Nano Innovation 2020 Rome, 15-18 September
Conference & Exhibition

School on Nanotechnologies

# UV Sensor Technology Integrated on Unmanned Aerial Vehicle for Air Pollution Monitoring

It-fab Italian Network for Micro and Nano Fabrication


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# Outline



Why Unmanned Aerial Vehicle (UAV)?

UAV for Air Pollution Monitoring

UV Sensing Technology to be Integrated on UAV

# What do we do in AeroDron?



AeroDron was born in Parma in 2013, it is a company with less than 10 employees, we provide drone-based service solutions

AeroDron provides:

- Photogrammetry Solutions (Topographic Issues and Generic 3D Reconstruction)
- Machine Learning Solutions (Asbestos Free project)
- Remote Sensing Solutions (Aladin project)
- Air Pollution Monitoring (In-Air project)

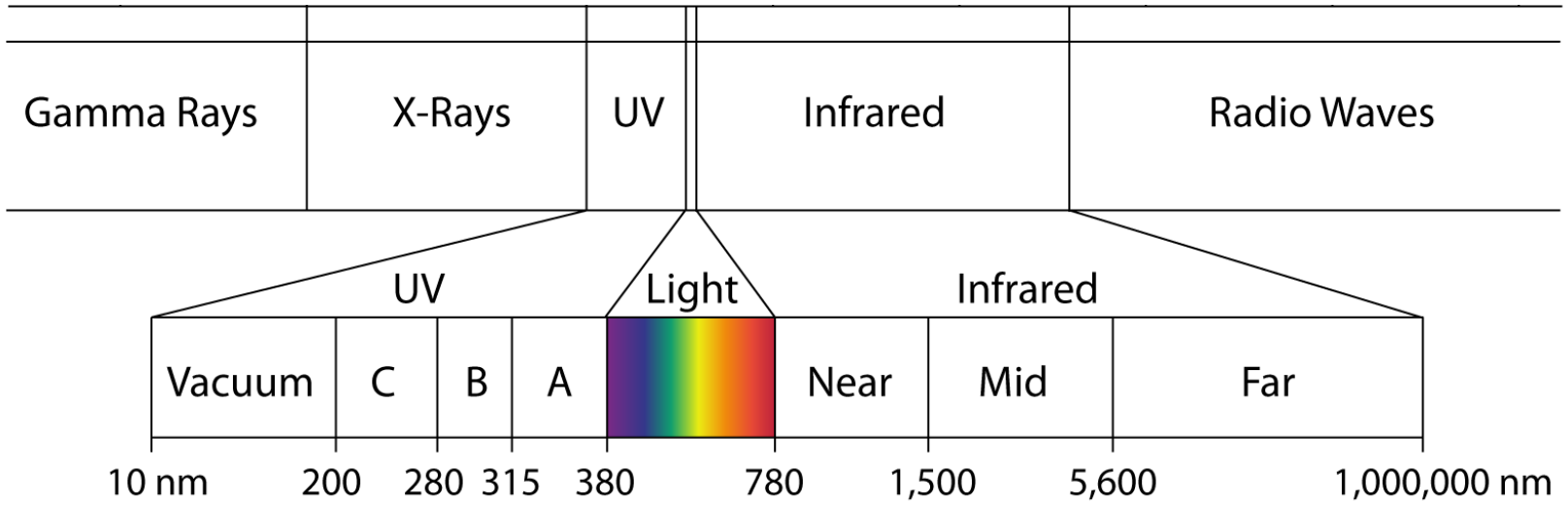
# Our Fleet



| | | |
|---|---|---|
|  | **DJI F550 Flame Wheel**<br>Training and learning school | **Payload**<br>• GoPro Hero 3 Black Edition |
|  | **SenseFly Swinglet Cam**<br>Short Range surveying<br>Precision Agriculture | **Payload:**<br>• Cannon S110 NIR<br>• Cannon S110 RGB |
|  | **SenseFly Swinglet Cam**<br>Medium Large Range surveying<br>Precision Agriculture | **Payload:**<br>• Cannon S110 NIR<br>• Cannon S110 RGB |
|  | **SKYROBOTICS SFR 6 uGo**<br>General purpose, multi-device vector | **Payload:**<br>• Sony QX100<br>• Sony SX100<br>• Tetracam Lite Multispetral<br>• GoPro Hero 3 Black Edition<br>Airinow Multispetral |
|  | **SKYROBOTICS SFR 6 uGo Thermal**<br>Thermal Imaging Survey | **Payload**<br>• FLIR A65 Radiometric Thermal Camera |
|  | **FUN STUFF!!** | |

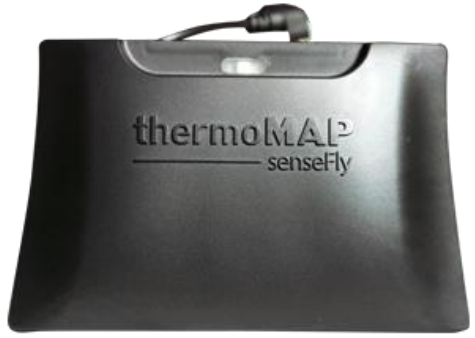
# Cameras for UAV

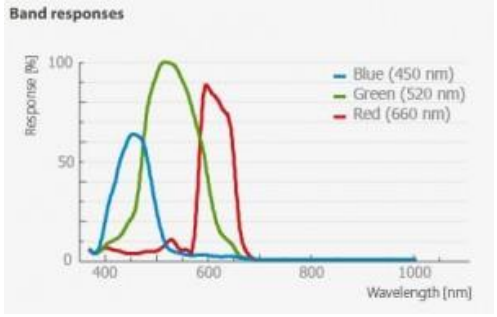


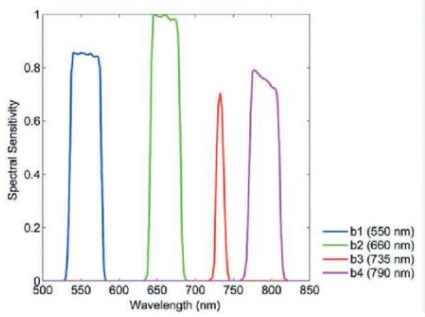


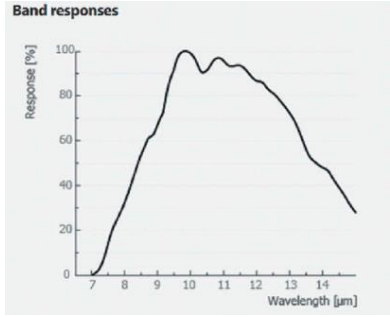

(1nm=$10^{-9}$ m)





