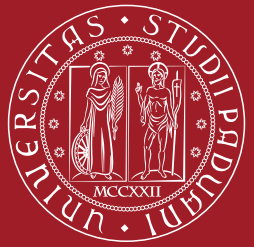

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Aerospace Technologies for Earth Monitoring and Observation

Federico Toson - 38th Cycle

Supervisor: Prof. Carlo Bettanini

Co-Supervisor: Dott. Giacomo Colombatti

2° year admission - 13/09/2023

International Framework and Objectives

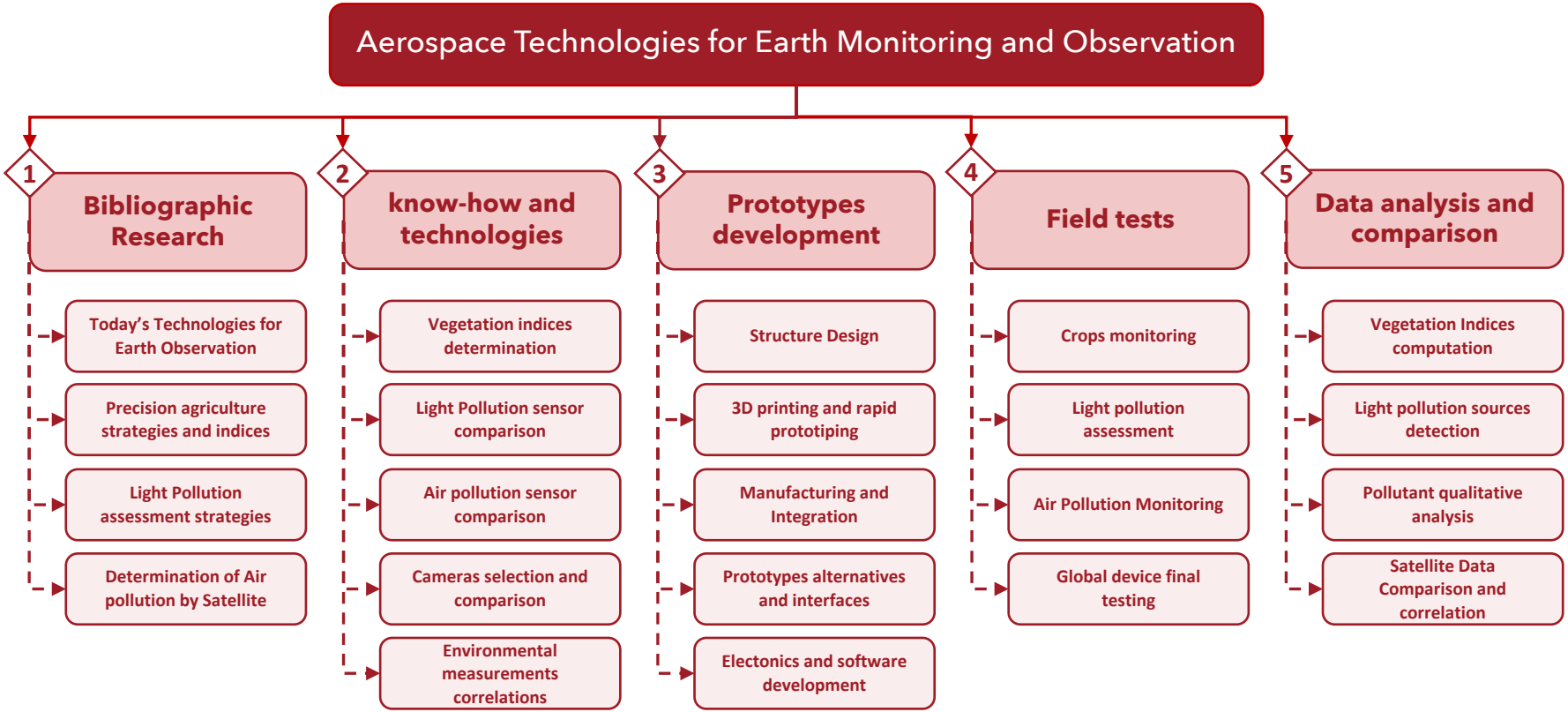
Motivation: Environmental safeguard by monitoring pollutants and ecosystem health

Objective: sensing platform for assess three analytes, namely vegetative indices, air pollution and light pollution.

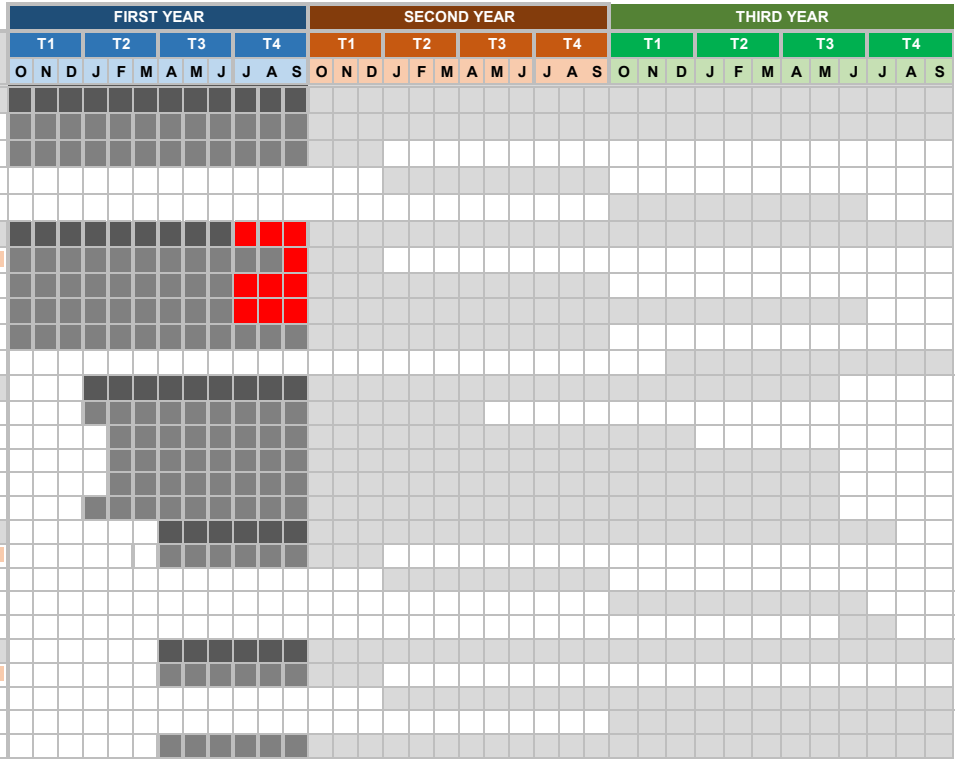
State of Art: Ground and satellite technologies for Earth monitoring

