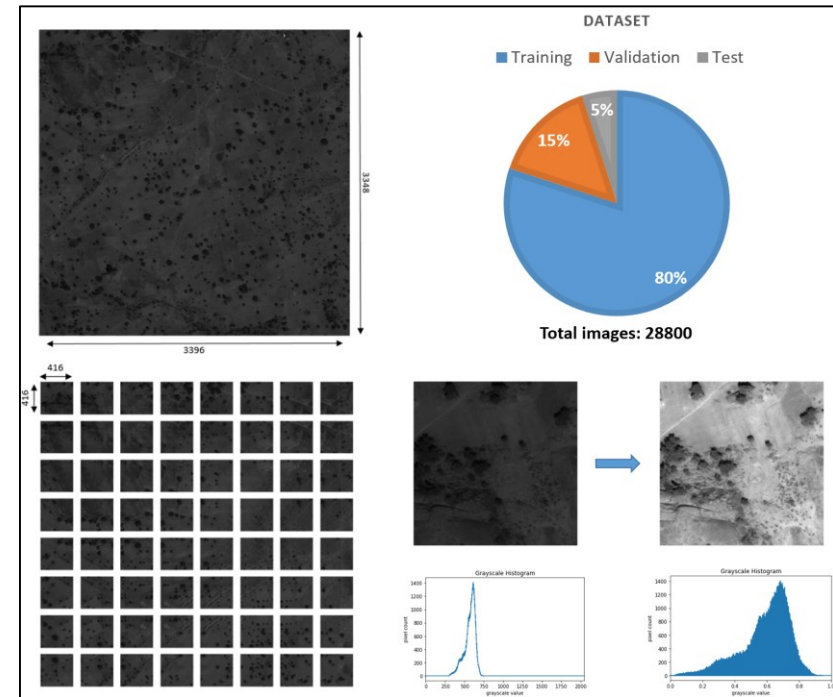
Research activity: Overview

- **Methodology – Dataset:** The UK *Defence Science and Technology Laboratory* (Dstl) offers an open satellite image dataset

Pair of Low-Resolution images

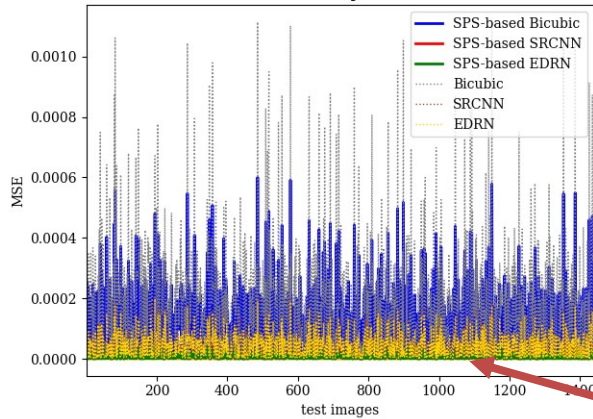- PAN products (GSD= 0.31 [m] at Nadir view) acquired by WordView-3 satellite

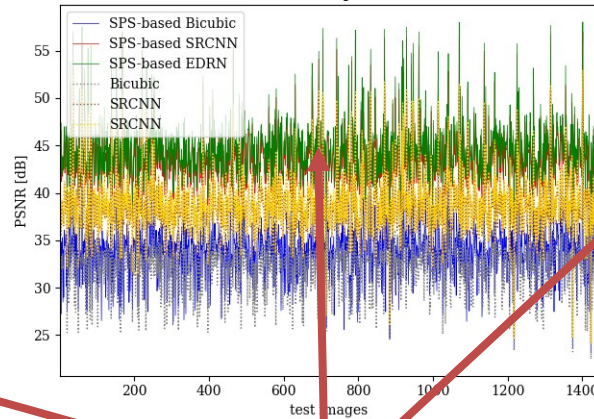**High Resolution ground truth**

Research activity: Overview

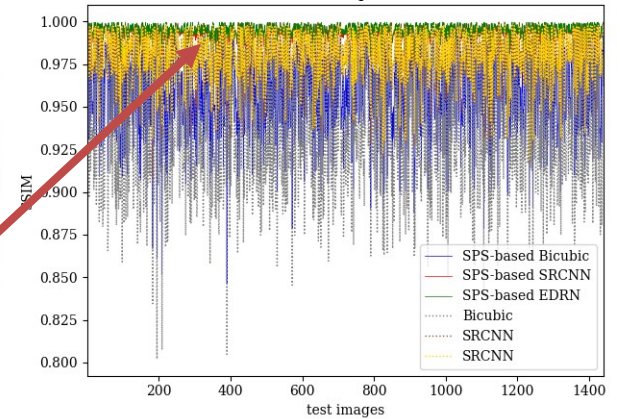- ## SR Quantitative Results

Dataset of test – WordView3 Satellite

The green and red lines represent the results achieved by our SR imaging methods. They demonstrate a significant enhancement in the quality of the reconstructed images.