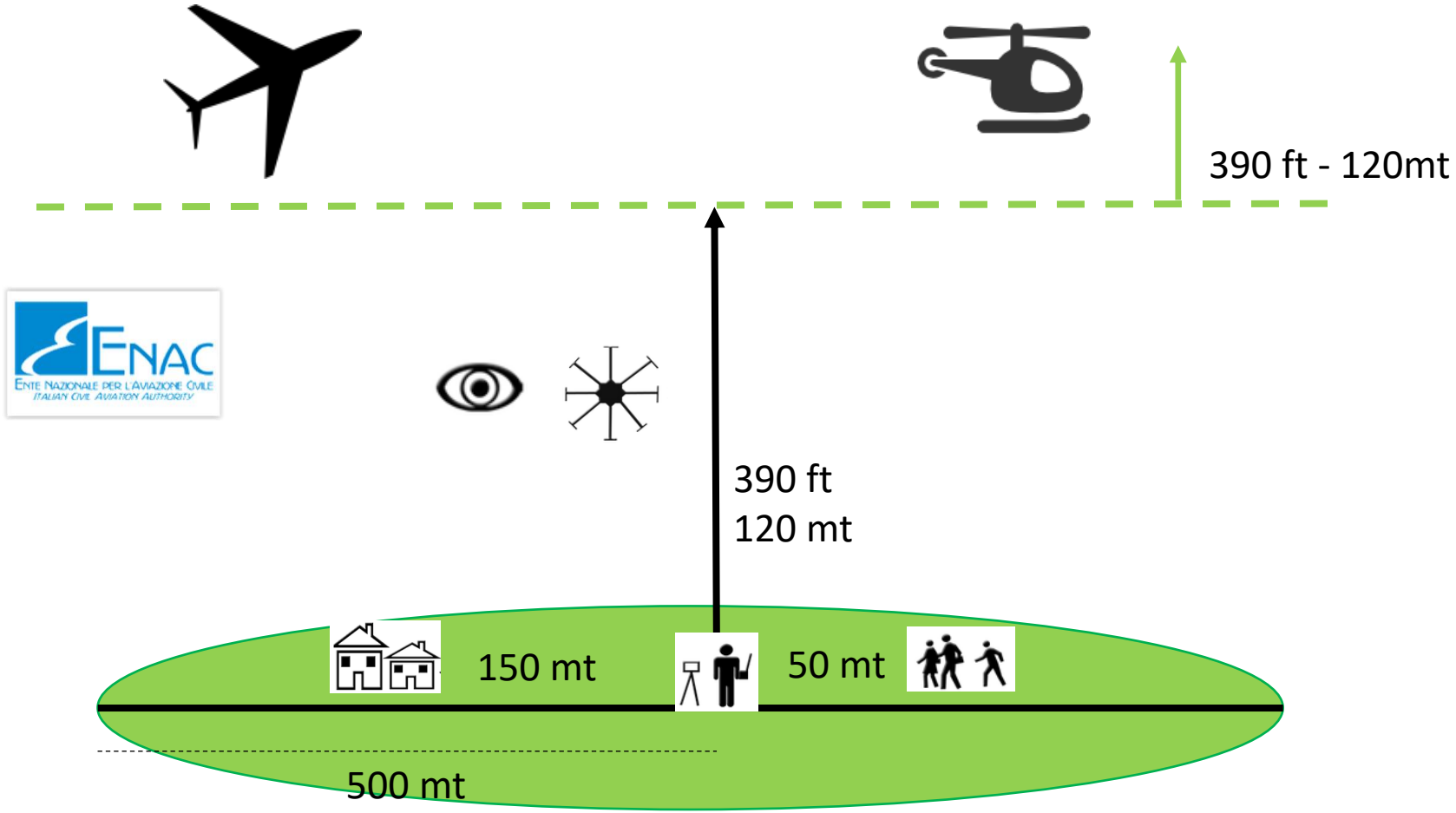



# Italian Regulamentation

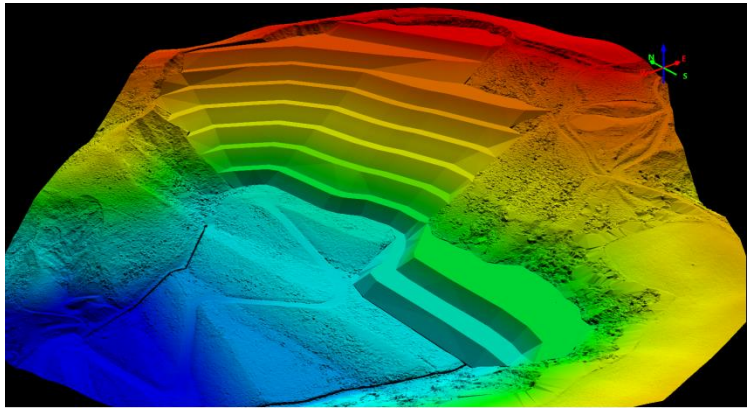




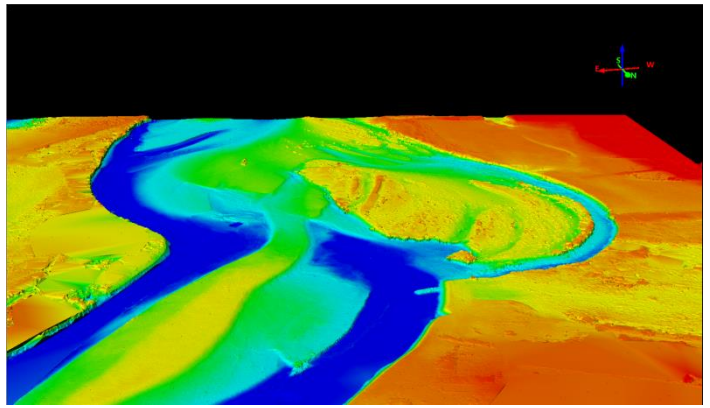
# Photogrammetry



## QUARRY AND MINES



## RIVERS AND LAND SLIDES



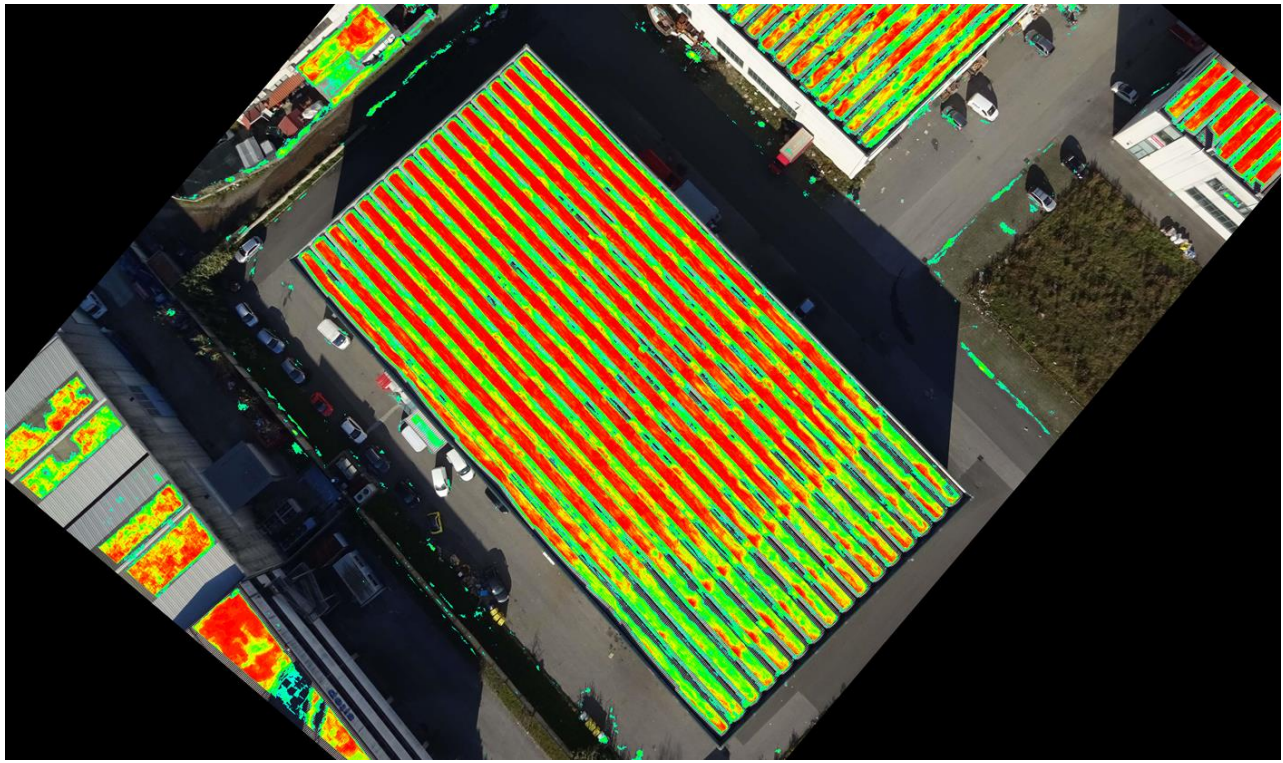
## GENERIC 3D RECONSTRUCTION

# Machine Learning



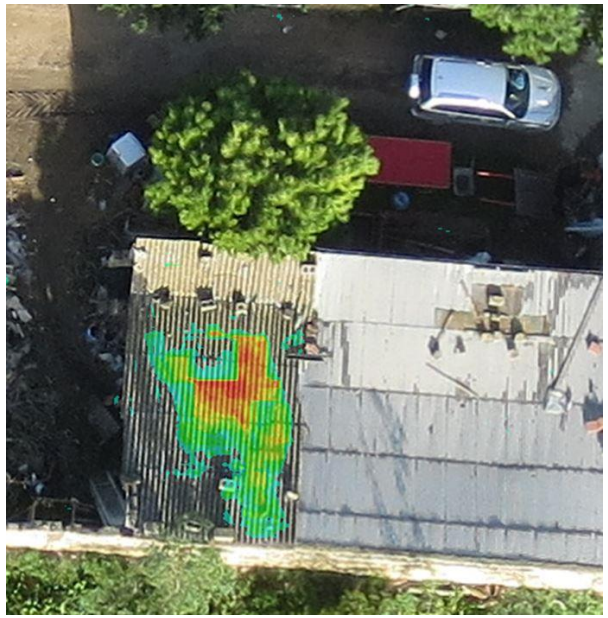
## SMART CITIES

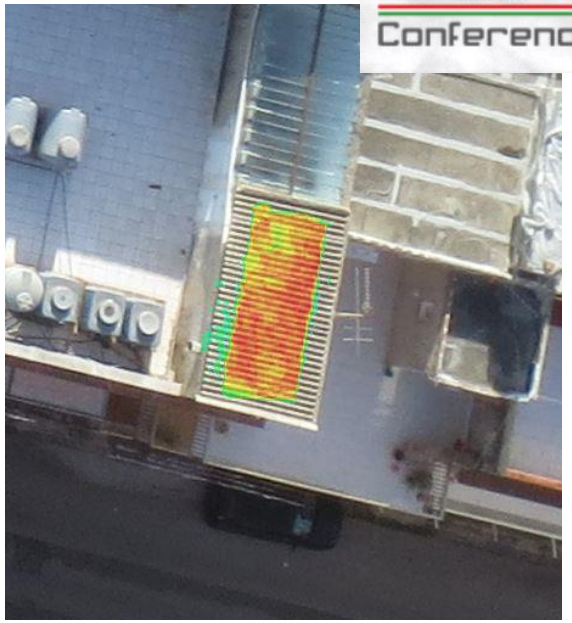
## MAPPING ASBESTOS ROOFING

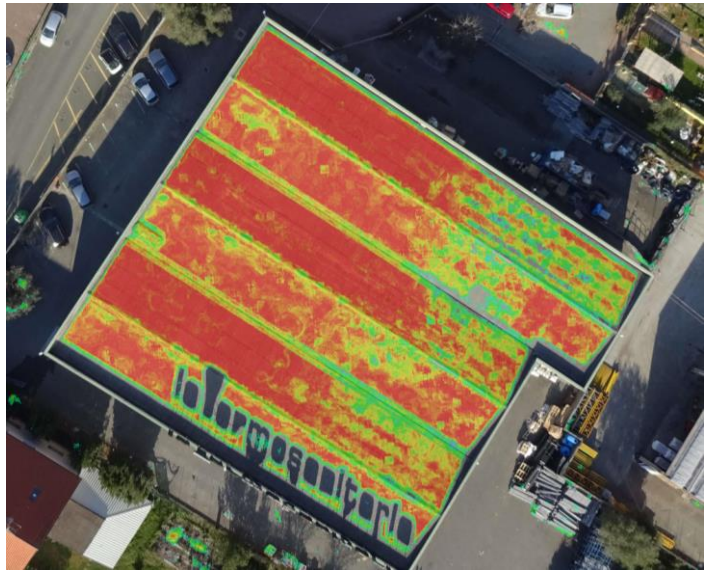


# Machine Learning










# How do we Detect Asbestos Roofing?

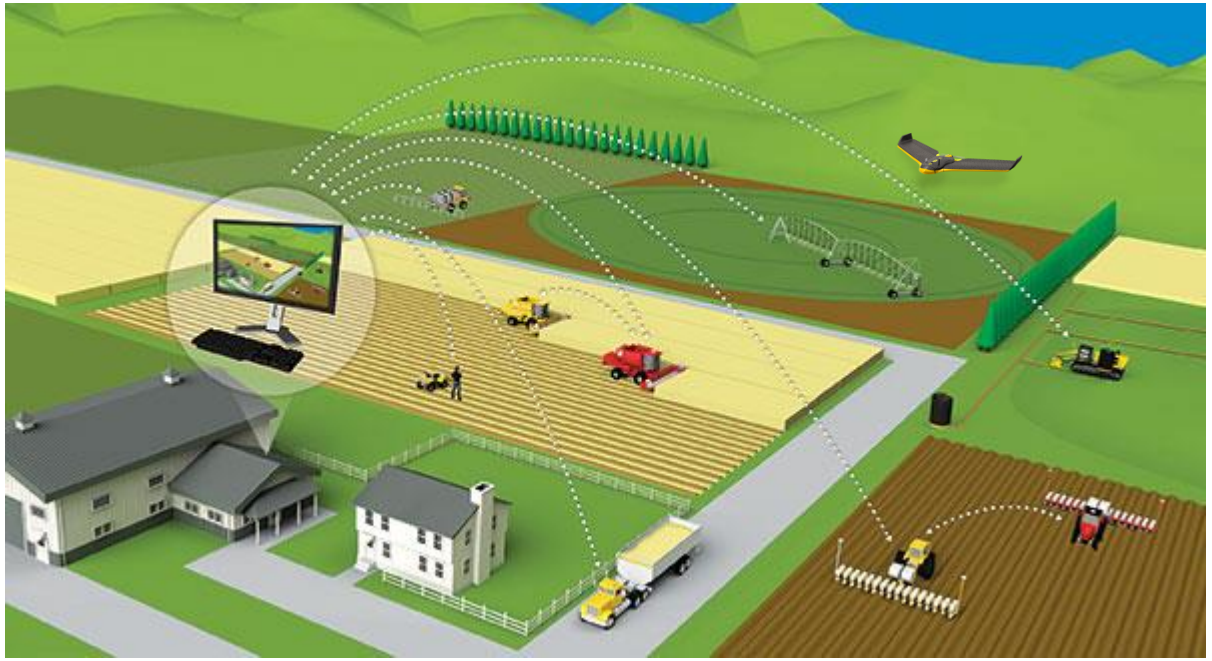


1. Multispectral analisys (aircraft data by CGR)
2. Drone flight
3. Data interpretation

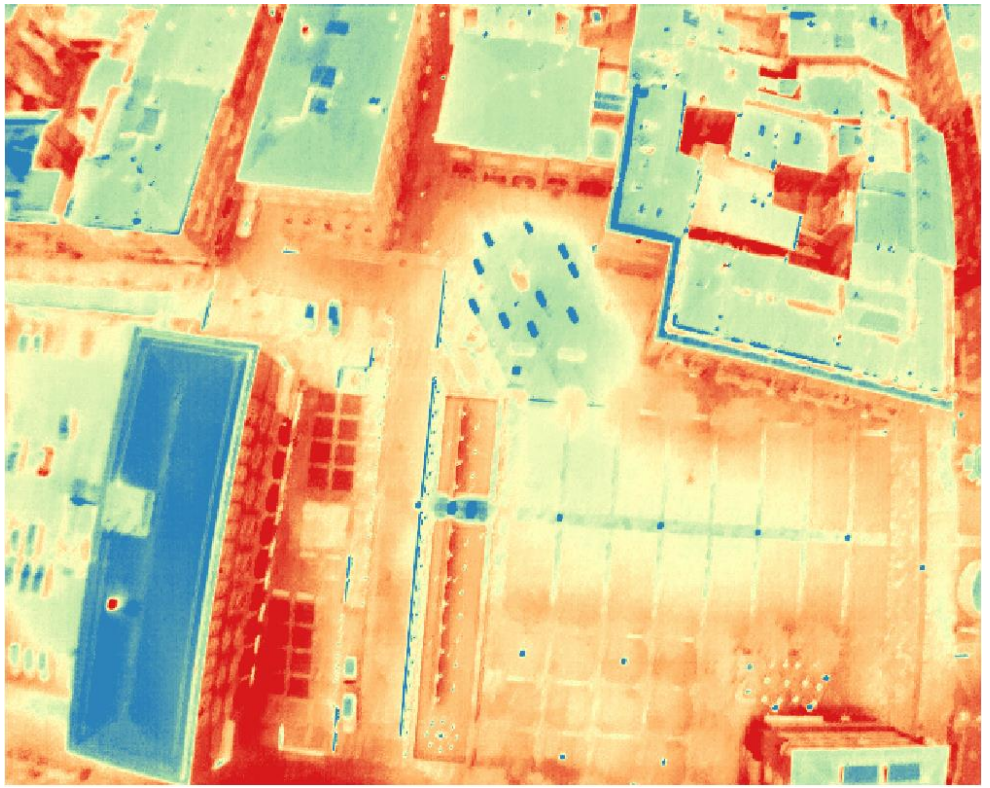
# Remote Sensing



## PRECISION FARMING



## THERMAL EFFICIENCY

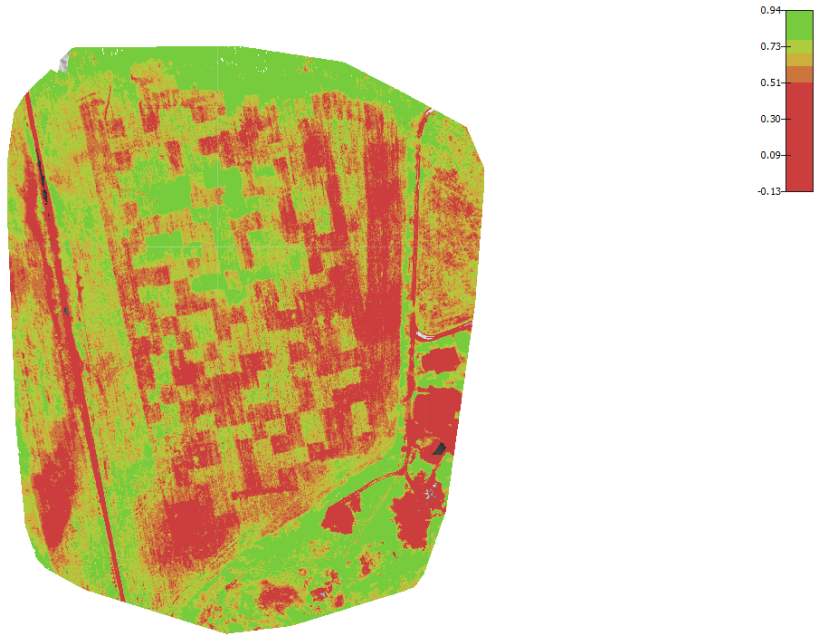


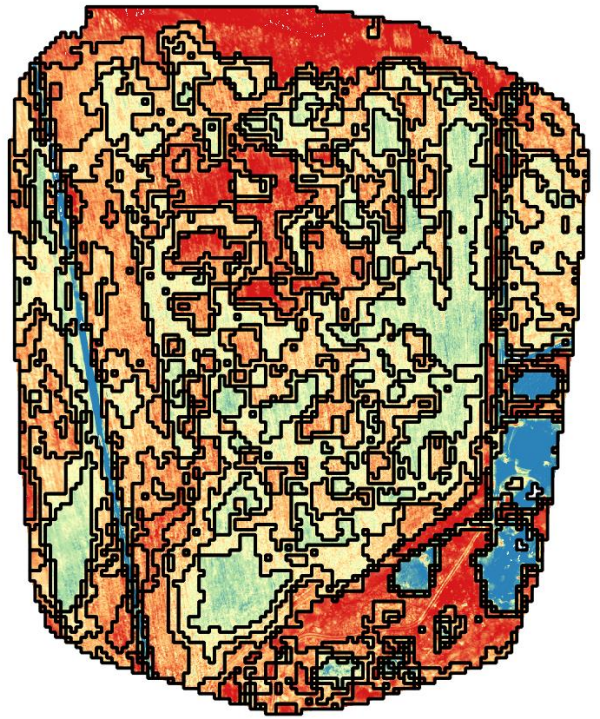
# Remote Sensing



## PRECISION FARMING

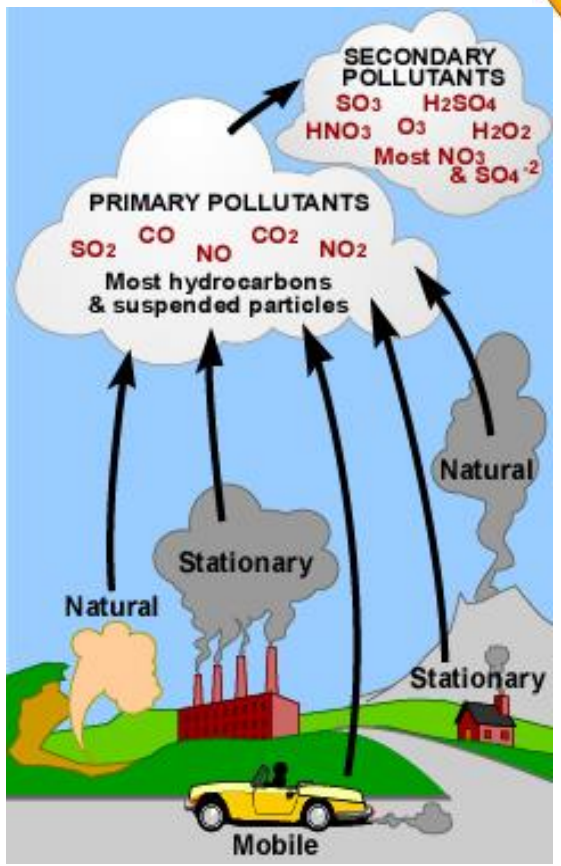