Integration on drones, tethered balloons and stratospheric balloons to increase spatial and temporal resolution and improve existing data

WBS Diagram

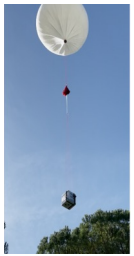

Aerospace Technologies for Earth Monitoring and Observation
1
Bibliographic Research
Today's Technologies for Earth Observation
Precision agriculture strategies and indices
Light Pollution assessment strategies
Determination of Air pollution by Satellite
2
know-how and technologies
Vegetation indices determination
Light Pollution sensor comparison
Air pollution sensor comparison
Cameras selection and comparison
Environmental measurements correlations
3
Prototypes development
Structure Design
3D printing and rapid prototiping
Manufacturing and Integration
Prototypes alternatives and interfaces
Electonics and software development
4
Field tests
Crops monitoring
Light pollution assessment
Air Pollution Monitoring
Global device final testing
5
Data analysis and comparison
Vegetation Indices computation
Light pollution sources detection
Pollutant qualitative analysis
Satellite Data Comparison and correlation

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE
1	Bibliographic Research	30%
1.1	Today's technologies for Earth Observation	30%
1.2	Precision agriculture strategies and indices	40%
1.3	Light Pollution assessment strategies	0%
1.4	Determination of Air pollution by Satellite	0%
2	Earth Observation measurements know-how and technologies	3%
2.1	Vegetation indices determination	75%
2.2	Light Pollution sensor comparison	45%
2.3	Air pollution sensor comparison	30%
2.4	Cameras selection and comparison	50%
2.5	Environmental measurements correlations	0%
3	Prototypes development	35%
3.1	Structure Design	50%
3.2	3D printing and rapid prototiping	30%
3.3	Manufacturing and Integration	27%
3.4	Prototypes alternatives and interfaces	27%
3.5	Electonics and software development	25%
4	Field tests	20%
4.1	Crops monitoring	75%
4.2	Light pollution assessment	0%
4.3	Air Pollution Monitoring	0%
4.4	Global device final testing	0%
5	Data analysis and comparison	20%
5.1	Vegetation Indices computation	75%
5.2	Light pollution sources detection	0%
5.3	Pollutant qualitative analysis	0%
5.4	Satellite Data Comparison and correlation	20%



Design and Development

Use of previous technologies for remote sensing studied by the research team (AREO, MINLU, OZONE)

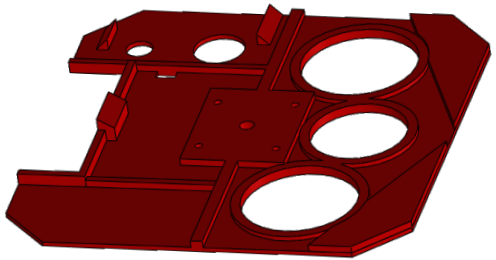


Improvement and versatility not only in analysis and monitoring but also in context (area, heights, hosting vehicles)

4 subsystems:

- Support structure
- Camera compartment
- Sensors and actuators
- On-Board PCU and electronics

TM subsystem



- Alluminium frame
- 3D printed plates and supports
- Weight: 2.5 kg (max)
- Base: 17 cm x 17 cm
- Height: 25 cm
- Fast assembly
- Variable setup

Acquisition

- Basler ace 2 (IMX546 8MP CMOS by Sony)
  - monochromatic camera
  - colour camera
- FLIR Vue Pro R
- Apeman "Space cam"
- Two main optical solutions

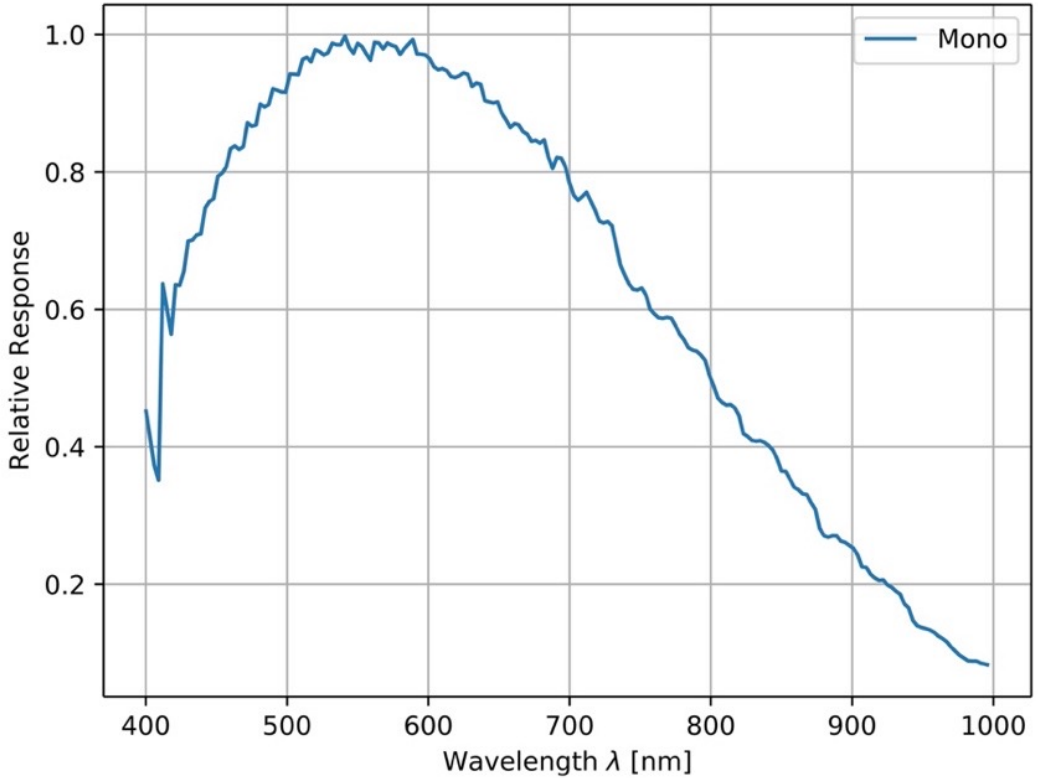
	Focal Length	Angle of View	FOV @ 50 m height
Kowa LM35HC	35 mm	13°	12 x12 m
Tuss LYM0814	8 mm	70°	100 x 100 m

