Aerial Robot for Sewer Inspection

PDTI Urban Challenge

D26.11-15 Marketability, technology readiness level and exploitation plan

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Reference Documents

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29/12/2014	N/A	ECHORD++ PDTI Urban Robotics – Challenge Brief – “Utility Infrastructures and condition monitoring for sewer network. Robots for the inspection and the clearance of the sewer network in cities”.
14/03/2015	v1.0	Aerial Robots for Sewer Inspection (ARSI) Consortium Proposal Document
07/2015	N/A	Market Study on Mobile Robots Market - Global Forecast to 2020 by marketsandmarkets.com. Report Code SE 3610.
03/12/2015	N/A	Robotics 2020 Multi-Annual Roadmap Release B published by SPARC – The partnership for Robotics

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17/02/2019	V1.0	Release and submission of the document to ECHORD++ PDTI Responsible

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1 Introduction and scope

The objective of this document is to analyse the marketability of ARSI results by reviewing the competition of existing commercial products and alternatives technologies and to describe the economic impact and route to market. An exploitation plan is also presented which is the same as in the beginning of the project since the market has not present any significant change affecting the consortium’s exploitation strategy

The document has been organized as follows:

- Section 2: reviews the commercial state of the art and existing products, describe the USP of ARSI and describes the achieved TRL
- Section 3: presents the economic feasibility and impact and describes the route to market and exploitation plan

2 Marketability and Technology Readiness Level

2.1 Competition

Most of the existing commercial solutions for sewer network inspection rely on specialized ground platforms. These systems are typically teleoperated through a tether cable that connects back to a control and surveillance unit at the street and provides both power and data link. Some of the most representative commercial robots are offered by Envirosight[1], IBAK[2] and Aries industries[3]. Some manufactures have started to focus on autonomous sewer robots (untethered), such as SOLO by RedZone[4], a non-tethered commercial robot whose autonomous navigation is based on visual sensors that requires a specific software[5] to plan the inspection. This system can be deployed in one man hole and recovered in a different one, but live streaming of images and video are not available on the control unit. Regarding sewer inspection and management software solutions, at present, sewer inspection is mostly based on subjective and manual visual inspection of the optical images (being image, video, laser scan, etc.) from the sewer's inner wall captured by sewer robots equipped in their majority with CCTV cameras, laser scanners or Sewer Pipe Scanner and Evaluation Technology (SSET) systems, such as Panoramo© system (IBAK). Thus, the quality of remote inspection depends totally on the operator, its qualifications and available time. There exists a wide range of tools: WinCan[6], IKAS-32[7] (IBAK), Granite XP[8], CoveGIS , ICOM3, etc.. Most of them are designed to complement their specific HW, while some of them such as WinCan can work with non-specific robots. It is important to note that most of the abovementioned systems are designed for circular sewer lines inspection, thus are useful for non-visitable sections (0.1-1.2 m). Furthermore, current commercial software and proposed algorithms for sewer analysis are focused on circular and egg-shape pipelines inspection, and are therefore not suited to inspect other type of sections. With respect to commercial aerial-based solutions, the only known product is Flyability[9], which, although offering the flexibility and ease of deployment as well as speed of operations of an aerial platform, it requires an expert pilot to be operated, it does not offer autonomous flight capabilities and its data acquisition systems are very limited in number and quality of data. Additionally, its communications range is limited to several tens of meters according to some of its clients which limits the productivity in large networks.

2.2 USP

ARSI results present several advantages compared with current technologies, coming both from the approach of using an aerial platform and the capabilities it provides and is able to integrate. In what follows we expose some of them:

- Widening the range of inspection to **visitable sections** (diameters over 1.2 m). Nowadays there is no any autonomous inspection system of application in visitable

[1] http://www.envirosight.com/index.php/crawlers/rovverx.html
[2] http://www.ibak.de/en/produkte/ibak_show/frontendshow/category/fahrwagen/
[3] http://www.ariesindustries.com/products/
[4] http://www.redzone.com/products/solo-robots/
[5] http://www.redzone.com/products/icom3-asset-management-software/
[6] http://wincan.com/
[7] http://www.ibak.de/en/produkte/software/ikas-32/
[8] http://www.cuesinc.com/Granite-XP.html
[9] https://www.flyability.com/