| Evaluation | Prescription | Operation |
|---|---|---|



# UAV for Air Pollution Monitoring






The composition of ambient air changes continuously, due to both natural and anthropogenic emissions which, when released into the atmosphere as aerosols or gaseous pollutants, affect air quality and human health

# UAV for Air Pollution Monitoring



Detailed information on aerosol distribution and gaseous pollutant concentrations is needed when quantifying their effects on human health and the environment

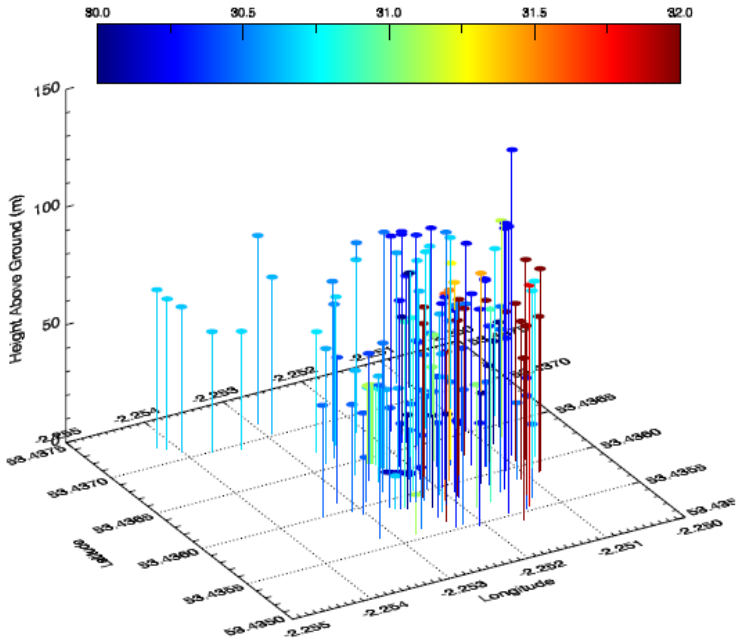

Small, lightweight UAVs can provide more accurate information on aerosol distribution throughout the atmospheric column, which is needed to better understand air quality and composition in specific atmospheric layers

# UAV for Air Pollution Monitoring



| Air Pollution Monitoring | | | |
|---|---|---|---|
| Monitoring Systems | Resolution | Flexibility | Cost/hectare |
