



**ETH** Shaping the future

# Innovative Drones for Environmental and Agricultural Monitoring

Prof. Dr. Roland Siegwart  
[www.asl.ethz.ch](http://www.asl.ethz.ch)  
[www.wysszurich.ch](http://www.wysszurich.ch)

**1st ONLINE Conference in Agri-Food Robotics**  
Cambridge, 19-20 March 2020



# World Food Supply

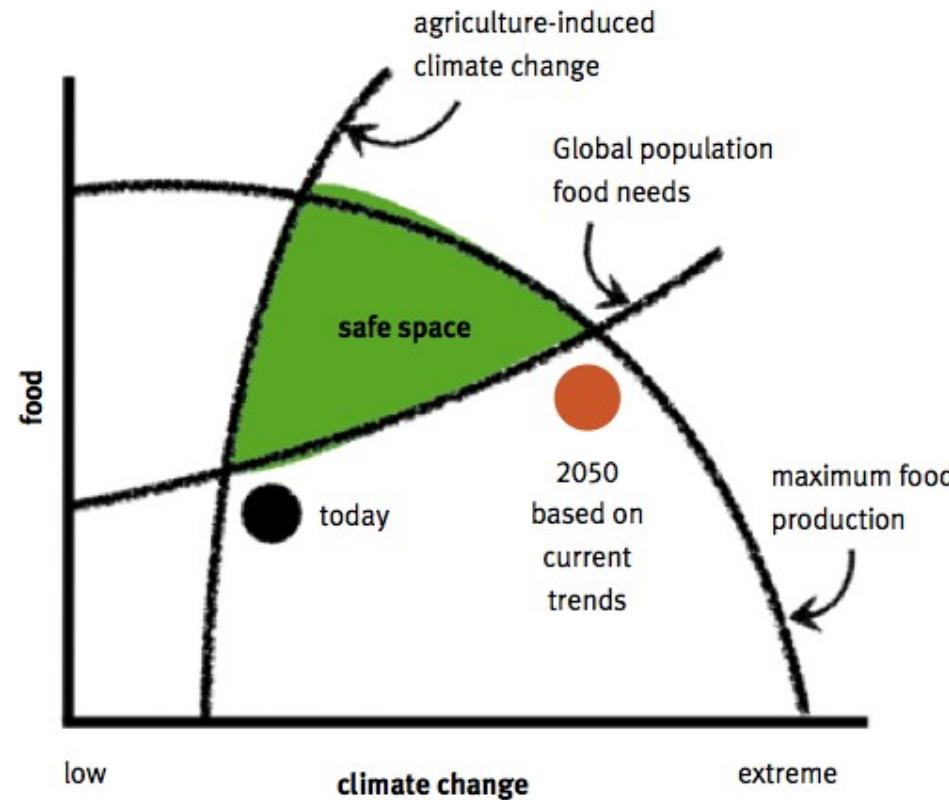
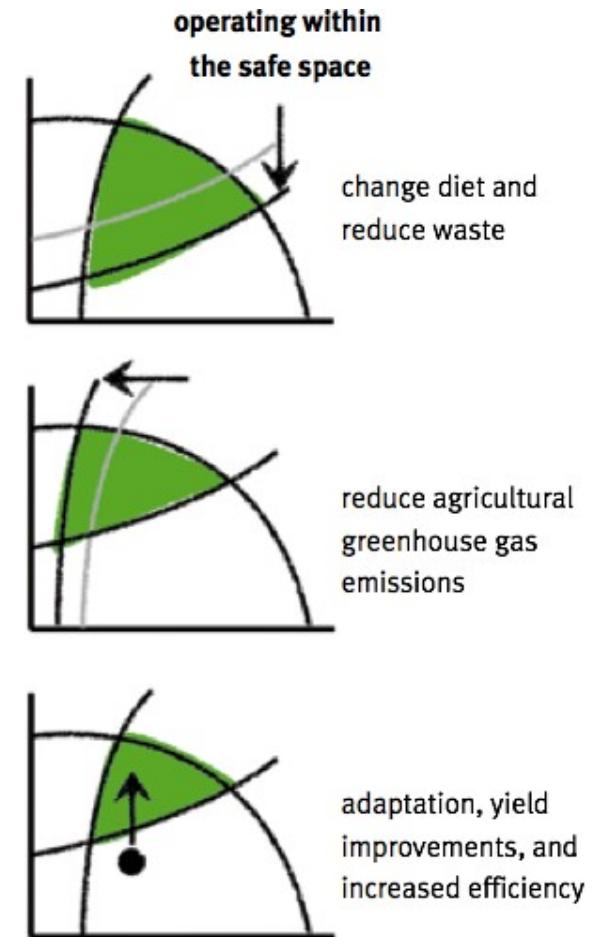


Image source: *Achieving food production in the face of climate change*, Beddington 2012



- Furthermore, agriculture is increasingly polluting our environment with **pesticides**

# Agriculture Monitoring

- Potential Contributions of Robotics and Especially Drones

- Monitoring:
  - Continuously **monitor** the development of the **agriculture fields**
  - Give precise indications to the farmer on **how and where intervene**
  - Enable **traceability** of the **food value chain** from the farmer up to the final customer
  
- Results:
  - Highly **increased productivity** and **yields**
  - Drastically **reduced** output of **fertilizers** and **herbicides**



# How to Fly | flight concepts

- Helicopters (video: Prof. D'Andrea, ETH)
  - < 20 minutes
  - Highly dynamic and agility
- Fixed Wing Airplanes
  - > some hours; continuous flights possible
  - Non-holonomic constraints
- Blimp: lighter-than-air
  - > some hours (dependent on wind conditions)
  - Sensitive to wind
  - Large size (dependent on payload)
- Flapping wings (video: Festo)
  - < 20 minutes; gliding mode possible
  - Non-holonomic constraints
  - Very complex mechanics

Hybrid and Omnidirectional Flight Concepts  
high potentials:



Festo BionicOpter



# Service Drones | flying robots for challenging tasks

**wingtra** – most elegant VTOL

| from student project to startup

<https://www.youtube.com/watch?v=QADvPDWtgFU>



**Atlantik Solar** - solar airplane

| 81 hours non-stop in summer 2015

| 5.64 m, 6.2 kg

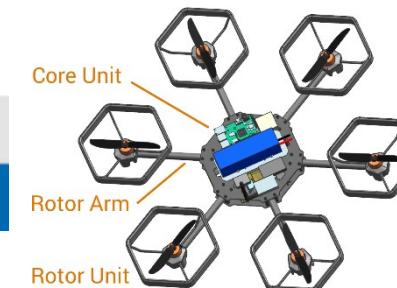
[https://www.youtube.com/watch?v=8m4\\_NpTQn0E](https://www.youtube.com/watch?v=8m4_NpTQn0E)

[https://www.youtube.com/watch?v=wyS6W1t\\_ryQ](https://www.youtube.com/watch?v=wyS6W1t_ryQ)

**Voliro** – future of flying robots

| the omni-directional multi-copter

[https://www.youtube.com/watch?v=9FJn\\_t-YCwM](https://www.youtube.com/watch?v=9FJn_t-YCwM)