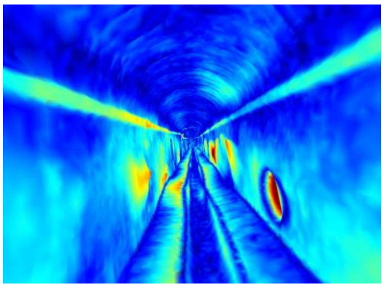
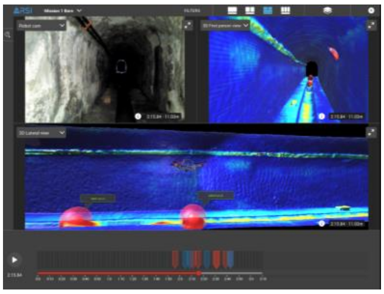
sewers. From long ago, when inspection of sewage networks started, it has been always necessary to rely on well prepared and trained humans to access these confined spaces. The aim is to avoid the need of having humans going across thousands of kilometres of visitable sewers. Related to the previous, avoid any danger at the level of **personal safety**, providing a system than can replace most of human interaction. This change of paradigm in the inspection allows reducing, or better eliminating, the danger generated at the safety level, by the fact of displacing humans to sewers.

- Previous to an inspection, it is **not necessary to clean the collector bed**. Since the inspection with an aerial platform is done with the vehicle traveling along the central axis of the pipe, the cleaning of the sewer bed, a task frequently unavoidable when inspecting with terrestrial vehicles, is not necessary anymore.
- Overcome limitations **due to physical obstacles and steps on the sewer bed**. Flying inside the sewer eliminates the probability of getting stuck in a solid or semi-solid obstacle that can be hidden on the pipe bed. Flying vehicles also avoid the problem that appears for terrestrial vehicles, that of stepped slopes, which the vehicles cannot overcome even if they have high traction values.
- At the productive level, the **inspection speed** (linear meter/hour) attainable with an aerial vehicle is much higher than the average inspection speed achieved by humans. The companies specialized in cleaning and maintenance of sewage networks will see a growth of their inspection performance in a labour journey.
- **Automatic inspection** to ease operator control and visual inspection. ARSI aims to introduce automatic recognition of various pipe defects, mainly cracks, enabling the assessment of large amount of pipelines image data, and overcoming main limitations of manual inspections such as problems of fatigue, subjectivity, ambiguity, time and cost, leading to economic benefits.

2.3 Technology Readiness Level

The following table summarizes the TRL of every ARSI results at the end of the project:

ARSI results	Description	TRL
	Aerial platform endowing autonomous forward and backward navigation and real time video streaming.	TRL6. Technology was validated and demonstrated in several real environments. Some functionalities needs to be more robust to achieve a complete system prototype (TRL7)

ARSI results	Description	TRL
	Defect detection software consisting on a 3D reconstruction module and a defect detection module based on structural assessment and deep learning techniques.	TRL6. The software component was validated and demonstrated in real conditions with real data. The robustness of this component needs to be tested in a higher variability of scenarios to achieve a marketable system prototype (TRL7)
	Visualization interface developed to analyse the gathered and processed data. Incidences and structural elements are highlighted in a timeline to ease inspection for the operators.	TRL7. The interface was tested with real data and in real conditions. The component is a standalone working solution and even if its user-friendliness can be improved, it is a full system prototype.

3 Economic feasibility and business plan

This section justifies the social interest and economic viability of ARSI project and defines the potential business model and exploitation plan for every member of ARSI consortium which compose a real and complete value chain able to bring research to the market.

