ECHORD++

The European Coordination Hub for Open Robotics Development

ECHORD++ Review Meeting

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EURECAT
Aerial Robot for Sewer Inspection

14/02/2017
Luxembourg

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Aerial Robot for Sewer Inspection

PDTI Urban Robotics: Sewer inspection

Public end-user Driven Technological Innovation

Sewer inspections require many humans to work in risky and unhealthy conditions.

The current need of **the City of Barcelona** is:

- reducing the labour risks,
- improving the precision of sewer inspections
- and optimizing sewer cleaning expenses

Introducing a **robotics solution** in this process aims at addressing all them.

Sewer inspection: Current procedures

The sewer network of Barcelona is 1532 km long

Approximately 50% is accessible to workers

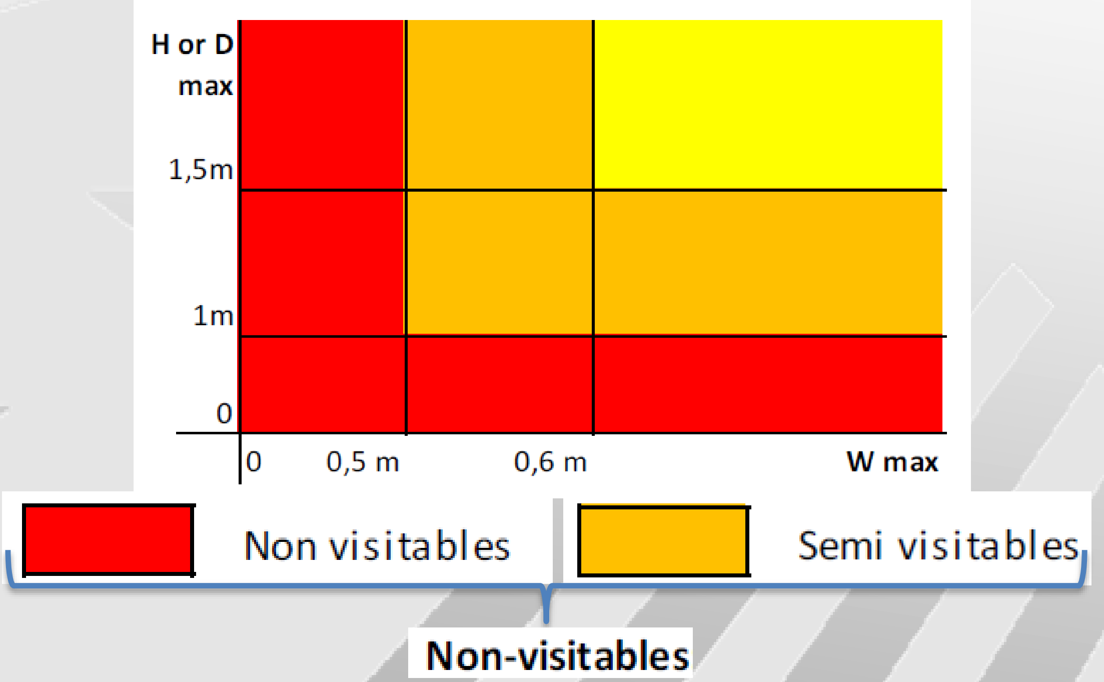
Workers walk all along the pipe and perform visual inspections and decide interventions

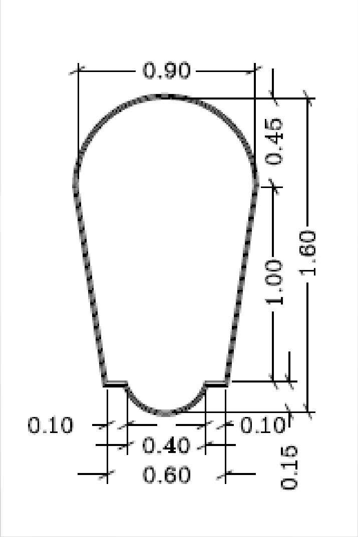
Special health and safety measures are required + other risks like slippery sections, obstacles or biological risks from the potential contact with wastewater

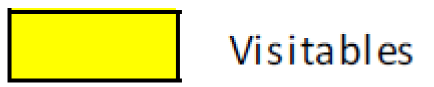
Currently: about 1.5 km of sewer every 6 hours

Sewer accessibility

Three categories:







TYPE OF SEWER	LENGTH (m)	PERCENTAGE
Non visitable sewers	541.000	35%
Semi visitable sewers	148.000	10%
Visitable sewers	843.000	55%
TOTAL	**1.532.000**	**100%**

Sewer accessibility

TYPE OF SEWER	LENGTH (m)	PERCENTAGE
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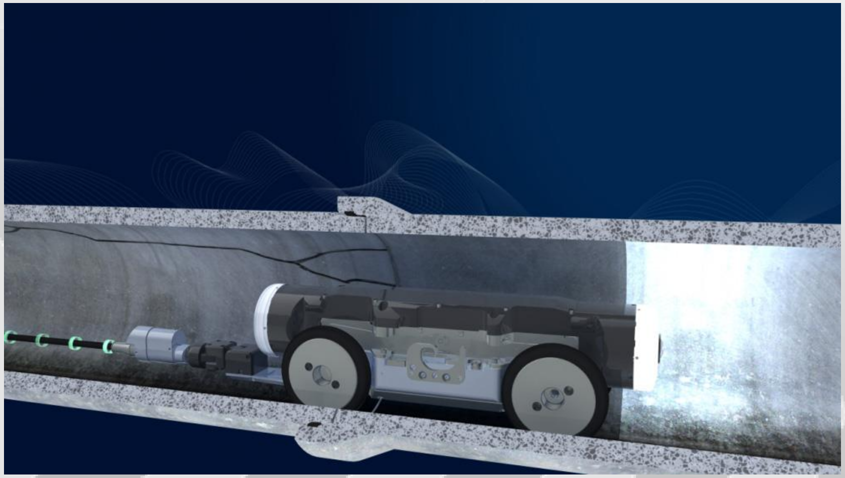
TOTAL	**1.532.000**	**100%**

State of the art in Inspection Vehicles

There exists some inspection vehicles, usually tethered and teleoperated, equipped with several type of sensors, capable to illuminate and perceive the environment and generate models of the sewer.