- SQM-L (Sky quality meter)
- Air composition sensors
- GPS system

Three possible solutions:

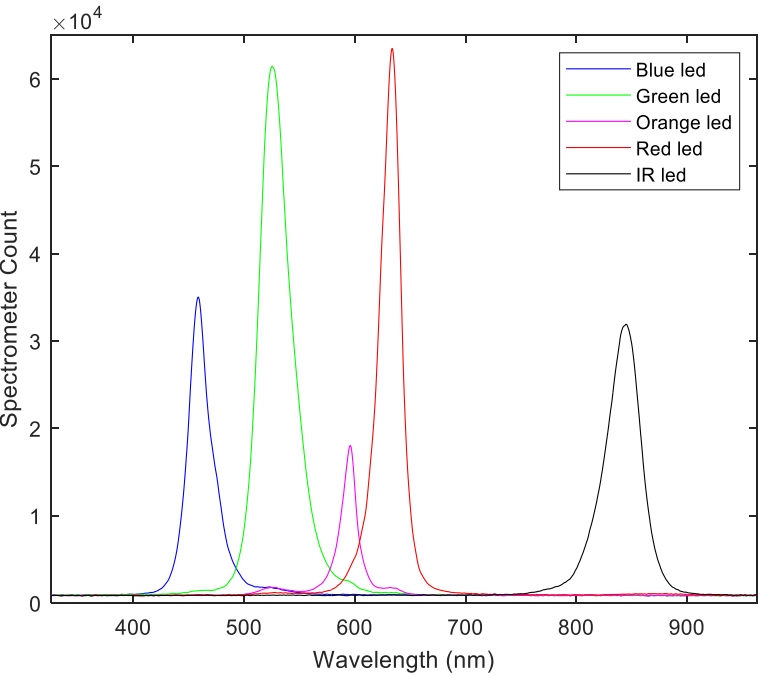
- **Drones:**
  - High resolution
  - Short time measurements
  - Easy access
- **Stratoshperic Balloons**
  - Large area of analysis
  - Low control
  - Long time measurements
- **Tethered Ballooons**
  - Long time measurements
  - Medium-high control
  - High resolution

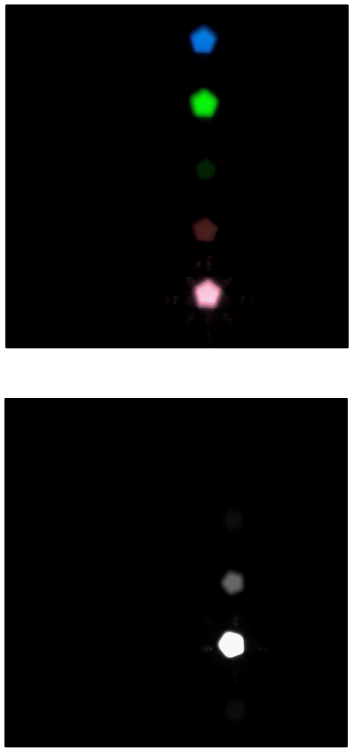
Calibration (1)

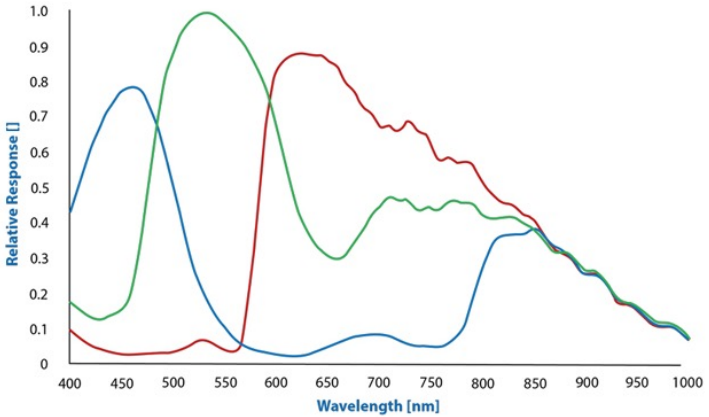


- Both cameras are equipped with IMX546 (Spectral response on the left)
- In the case of the colour camera, the IR filter has been removed
- This makes full use of the sensor's response curve
- Different filtering depending on measured parameters
- Camera calibration required

Calibration (2)







On the left RGB Spectral response without IR filter

- Camera characterisation using known sources, knowledge of optical system transmission and Black Comet C-SR-14 spectrometer

Vegetative indexes computation

- Planetscope data (constellation of 130+ CubeSat in sun-synchronous orbits which permits a revisit time of 24h on the field, at 9 am LT)

- The satellites' operative bands (res. 3 m):
  - Coastal Blue (431 - 452 nm)
  - Blue (465 – 515 nm)
  - Green I (513 - 549 nm)
  - Green (547 – 583 nm)
  - Yellow (600 - 620 nm)
  - Red (650 – 680 nm)
  - Red-Edge (RE) (697 – 713 nm)
  - Near-Infrared (NIR) (845 – 885 nm)

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$GNDVI = \frac{NIR - Green}{NIR + Green}$$