The section is structured as follows:

- Market overview and interest of inspection and maintenance robotics
- Description of ARSI exploitable results and IP distribution
- Business model and exploitation plan, including a description of ARSI value chain
- Economic viability for the companies and institutions involved, including economic prospects

3.1 Market overview and interest in Inspection and Maintenance Robotics

The interest of robotics technology for inspection and maintenance applications is growing rapidly through different industrial sectors such as petrochemical, off-shore, power and nuclear plants and civil infrastructures. The cost of inspection and repair tasks of infrastructure keep growing vastly and incessantly due to the ageing of infrastructure and with the gradual expansion of distributed installations. This reality can be addressed by robotic technology in order to procure automated, reliable and cost-effective solutions that will not only reduce costs, but will also minimize risks to personnel and asset safety. With all, the coming decade will probably witness the rapid expansion of inspection robots. Key market drivers for that to be a reality are:

- Growing interest in robotics not only by US and European countries but also by emerging countries.
- Potential for improved coverage of large areas thanks to technical improvements.
- Increase in quality of monitoring data and regularity of monitoring due to lower cost per task.
- Reduction of total operational costs with respect to existing manned solutions.
- Increasing acceptance of robotics technology.

According to a new market research report on the “Mobile Robots market by Environment, Component, Application and Geography – Global Forecast to 2020” by Markets and Markets[10], the global mobile robots market was valued at USD 4,438.9 Million in 2014 and it is expected to reach USD 10,605.4 Million by 2020, at an estimated CAGR of 16.31% between 2015 and 2020. The professional service sector constituted the largest application for the mobile robots market in 2014 and it is expected to continue to grow at a significant rate because of the increasing applications, such as logistics, inspection & maintenance, telepresence and field robots across the globe. The market for these applications is expected to grow at a significant rate during the forecast period, because of the increasing adoption of the mobile robots due to the decline in the prices of several robotics components such as sensors, actuators, and others. Furthermore, these systems have been able to overcome the difficulties faced by humans in saving costs and time apart from avoiding danger in several applications.

[10] Markets and Markets http://www.marketsandmarkets.com/PressReleases/mobile-robots.asp

More specifically, for inspection and maintenance robots, the International Federation of Robotics (IFR) estimates that 4.000 units will be sold in the period of 2015-2018[11]. However, this is recommended by the IFR Statistical Department to be seen as a trend concerning market direction rather than actual and precise sales forecast.

3.1.1 ECHORD++ PDTI Urban Challenge use case: Sewer network inspection

Sewer inspections require many humans to work in risky and unhealthy conditions. Introducing a robotics solution in this process aims at reducing the labour risks, improving the precision of sewer inspections and optimizing sewer cleaning resources of the city, not only in terms of economic expenses but also in terms of water required for the cleaning process and of machinery needed. For ECHORD++ the city of Barcelona will provide its sewer network as use-case and test site.

In many points of the sewer network the terrain is highly irregular and with obstacles. The presence of significant levels of liquid waste and litter, produced by the collection of residual and pluvial waters, limit the operability of terrestrial vehicles and frequently, a cleaning of the sewer is necessary previous to an inspection with one such vehicle.

The ARSI consortium plans to tackle the pipelines and galleries inspection using an unmanned aerial vehicle (UAV), quadrotor type, endowed with sensors for its autonomous navigation along the network, collecting data for its inspection. The aerial option avoids the mobility constraints that suffer the vehicles that should advance along paths having steps, steep drops and even objects like the own domestic waste or elements dragged by pluvial waters.

3.1.2 Expected impact

While the expected impacts identified during the proposal stage are still valid and targeted by ARSI project, the Phase I of ECHORD++ Urban Challenge allowed the consortium to be more specific with respect to the economic, social and scientific-technological impacts.

Economic impact: This impact is deeply discussed in section *3.4 Economic viability for every institution involved* showing great commercial opportunities for the actors involved and high efficiencies up to 43,2% reduction in cost with respect to current sewer inspection methods.

Social impact: The solution has proven to be valid for the improvement of working conditions of inspection staff, frequently exposed at risky and unhealthy situations. FCC, a service company currently offering sewer inspection services worldwide has validated the technical approach for its inspection brigades.

Scientific-Technical impact: Phase I has established the grounds for ARSI consortium to be able to efficiently achieve significant step changes in a number of technologies such as localization and navigation in harsh environments, precise control of aerial platforms in confined spaces and inspection techniques in low visibility conditions.