Courtesy: IBAK

Echord ++ seeks advances in:

Robot autonomy

Real-Time Decision Making

Mobility

Possibility to Focus on Defects

Functional Requirements

FUNCTIONS			WEIGHT	
Sewer serviceability inspection	Sewer performance (at least 1000 lineal meter/labour day)		10%	**80%**
	Images (Video)		40%	
	Geometric analysis (scanning)		20%	
	Monitoring	Air	9%	
		Water	1%	
Structural defect inspection				**15%**
Sampling				**5%**

Operational Requirements

perception

Integration in the environment

robustness

dependability

scalability

adaptability

intuitiveness

endurance

decisional autonomy

communication

cognitive ability

configurability

flexibility

motion capability

ARSI Robot

ARSI Consortium

The ARSI Consortium is composed by:

The consortium covers the entire value chain including:

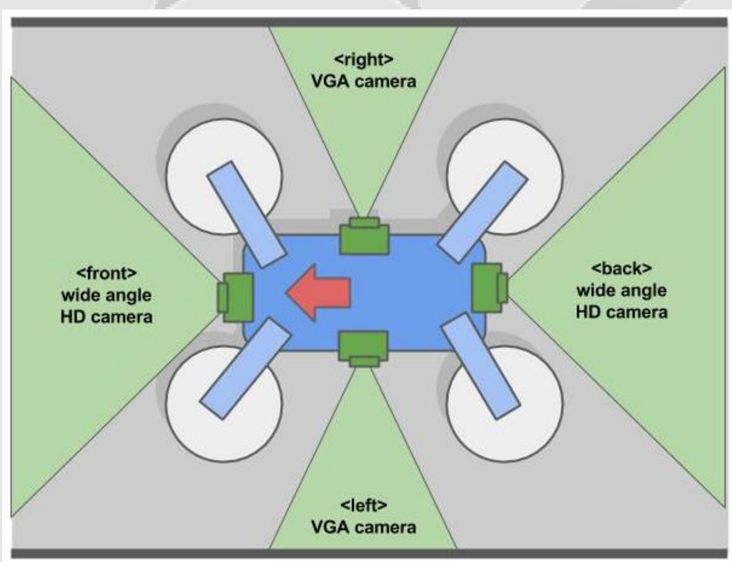
- FCC is a world reference company in environmental urban services company,
- a worldwide leader in sewer inspection robots manufacturing
- a research center with experience in both aerial robots for harsh environment and perception
- a company specialized in aerial robots operation, manufacturing, simulation and training.

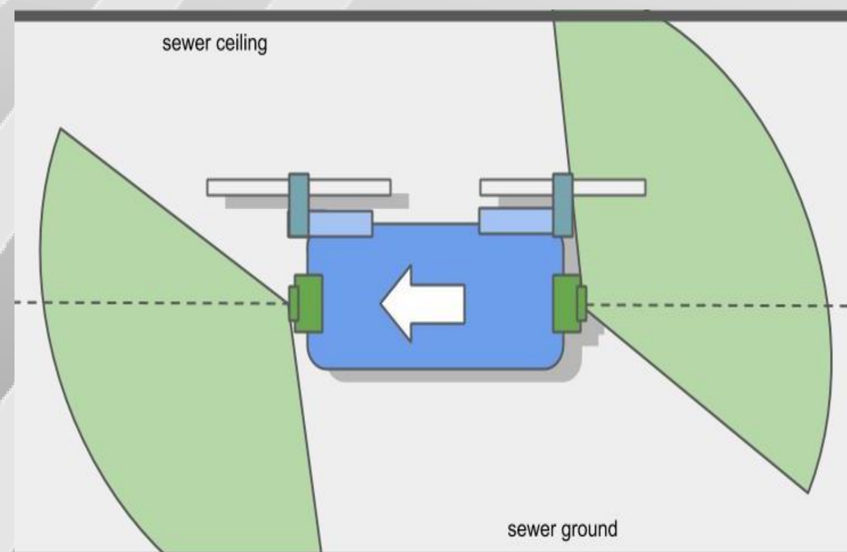
The ARSI concept

ARSI is

- a micro aerial vehicle (MAV), multi-rotor type,
- endowed with sensors for
  - its safe autonomous navigation along the network and
  - data collection for its inspection.
- to be fully integrated into FCC standard inspection procedures

The ARSI concept





Pros and Cons

Advantages

High-maneuverability

Overcomes mobility constraints with obstacles

Offers faster inspections

Untethered

Drawbacks

Strong constraints on size, weight and energy

Low weight sensors

Limited endurance

Untethered

ARSI Objectives

The ARSI Consortium is targeting the following objectives:

