

ONERA

THE FRENCH AEROSPACE LAB

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3D laser imaging techniques to improve USaR operations for wide-area surveillance and monitoring of collapsed buildings

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General context

Our business, expertise in the field and facilities

▪ ONERA, The French Aerospace Lab

1st French actor of research on aeronautics, space and defense

2,100 persons



70 2016
ans

EPIC State-controlled entities of an industrial or commercial nature

15% of PhD students

8 Sites

▪ Missions

☒ Anticipate technological breakthroughs

☒ Promote the technology transfer to industry

☒ Realization and implementation of simulation and experimental facilities (1st European wind tunnels...)

☒ Expertise to government and industries



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General context

Our business, expertise in the field and facilities

▪ How can we improve the vision for situational awareness?

- ☒ To perform the **strategic surveillance** of the environment for various worldwide operations
- ☒ To perform the **enhanced navigation** of an aircraft, a drone or a ground vehicle

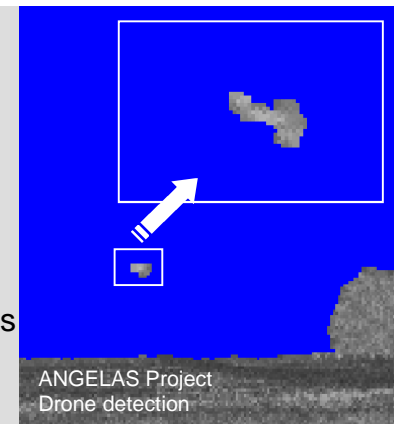


- ⇒ Imaging systems must operate **at night** in all ambient illuminations and **weather** conditions
Active / Passive Imaging systems for **security and defense applications**



▪ Performance Analysis of Sensors at ONERA

- ☒ ONERA develops **new systems** and **models** for **remote sensing applications** based on laser sources (imaging or not)
- ☒ Challenges
 - To evaluate **original** / **complementary** imaging techniques vs conventional imaging systems
 - To identify **new concepts** (3D, hyperspectral...) using new sensors



What about Laser Imaging Techniques ?

Laser Imaging

① 2D Flash Laser Systems

1

Burst illumination imaging system combines active laser illumination with time gating
Long range aerial / terrestrial applications: Defense, Security and Survey
Targeting, camouflage, observation, up to identification

② 3D Laser Scanner Systems

2

Range estimation using pulsed laser and scanner \Rightarrow 3D point clouds restoring the shape of the target
Time Of Flight (TOF) + Full Wave Form imaging technique
Applications to camouflage, detection, up to identification

③ 3D Focal Plane Array (FPA) Systems

3

Multi-pixel 3D arrays (eg. photon counting avalanche photodiodes) provide a 3D laser image with one single large laser beam, thanks to the temporal independence of each pixel on the matrix
3D Geiger-mode Avalanche PhotoDiode (GmAPD) array offers single photon detection capability