$$NDRE = \frac{NIR - RE}{NIR + RE}$$

$$ENDVI = \frac{(NIR + Green) - 2Blue}{(NIR + Green) + 2Blue}$$

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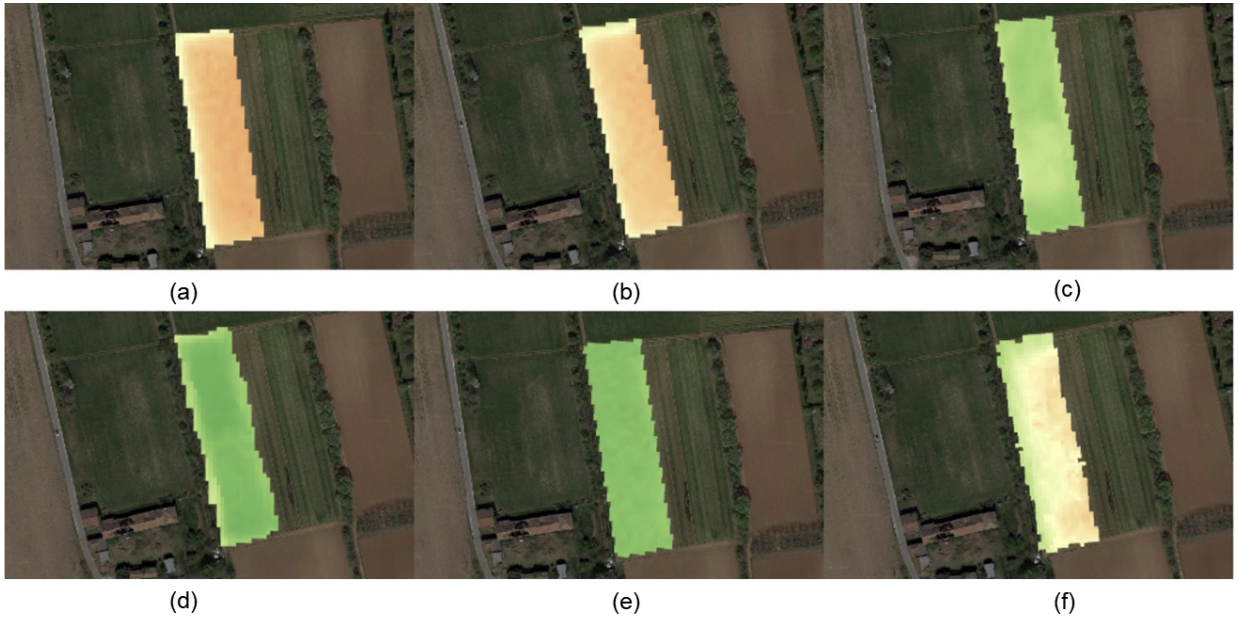
Satellite Example



NDVI index calculated from Planetscope images in the study area: (a) 20 May 2022;

(b) 15 June 2022;

(c) 16 July 2022;

(d) 14 August 2022;

(e) 15 September 2022;

(f) 11 October 2022.

- Sowing: 15 June 2022
- Harvest: 6 october 2022

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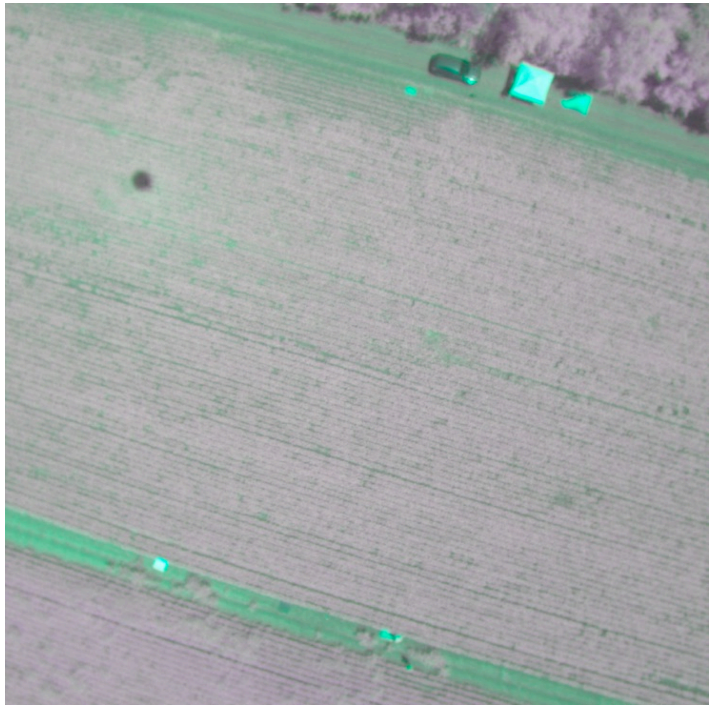
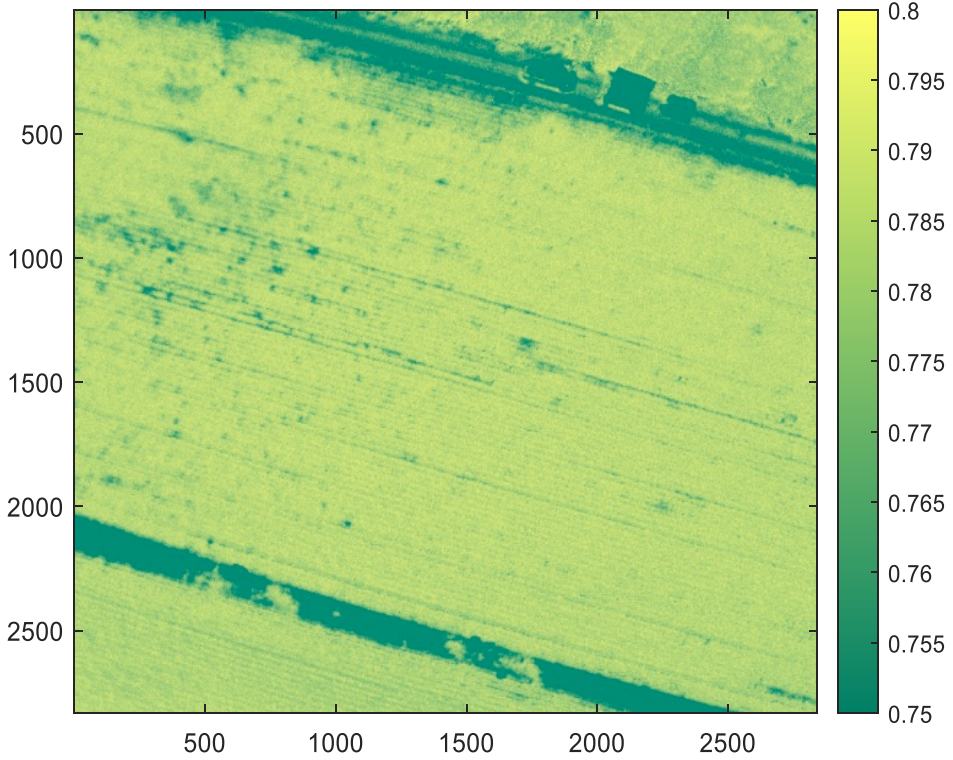
Tethered Balloon Example (Castelfranco)