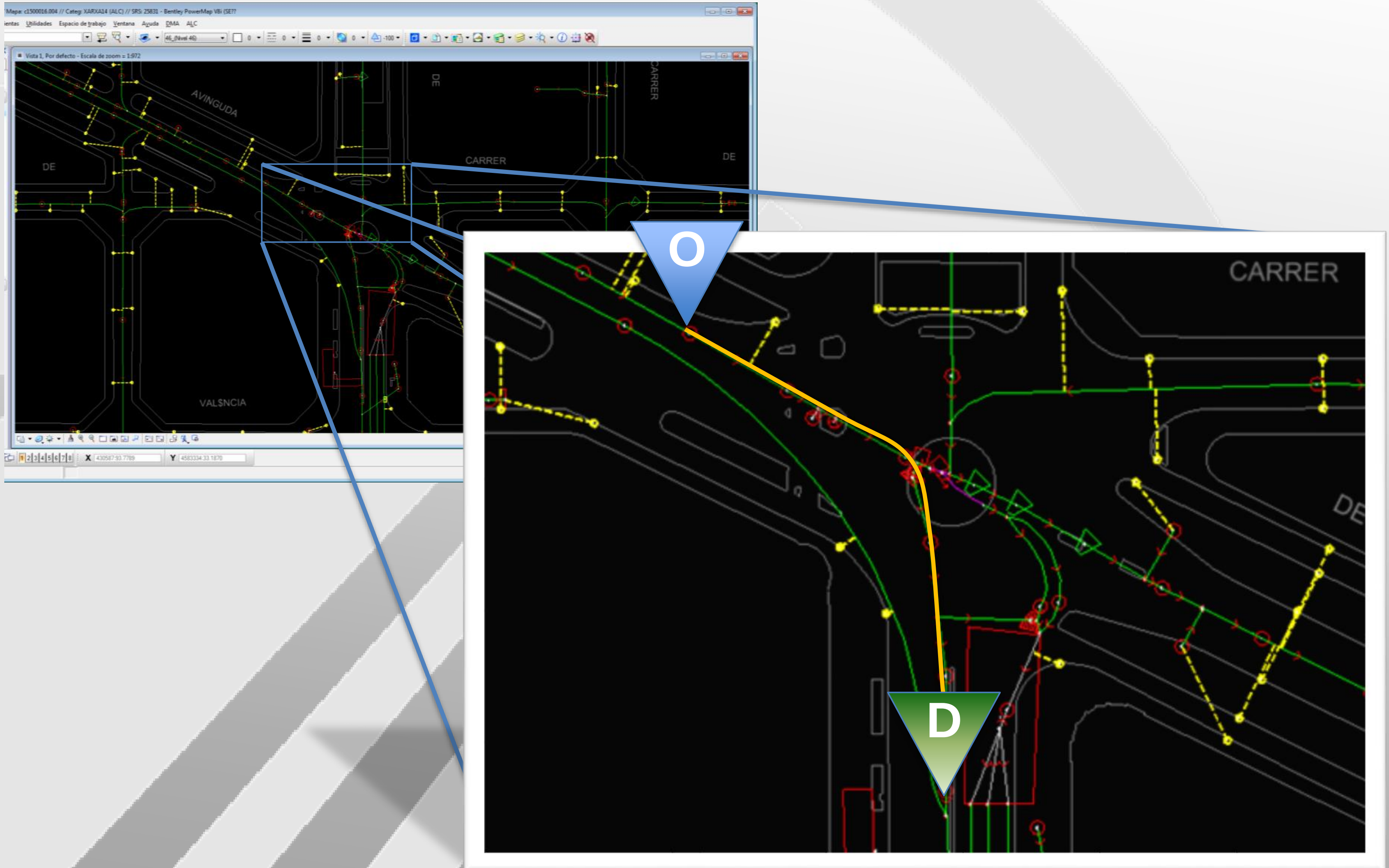
- **Objective 1: Adaptation of a MAV for sewer inspection**

- **Objective 2: Development of an assured navigation system for confined underground environments**