Laser Imaging

① 2D Flash Laser Systems

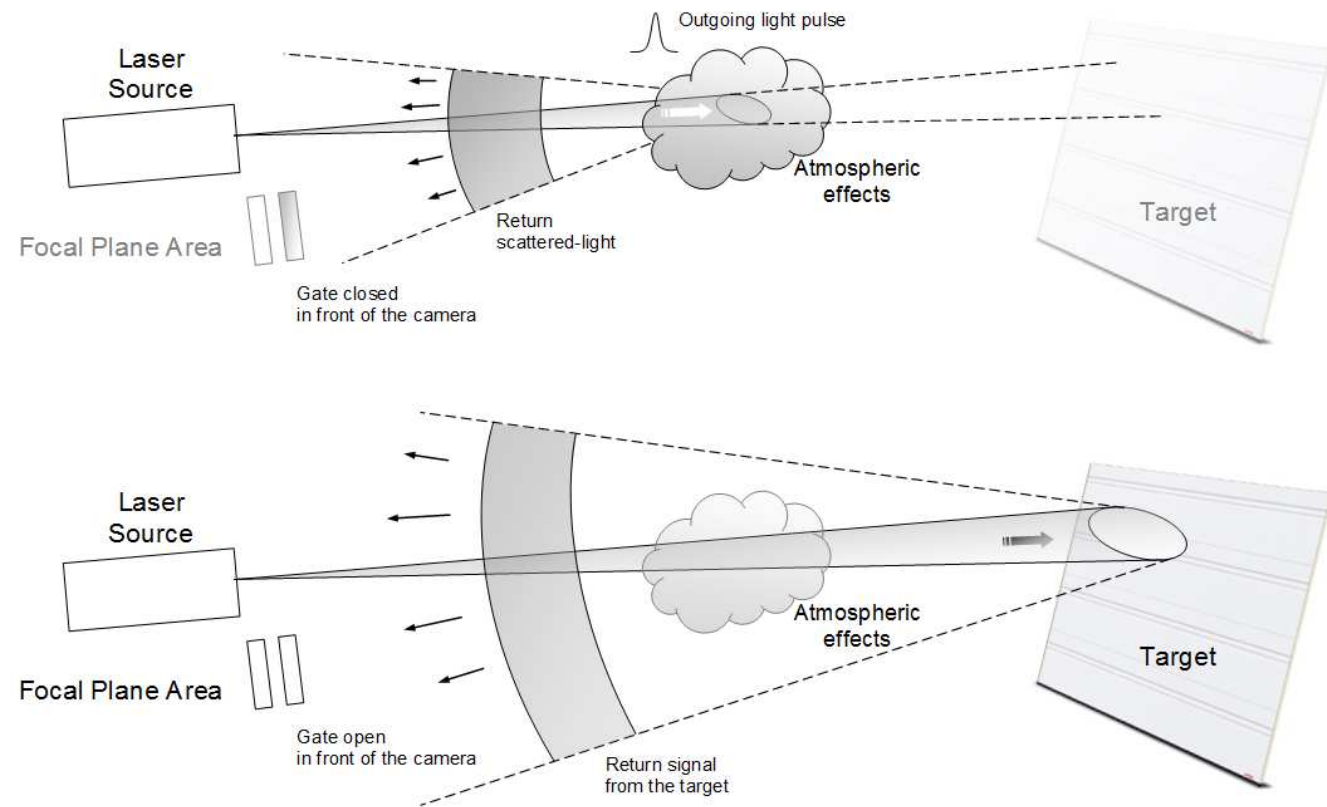
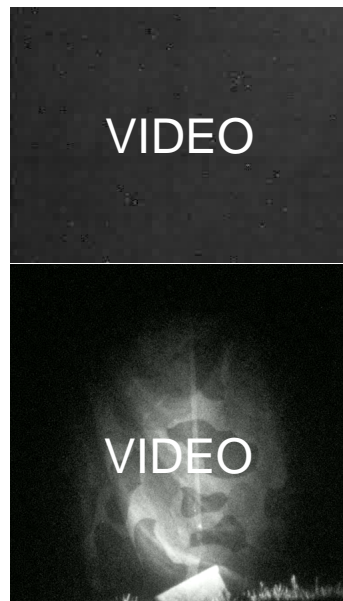
1

Burst illumination imaging system combines active laser illumination with time gating

Long range aerial / terrestrial applications: Defense, Security and Survey

Targeting, camouflage, observation, up to identification

- ✓ Observation at long range
- ✓ 2D video mode
- ✓ Identification
- ✗ Resolution and SWaP ?



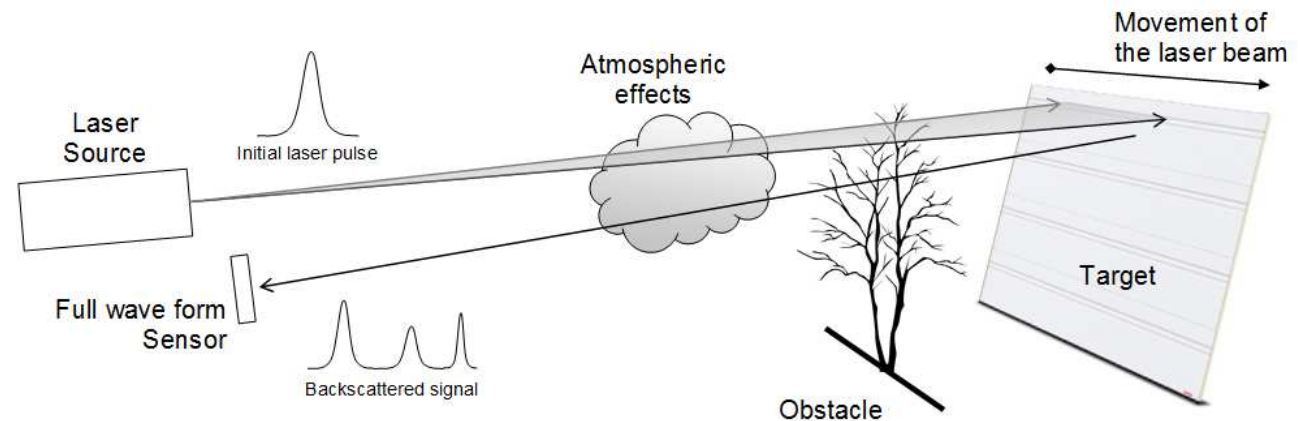
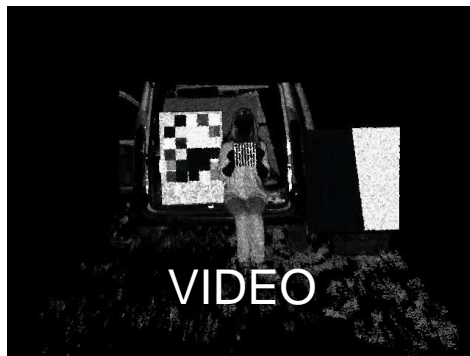
Laser Imaging