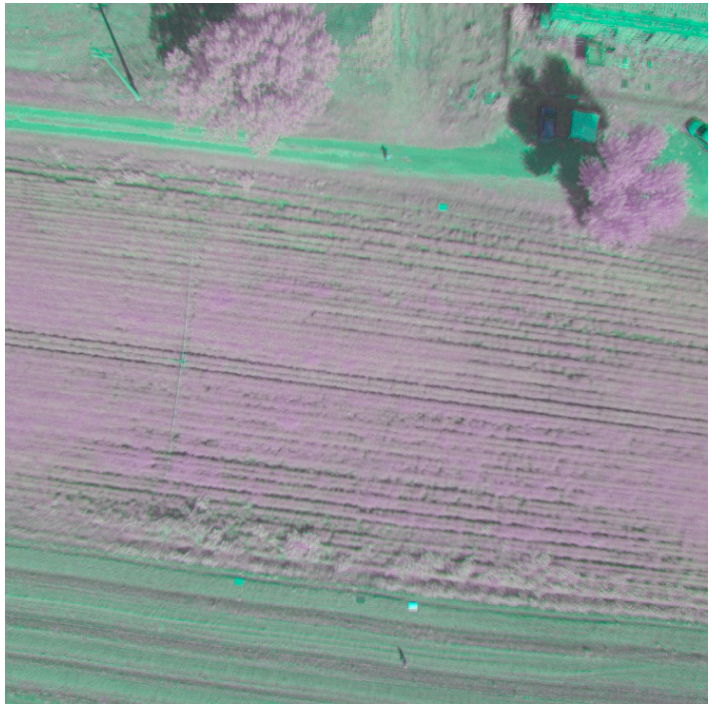
RAW image in RGB TB filter (475, 550, 850 nm)

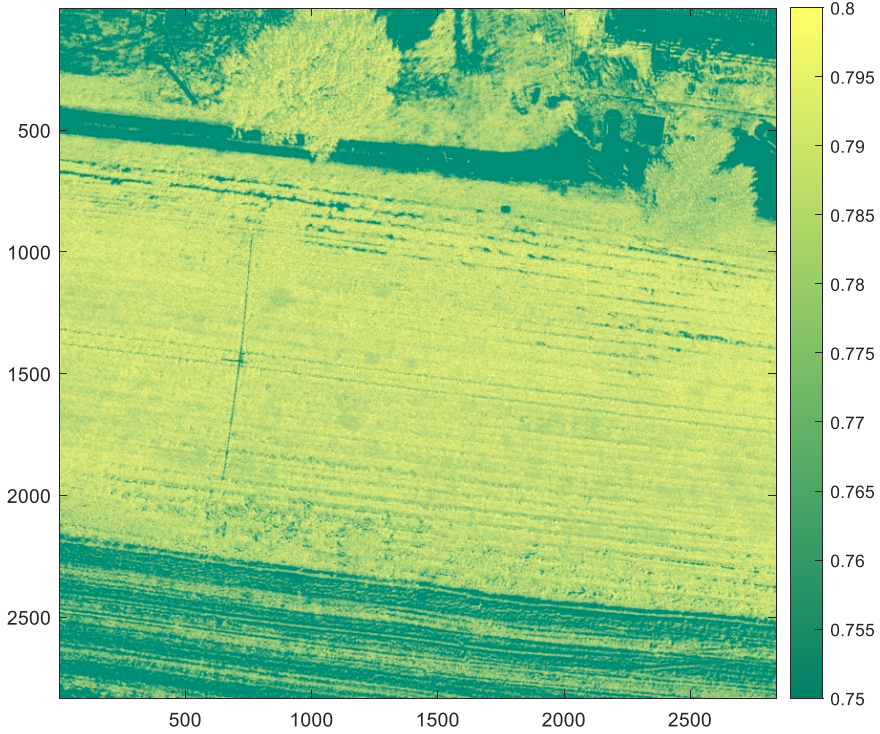


GNDVI computation

Slides credits to Carlo Bettanini

Tethered Balloon Example (Cortona)