# Tiltwing Aircraft | High performance VTOL (Hybrid)

in collaboration with



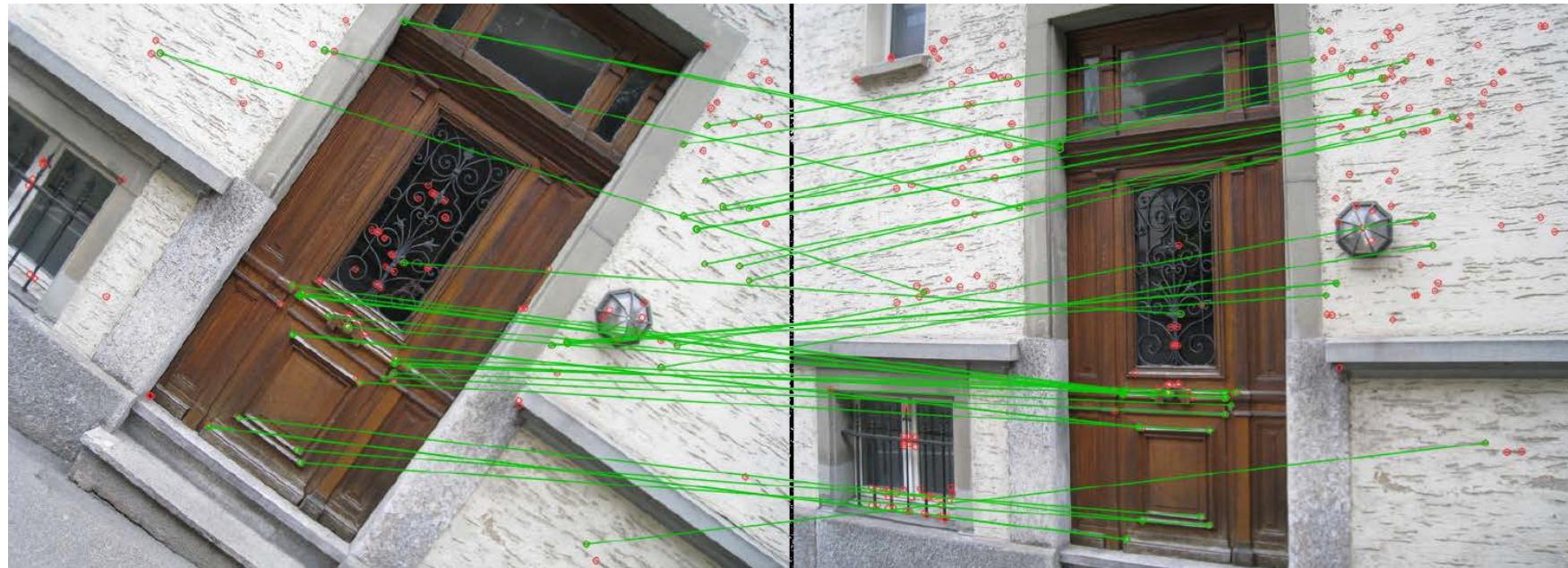
DUFOUR AEROSPACE



# “Seeing” | Visual-Inertial Motion Estimation



<https://www.youtube.com/watch?v=yvgPrZNp4So>



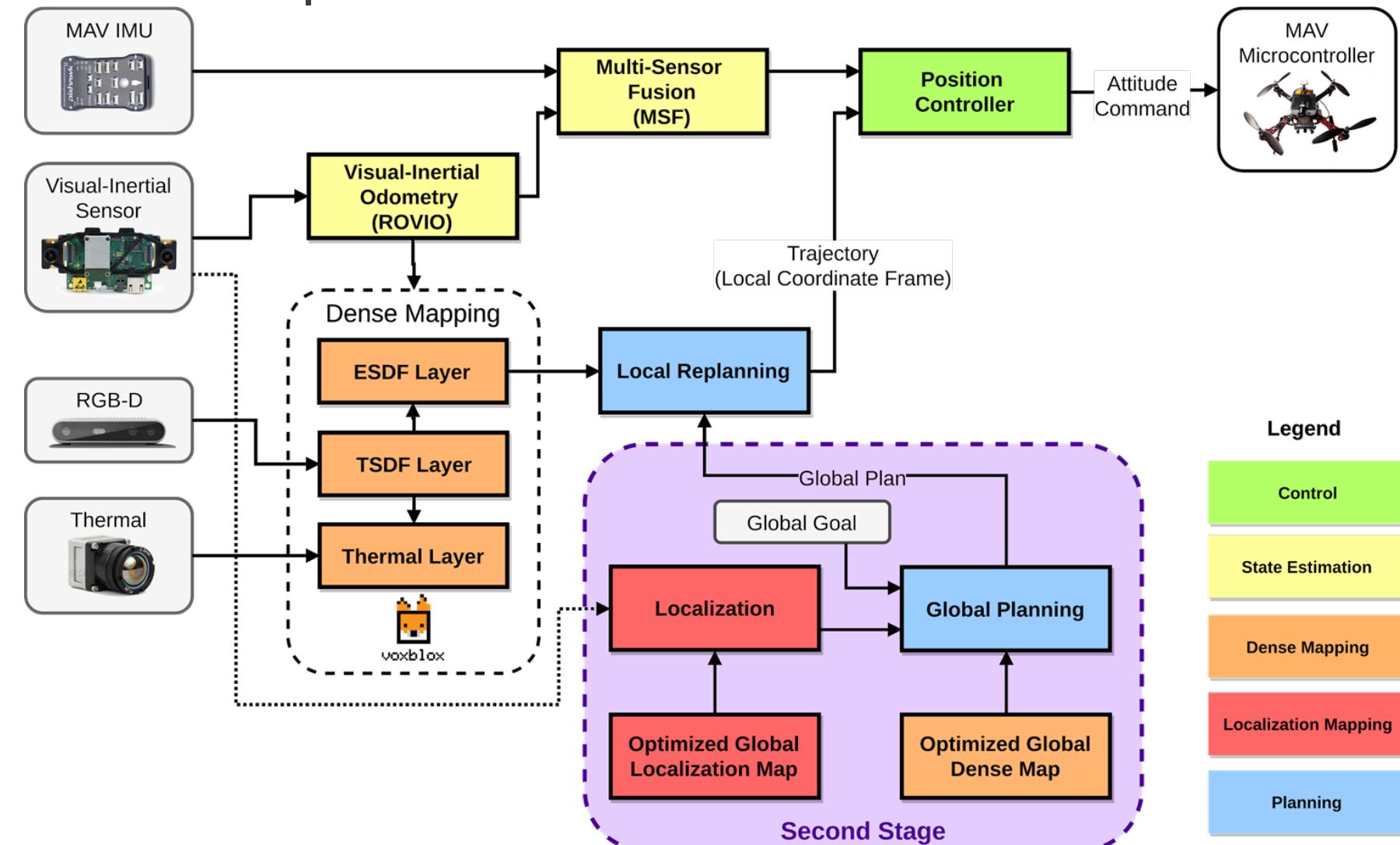
# Collaborative Visual-Inertial Navigation | teach and repeat