② 3D Laser Scanner Systems

Range estimation using pulsed laser and scanner \Rightarrow 3D point clouds restoring the shape of the target
 Time Of Flight (TOF) + Full Wave Form imaging technique
 Applications to camouflage, detection, up to identification

- ✓ Observation at short / medium range
- ✓ Recognition
- ✓ Full wave form information, not only first or last echoes
- ✗ Single image

ONERA simulation tools for performance analysis



Laser Imaging

② 3D Laser Scanner Systems

2

Range estimation using pulsed laser and scanner \Rightarrow 3D point clouds restoring the shape of the target
 Time Of Flight (TOF) + Full Wave Form imaging technique
 Applications to camouflage, detection, up to identification

Enhanced vision in all weather conditions

Natural / controlled bad weather conditions

Cloud chamber

A facility to create controlled fog and rain at ONERA

ONERA – Optronics Department ©2017



Controlled meteorological phenomena

Temperature, Humidity, Wind speed, PSD,
 Radiance, Pressure, Rain rate...



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Laser Imaging

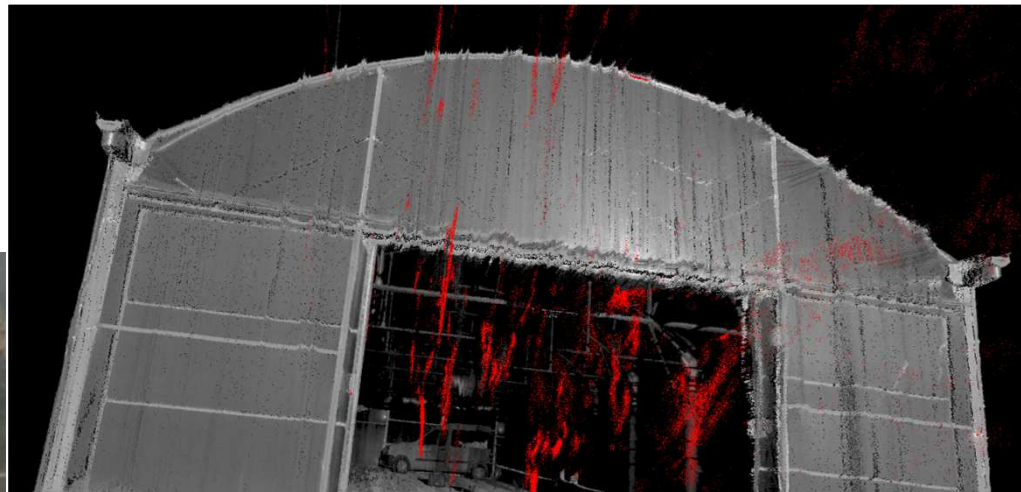
② 3D Laser Scanner Systems

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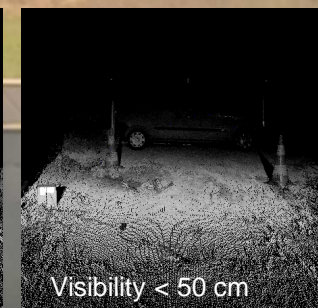
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Enhanced vision in all weather conditions

Natural / controlled bad weather conditions



FOG particles can be removed from the image thanks to the optical properties knowledge and the FWF signal
 \Rightarrow The surrounding perception increases