With all, and according to the Robotics 2020 Multi-Annual Roadmap Release B 03/12/2015[12] published by SPARC - *The partnership for Robotics in Europe*, ARSI will contribute to the achievement of at least 3 out of the 6 envisioned prioritized targets for the Inspection and

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[11] http://www.ifr.org/service-robots/statistics/

[12] https://eu-robotics.net/cms/upload//H2020_Robotics_Multi-Annual_Roadmap_ICT-2016.pdf

Robotics sub-domain (see section 2.6.3.2 of the Sub-Domain Inspection and Maintenance, section 2.6.3), namely:

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.

3.2 ARSI exploitable results and IP Rights management

Despite the large number of robots currently available for pipe inspection, there is no system on the market suitable for sewer networks inspection. Sewer networks characteristics in terms of the different type of sizes, spaces and surfaces to inspect need of bigger and more agile robots compared to pipeline robots. Additionally, pipelines robots, and current inspection robots in general, are always remotely operated and include low levels of autonomy in their operations. On the other hand, a sewer inspection robot will have to have certain levels of autonomy in order to cover higher distances of the network, facilitate operators' tasks such as navigation and inspection and make it commercially feasible to become a real business opportunity.

3.2.1 Definition of ARSI exploitable results

ARSI technical developments and contributions seek to fill that commercial gap with the achievement of the following results.

- An aerial quadrotor platform
- A customized sensor configuration
- An advanced navigation and inspection system
- A remote station for ARSI system operations
- A customized integration of the collected data to an existing information management software

3.2.1.1 Aerial quadrotor platform

An aerial quadrotor platform designed specifically for the strict operational requirements of sewer inspection based on a custom-made carbon body and landing gear with commercial components, including propeller protection. The platform was designed, built and tested by SimTech Design and Eurecat.

3.2.1.2 Customized sensor configuration

The strict weight limitations of an aerial platform in general impacts the type and number of sensors that can be included as payload. On the other hand, the performance level required to ensure the feasibility and quality of the inspection operations represent a tough challenge given the later premise. Therefore, ARSI platform and sensor configuration, and possible future modifications to adapt the platform to other sewer network particularities, require of expert knowledge on platform operations and sensor configuration to provide a feasible solution.

3.2.1.3 Advanced navigation and inspection system

The advanced navigation solution makes use of the customized sensor configuration to provide high levels of autonomy so that the platform can self-resolve operators' orders and facilitate navigation and inspection tasks in the sewers. The navigation solution is represented by a combination of methods and software implementations which fuse different data sources to obtain a robust navigation functionality, all embedded into a powerful processing core. This module provides, on one hand, a set of pilot-centered flight modes which enables reliable operations under any of the circumstances expected during the sewer inspection tasks, and, on the other hand, it implements an autonomous inspection mode which automatically generates a combination of the previous flight modes which will be executed under the supervision of the operator as long as there is no unexpected events detected or human intervention.

3.2.1.4 Remote Station for the system operations

The ARSI Remote Station is a software package designed to facilitate platform operations and maximize efficiency during all the stages of the inspection tasks (planning, mission execution, data analysis and reporting). The remote station is composed by a set of plugins and monitoring displays that provides full visibility and control of the platform operations and the necessary visualization tools to plan, analyze and report the collected data.

3.2.1.5 Customization for integration with existing software: DRACMA use case

DRACMA (Drainage Resource Administration and Cleaning Management) is a proprietary cloud-based platform owned by FCC used to plan inspections, to represent data on a GIS, to manage inspection resources and teams, to analyze data and to generate reports. In order to maximize end user uptake of ARSI project results, Eurecat has developed a plugin for the integration of the Remote Station inputs and outputs into DRACMA. This plugin takes into account ARSI platform information such as battery life, communication range, size limitations, etc. in order to plan inspection tasks and report and analyze ARSI collected data. While the Remote Station does not need any additional software to plan ARSI inspection or report data, the integration with existing end user platform significantly reduces market entry barriers, minimizes training needs and ease user acceptance. Therefore, it is expected that this service will be of high value in future commercial opportunities to integrate ARSI system with other existing platforms.

3.2.1.6 ARSI sewer inspection system

Finally, the integrated combination of the previous results into a unique and innovative system represents the main commercial result of ARSI project, the ARSI inspection system.