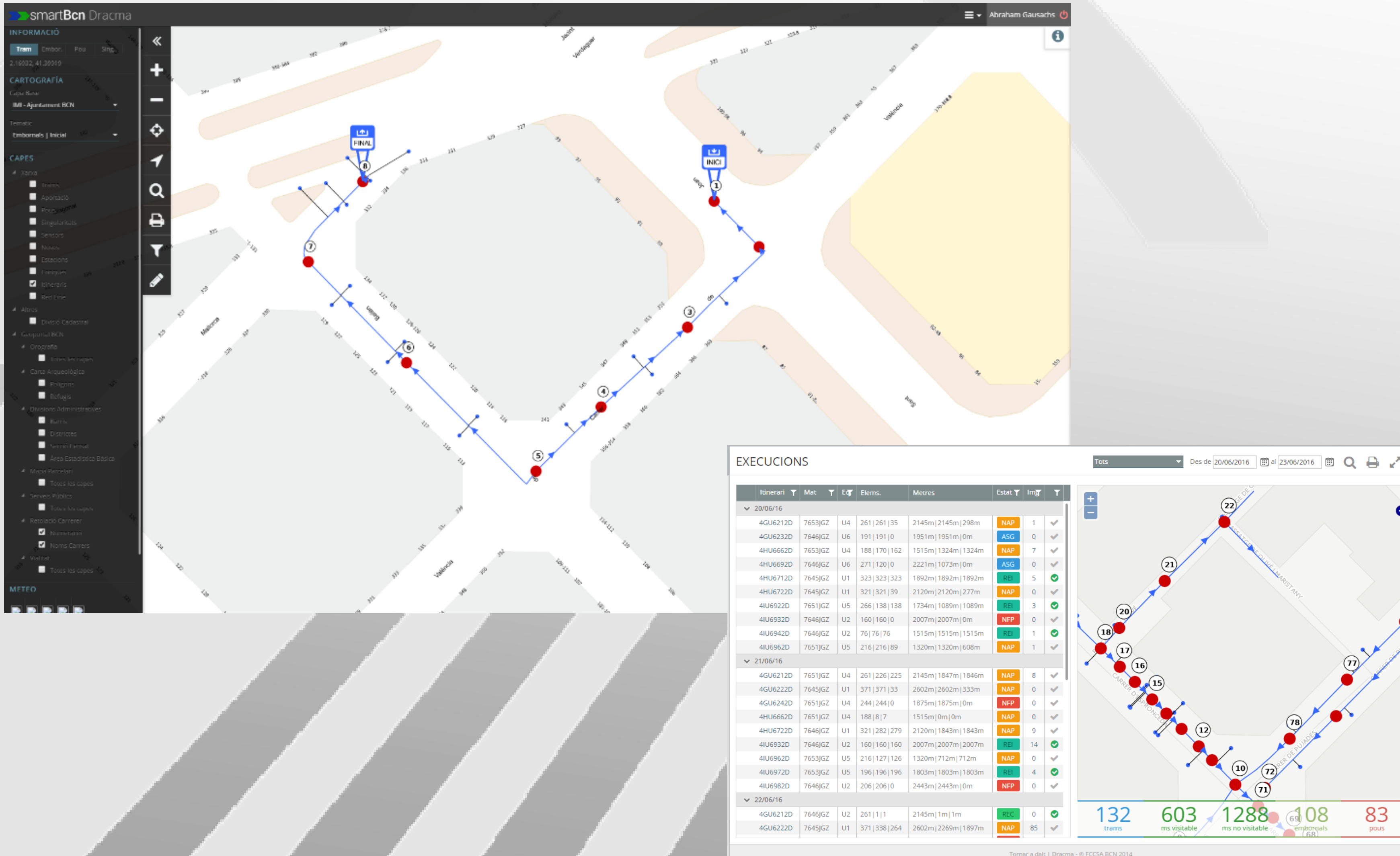
- **Objective 3: Development of the monitoring and inspection capabilities with low-medium quality sensors**

- **Objective 4: Integration/adaptation into a GIS and management software and with present technology**