Laser Imaging

② 3D Laser Scanner Systems

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Range estimation using pulsed laser and scanner \Rightarrow 3D point clouds restoring the shape of the target
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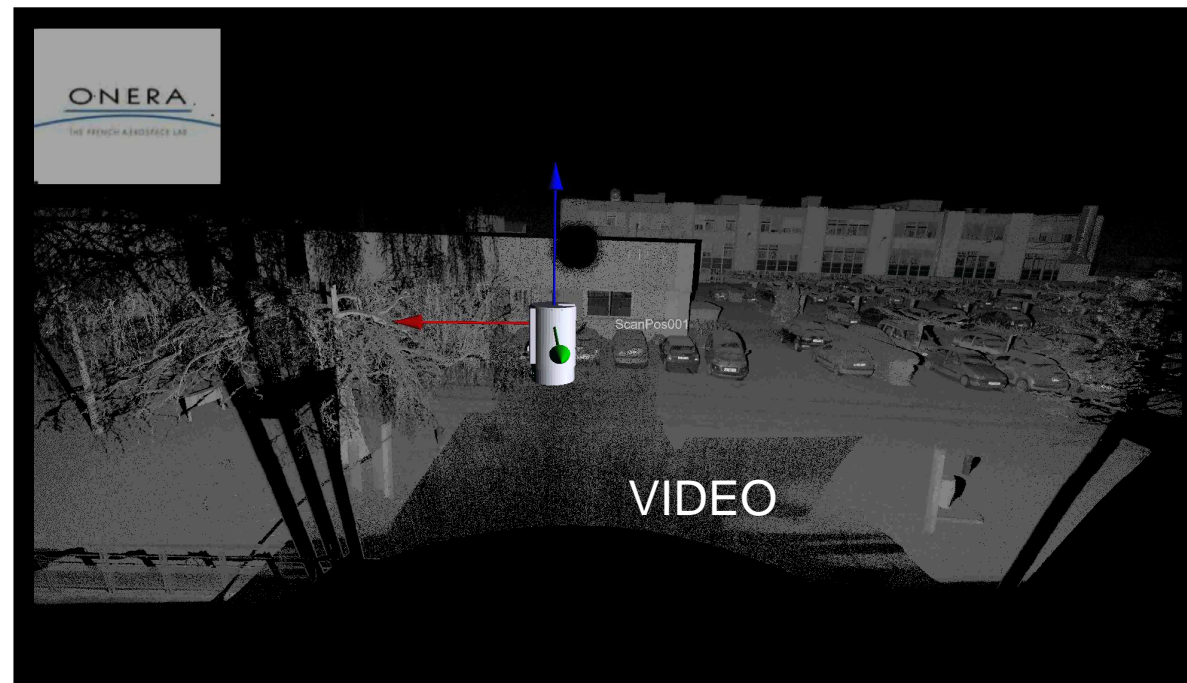
Enhanced vision in all weather conditions

Validation of the real-time processing algorithms



**Real-time
processing**

Snow



Laser Imaging

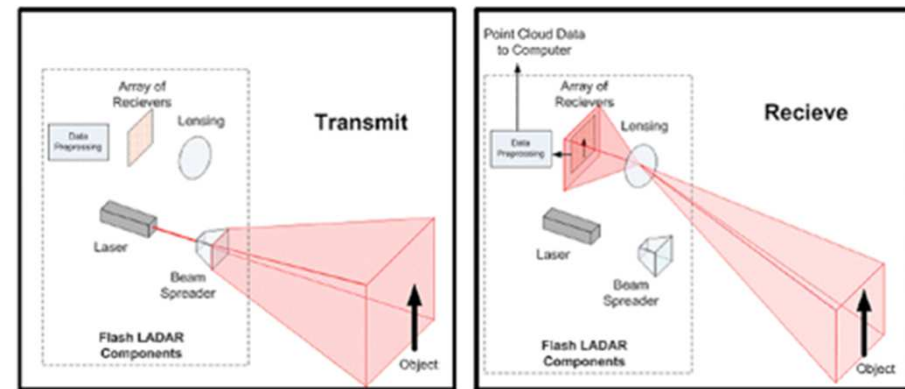
③ 3D Focal Plane Array (FPA) Systems

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3D Geiger-mode Avalanche PhotoDiode (GmAPD) array offers single photon detection capability

- ✓ Observation at very long range (a pencil at 7km)
- ✓ 3D video mode
- ✓ Object detection and surveillance applications
- ✓ Real-time accurate DSM generation
- ✗ Small matrix size (128x32pxl)
- ✗ Big data storage