| Satellite | Low | Low | High |
| Manned Aircraft | Medium | Medium | High |
| Ground Station | High | Low | Medium |
| UAV | High | High | Medium/Low |

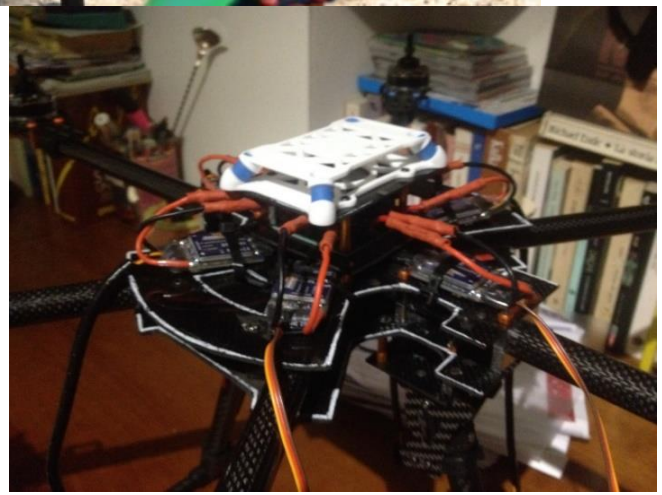
3D Maps of Pollutants:




Monitoring after Enviromental Disasters:

# In-Air UAV Prototype





- The multirotor chosen is a hexacopter type featured by greater loading capabilities
- The UAV is mostly made up of carbon and aluminum elements
- The total weight is going to be around 9Kg, and diameter 1.3m
- The power supply system uses a high voltage battery capable of supporting a payload of up to 2.5 Kg for about 30 minutes of flight

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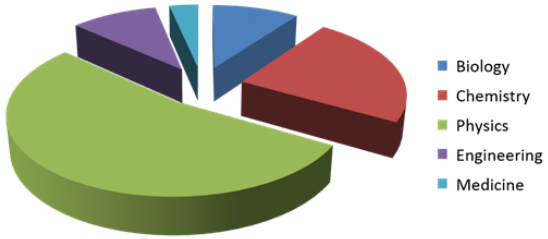
## 12.000 sqm Labs


STAFF




NANOTEC @ Lecce is a multidisciplinary center for nanotechnology research and development with more than 120 researchers coming from physics, chemistry, biology, medicine and engineering