ARSI Operational Concept

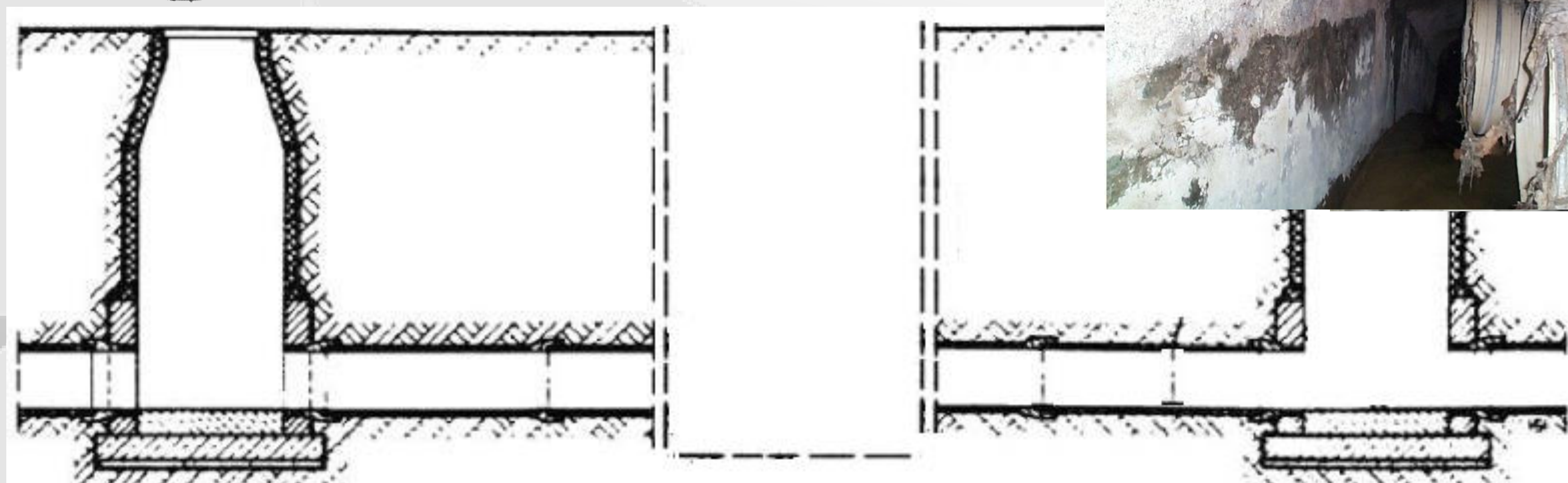


ARSI Operational Concept



Itinerari	Mat	Eq	Elems.	Metres	Estat	Img	
20/06/16							
4GU6212D	7653JGZ	U4	261 | 261 | 35	2145m | 2145m | 298m	NAP	1	✓
4GU6232D	7646JGZ	U6	191 | 191 | 0	1951m | 1951m | 0m	ASG	0	✓
4HU6662D	7653JGZ	U4	188 | 170 | 162	1515m | 1324m | 1324m	NAP	7	✓
4HU6692D	7646JGZ	U6	271 | 120 | 0	2221m | 1073m | 0m	ASG	0	✓
4HU6712D	7645JGZ	U1	323 | 323 | 323	1892m | 1892m | 1892m	REI	5	✓
4HU6722D	7645JGZ	U1	321 | 321 | 39	2120m | 2120m | 277m	NAP	0	✓
4IU6922D	7651JGZ	U5	266 | 138 | 138	1734m | 1089m | 1089m	REI	3	✓
4IU6932D	7646JGZ	U2	160 | 160 | 0	2007m | 2007m | 0m	NFP	0	✓
4IU6942D	7646JGZ	U2	76 | 76 | 76	1515m | 1515m | 1515m	REI	1	✓
4IU6962D	7651JGZ	U5	216 | 216 | 89	1320m | 1320m | 608m	NAP	1	✓
21/06/16							
4GU6212D	7651JGZ	U4	261 | 226 | 225	2145m | 1847m | 1846m	NAP	8	✓
4GU6222D	7645JGZ	U1	371 | 371 | 33	2602m | 2602m | 333m	NAP	0	✓
4GU6242D	7651JGZ	U4	244 | 244 | 0	1875m | 1875m | 0m	NFP	0	✓
4HU6662D	7651JGZ	U4	188 | 8 | 7	1515m | 0m | 0m	NAP	0	✓
4HU6722D	7646JGZ	U1	321 | 282 | 279	2120m | 1843m | 1843m	NAP	9	✓
4IU6932D	7646JGZ	U2	160 | 160 | 160	2007m | 2007m | 2007m	REI	14	✓
4IU6962D	7653JGZ	U5	216 | 127 | 126	1320m | 712m | 712m	NAP	0	✓
4IU6972D	7653JGZ	U5	196 | 196 | 196	1803m | 1803m | 1803m	REI	4	✓
4IU6982D	7646JGZ	U2	206 | 206 | 0	2443m | 2443m | 0m	NFP	0	✓
22/06/16							
4GU6212D	7646JGZ	U2	261 | 1 | 1	2145m | 1m | 1m	REC	0	✓
4GU6222D	7645JGZ	U1	371 | 338 | 264	2602m | 2269m | 1897m	NAP	85	✓

ARSI Operational Concept

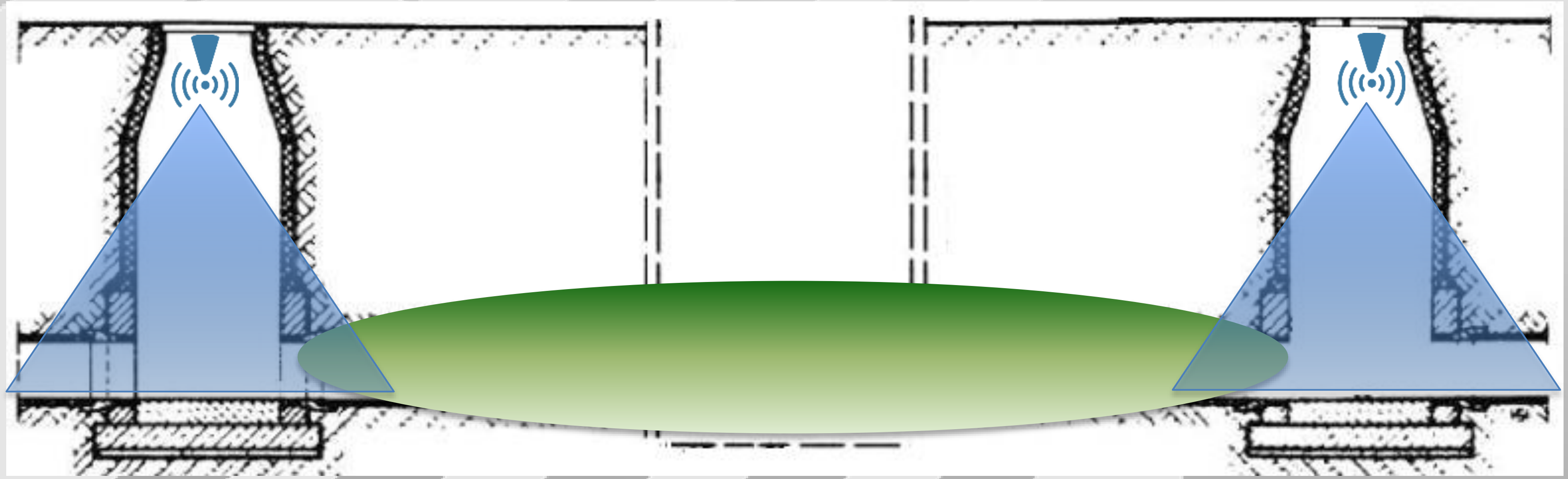


1. Deployment of the system
2. Start autonomous flight
    1. Detect bifurcations
    2. Avoid obstacles
    3. etc
3. Arrive to recovery point
4. Recovery of the system

Communications vs Adaptable Autonomy

The ARSI MAV will implement adaptable autonomy:

- the **level of automation** will adapt to the scenario
- in areas with communications the operator will be allowed to **teleoperate**
- as soon as the link is lost, the platform will continue the flight plan in **autonomous flight** mode



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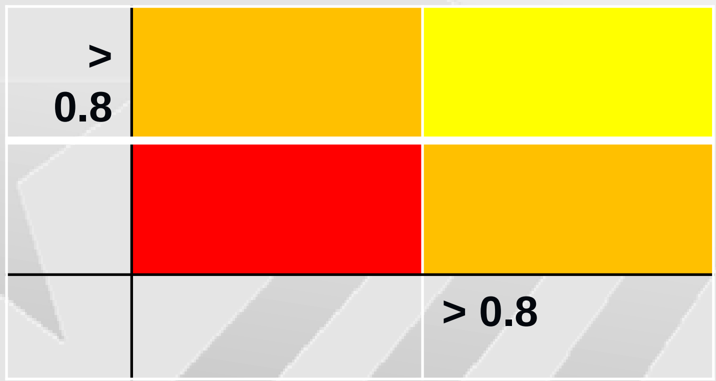
New definition: sewer navigability

