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HYbrid FLying rollIng with-snake-aRm robot for contact inSpection

HYFLIERS

D7.3

HYFLIERS Dissemination and Exploitation Report P1, and Plan Update

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Abstract:

This deliverable reports about the dissemination and exploitation activities of the consortium partners during period P1, and the update of the dissemination and exploitation plans.

Keywords:

Conference. Dissemination. Exploitation. Horizon 2020. HYFLIERS. Innovation. IPR management. Journal. Magazine. Workshop. Risk mitigation.

Executive summary

This deliverable reports about the dissemination and exploitation activities of the consortium partners for the first reporting period P1 (from 1 January 2018 to 30 June 2019). The exploitation activities at this stage concentrate on risk mitigation for successful deployment in an operational scenario. An update of the dissemination and exploitation plans is also included in the deliverable.

Abbreviations and symbols

AEND	Spanish association for non-destructive testing
ATEX	ATmosphères EXplosives
EC	European Commission
ECNDT	European Conference of Non-Destructive Testing
EMAT	Electromagnetic Acoustic Transducer
ERF	European Robotics Forum
HYFLIERS	Hybrid flying rolling with-snake-arm robot for contact inspection
ICRA	International Conference on Robotics and Automation
ICT	Information and Communications Technology
ICUAS	International Conference on Unmanned Aircraft Systems
IROS	International Conference on Intelligent Robots and Systems
ISAR	International Symposium on Aerial Robotics
NDT	Non-Destructive Testing
RSS	Robotics, Science and Systems
SPE	Society of Petroleum Engineers
UAS	Unmanned Aerial Systems
UT	Ultrasound Transducer, Ultrasonic Testing
WCNDT	World Conference of Non-Destructive Testing

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Foreword

The following text reports the review comments (in italics and between quotation marks) followed by a summary of the changes implemented in this revised version of the deliverable:

“The plan update is missing. This is important to be included in this deliverable because the dissemination level has been limited by the innovations developed in the project (4 patent applications)”.

The dissemination section has been improved and updated, including the accepted journal and conference papers that were sent by the consortium in period P1, but at the time of the first submission we did not yet have notice of acceptance. Then, 2 new accepted journal papers and 3 new accepted papers in international conferences have been included, for a total of 11 HYFLIERS scientific publications (4 papers in journals and 7 papers in international conferences). The links to open access versions of the papers uploaded to Zenodo repository have been included for all papers. The updated dissemination plan has also been included in a new section. The exploitation section has also been improved, and an update of the exploitation plan has been included in a new section.

1. Dissemination

The HYFLIERS research results are targeted to reach:

- Scientific community,
- Industry and end users,
- Educational community,
- General public.

All HYFLIERS project outputs include a project acknowledgement statement, or otherwise suitable identification means, to help to identify them as originating from the project.

Publications are written on both the methods and technologies developed during the project and the applications. Scientific publications are made primarily through high-level international conferences and journals, favouring open-access models. Dissemination also exploits social networks (including LinkedIn, Twitter, etc.), national and local newspapers and television, as relevant. In addition to publications, the consortium also aims at organising international workshops on the research areas related to the project, summer schools, academic courses, seminars and events.

1.1. Dissemination Actions

The following contains the dissemination actions of each individual partner in the consortium.

1.1.1. Academic Partners

University of Oulu

The kick-off held in Oulu was covered by an interview to Juha Röning and Aníbal Ollero for a Finnish newspaper with both paper and online (also open) distribution.

- Röning J, Ollero A (2018) Flying robot gets wheels and arm. Interview by Mikkola A, Finnish newspaper **Kaleva** (in Finnish). 11 Jan.
Available: <http://www.kaleva.fi/uutiset/oulu/lentorobotti-saa-pyorat-ja-kasivarren-oulun-yliopiston-johdolla-automatisoidaan-kaasu-ja-oljyteollisuuden-kunnossapitoa/781449/>

HYFLIERS project was presented at the European Robotics Forum (ERF 2018) held in Tampere, Finland, on 13-15 March 2018 and the progress was disseminated at the ERF 2019 held in Bucharest, Romania, on 20-22 March 2019.

- Röning J, et al. (2018) Presentation of HYFLIERS project. **European Robotics Forum** (ERF 2018). Tampere, Finland. 13-15 Mar.
- Brown R, Röning J (2019) Hyfliers – UT inspections at height in congested pipe racks. **European Robotics Forum** (ERF), Aerial Robotics Technologies and Applications. 20-22 March, Bucharest, Romania.