800 sqm (class 100-100000)
fully equipped Clean Room

Dr. Massimo Cuscunà
Email: massimo.cuscuna@cnr.it

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# Epitaxy/Thin Films

## Lithography

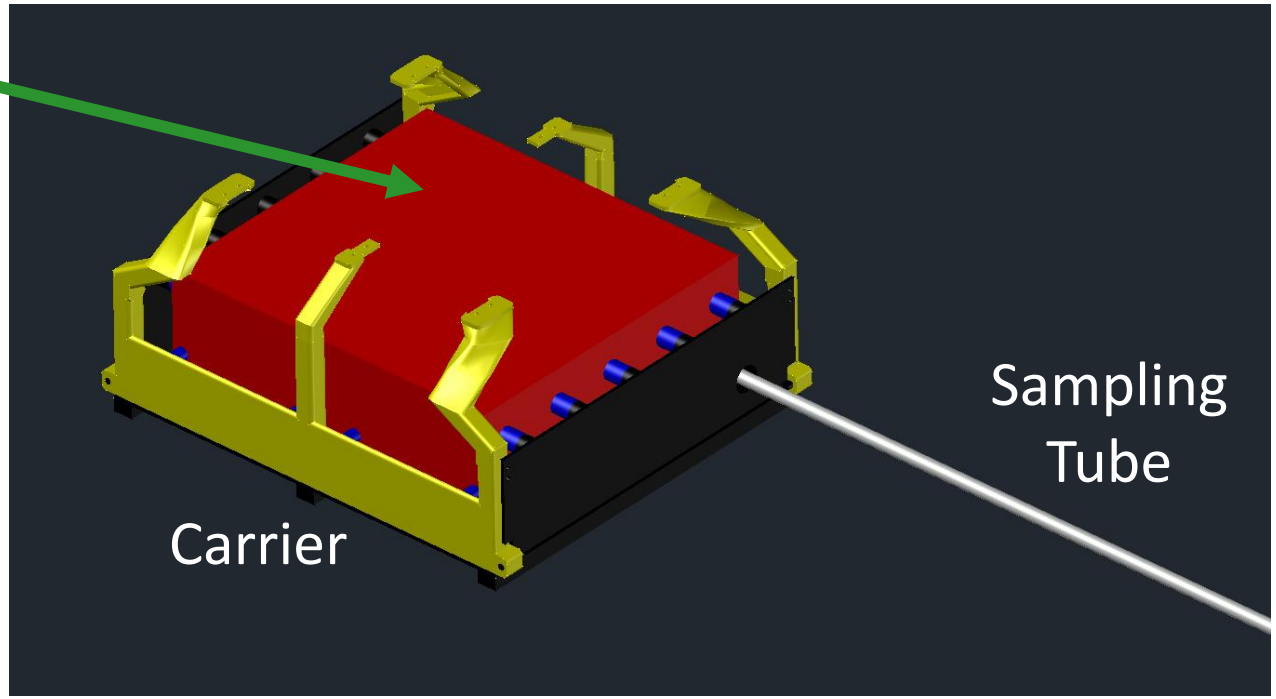
## Etching

## Imaging


# In-Air Payload

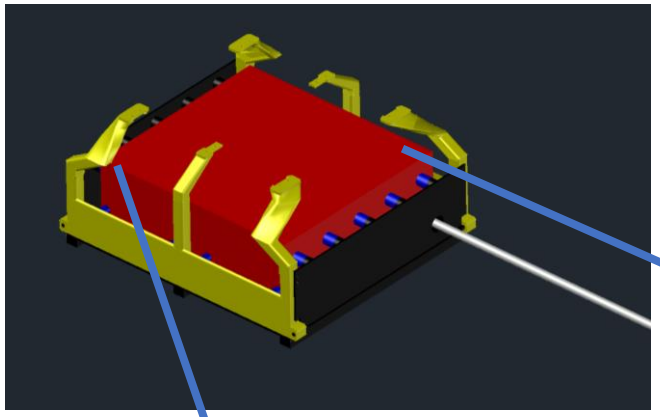


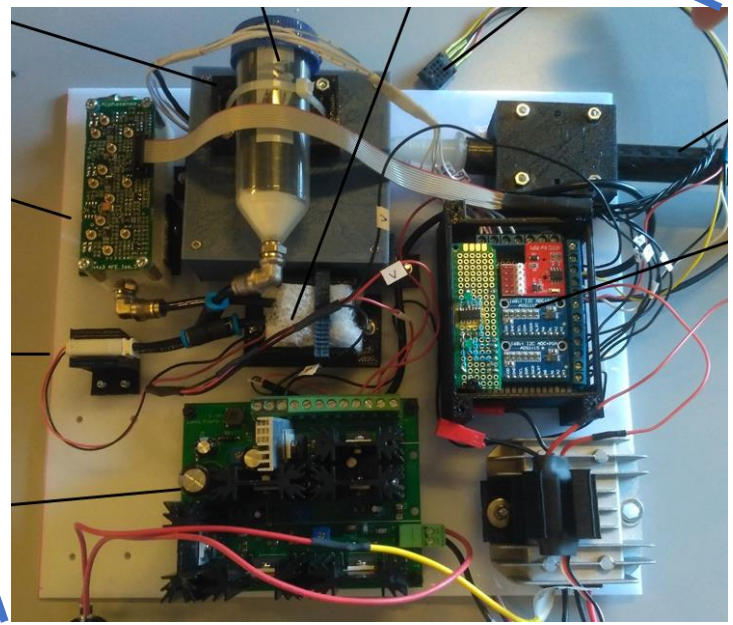
Multifunctional Sensing Platform



# Multifunctional Sensing Platform



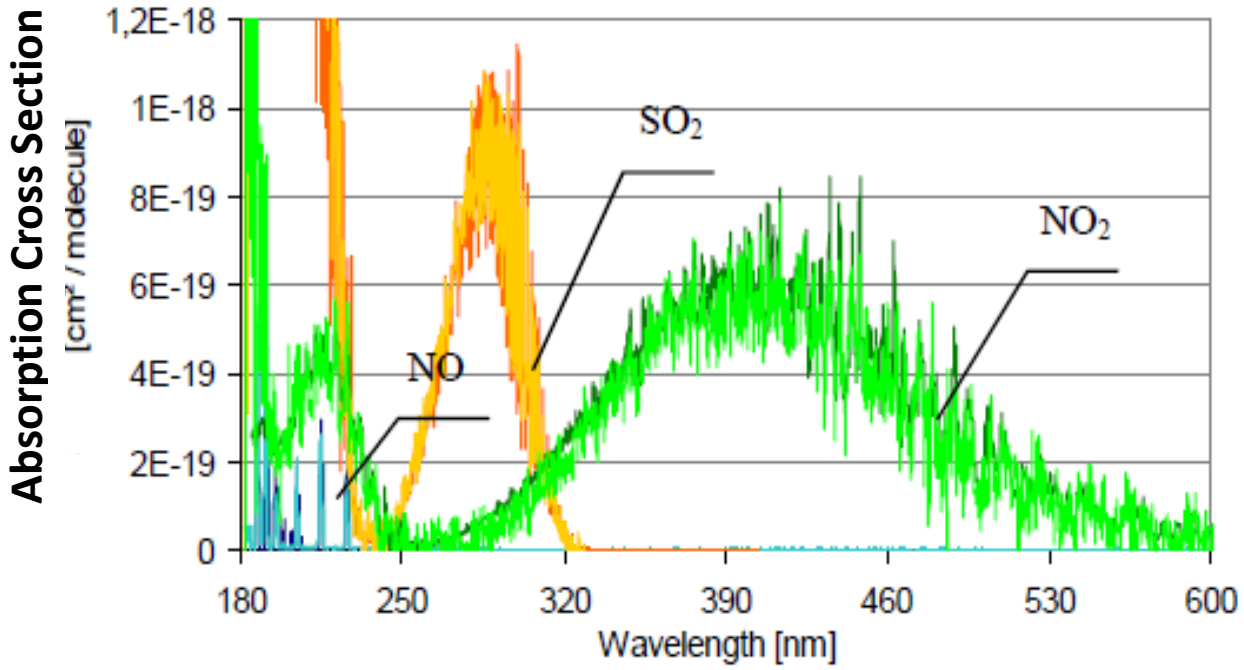




+ Optical Sensors

# Optical Sensors for Air Pollutant Detection

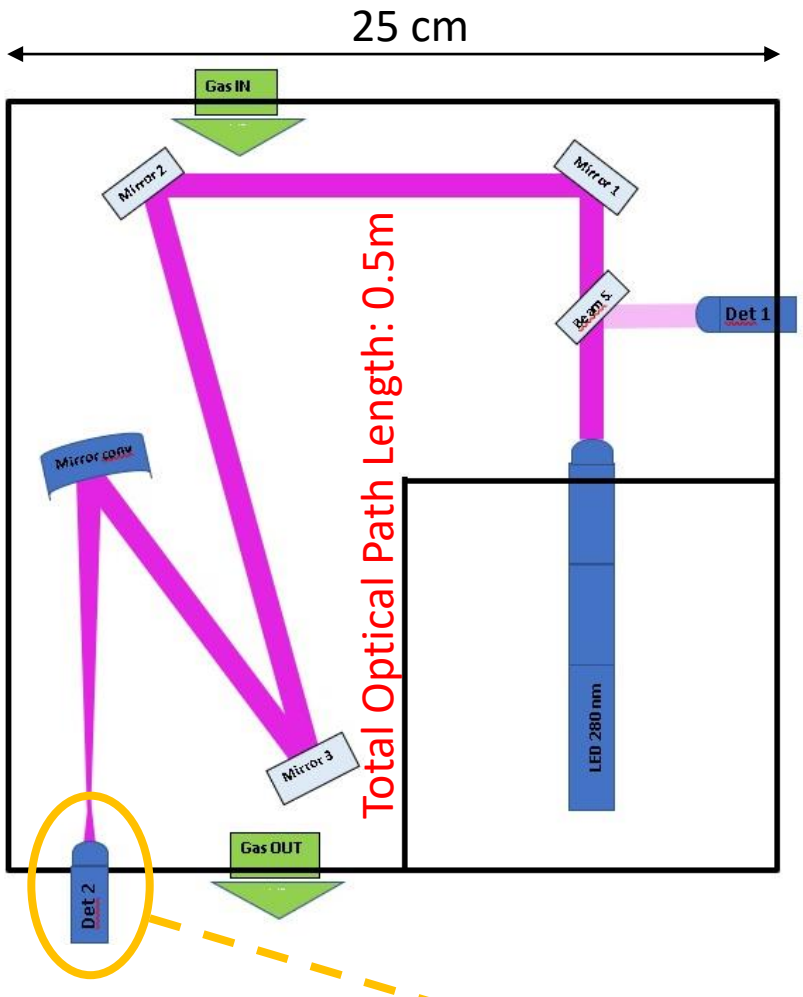




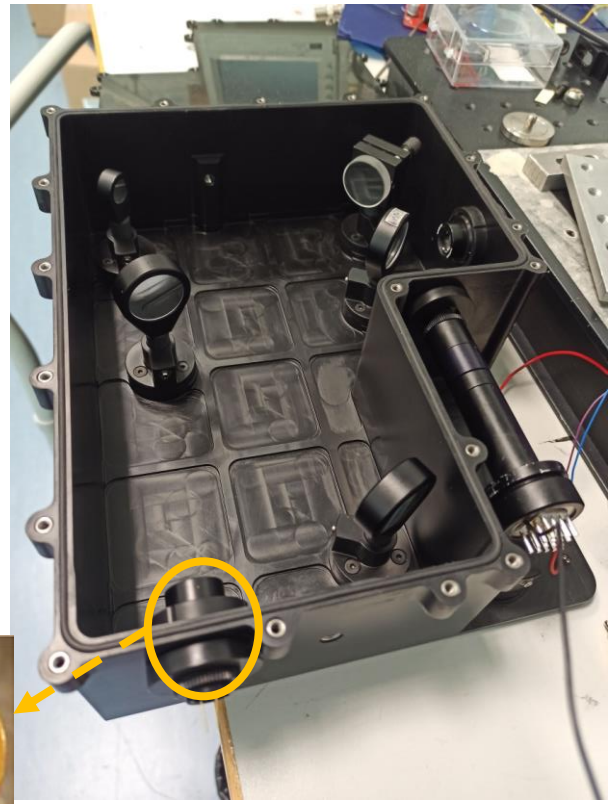

$SO_2$ and $NO_2$ concentration in atmosphere ranging from a few ppb to ppm

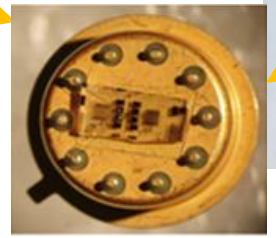
# UV Radiation-based Sensing System



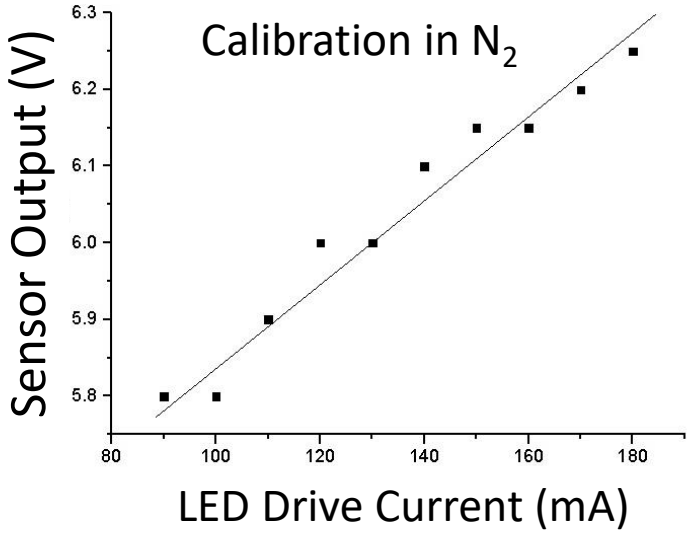



**LONG OPTICAL PATH ABSORPTION CELLS** are used to measure weak spectra in gases. The goal of this type of cells is to improve detection sensitivity by increasing the total optical path length that travels through a small, constant sample volume



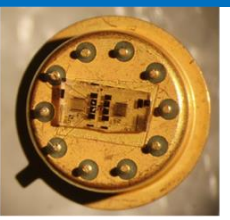