Definition of sewer navigability (equivalent to accessibility for humans)



Non Navigable

Semi Navigable

Navigable

	Nº de trams	metres	%
NO NAVIGABLE	27.956	574.925,32	37%
SEMINAVIGABLE	14.398	370.236,05	24%
NAVIGABLE	26.279	597.400,68	39%
TOTAL BCN amb servei	**68.633**	**1.542.562,05**	**100%**

ARSI MAV

The MAVs developed will be adapted to the requirements of sewer inspections:

- sensors integration for both navigation and inspection
- all electronics and propulsion systems will be tolerant to humidity, by integrating water resistant components and isolating the others by design

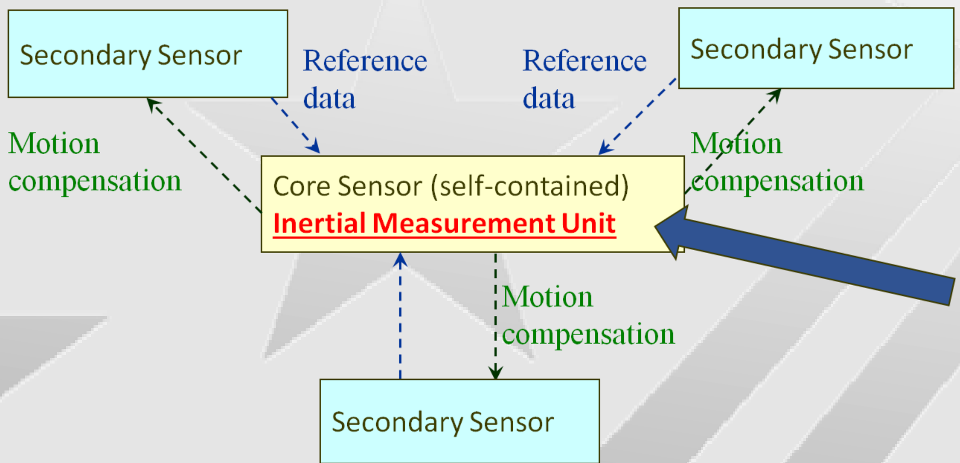
Challenge: Miniaturization of the platform

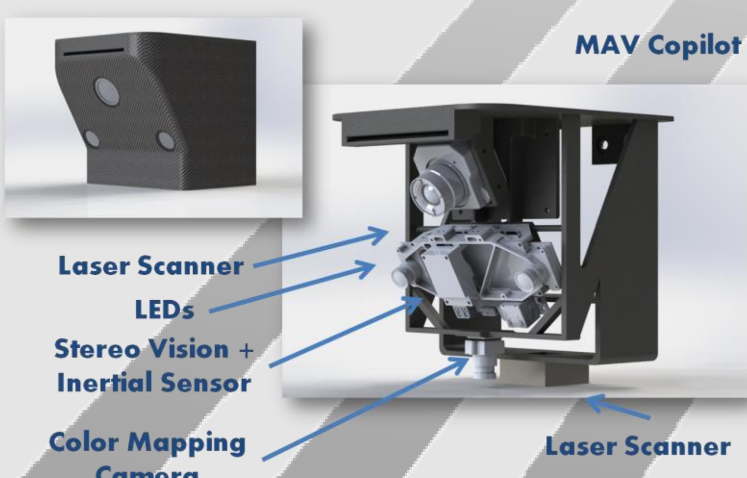
trade-off between payload weight and system performance (i.e. maximum flight time). Example of commercial platforms:

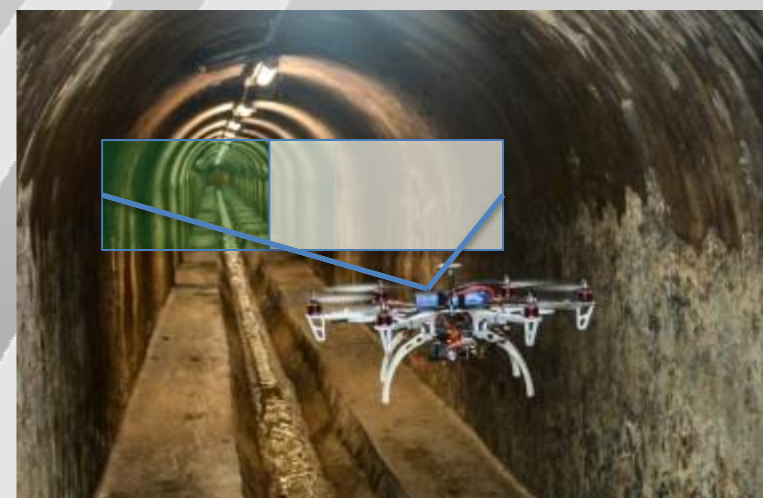
Dimensions	Payload weight	Endurance
540 x 540 mm	200g	20 min
665 x 605 mm	600g	12-14 min
651 x 651 mm	650g	16 min
570 x 570 mm	720g	14 min

Eurecat Navigation Copilot - Background

Eurecat will develop a Robust Multi-Sensor Localization algorithms based on a complementary EKF