Prof. Juha Röning participated the Maker Faire in Rome, Italy, 12-18 October, see Section 0.0.0 for details.

The project's web-site (<http://hyfliers-project.eu/>) is maintained up-to-date with the progress. The University of Oulu also promotes major steps of the project through social media (#hyfliers-project).

University of Seville

USE is disseminating HYFLIERS results through the publication of scientific papers in journals and at international conferences and workshops. Up to now, two papers in journals have been published (one in cooperation with CREATE), and another seven papers have been accepted for publication in international conferences:

- Ruggiero, F., Lippiello, V. and Ollero, A. Aerial Manipulation: A Literature Review. **IEEE Robotics and Automation Letters**, 3(3): 1957-1964. 7 2018.
Open access pdf: <https://zenodo.org/record/2626652>
- Ramon-Soria, P., Arrue, B.C. and Ollero, A. A 3D-Printable Docking System for Aerial Robots: Controlling Aerial Robotic Manipulators in Outdoor Industrial Applications. **IEEE Robotics and Automation Magazine**, vol. 26, no. 1, pp. 44-53, March 2019.
Open access pdf: <https://zenodo.org/record/2621758>
- Caballero, A., Bejar, M., Ollero, A. On the use of velocity adaptation to outperform the motion planning with dynamics awareness in aerial long-reach manipulators with two arms. In 2018 **International Conference on Unmanned Aircraft Systems (ICUAS)**, pp. 1125–1133.
Open access pdf: <https://zenodo.org/record/2621711>
- Ramon-Soria, P., Gomez-Tamm, A.E., Garcia-Rubiales, F.J., Arrue, B.C. and Ollero, A. Autonomous landing on pipes using soft gripper for inspection and maintenance in outdoor environments. In 2019 **IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)**, Macau, China, 2019, pp. 5832-5839.
Open access pdf: <https://zenodo.org/record/3647962>
- Sanchez-Cuevas, P. J., Martin, V., Heredia, G. and Ollero, A. Multirotor aerodynamic effects close to obstacles: Modelling and Mapping. **4th Iberian Robotics Conference (ROBOT 2019)**, Porto, Portugal, 2019 (accepted).
Open access pdf: <https://zenodo.org/record/3647908>
- Nekoo, S.R., Acosta, J.A. and Ollero, A. Fully Coupled Six-DoF Nonlinear Suboptimal Control of a Quadrotor: Variable-pitch Rotor Design. **4th Iberian Robotics Conference (ROBOT 2019)**, Porto, Portugal, Nov. 2019 (accepted).
Open access pdf: <https://zenodo.org/record/3647932>
- Perez, M., Suarez, A., Heredia, G. and Ollero, A. Positioning System for Pipe Inspection with Aerial Robots using Time of Flight Sensors. **4th Iberian Robotics Conference (ROBOT 2019)**, Porto, Portugal, Nov. 2019 (accepted).
Open access pdf: <https://zenodo.org/record/3648017>
- Ramos, A., Sanchez-Cuevas, P. J., Heredia, G. and Ollero, A. Spherical Fully Covered UAV with Autonomous Indoor Localization. **4th Iberian Robotics Conference (ROBOT 2019)**, Porto, Portugal, Nov. 2019 (accepted).
Open access pdf: <https://zenodo.org/record/3647952>
- Nekoo, S.R., Acosta, J.A., Gomez-Tamm, A.E. and Ollero, A. Optimized Thrust Allocation of Variable-pitch Propellers Quadrotor Control: A Comparative Study on Flip Maneuver. **2019 Workshop on Research, Education and Development of Unmanned Aerial Systems (RED-UAS)**, Cranfield, UK, Nov. 2019 (accepted).
Open access pdf: <https://zenodo.org/record/3685593>

HYFLIERS results have been presented in several workshops organized at the main robotics conferences:



Figure 1: RSS 2019 workshop at Freiburg (Germany).