Gas absorbs energy from the LED beam, resulting in an attenuation of the output, that is detectable by the photodiode



# Deep UV Detector

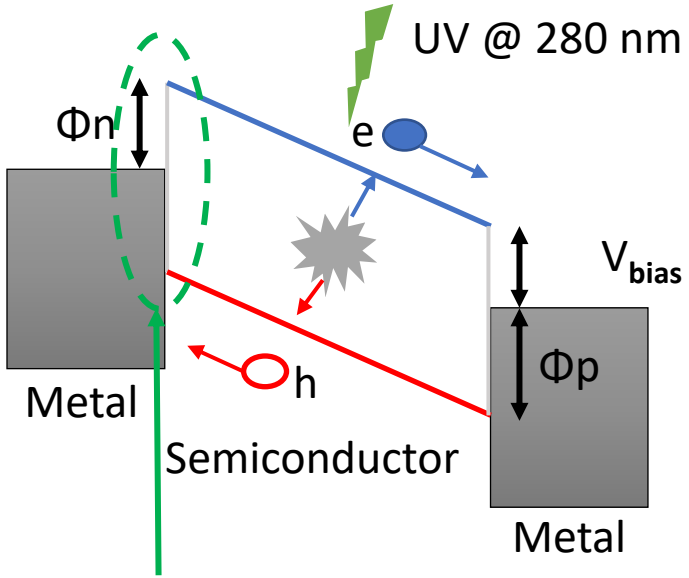




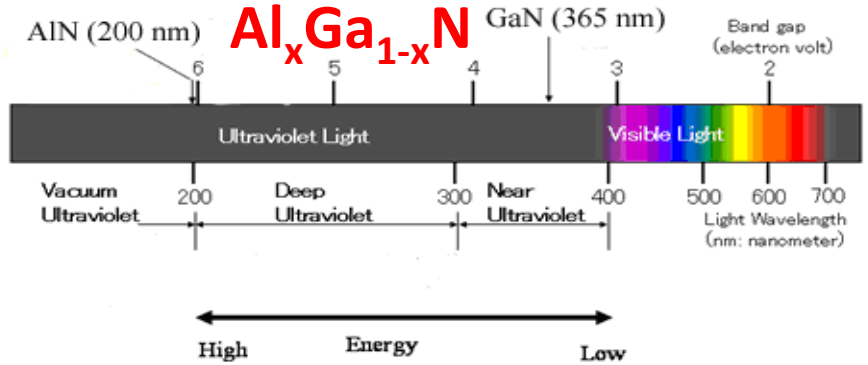
## A Schottky Diode can be used as a High-Efficiency Photodetector

Light absorption in the semiconductor produces hole-electron pairs **Photovoltaic Effect**

Photocurrent Generation Mechanism

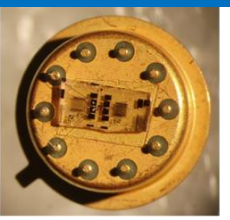



Metal-Semiconductor Junction (Schottky Junction)




**$Al_xGa_{1-x}N$** is a material with a direct band gap ranging from 365 nm (Eg = 3.40 eV in the case of **x=0**) to 200 nm (Eg = 6.20 eV for **x=1**) at room temperature

# AlGaN Epilayer Growth



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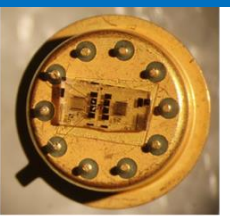
## Metal Organic Chemical Vapor Deposition (MOCVD) of III-N's Semiconductor

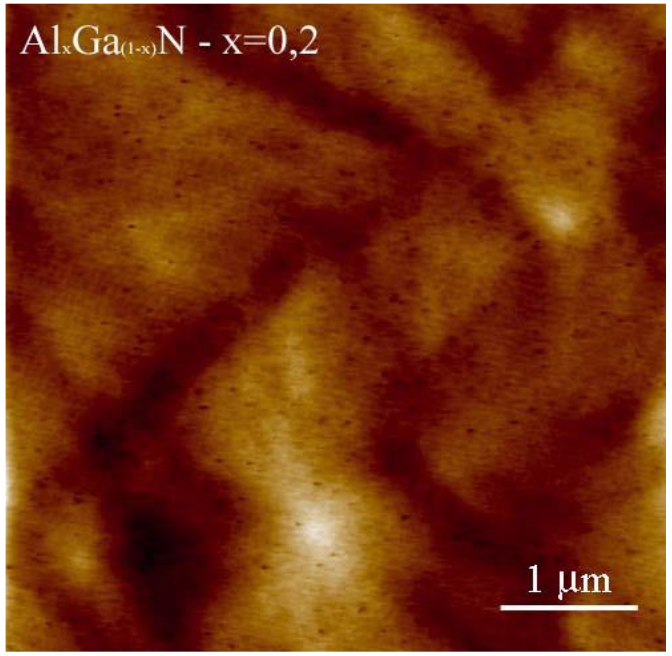

- (0001) c-plane $Al_2O_3$ substrate
- MOCVD system equipped with a rotating substrate holder
- Hydrogen was used as the carrier gas of trimethylgallium (TMGa), trimethylaluminum (TMAl), and ammonia ($NH_3$) were used as Ga, Al, and N sources, respectively