Research activity: Overview

- **SR Qualitative Results**

Dataset of test – WordView 3

LR reference · Bicubic · SRCNN · EDRN · HR Ground Truth · Bicubic$_{SPS}$ · SRCNN$_{SPS}$ · EDRN$_{SPS}$
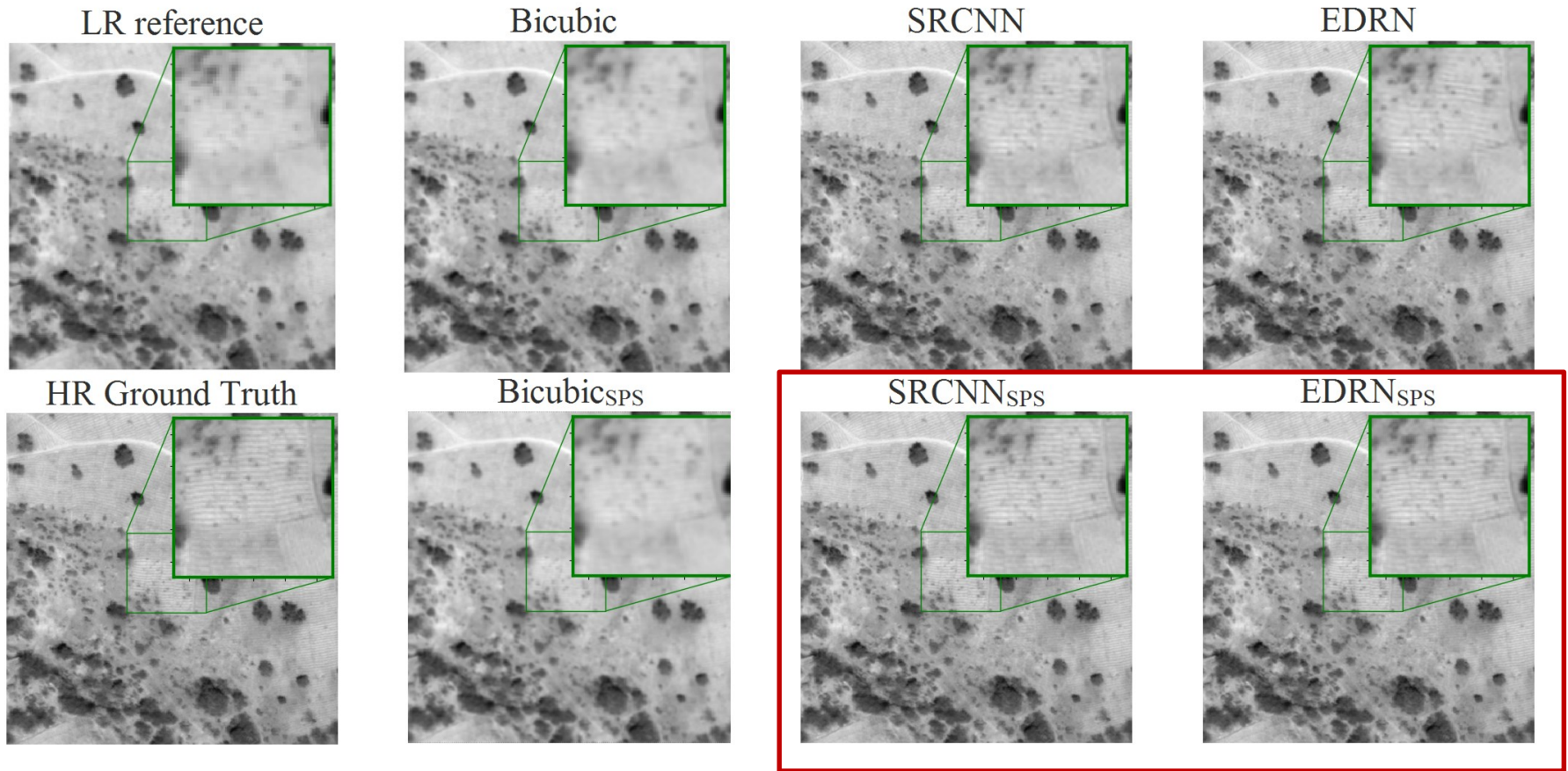
Our SR methods