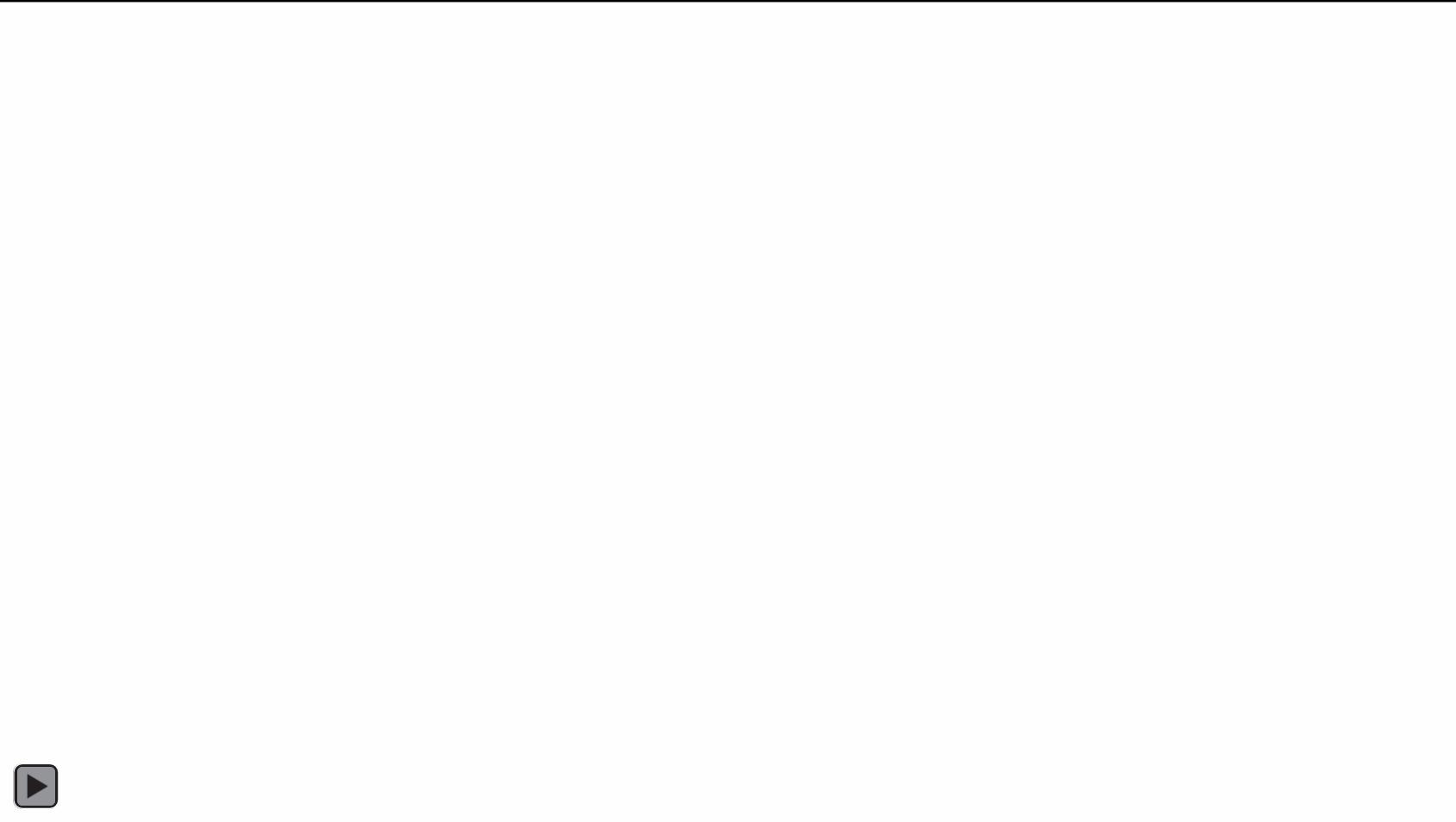
<https://www.youtube.com/watch?v=pDIQxsOrgI4>

# Visual-Intertial Navigation | System Overview

- localization
- mapping
- SLAM
- 3D reconstruction
- planning



# Navigation & Planning in Cluttered Environments

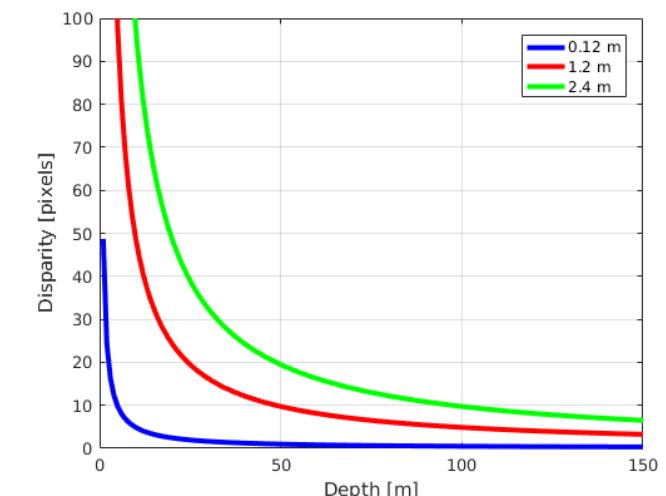
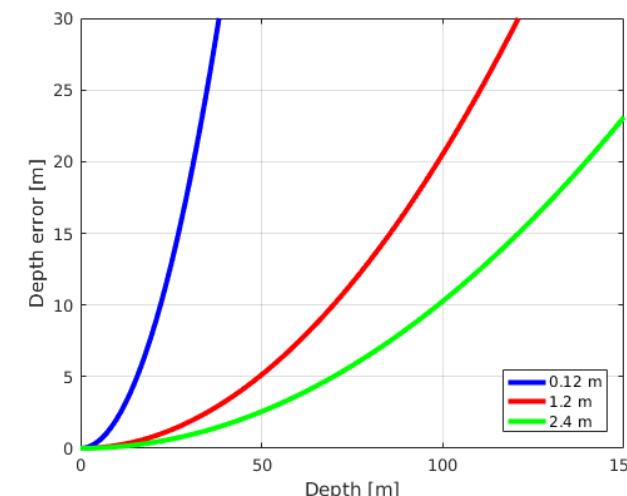
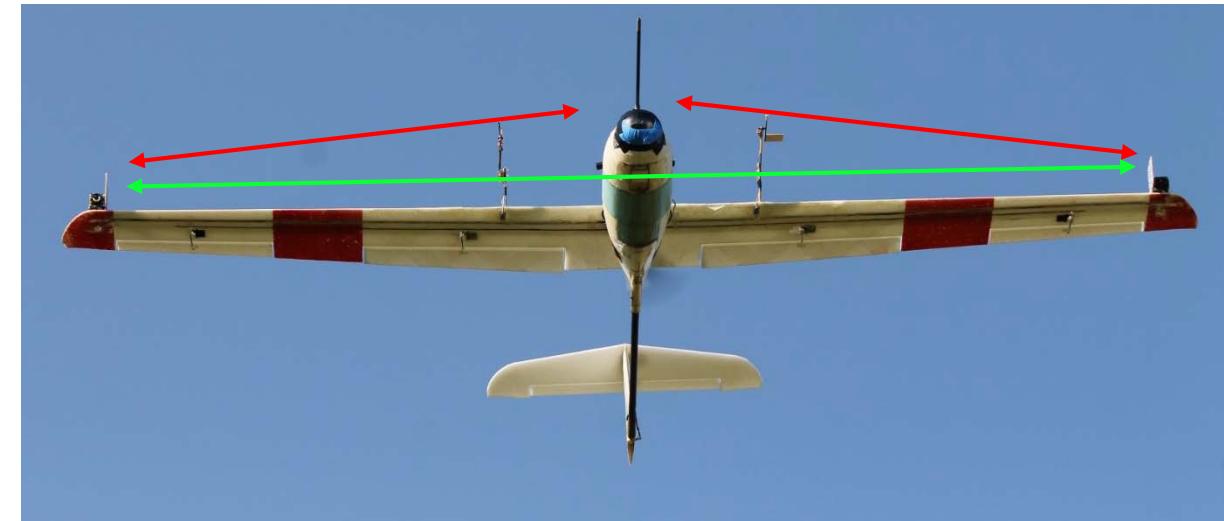