3.2.2 IP Rights Management

The agreed IPR framework for the protection and exploitation of the project results is detailed in the table below:

#	Project results	IPR protection	Owners & Involved partners
1	Quadrotor platform inspection system for sewer networks	Patent (under discussion)	EUT
2	Advanced navigation system for confined environments (Software)	Copyright	EUT
3	Structural inspection and sewer monitoring system (Software)	Copyright	EUT
4	Remote station for platform operations and data analysis	Copyright	EUT
5	Customized integration with existing information managements software (DRACMA use case)	Copyright	EUT, FCC
6	ARSI sewer inspection system	Patent (under discussion)	FCC, EUT

3.2.2.1 Clarification of DRACMA Background use within and after the project

As described in *Attachment 1 - Background IPR included* of the Consortium Agreement (CA), DRACMA is an FCC's Background asset to which access rights are granted during the project with no limitations or conditions for implementation and on a royalty-free basis. On the other hand, as indicated in the CA, the access to this background beyond the project during the exploitation phase could be provided by FCC, if required, under fair and reasonable conditions still to be determined.

As indicated in section 3.2.1.5, the customization of the system to DRACMA it is recognized by the consortium to bring great market value to the project as a professional tool developed by an inspection company such as FCC, facilitating market uptake and reducing entry barriers. However, DRACMA is not a background needed for the use of ARSI project results as the remote station provides the required operational and reporting functionalities on a standalone basis. Therefore, regarding the future exploitation of the system, the remote station could be adapted to other existing information management systems when required by the end user, as it was done for DRACMA, on a contract basis.

3.3 Business model and exploitation plan

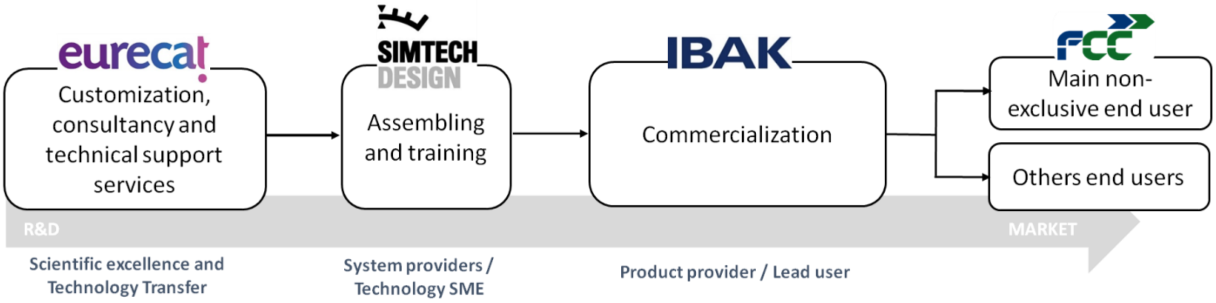
Additionally to an excellent set of technical results, a clear route to market strategy is needed to hit the market. Therefore, ARSI members have defined a clear value chain that sets the commercial client-provider relationships among the consortium in order to define an appropriate business model to satisfy early market demands. While this value chain is based on the current exploitation interests expressed by the partners (see table below), it is recognized that it may change along the first years of the commercialization based on market needs, industrialization requirements, changes on exploitation interests or the entry of new actors.

The business model will be based on the following exploitation interests indicated by the partners:

Partner	Exploitation interest
SIMTECH	Design and manufacturing of platforms, training and technical consultancy.
Eurecat	Technology transfer (licensing, etc.), technical consultancy and customization services.
IBAK	Commercialization of innovative sewer inspection systems.
FCC	Early access on innovative products on advantageous economic conditions.

3.3.1 Value chain

Based on the expressed exploitation interest and the discussions during the ECHORD++ PDTI Phase I - Solution Design, the consortium defined the following value chain:



3.3.2 Business model and Exploitation plan

According to the defined ARSI exploitable results, the agreed IPR distribution and value chain, the following products and services are defined by partner:

EURECAT			
# - Product/Service	***Origin***	***Commercialization***	***Revenues from***
1 - Advanced navigation and inspection system and Remote Station integrated in ARSI inspection system	Results #2,#3, #4	Price per unit sold (License)	SIMTECH (IBAK sales)
2 - Technical support to platform manufacturing and validation	Results #1 and Background	Price per hour	SIMTECH
3 - Upgrades of ARSI inspection system (navigation and inspection system and remote station)	Results #2, #3, #4 and Background	Price per unit sold (License)	SIMTECH (IBAK sales)