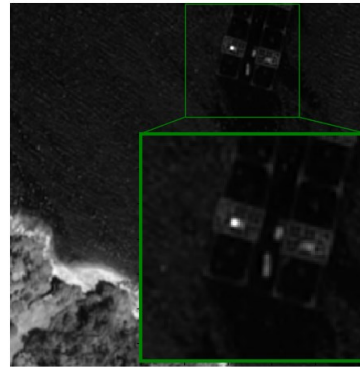# Research activity: Overview
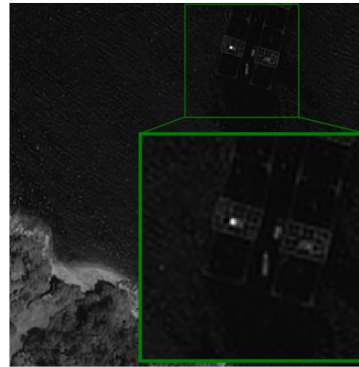
- **Methodology – Qualitative Results**
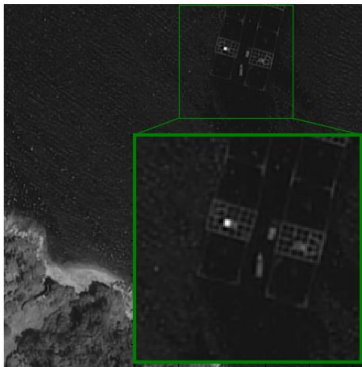
Dataset of test – DOTA

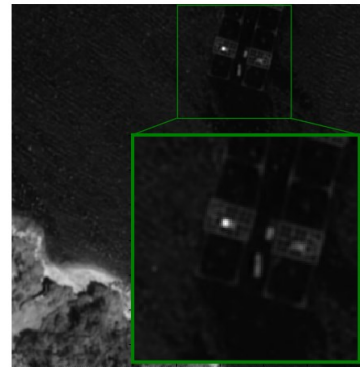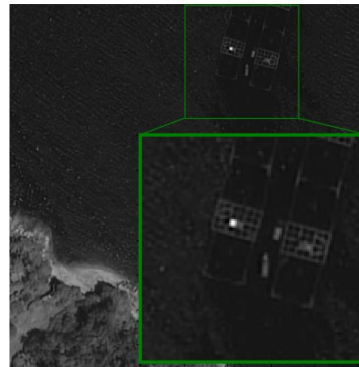LR reference   Bicubic   SRCNN   EDRN

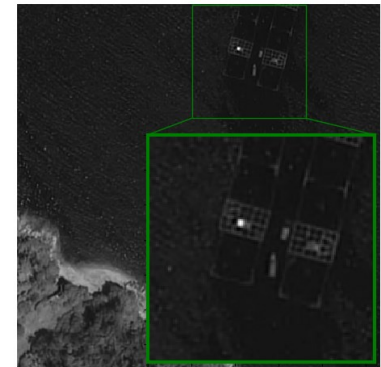HR Ground Truth   Bicubic$_{SPS}$ SRCNN$_{SPS}$ EDRN$_{SPS}$

Our SR methods

Research activity: Overview

- ## SR Qualitative Results

LR reference image

Our SR method (SPS-EDRN)

Research activity: Overview

- **SR Qualitative Results**

LR reference image

Our SR method (SPS-EDRN)

Products

[P1]	Paper Conference (IAC23) Giovanni Maria Capuano, Antonio Strollo, Nicola Petra; «*Super Resolution CNN for a Quincunx Sampling-based Panchromatic Earth Observation Imager for Nanosatellites*». International Astronautical Congress (IAC)

Next Year

- Developing a novel NN model for Super-resolution, specifically tailored for the piezo-actuated FPA (on going)

- Dataset augmentation - incorporating low resolution image pairs with different sub-pixel misalignment

- Super-Resolution as a pre-processing step: Enhancing the detection capabilities of AI-based detectors

- Optimizing Neural Network for FPGA Deployment

- FPGA acceleration for Deep Learning-based detection of targets of interest in satellite images for Early Warning applications

Thanks for your attention