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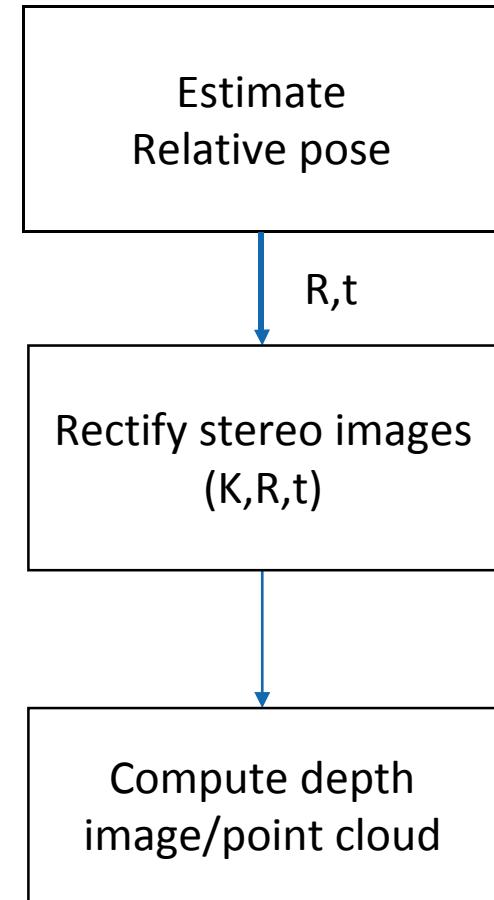
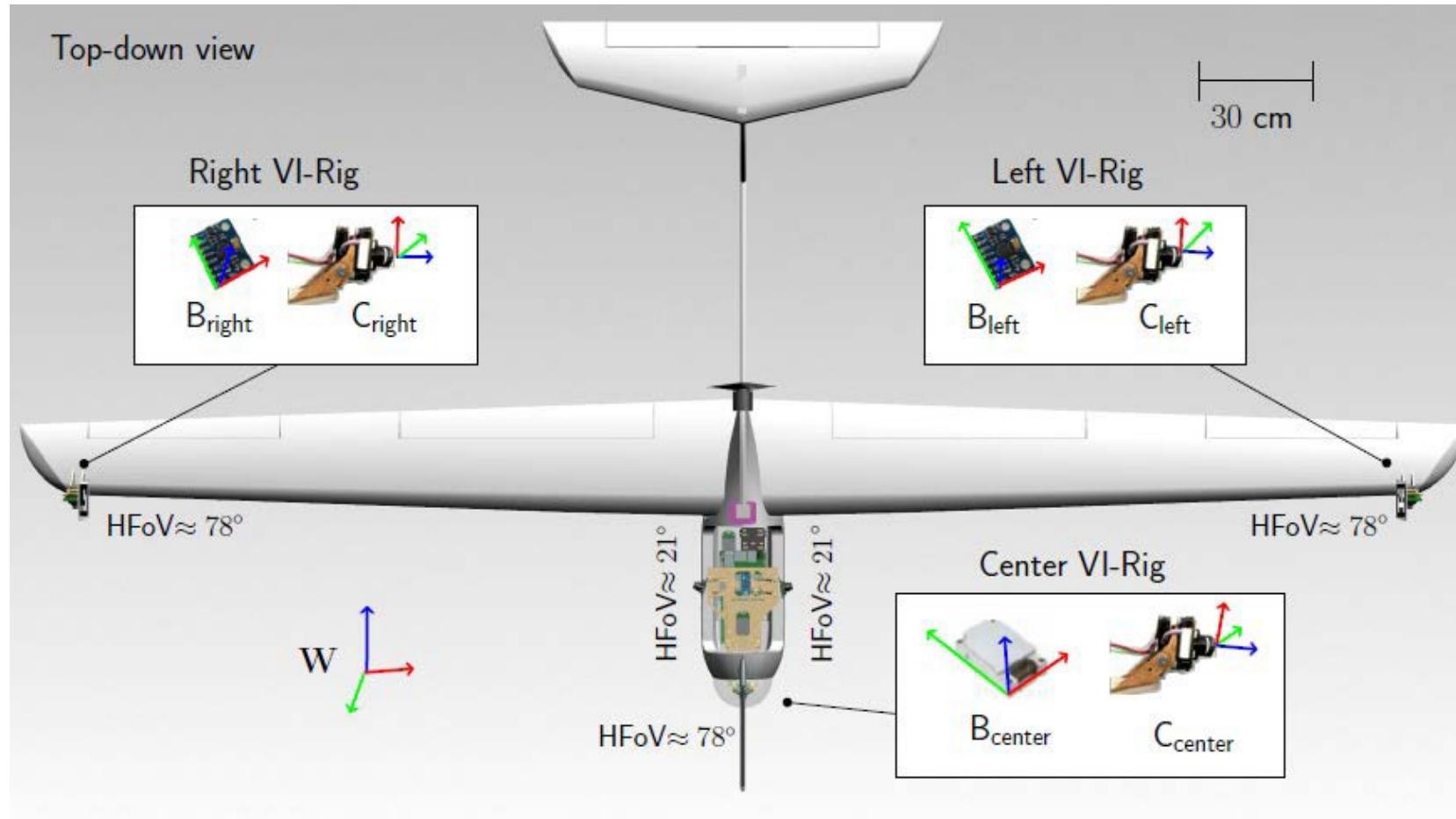
# Flexible Trinocular | Non-rigid Multi-Camera-IMU Dense Reconstruction for UAV Navigation and Mapping

3D perception

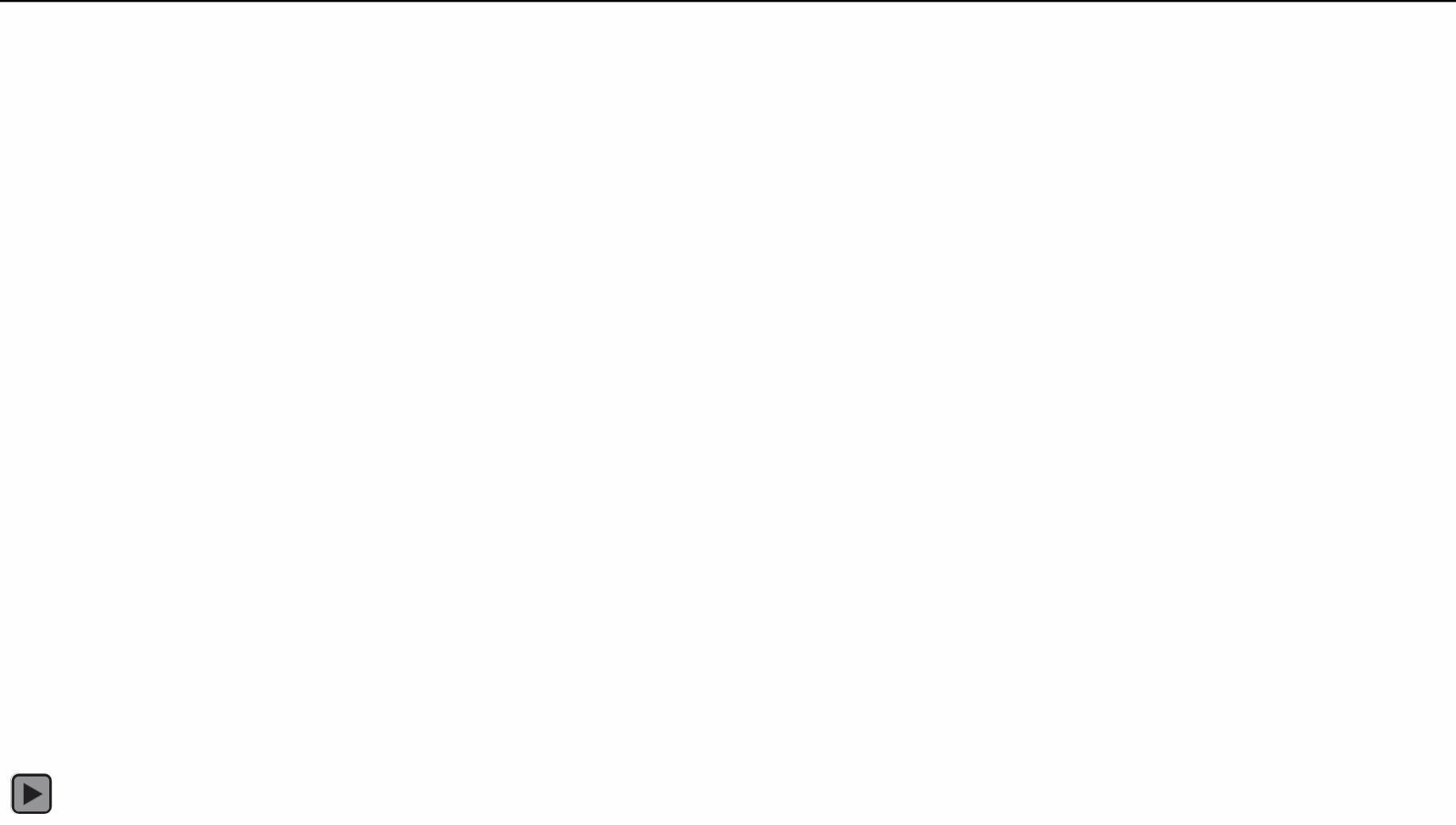
- Weight?
- Dimensions?
- Range?
- Resolution?
- Price?