SIMTECH			
# - Product/Service	Origin	Pricing method	Revenues from
4 - ARSI sewer inspection system and technical support (helpdesk, training)	Result #5 and Background	Price per unit sold	IBAK

IBAK			
Product/Service	Origin	Pricing method	Revenues from
5 - ARSI sewer inspection system and technical support	Results #5	Price per unit sold	FCC and other end users

FCC			
Product/Service	Origin	Pricing method	Revenues from
9 - Use of ARSI inspection system in their inspection service contracts*	Result #5	Price per service	Public Entity

(*) By using ARSI sewer inspection system, FCC (and other service companies, end users) will be able to significantly reduce the cost of the inspection service (see section 3.4.5), hence, obtaining higher profit per service offered.

3.4 Economic viability for every institution involved

Based on the products and services and the business model defined in the previous section, we describe and quantify the commercial opportunity for each institution involved that makes the ARSI project an economically viable market opportunity.

Assumptions, commercial estimations and other market considerations are indicated, where applicable, based on the market knowledge and expertise of every partners.

3.4.1 Sales forecast

As described in the market overview (section 3.1) by different market studies, sales in the sector of professional robotics, and specifically inspection and maintenance robots, are expected to growth double digit in the following years. The International Federation of Robotics (IFR) prudently estimates that 4.000 units will be sold by 2018.

On the other hand, a commercial prototype of the ARSI inspection system is expected to reach TRL7 (maybe up to TRL8) by mid-2018. Then, it is estimated that a time-to-market of approximately 6 months will be needed for product certification and achieving a ready-to-sell product. Therefore, by 2019 ARSI inspection system may hit the market.

Therefore, based on the market reports estimations, the commercialization experience of IBAK and the current sales of IBAK's robots, the following sales prospects where estimated during the first 5 years of commercialization, from 2019 to 2023:

	2019	2020	2021	2022	2023
Units	30	45	65	90	120

Based on this estimation, the following sections present the economic viability of ARSI project by institution involved according to the value chain defined (from left to right).

3.4.2 For the Research Institute - EURECAT

EURECAT will have benefits from the exploitation of the following products and services:

- (Result #1) Navigation and inspection system sold to SimTech Design for platform manufacturing at an estimated price per unit of 1.750€. The total profit will indirectly depends on the ARSI system units sold by IBAK.
- (Result #4) ARSI Remote Station sold to SimTech Design for platform operations at an estimated price of 2.500€. The total profit will indirectly depends on the ARSI system units sold by IBAK.
- Technical support for manufacturing and validation to SimTech Design. At least during the first five years it is expected that Eurecat will contribute with its expertise on platform development for the product manufacturing and validation. The estimated price of this service is of 1.200€ per ARSI unit produced.
- Navigation and inspection system upgrades. It is expected that as of the third year of exploitation, upgrades of the navigation and inspection system will be released by Eurecat based on the customers feedback. It will be sold as a license of a new software to SimTech Design and the estimated price of the upgrades is of 300€ per unit sold.

The following table present the estimated economic prospects for Eurecat:

Figures in €	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues	163.500	245.250	375.250	525.000	706.500
- R#1 - ARSI inspection system (navigation and inspection system and remote station)	127.500	191.250	276.250	382.500	510.000
- R#2 - Technical support to platform manufacturing and validation	36.000	54.000	78.000	108.000	144.000
- Upgrades of ARSI inspection system	0	0	21.000	34.500	52.500
Cost of goods	-57.225	-85.838 €	-131.338	-183.750	-247.275
Gross margin	269.775	404.662	619.162	866.250	1.165.725
Operating costs	-67.444	-101.166	-154.791	-216.563	-291.431
Net income	202.331	303.497	464.372	649.688	874.294
Accumulated income	202.331	505.828	970.200	1.619.887	2.494.181

The estimations shows that ARSI could potentially represent a business of an accumulated 2.5M€ profit for Eurecat in 5 years time after the end of the project