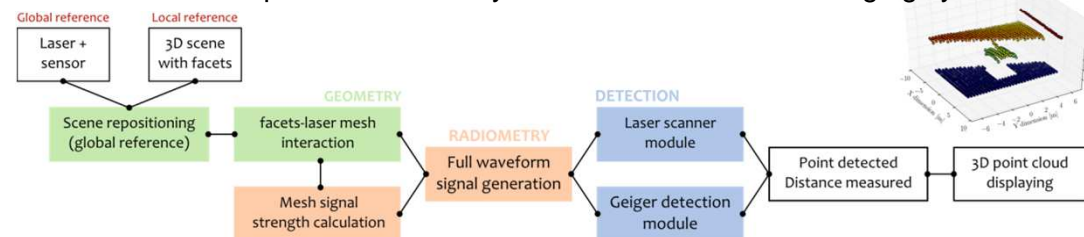
Research and first concepts : TRL 3-4

System developed by Onera including a 3D FPA imaging system



MATLIS code:

A new version for performance analysis of FWF and 3DFPA imaging systems



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Laser Imaging

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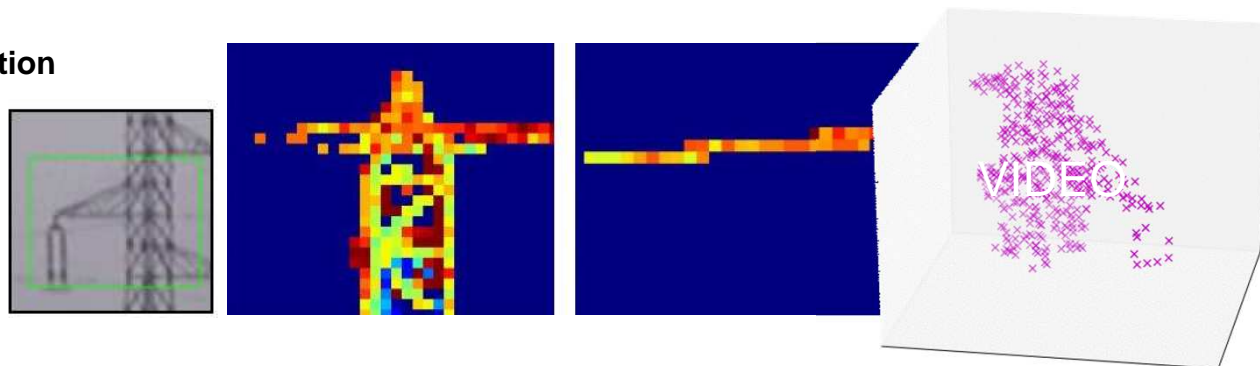
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Obstacle detection in high resolution

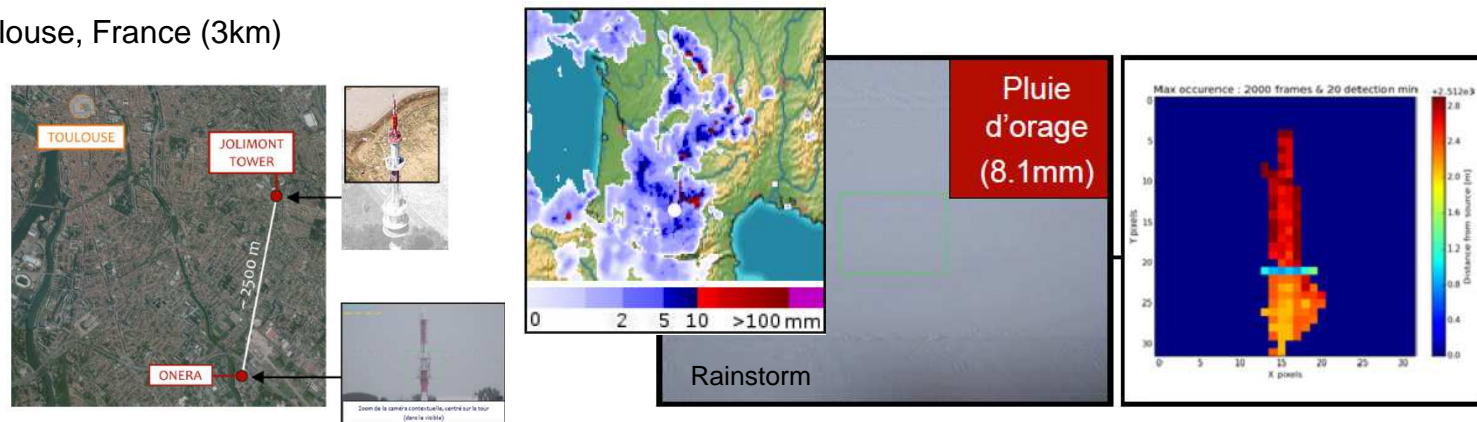
Cables at several kilometers

Day and night vision



Enhanced vision in all weather conditions

Jolimont Tower in Toulouse, France (3km)