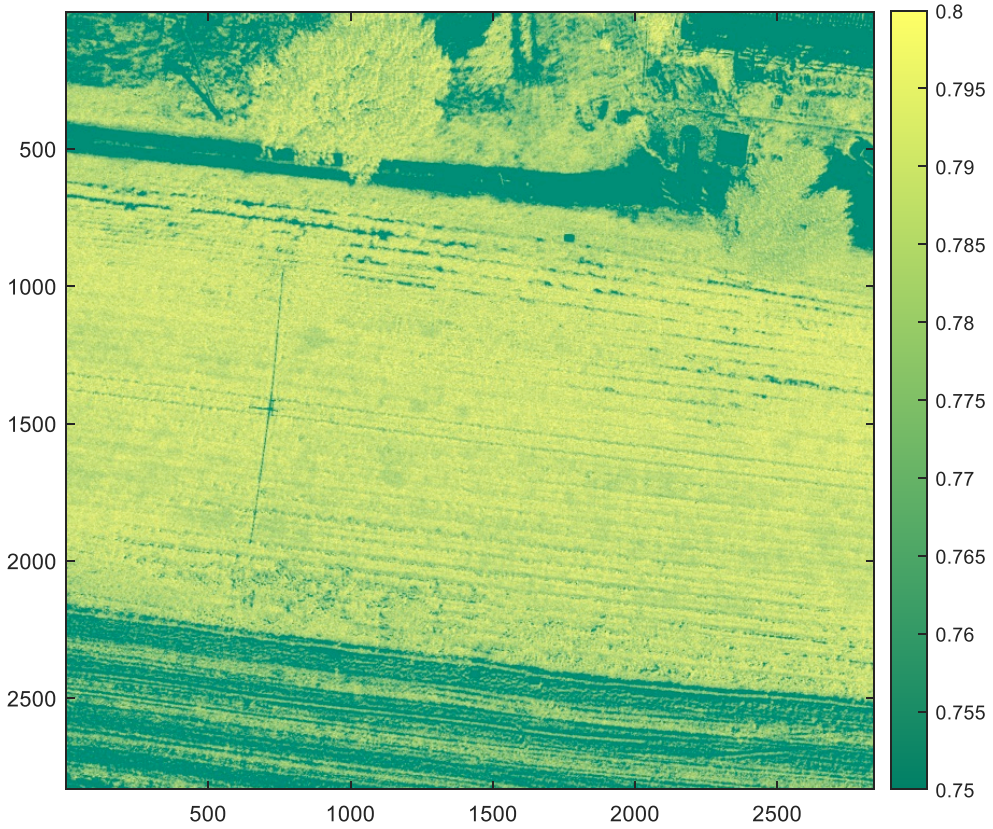


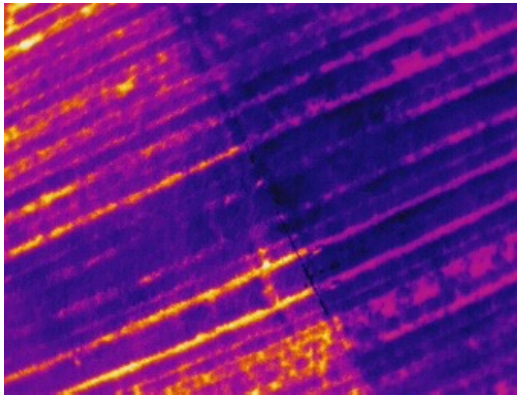
RAW image in RGB TB filter (475, 550, 850 nm)