# AlGaN Characterization



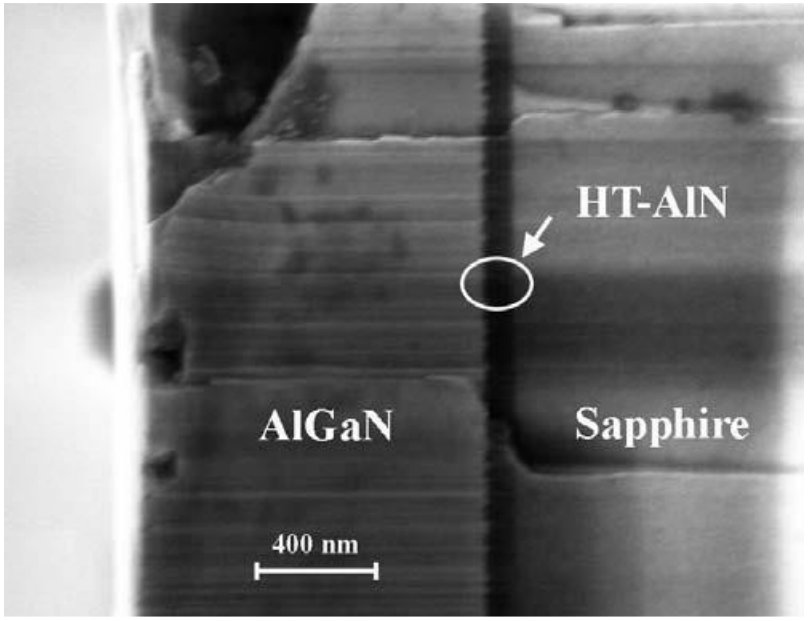
## Morphological Characterization:

### Atomic Force Microscopy




- Smooth surface without cracking phenomena
- RMS roughness value of 0.5÷0.7 nm

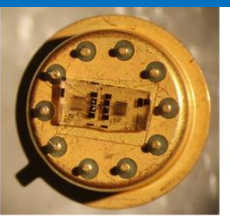
### Scanning Electron Microscopy



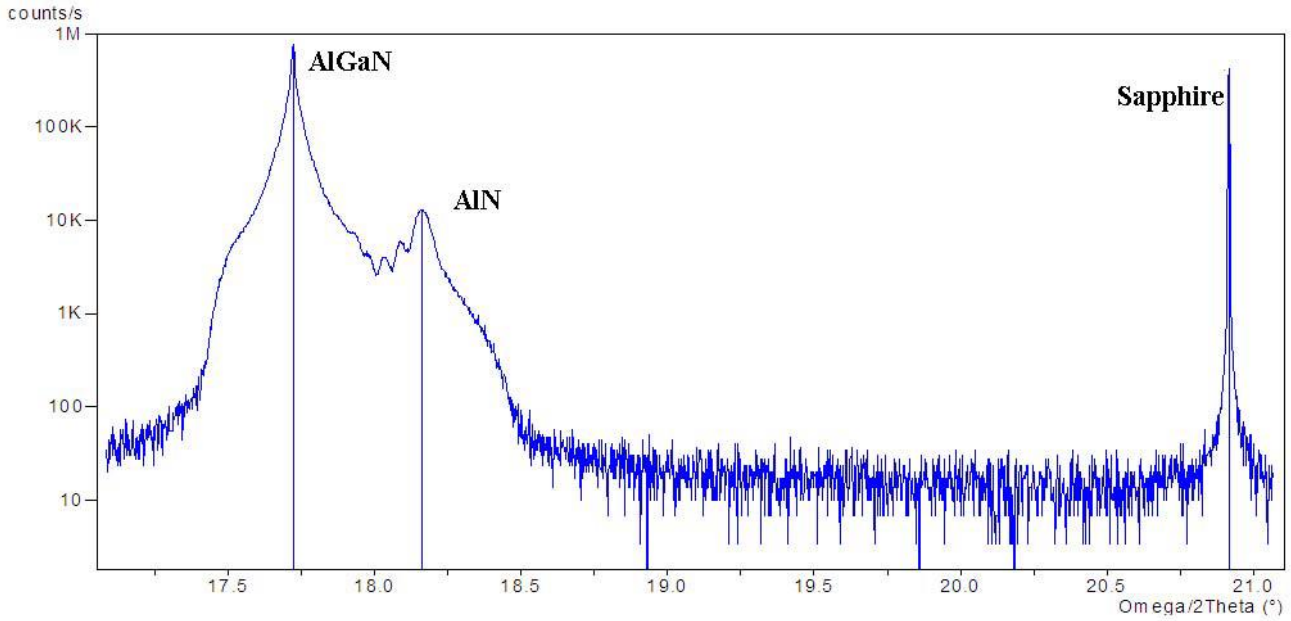

**$Al_xGa_{1-x}N$ (*x*=30%):**
High temperature AlN = 100 nm
AlGaN = 1 µm

The interfaces between AlN and AlGaN are clear and sharp

# AlGaN Characterization



## Structural Characterization:

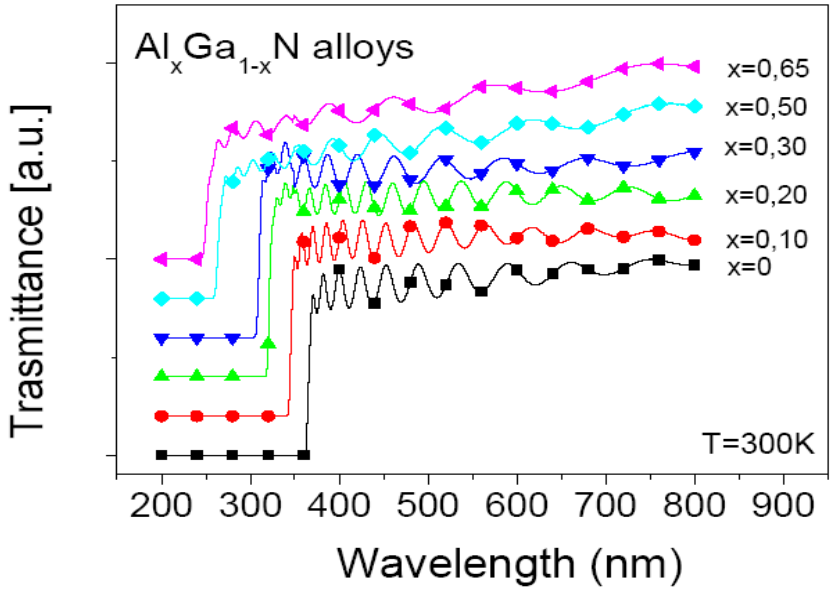



X-Ray diffraction analyzes the compositional and structural properties

The very narrow linewidth of the AlGaN peak indicates a high crystal quality of this epitaxial layer due to the employment of high temperature AlN buffer layer

## Optical Characterization:

Transmittance measurements provide the material optical properties, like the cut-off wavelength



# Deep UV Detector Fabrication for $SO_2$ Monitoring

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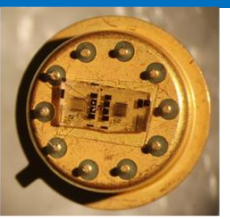
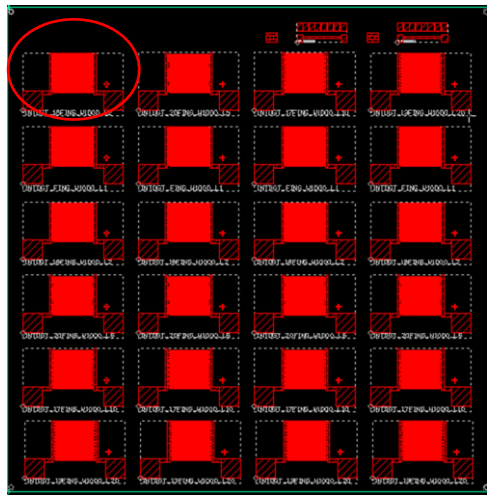
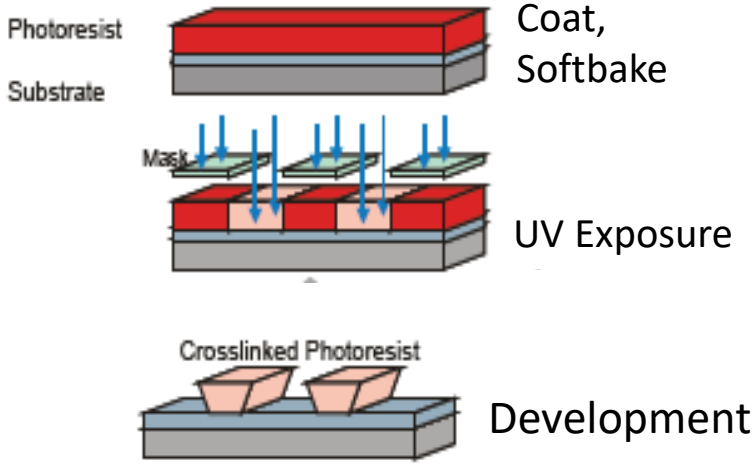