- International Symposium on Aerial Robotics 2018 (ISAR), Philadelphia, USA, June 2018. A. Ollero, Dissemination of HYFLIERS results in the talk “New systems for industrial contact inspection of pipes and bridges by using aerial robotic manipulators.”
- 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems, Madrid, Spain, October 2018:
 - Keynote talk by A. Ollero “Challenges in Aerial Robotic Manipulation”.
 - Tutorial on “Aerial Robotic Manipulation”, organized by G. Heredia.
- European Robotics Forum 2019, Bucharest, Romania, March 2019, Organisation of the Workshop “Aerial Robotics Technologies & Applications with the new European UAS regulation” by A. Ollero (USE) and M. Calva (CHEVRON). Presentations:
 - “Update on the new European UAS regulation”, by A. Viguria (CATEC)
 - “Aerial robotic manipulation new technologies and contact inspection applications”. By A. Ollero (USE).
- Conference “Drones and robots for mapping, inspection and maintenance”, Oslo, Norway, May 2019. Dissemination of HYFLIERS results in the talk “Aerial Robotics for Inspection and Maintenance” by G. Heredia.
- IEEE International Conference on Robotics and Automation 2019 (ICRA), Montreal, Canada, May 2019, organization of the workshop: “The future of aerial robotics: Challenges and opportunities”, co-organised by A. Ollero with 150 attendants. Dissemination of HYFLIERS developments in the presentations of:
 - G. Heredia, “Compliance in Aerial Manipulation”
 - A. Ollero, “Aerial Robotics: Challenges and Opportunities”
- International Symposium on Aerial Robotics 2019 (ISAR), Toronto, Canada, May 2019, talk by A. Ollero: “Aerial Robots with Manipulation Capabilities in Flight and Perched”.
- 14th Congress of the NDT Association (AEND), participation of G. Heredia in the round table “New technologies for inspection, applications and R&D needs”, Vitoria, Spain, June 2019.

- Robotics, Science and Systems 2019 (RSS), Freiburg (Germany), June 2019, organization of the workshop: “Aerial Interaction and Manipulation: Unsolved Challenges and Perspectives”, co-organised by G. Heredia with 50 attendants, see Figure 1. Dissemination of HYFLIERS developments in the presentations of A. Ollero “Aerial robotic manipulators: unsolved challenges and perspectives”.

1.1.2. Research and Technological Centres

CREATE

CREATE is disseminating the achievements of the HYFLIERS project through scientific publications, workshops and exhibitions. Up to the date of this deliverable, three papers on journals have been published:

- 6D Pose Task Trajectory Tracking for a Class of 3D Aerial Manipulator from Differential Flatness. Yu, Y. and Lippiello, V. **IEEE Access**, 7: 52257-52265. 2019.
Open access pdf: <https://zenodo.org/record/3659190>
- Aerial Manipulation: A Literature Review. Ruggiero, F., Lippiello, V. and Ollero, A. **IEEE Robotics and Automation Letters**, 3(3): 1957-1964. 7 2018.
Open access pdf: <https://zenodo.org/record/2626652>
- Nonlinear Model Predictive Control for the Stabilization of a Wheeled Unmanned Aerial Vehicle on a Pipe. Zhao, S., Ruggiero, F., Fontanelli, G.A., Lippiello, V., Zhu, Z. and Siciliano, B. **IEEE Robotics and Automation Letters**, 4(4): 4314-4321. Oct 2019.
Open access pdf: <https://zenodo.org/record/3659195>

Further papers have been submitted and are under review, both at conferences and journals.

Moreover, the HYFLIERS project has been disseminated at the **Maker Faire** (<https://makerfaire.com/>) from 12 to 18 October 2018 in Rome, Italy through a dedicated booth and participation at a workshop. This international event is one of the most attended in Italy, with around 105.000 visitors during the last edition and a large coverage of TV and newspapers (e.g., looking for “maker faire 2018” on Google gives 58.300 links).

In Figure 2, the HYFLIERS booth is shown. Several visitors have been attracted by the videos and live demos of preliminary prototypes that have been shown there.



Figure 2: Maker Faire 2018 at Rome (Italy), HYFLIERS booth.

Moreover, CREATE organized the workshop “Drones beyond the hobby” (<https://2018.makerfairerome.eu/it/drones-beyond-the-hobby/>) on 13/10/2018 in one of the conference rooms at the Maker Faire (Padiglione 10, Room 2 sala Aurelia). The workshop has been led by prof. Bruno Siciliano (CREATE/UNINA) and several international scientists have been involved. For the HYFLIERS project, three contributions have been presented, respectively by prof. Anibal Ollero (USE), prof. Juha Röning (UOULU), and prof. Vincenzo Lippiello (CREATE/UNINA).



Figure 3: Maker Faire 2018 at Rome (Italy), “Drones beyond the hobby” workshop.