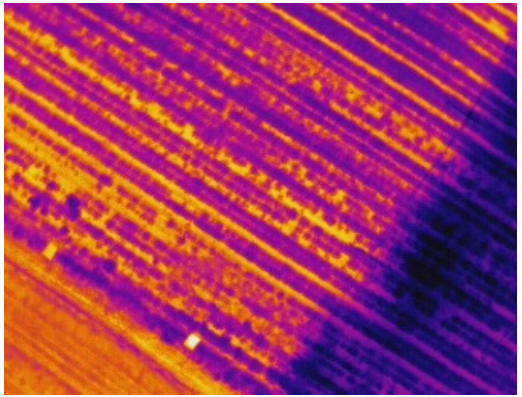
Slides credits to Carlo Bettanini

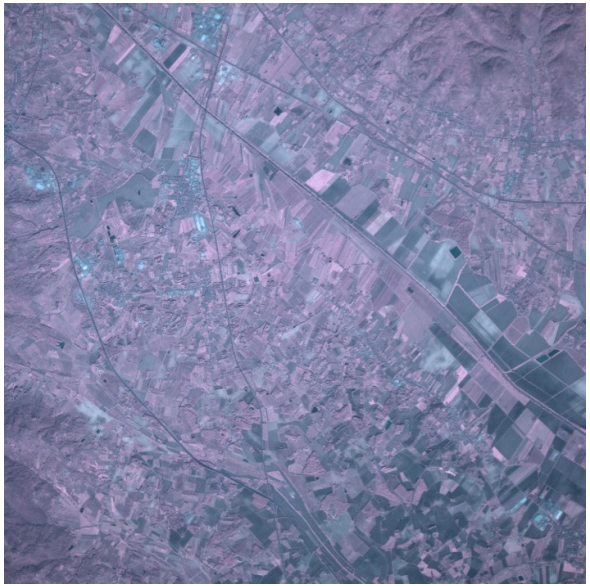
GNDVI computation

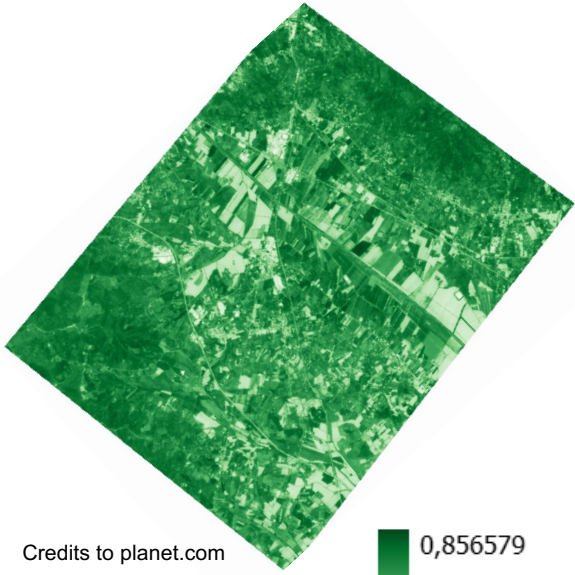
Termocamera comparison



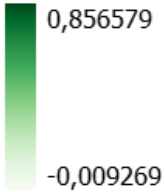




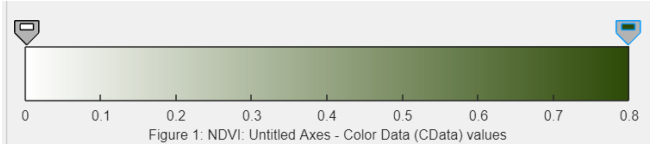




Credits to planet.com



$$GNDVI = \frac{NIR - Green}{NIR + Green}$$



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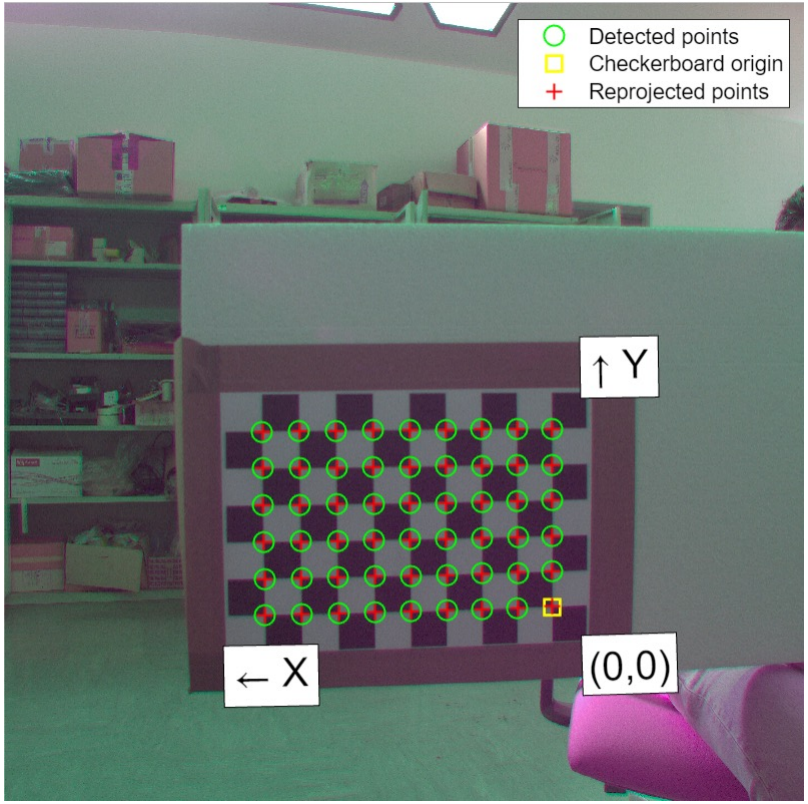
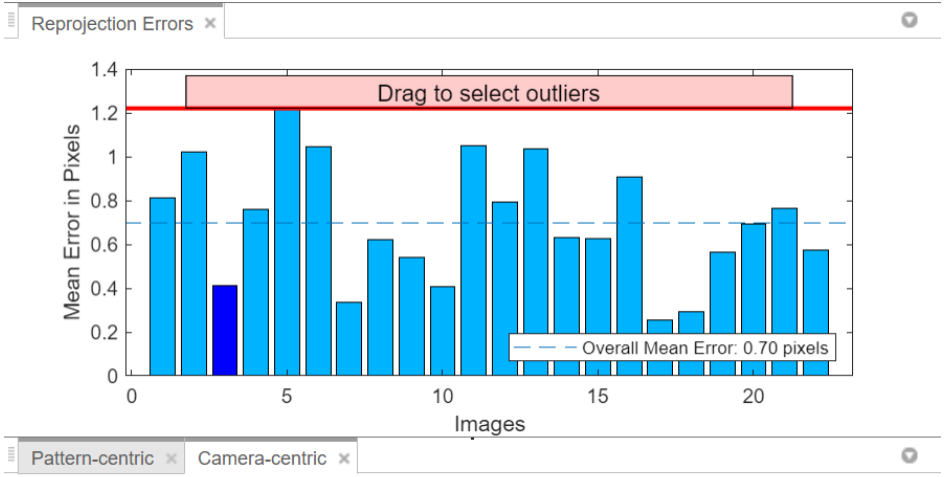
Other possible uses (1)





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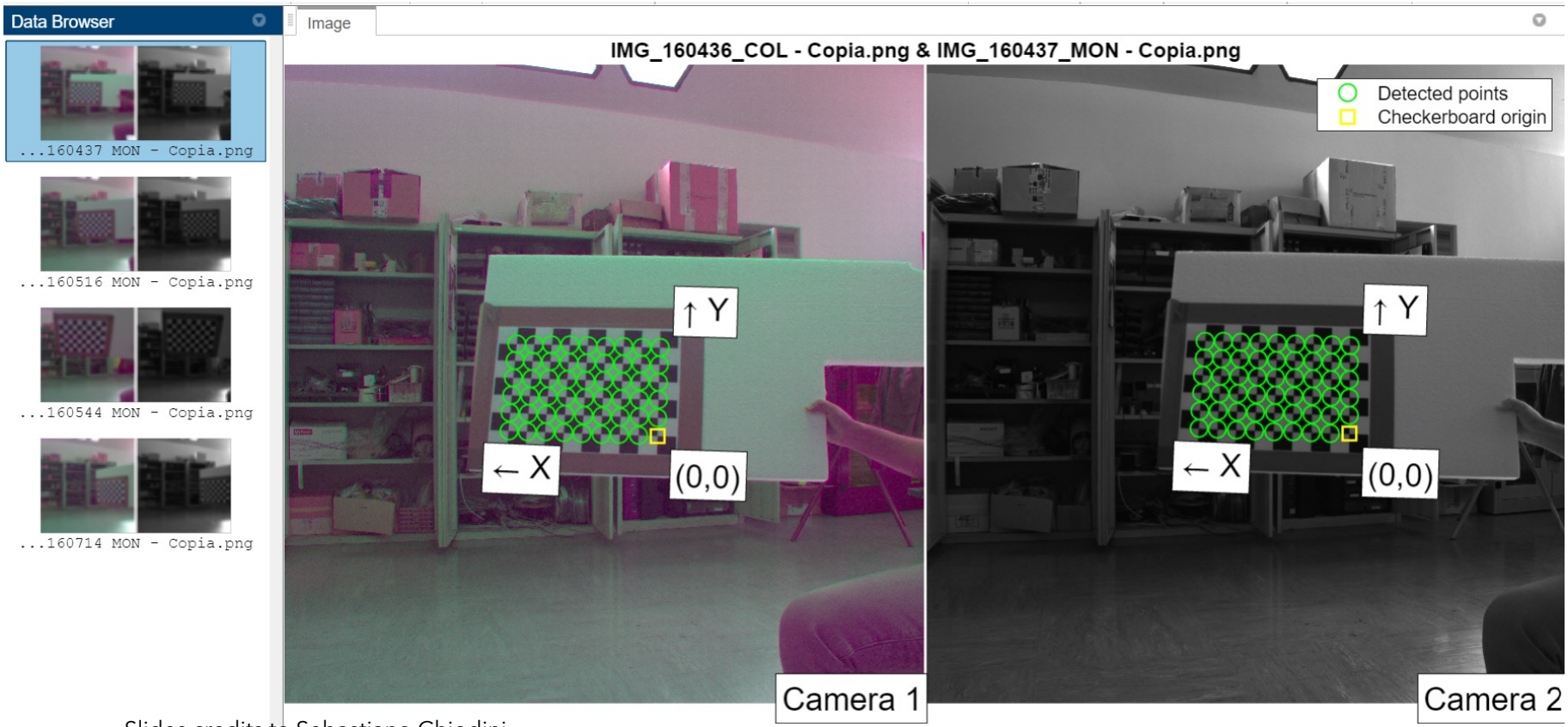
Other possible uses (2)