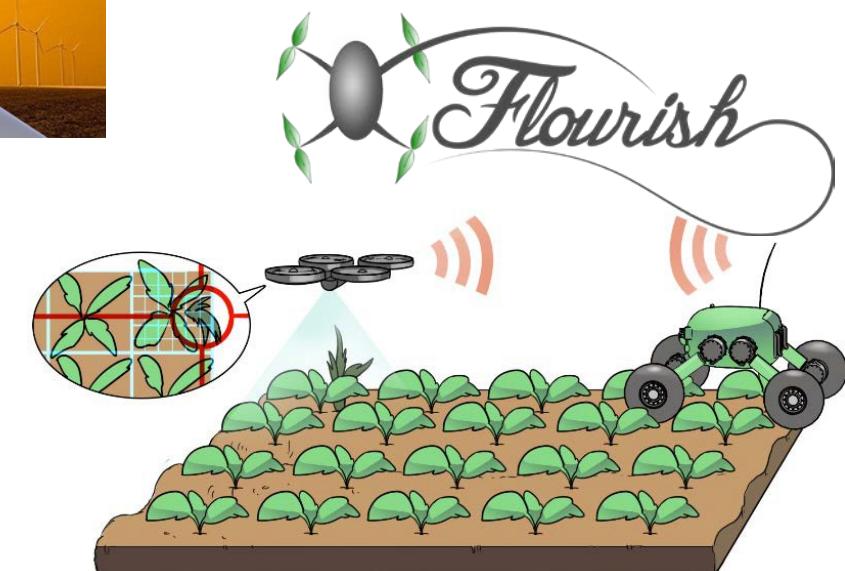
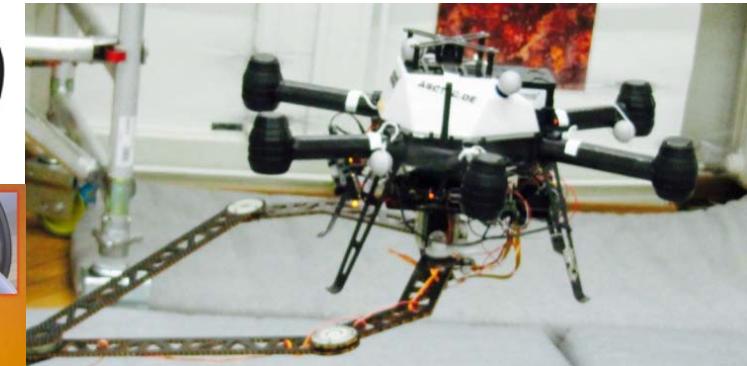
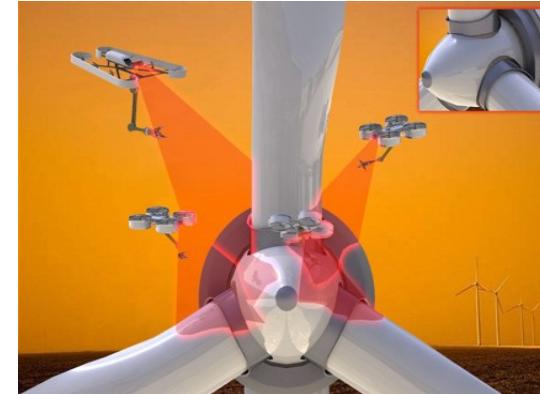
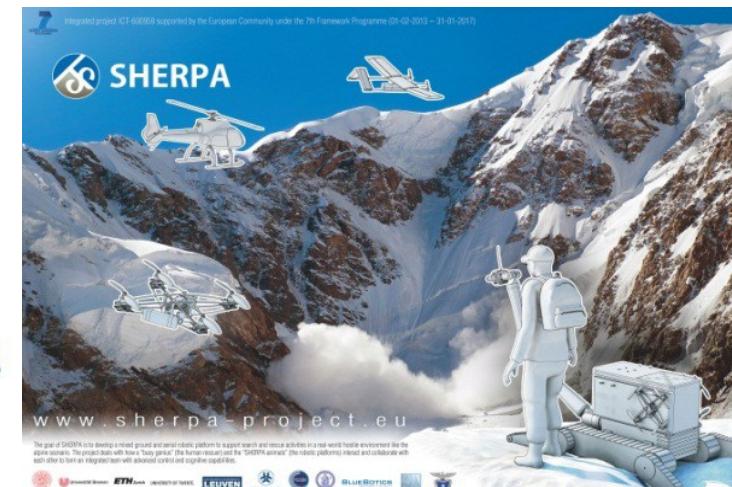
# Flexible Trinocular | Non-rigid Multi-Camera-IMU Dense Reconstruction for UAV Navigation and Mapping