3.4.3 Economic viability for the SME - SimTech Design

The following table presents a cost breakdown of the aerial robot and platform. The breakdown includes materials, manpower and maintenance costs as well as the cost for the products and services provided by Eurecat:

Materials costs	
Platform costs	**1.220 €**
Frame (arms, plates, landing gear and protection)	200 €
Motors	250 €
Propellers	10 €
ESCs	160 €
Battery	100 €

Navigation and inspection system (provided by Eurecat)	1750 €
Electronics (converters, LEDs, power distribution board)	150 €
Payload costs	**6.067 €**
Onboard PC	125 €
Laser	3.000 €
LEDs	100 €
4 Cameras	2.627 €
Other sensors	100 €
Wi-Fi adapter	35 €
Air monitoring system	80 €
Support equipment costs	**3.200 €**
Remote station (provided by Eurecat)	2.500 €
Router	300 €
RC	400 €
Man power* costs (40 hours x 20€/hour)*	**800€**
Maintenance costs	**1.169€**
ARSI system validation (20 hours x 60€/hour)	**1200**
TOTAL COSTS	**13.656 €**

* It is estimated that assembling a robot manually will take 40 hours. The estimated cost per hour cost is of 30€/hour.

Based on a preliminary product benchmark and the know-how and the market expertise of the consortium, it is considered that a price of 18.500€ for the acquisition of ARSI inspection system by IBAK would make a competitive business opportunity and increase its economic viability for all the actors in the value chain.

In the following table the forecast sales of SimTech Design are offered:

SD	2019	2020	2021	2022	2023
Revenue	555.000	832.500	1.202.500	1.665.000	2.220.000
Cost of goods	-409.680	-614.520	-887.640	-1.229.040	-1.638.720
Gross margin	145.320	217.980	314.860	435.960	581.280
Operating costs	-87.192	-130.788	-188.916	-261.576	-348.768
Net income	58.128	87.192	125.944	174.384	232.512
Accumulated incomes	58.128	145.320	271.264	445.648	678.160

The estimations shows that ARSI could potentially represent a business of an accumulated 678.000€ profit for SimTech Design in 5 years time after the end of the project

3.4.4 For the Large Industry - IBAK

IBAK estimates for the solution to be competitive it could be offered at a 50% margin over cost, which results in a market selling price of 27.750€. The following table shows the sales forecast of ARSI inspection system for IBAK. The operating costs include mainly the commercialization costs, marketing costs and salaries.

IBAK	2019	2020	2021	2022	2023

Revenue	832.500	1.248.750	1.803.750	2.497.500	3.330.000
Cost of goods	-555.000	-832.500	-1.202.500	-1.665.000	-2.220.000
Gross margin	277.500	416.250	601.250	832.500	1.110.000
Operating costs	-99.900	-149.850	-216.450	-299.700	-399.600
Net income	177.600	266.400	384.800	532.800	710.400
Accumulated incomes	177.600	444.000	828.800	1.361.600	2.072.000
ROI	0,2	0,5	1,0	1,7	2,5

According to the estimations, IBACK could its breakeven point on 2021 and have its own Return of Investment (ROI) already in the third of exploitation. The estimations shows that ARSI could potentially represent a business of an accumulated 2M€profit for IBAK in 5 years time after the end of the project

3.4.5 For the Service Company - Fomento de Construcciones y Contratas (FCC)

The economic benefits obtained by FCC will not come directly from the sales of ARSI inspection system (as FCC is the target client), but from the potential cost reduction in their inspection service contracts thanks to the use of ARSI. Then, this section presents a comparison of the service cost reduction that FCC could obtain by using ARSI. The table below shows the inspection cost per inspection brigade comparing the current set up with the use of ARSI.

Considerations: For safety reasons the inspection brigades of the accessible galleries are composed always for a minimum of 4 operators. Operators will always work in pairs, either outside of the sewers placed in each sewer access (entrance and exit) and within the sewer galleries. According to FCC, it is expected that ARSI system will replace the operators inside the sewer and therefore two operators will be enough to perform inspection missions.

Reductions in costs with the proposed ARSI Concept of Operations are highlighted in the table below.