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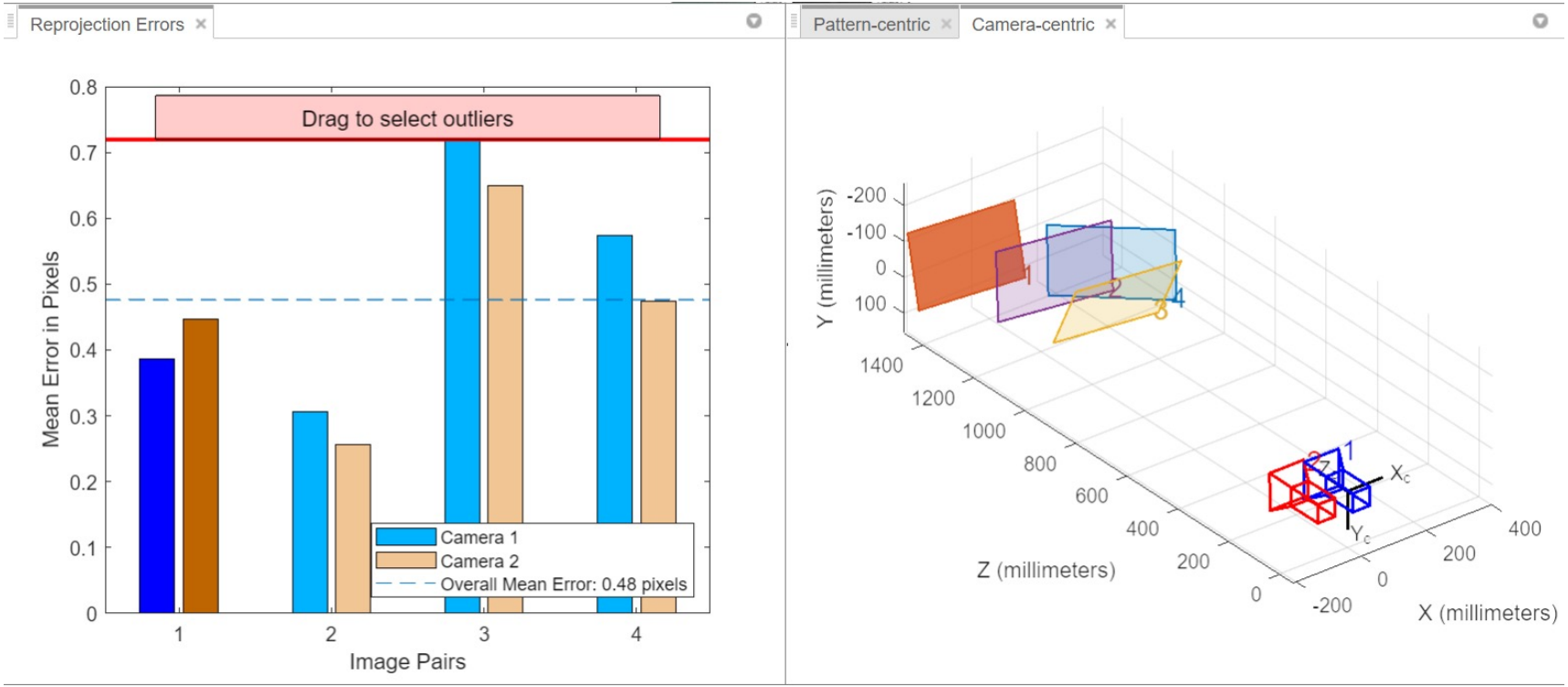
Other possible uses (3)



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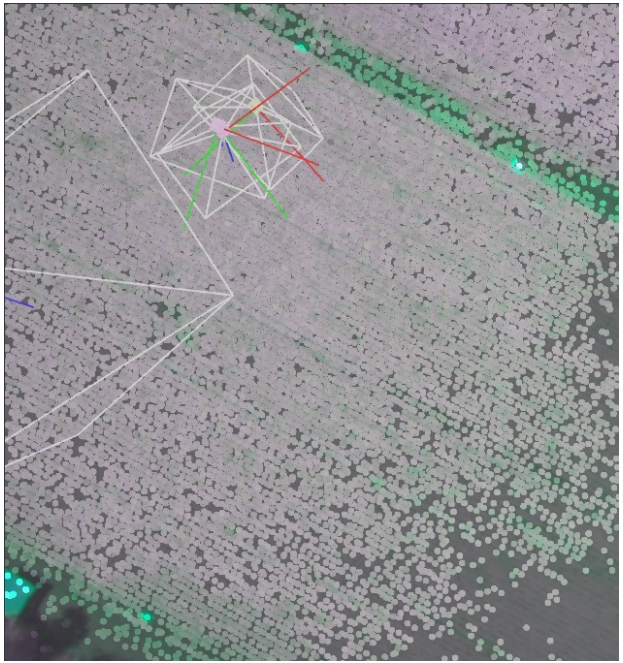
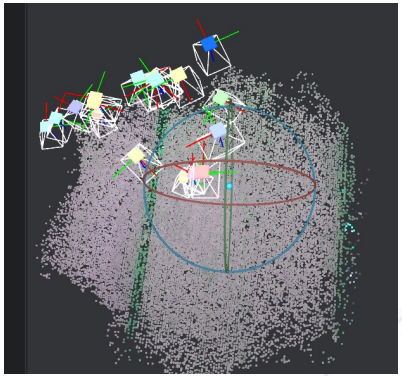
Other possible uses (4)





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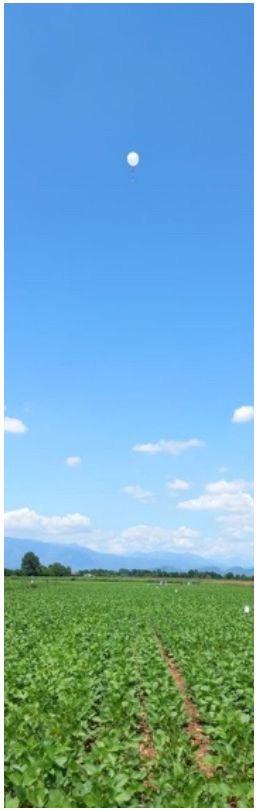
Conclusions



- All-in-one sensing platform to determine
  - Vegetation health
  - Air pollution
  - Light pollution
- currently meets the functional requirements
- Extensive tests needed
- Future applications and collaborations
- Lot of fields of application

External Collaborations

- **DAFNAE & TESAF**: Crops monitoring and study
- **University of Pisa:** Stratospheric balloon launches
- **University of Chile**: Light Pollution research
- **Officina Stellare**:
  - *Earth Observation*
  - *Astronomy*
  - *Satellite data*
- ***Others**: TBD*

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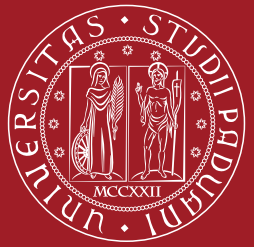

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Thank you for your attention

Federico Toson - 38th Cycle

Supervisor: Prof. Carlo Bettanini

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Research work presentation - 13/09/2023