# Flexible Trinocular | Non-rigid Multi-Camera-IMU Dense Reconstruction for UAV Navigation and Mapping



# Flying Robots | inspection, agriculture, search and rescue



# Smart Farming | The flying sensor platform



FLIR Tau2  
thermal cam  
640x512 px

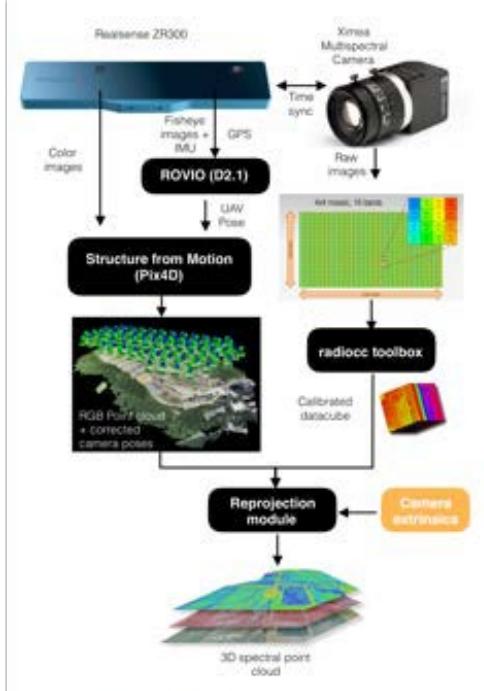
FLIR Blackfly-S  
RGB cam 5MP

Ouster OS-1-64  
64 channels LIDAR

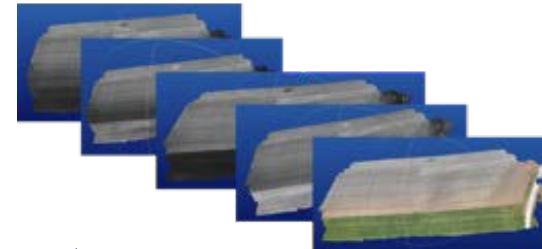
Photonfocus vis & nir  
Hyperspectral cams  
16 and 25 bands  
470-630 & 600-975 nm

# Flourish

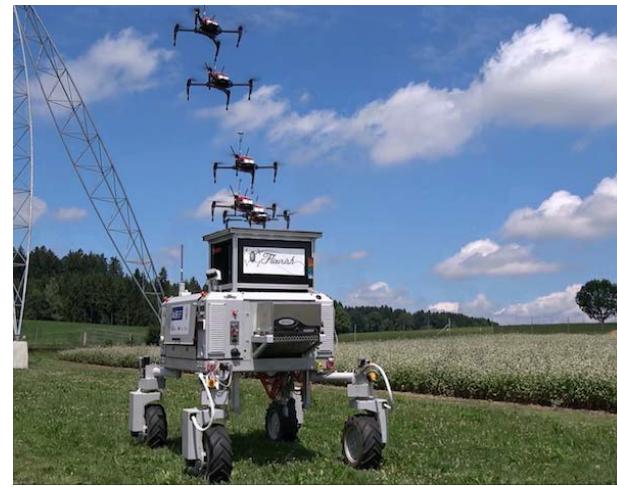
## Spatio-Temporal Spectral Environment Modeling



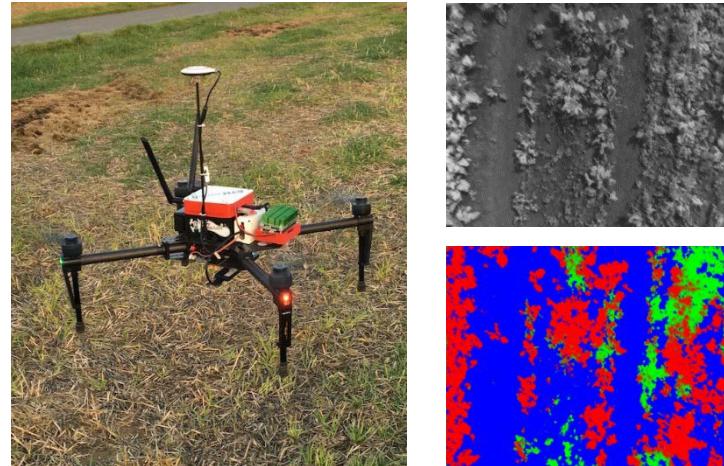
<https://youtu.be/5f1EtffW76Qc>



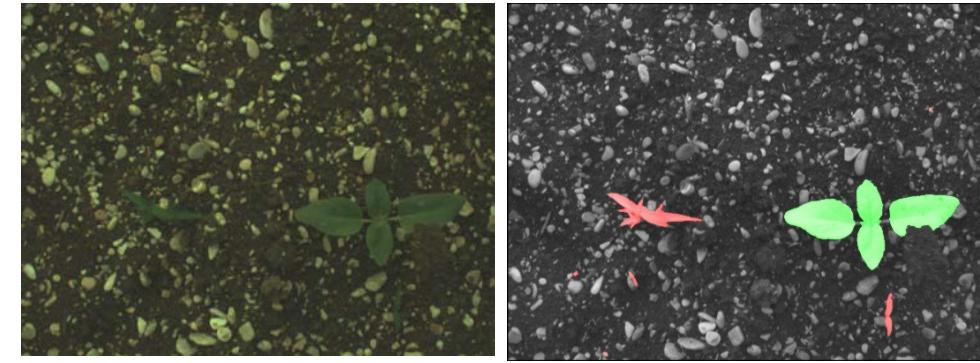
## Autonomous UAV landing



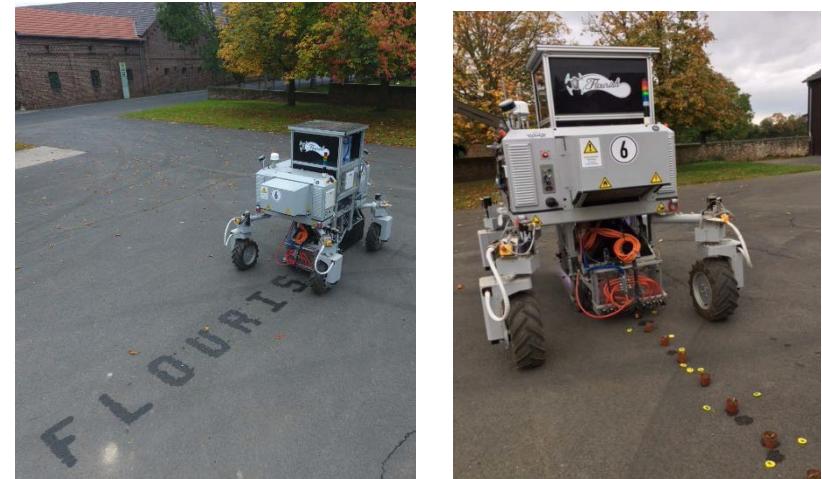
UAV onboard weed detection



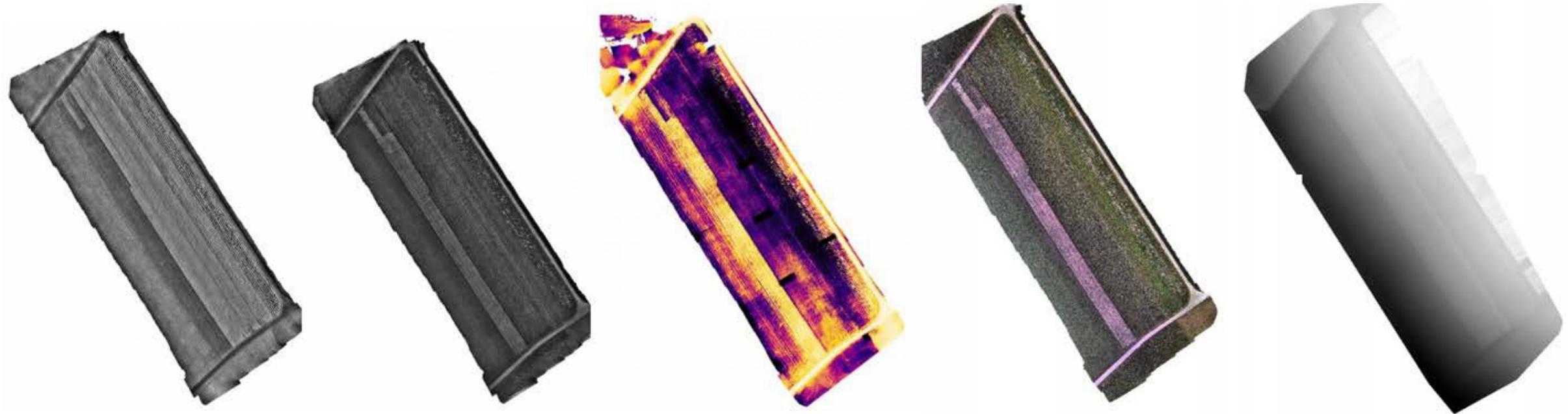
## Weed classification on UGV (Sunflower ~95% acc.)