3D laser imaging and USaR operations

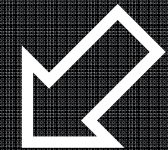


■ INACHUS Project

Objectives and approaches

To achieve a significant time reduction related to Urban Search and Rescue phase

To provide wide-area situation awareness solutions for improved detection and localization of the trapped victims



www.inachus.eu



3D laser imaging and USaR operations



■ INACHUS Project

Wide-area surveillance tools for monitoring of collapsed buildings

1. Wide area in limited resolution (~ 1 m) from drones
2. Small scale in high resolution (< 10 cm) from ground and drones

- Up to the area of a **city** in limited resolution
 - Compact drones, easy to deploy and operate (less than 1 hour)
 - Available under **bad weather conditions** (rain, fog, haze, wind)
 - Available **H24** (day and night vision)
-
- ✓ Classification of the typologies (building, road, tree, vegetation,,)
 - ✓ Maps of rescue paths
 - ✓ Classification maps of buildings with associated survival probabilities



1

10 x 10 km²

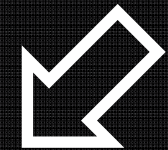
3D laser imaging and USaR operations



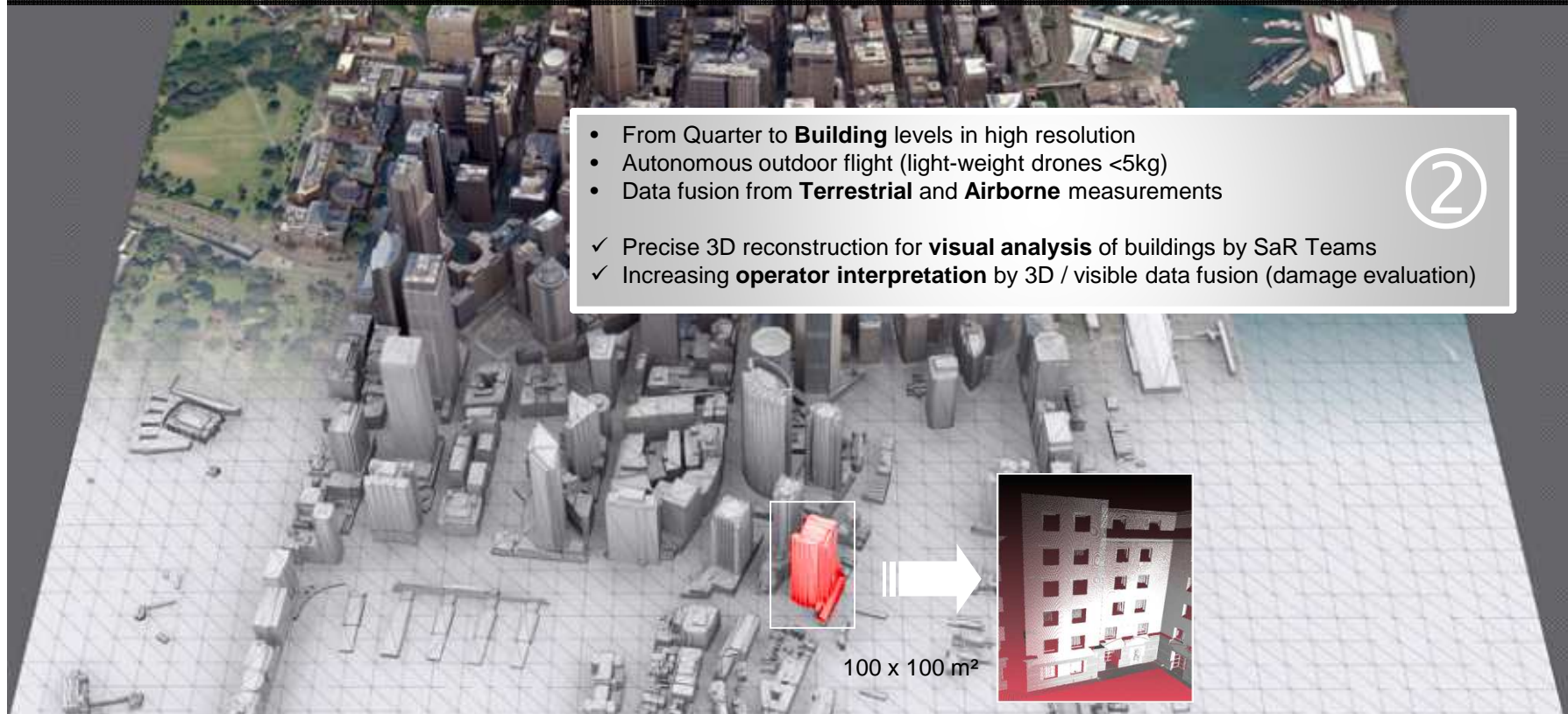
INACHUS Project

Wide-area surveillance tools for monitoring of collapsed buildings

1. Wide area in limited resolution (~ 1 m) from drones