Eurecat Navigation Copilot - ARSI

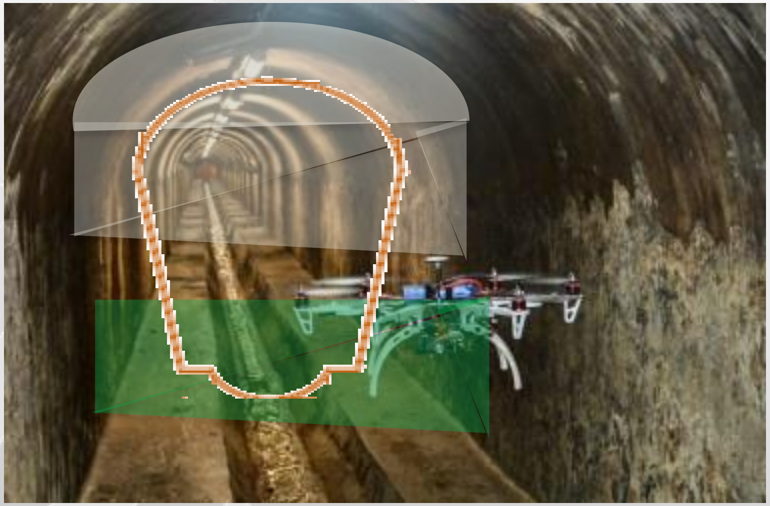
Eurecat will develop a Safe Navigation system

Focused on:

- Obstacle detection
- Detect bifurcations
- Fly-by-wire keeping constant distance to the walls

Automatic Inspections

Eurecat will develop a Robust Multi-Sensor Localization algorithms



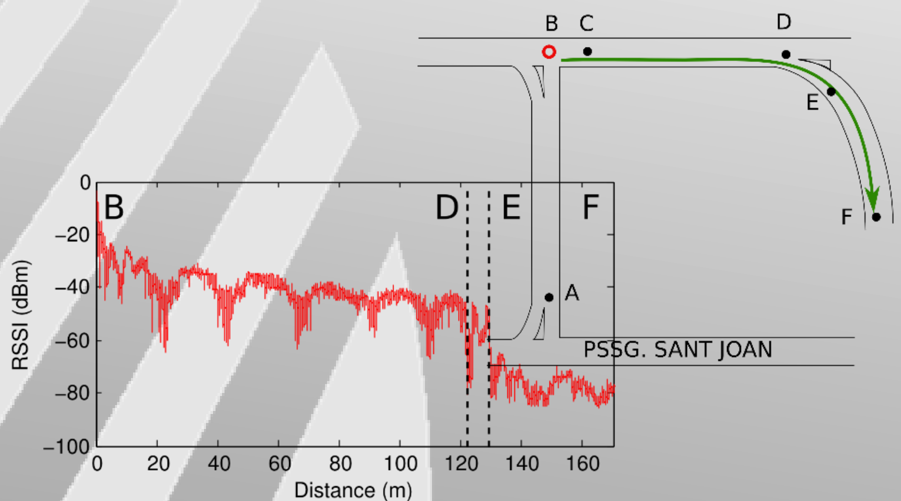
Focused on:

- Cameras to provide visual inspection
- Synchronized LEDS to solve illumination

Achievements, Impact and Next steps

ARSI main achievements

Specific landing gear



Technology validated in real conditions

Communications tests

Impact from participation in ECHORD++

Priority	Target	ARSI contribution
1	Move People away from hazardous spaces to safe areas by 50%	ARSI solution prevents brigades for accessing unhealthy and risky areas. Additionally, where ARSI solution will be used, this will require brigades of 2 operators, instead of the current 4-members brigades needed for inspection.
4	Coherent standards for robotic deployments	An operations procedure has been defined for the deployment and user of ARSI solution by a worldwide inspection service company.
5	Step Change in data and information management	ARSI proposes a holistic way of integrating sensor data into an existing information management systems, facilitating market uptake of project results. The designed ARSI remote station adapts formats to make it compatible with DRACMA, FCC's own planning platform.

Impact from participation in ECHORD++

Inspection cost per meter of sewer serviceability inspection (considering 1.000.000 of meters)		
Method	Total cost	Cost per meter
Current inspection methods	712.005,76 €	0.712 €/meter
Inspection using ARSI	476.127.60	0.471 €/meter

This represents an overall cost reduction of 33,8%

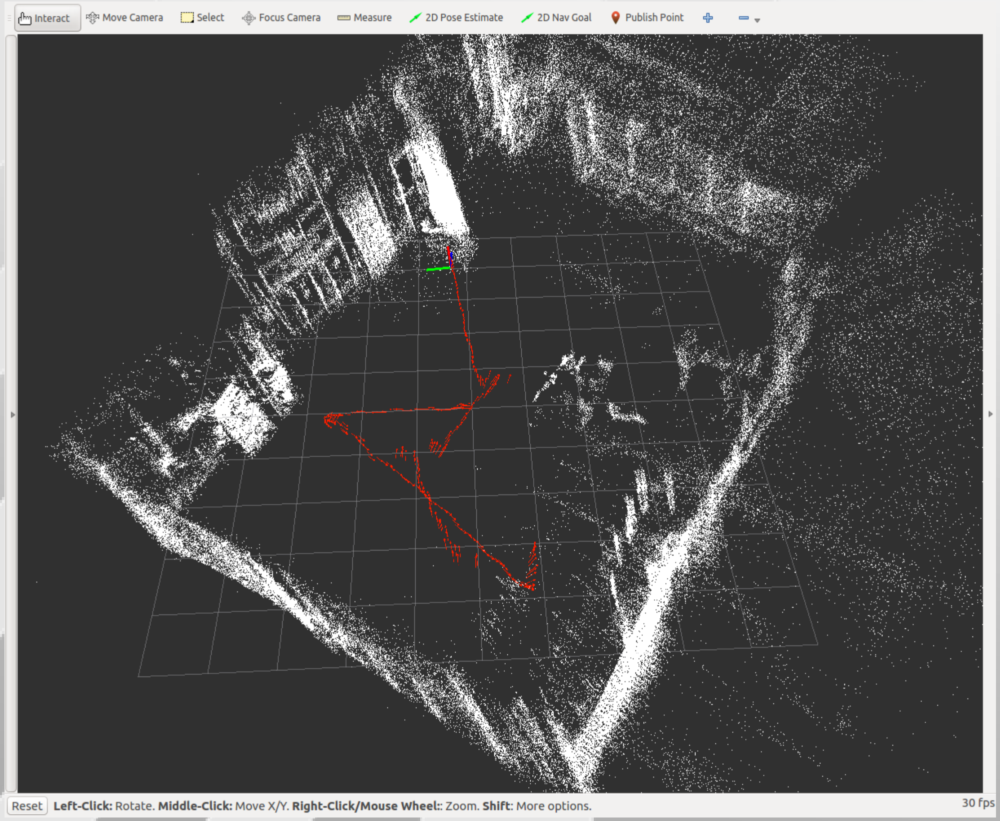
	Total cost per 1 brigade	Total cost per 4 brigades
Current Inspection methods	178.001,19 €	712.004,76 €
Inspection using ARSI	119.031,90 €	476.127,60 €