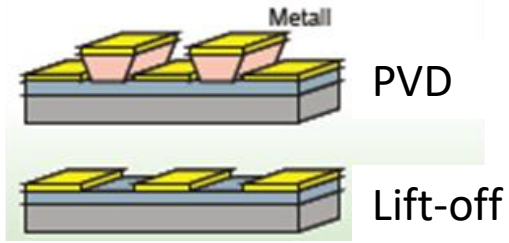
## 1) Optical lithography:

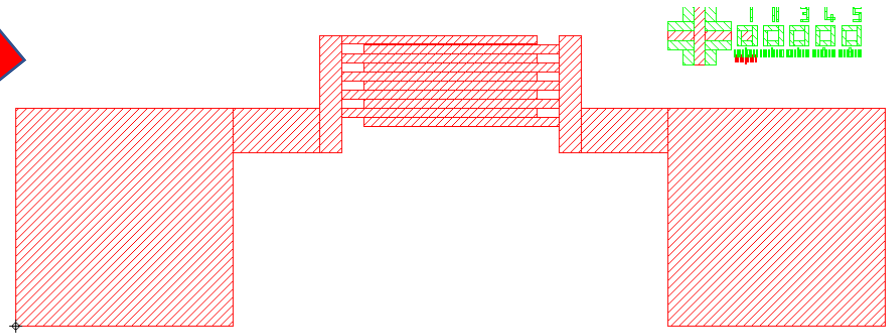




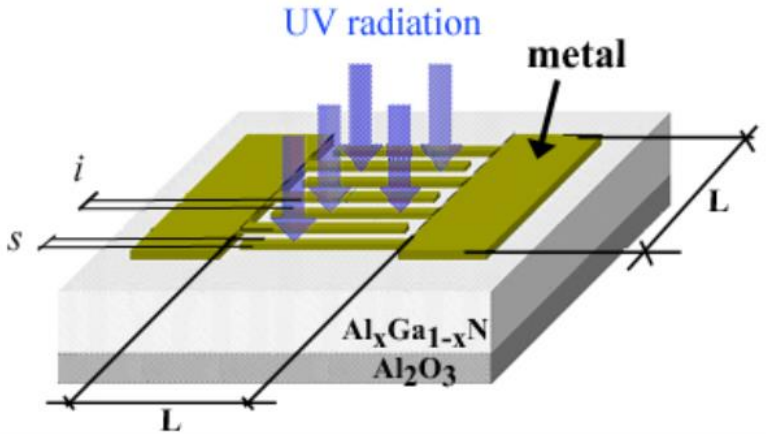

## 2) Thin film deposition:

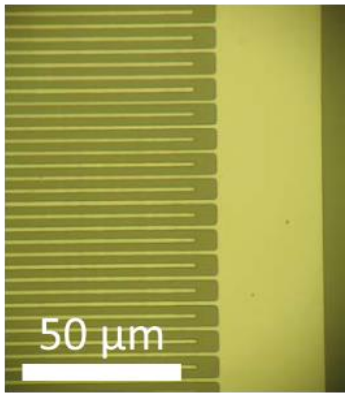
- Cr/Au (20/100nm)
- W (130nm)
- Ti/Pt (30/150nm)



## 3) Final Detector :

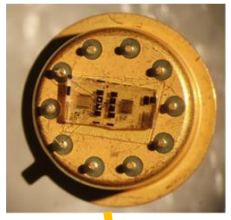


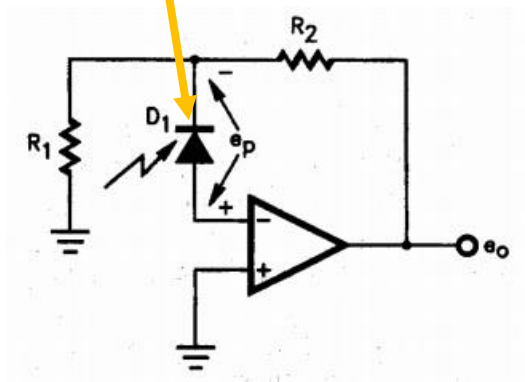



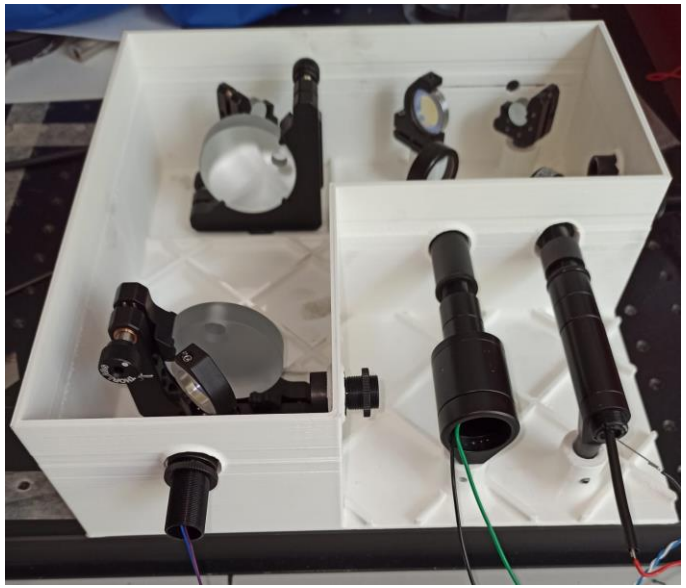

Detection area = 1x1 $mm^2$

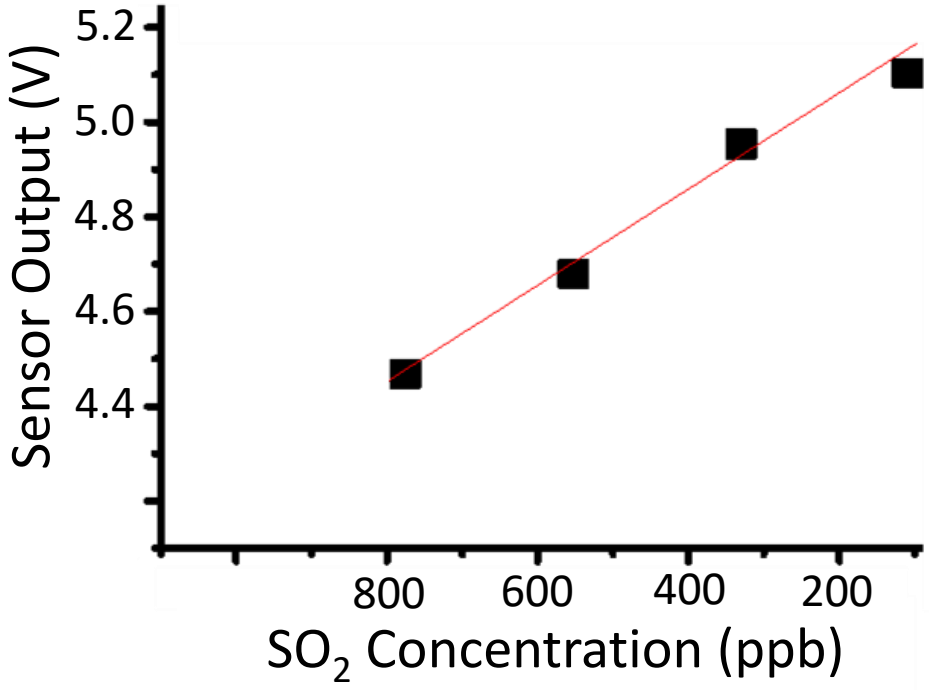
s=1 µm, i=3 µm

# Optical Sensor Characterization in $SO_2$ Environment








Readout Electronics:

Photodiode is placed in series with the input of an transimpedance amplifier converting current to voltage

Fast Response Time: in the range of ms

# Conclusions



- Customized UAV Development and Flight Testing

- Multifunctional Sensing Platform Realization and Laboratory Testing

- Next step: UAV and Sensing Platform Integration for 3D Air Pollution Monitoring

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