2. Small scale in high resolution (< 10 cm) from ground and drones



- From Quarter to **Building** levels in high resolution
 - Autonomous outdoor flight (light-weight drones < 5 kg)
 - Data fusion from **Terrestrial** and **Airborne** measurements
- ②
- ✓ Precise 3D reconstruction for **visual analysis** of buildings by SaR Teams
 - ✓ Increasing **operator interpretation** by 3D / visible data fusion (damage evaluation)



3D laser imaging and USaR operations



■ INACHUS Project

Experiments to collect **3D data** with aerial / ground-based systems \Rightarrow Dense high-accuracy data
 3D laser cameras (3D TOF) integrated on helicopter UAV and gyrocopter
 50-100kg, 2-3m rotor span, payload 5-10kg
 3D measurements in Ågesta, Toulouse... Scenarios shared with ALL partners + End-Users



Gyrocopter experiments



Experiments in Toulouse, France
 March 2016



Ground laser scanner

VIDEO



3D point cloud (FWF) on wide area from gyrocopter platform

3D laser imaging and USaR operations



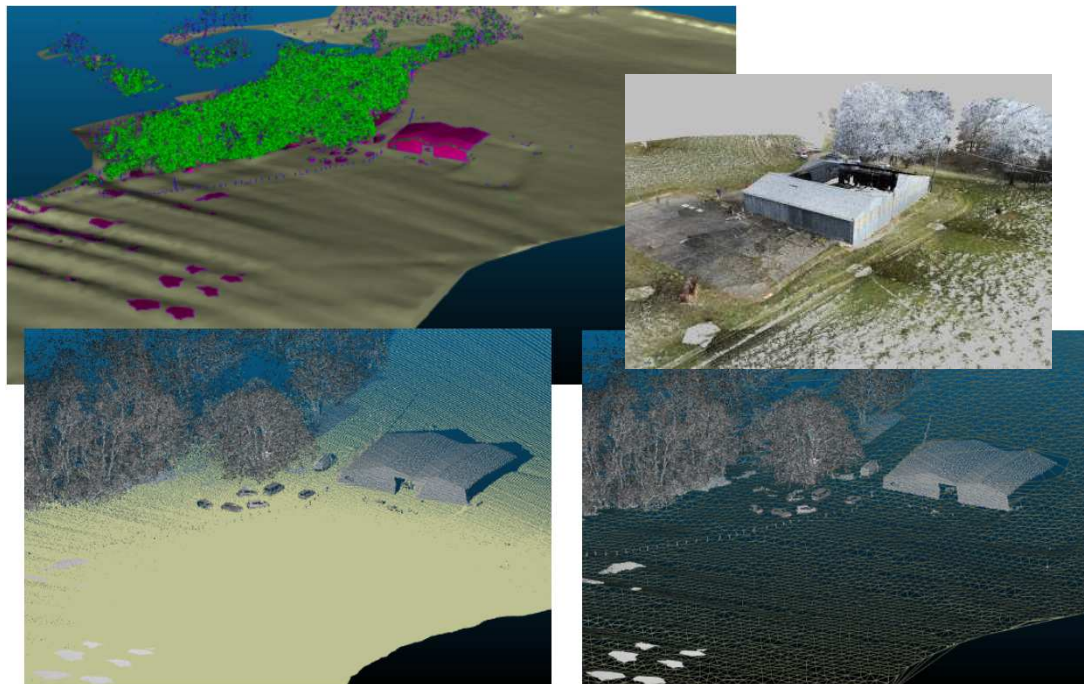
■ INACHUS Project

Data fusion from 3D aerial and ground data

Airborne and ground-based laser data collected during common experiments
⇒ Input data for subsequent processing (3D data fusion and exploitation)