Automated spraying and stamping



# Smart Farming | Orthorectified Maps Reflectance, thermal, RGB and DSM



25-bands NIR  
reflectance  
Photonfocus

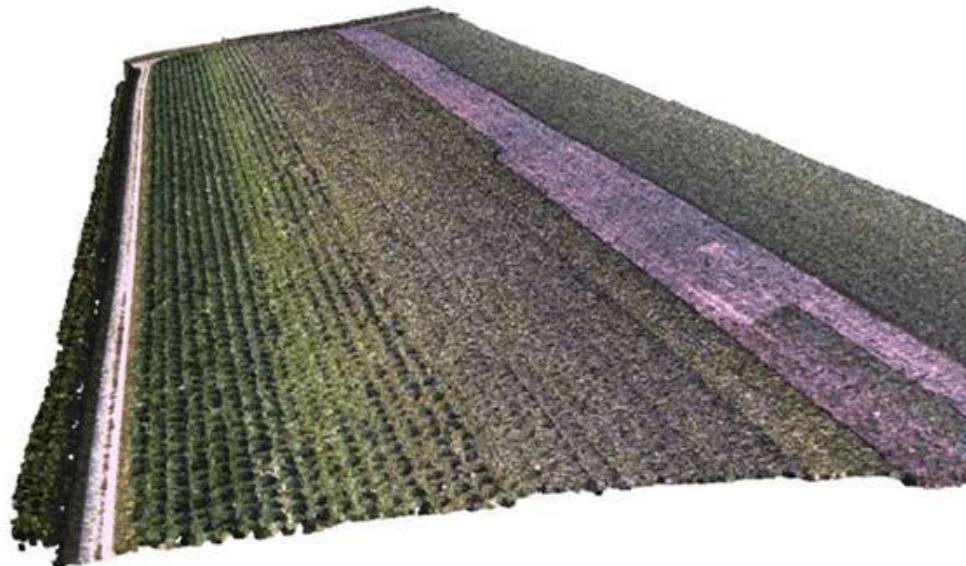
16-bands VIS  
reflectance  
Photonfocus