Technical progress (1/2)

After a successful design & prototyping phase, the ARSI consortium is now developing the technology which will allow the robot to **fly autonomously** in tunnels.

Extensive sensor datasets were collected during several visits to the sewers in Barcelona, and were used to test and compare various Computer Vision algorithms.

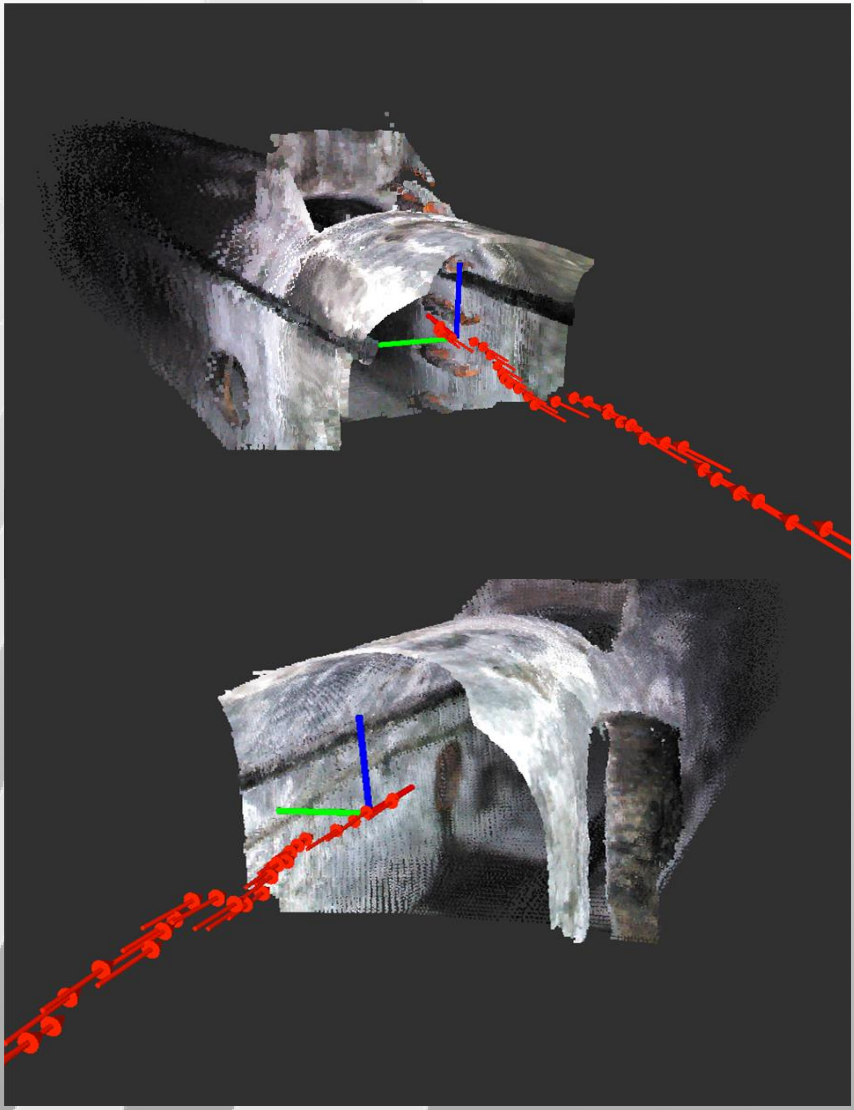
These algorithms allow us to estimate the **robot trajectory in real time** and **produce 3D models** of the sewers tunnels.



trajectory (red) and 3D features (white) in the flight area at Eurecat

Technical progress (2/2)

We are now starting to develop embedded software which uses this local 3D model to **calculate a safe trajectory** for the robot to follow while collecting video data during an inspection in the sewer tunnels.



trajectory (red) and 3D model in Barcelona sewers

Demonstrator/ prototype

The ARSI team developed a second prototype specifically for the development of the autonomous flight technology. The prototype integrates Pixhawk autopilot, LEDs, an IMU/compass an embedded PC, and a **3D camera** (color+depth), used both for **autonomous flight** and **obstacle avoidance**.

Thank you.

Any questions?

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www.eurecat.org