- ▶ 3D measurements through **image analysis** with light-weight UAV (<5kg)
- ▶ Validation test in different weather conditions and comparison with laser imaging



VIDEO

Data fusion
Digital elevation / surface models
Identification by segmentation

3D laser imaging and USaR operations

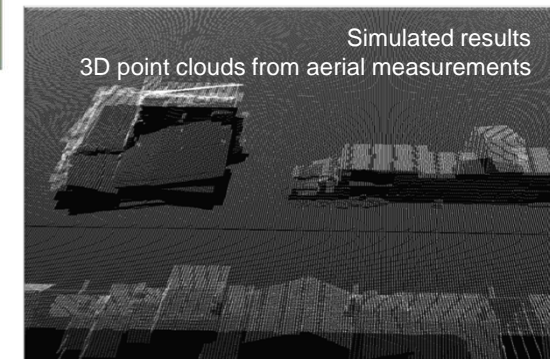
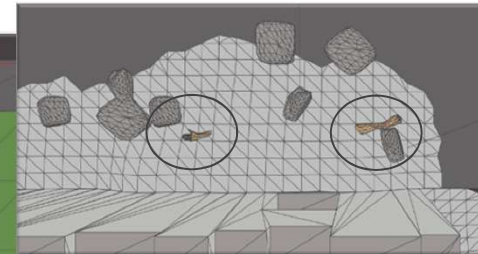
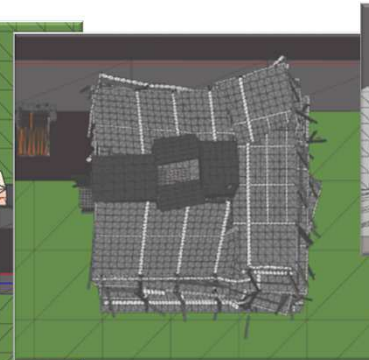


INACHUS Project

Performance validation and simulation of the systems

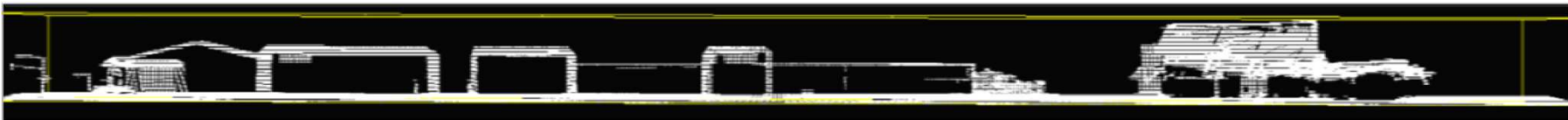
Numerical 3D data point clouds

To test / define strategies of airborne observation considering both ethical issues and USaR requirements



MATLIS code for 3D Laser Scanner **performance analysis**

End-to-end / Physical model including optical properties of materials, turbulence effects, bad weather conditions...



3D laser imaging and USaR operations



INACHUS Project

To achieve a significant time reduction related to Urban Search and Rescue phase
To provide wide-area situation awareness solutions for improved detection and localization of the trapped victims



Expected results

New methods to refine priority areas

Based on satellite data + actual pop. dynamics estimation

High resolution 3D digital surface/terrain models

Measured on a disaster site

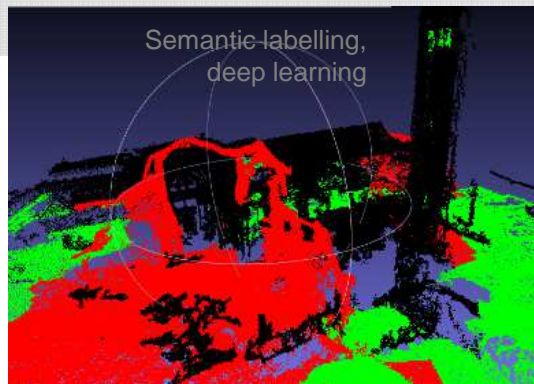
Probability map of survival space, maps of rescue paths and dasymetric population

New data processing and fusion methods

3D mapping (UAV / ground measurements + passive / laser)

New semantic analysis methods

3D damage assessment and SoTA process



- ▶ **Point clouds and images**
- ▶ Annotation of point clouds
- ▶ Data exchange to the COP
- ▶ Semantic labelling





Questions

Thank you for your attention