thermal-map  
FLIR Tau2

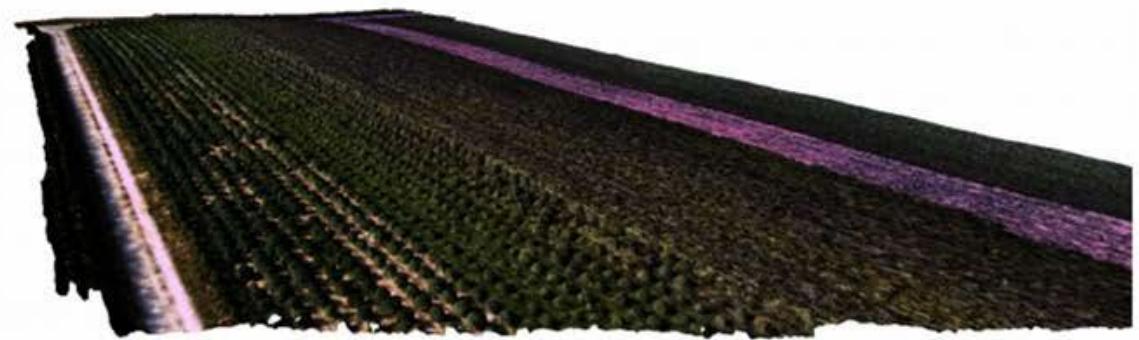
RGB-map  
FLIR Blackfly-S

DSM  
FLIR Blackfly-S

# Smart Farming | 3D Mesh Models

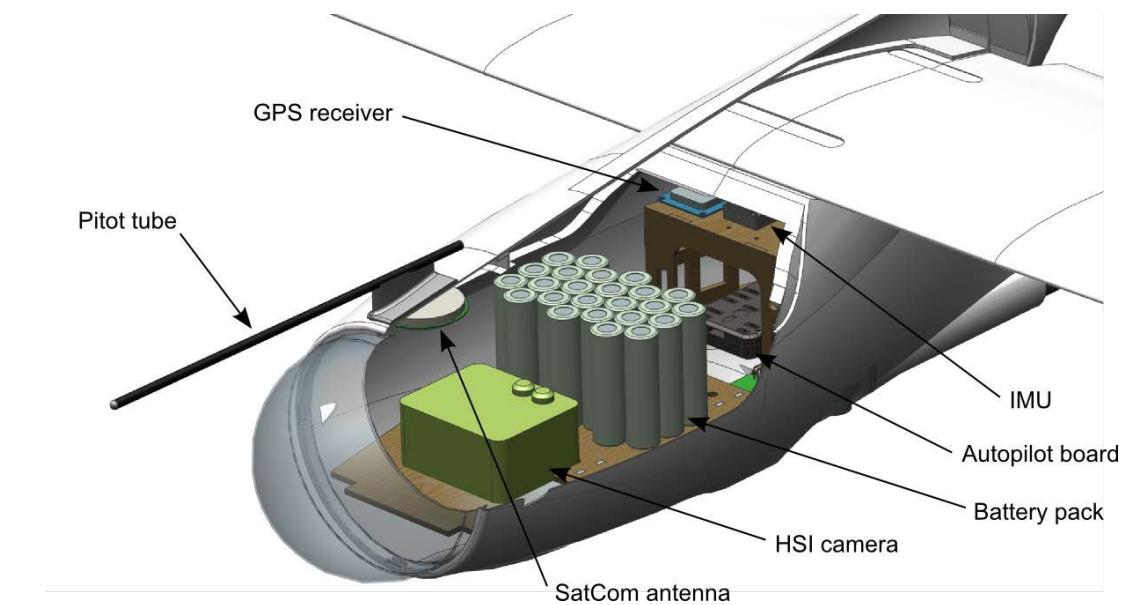


point cloud

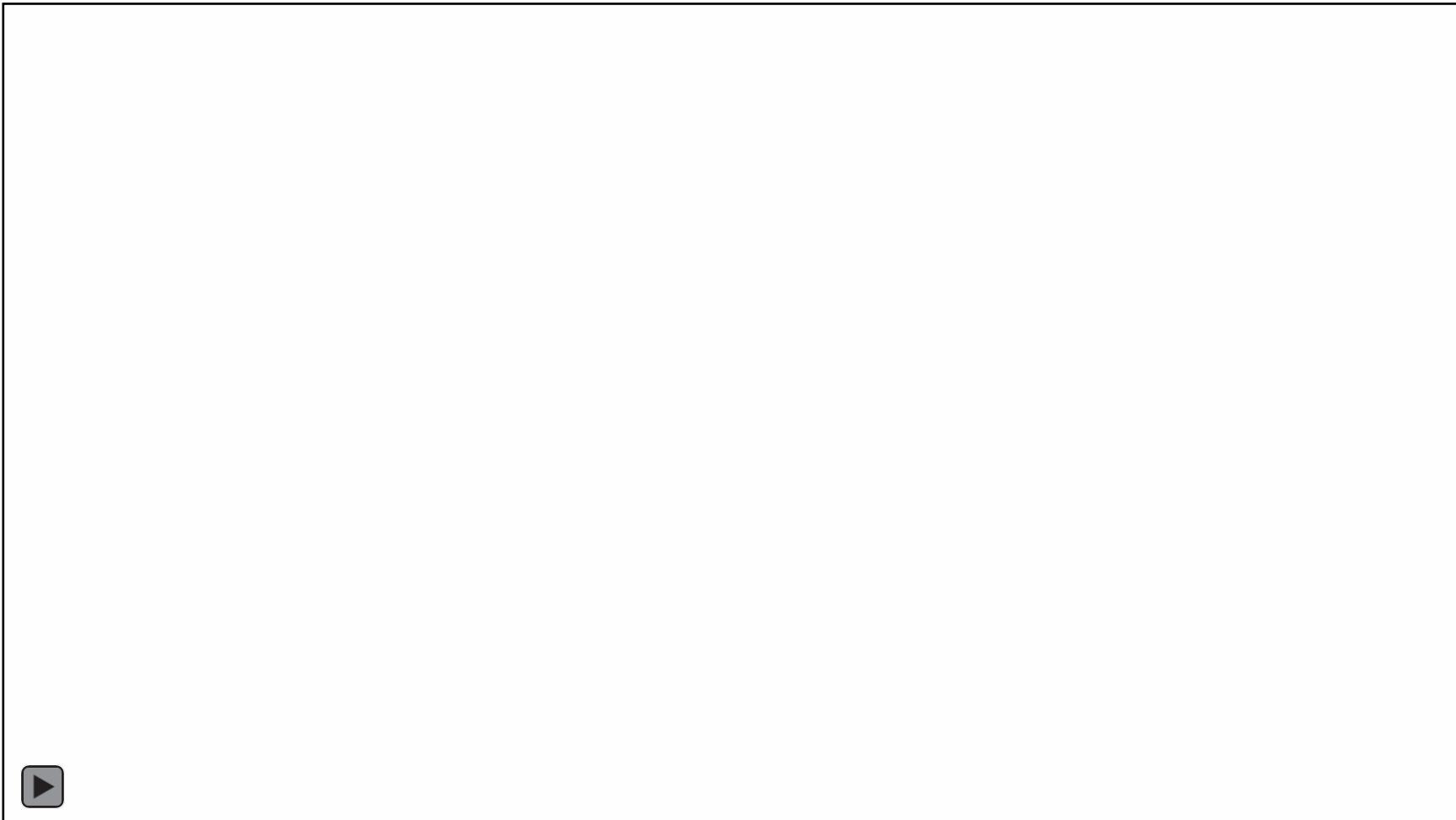


3D mesh

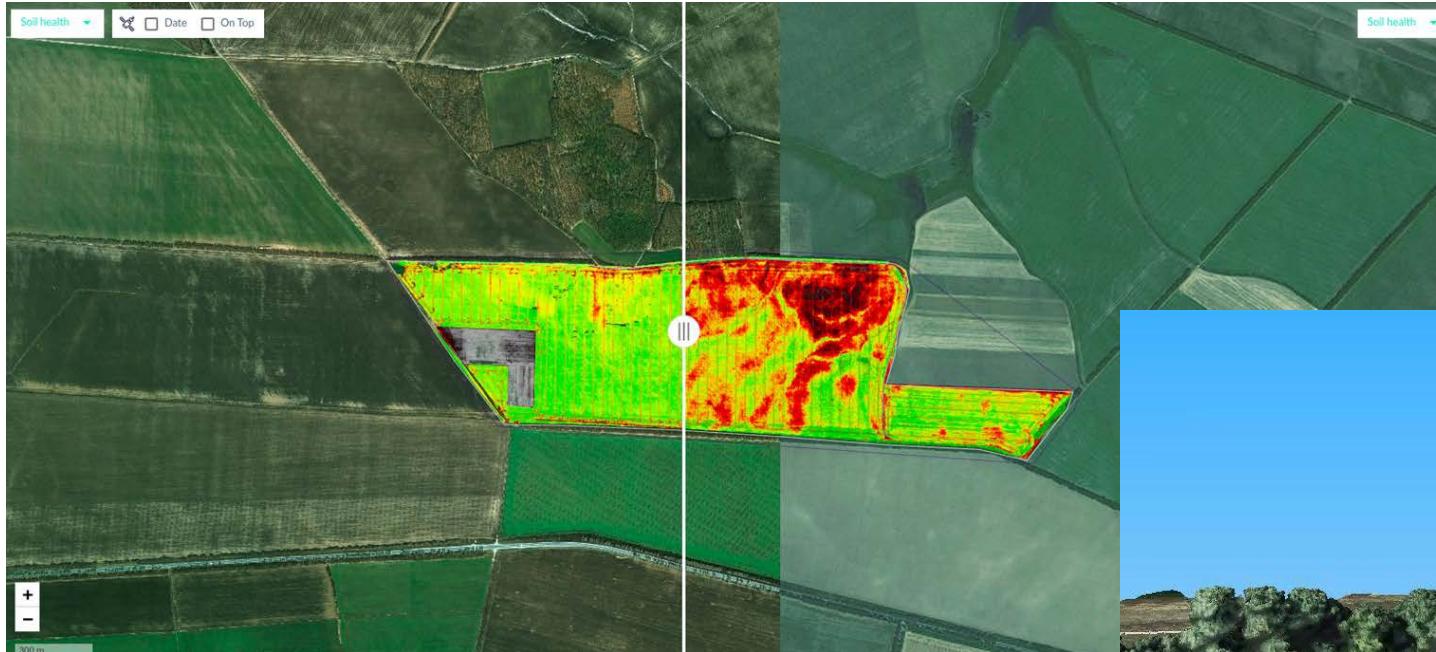
# Solar<sup>3</sup> | fixed-wing drone for ultra large coverage



# Solar<sup>3</sup> | fixed-wing drone for ultra large coverage



# Solar3 | geo-referenced 2 and 3D sensor data



# Solar3 | BVLOS (beyond visual line of sight) – January 2019



70 km autonomous flight  
Controlled via 4G from Zurich



# Drone startups out of ETH and EPFL



[sensefly.com/](http://sensefly.com/)

aerial imaging drones for professional applications



[veritystudios.com/](http://veritystudios.com/)

The magic of flying robots



[aerotain.com/](http://aerotain.com/)

blimp aerial entertainment



[fotokite.com/](http://fotokite.com/)

aerial filming made simple



[flyability.com/](http://flyability.com/)

collision-tolerant flying robot



[wingtra.com/](http://wingtra.com/)

aerial imaging drones  
for professional applications



[auterion.com/](http://auterion.com/)

software for drones



[flybotix.com/](http://flybotix.com/)

professional inspection drones



[www.voliro.ch/](http://www.voliro.ch/)

hand in the sky



# Conclusion | Drones for Environment and Agriculture Monitoring

- Drones allow for continuous monitoring of agriculture fields
  - Enables to give precise indications to the farmer
  - Enable traceability of the food value (field to customer)
- Drones technology is ready to be broadly deployed
  - Fixed-wing and hybrid drones are best adapted to fast coverage
  - However there are still various open problems
    - reliable analytics and predictions from the multi-model sensory inputs
    - autonomous flight closed to the ground
    - Integration of drones in public airspace
    - industrialization
- Technology for food
  - Robots and especially drones can make food production much more sustainable

# Thank you / Danke / Merci / Gracie

- To the ASL Team →
- Industrial partners



- Spin-off partners



- Institutional partners