Current inspection brigade costs (€)			
Description	**Units**	**Unit cost**	**Total Cost**
Staff	4	36.312,64	145.250,58
IVECO Daily Van*	1	19.840,77	19.840,77
Auxiliary Material	1	3.047,60	3.047,60
Necessary Material	1	9.362,24	9.362,24
Fuel	1	500,00	500,00
TOTAL			**178.001,19**

Brigade inspection costs using ARSI (€)			
Description	**Units**	**Unit cost**	**Total Cost**
Staff	**2**	36.312,64	**72.625,29**
IVECO Daily Van*	1	19.840,77	19.840,77
Auxiliary Material	1	3.047,60	3.047,60
Necessary Material	1	9.362,24	9.362,24
Fuel	1	500,00	500,00
ARSI solution	**1**	11.800	**13.656,00**
TOTAL			**119.031,90**

**According to FCC: The vehicle and the materials costs are amortized along the service. An amortization of 9 years was considered for the vehicle.*

This represents cost reduction per brigade of 43,2%

Additionally to this cost reduction, that will increase the profit margin of FCC in their inspection service contracts, market advantages will be discussed and negotiated with FCC so that the company is acknowledged as the end user leading to the introduction of this product to the market.

3.4.6 For the Public Entity – BCASA

According to the Challenge Brief *Urban Robotics document version 29.12.2014* released by the Public Entity, Barcelona Cicle de l'Aigua SA (BCASA), describing the challenges to address in the PDTI, there are currently 4 brigades operating for the inspection of the sewer network. Then, taking into account the cost analysis performed from FCC information (previous section) the cost of 4 brigades using current inspection methods compared to the use of ARSI is as follows:

	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 €

Taking into account the labour days (214 working days) and journey duration (8 hours), which gives a total of 1,712 hours/year the cost per hour of an inspection brigade is:

	Cost/ per hour
Current Inspection methods	103,97€/h
Inspection using ARSI	69,53 €/h

NOTE*: The information used to obtain this calculations is the real data provided by the Service Company and it may slightly differ from the information presented by BCASA in its documentation, namely, Challenge Brief Urban Robotics document version 29.12.2014. More specifically the differences are highlighted in here:*

	BCASA document	***Obtained thanks to the service company***
Cost per hour per brigade	110€/h	753.280 €/year
Total cost per 4 brigades	103€/h	712.004,76 €/year

Taking into account that the sewer inspection cost in Barcelona, as reported by BCASA, is about 1 million € (12,5% of total cost of sewer management), **the public entity will be able to reduce almost 440.000€ cost per year in sewer inspection by using ARSI system**.

3.4.6.1 Analysis of the productivity (meter a day)

Taking into account the battery life limitation of current aerial platforms and, hence, of ARSI system, the consortium offers here an analysis of the productivity expected by the ARSI system compared to current methods.

Considerations: One inspection mission will last an hour on average. Also it is considered an effective inspection time of 6 hours per day. Therefore, the brigades are able to carry out 6 missions/day on average.

The aerial robot have an autonomy of 10 minutes. As described in section 4.3.2, in this 10 minutes of mission brigades are expected to inspect a minimum of 300 meters (at a minimum flight speed of 0,5m/s) and a current maximum of 600 meters (at 1m/s flight speed). Therefore:

USING ARSI SYSTEM			
Pessimistic scenario		**Optimistic scenario**	
Aerial robot speed 0,5m/s -> **300 meters inspected per hour**	6 missions/day	Aerial robot speed 1m/s -> **600 meters inspected per hour**	6 missions/day
Total meters inspected/day	6 missions/day * 300 meters = **1800 meters/day**	Total meters inspected/day	6 missions/day * 600 meters = **3600 meters/day**

Based on the experience of the FCC, current brigades inspect a total of 2000 meters/day (333 m/hour), therefore the use of ARSI system would increase and in any case, maintain, the current productivity but a lower cost.

3.4.7 Cost per meter comparison

Taking into account the total cost presented (4 brigades), the following table provides a comparison of the cost per meter of sewer serviceability inspection considering 1.000.000 meters.

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**

Total cost per meter using ARSI system will be around 0.471 €/m, below of the targeted threshold of 0,50 €/m