FADA-CATEC

In this first period, FADA-CATEC has carried out the following dissemination activities:

- Participation in SPRINT Robotics Demonstration Event at Rotterdam RDM (April 2018) where HYFLIERS technologies were discussed with potential end-users (<https://www.sprintrobotics.org/sprint-robotics-demonstration-event-at-rotterdam-rdm-campus/>).
- FADA-CATEC stand in ADM aeronautical fair (May 2018) where HYFLIERS project was presented.
- FADA-CATEC stand in S-MOVING conference and exhibition (October 2018) where HYFLIERS project was presented (<https://smoving.fycma.com/>).
- FADA-CATEC presented HYFLIERS in joint event organised by EASA (through the EU-LAC APP project) and SRVSOP in Lima (Peru).
- FADA-CATEC stand in Global Robot Expo (May 2019) where HYFLIERS project was presented (<https://www.globalrobotexpo.com/>).
- HYFLIERS work has been presented at the 14th AEND Congress in Spain (June 2019) together with DASEL.
- HYFLIERS project was presented at INECO workshop about application of drones for inspection (June 2019).

1.1.3. Industrial Partners

Chevron Oronite

The results of the HYFLIERS project are disseminated on the following platforms:

- Chevron.com website and Chevron social media channels
- Workshops, posters and/or short papers at workshops and industrial conferences
 - European Robotics Forum (ERF);
 - SPE Offshore Europe;
 - SPRINT Robotics Seminar;
 - World Conference NDT;
- Innovation Events, forums and newsletters within Chevron.

The results of the HYFLIERS project have to date been disseminated as follows:

- European Robotics Forum 2018. Tampere, Finland, March 2018
 - Aerial Systems workshop, joint presentation with University of Oulu
 - Audience 100 persons;
- SPRINT Robotics 1st World Conference for Inspection and Maintenance Robotics, Galveston, Texas, USA, November 2018
 - Joint presentation with University of Oulu
 - Audience 100 persons;
- European Robotics Forum 2019. Bucharest, Romania, March 2019
 - Aerial Systems workshop, joint presentation with University of Oulu
 - Audience 100 persons;
- Chevron Operational Excellence Forum 2019. Houston, Texas, USA, April 2019
 - Presentation title: Robotics Enhancing Safety – Removing Personnel from Hazards.
 - Audience 200 persons;
- Chevron Unmanned Aerial Systems workshop, Houston, Texas, USA, April 2019
 - Audience 40 persons;
- Unmanned Aerial Vehicles Industry Engagement Session, Oil & Gas Technology Centre, Aberdeen, UK, July 2019
 - Audience 30 persons.

Total

The results of the HYFLIERS project has to date been disseminated as follows:

- Annual Exploration & Technology Research & technology Review, June 2018
 - Audience 100 persons;
- Annual Technology Group Committee Workshop on unmanned aerial vehicles, December 2018
 - Audience 20 persons;
- ORCA (Offshore Robotics for Certification of Assets) Hub / Industry Workshop, Edinburgh UK, January 2020
 - Audience 20 persons;
- Annual R&D Technical Orientation Committee February 2020
 - Audience 20 persons.

GEIR

The results of the HYFLIERS project are disseminated on the following platforms:

- Workshops, posters and/or short papers at workshops and industrial conferences
 - ERF;
 - ECNDT;
 - WCNDT;
 - Minds and Machines;
- GEIR homepage, section “projects”
- Innovation Events, platforms and newsletters within GE;
- Application for GE internal innovation awards;
- School and youth programs
 - GE Girls Day – dedicated to promoting female engineers;
 - GE Tech Days – dedicated to growing interest for engineering/technology in schools.

Dasel

The divulgation of the activities is carried out in the scope of congresses and events of NDT. Dasel has a particular interest in using this type of technology in the field of aerospace inspection. A work has been presented at the 14th AEND Congress, together with one of the FADA-CATEC partners:

- Giacchetta, R., Brizuela, J., Fernández-Cruza, J. and Alarcon, F. HYFLIERS: intelligent drones to automate the ultrasound inspection of oil and gas infrastructure. 14th AEND Congress.

1.2. Dissemination plan update.

The dissemination plan of the project was presented in Deliverable D7.2 in month M6 [D7.2]. The dissemination plan included actions targeted to the scientific, industrial/end users and educational communities and the general public. The actions implemented by the consortium in the P1 period of the project have been presented in the previous section. The update of the dissemination plan for the rest of the duration of the project is presented in the following subsections for the four different target groups.

1.2.1. Dissemination to the Scientific Community

The dissemination of the HYFLIERS results is being done through publication of scientific and technical articles in journals and at international conferences and workshops. This task is being undertaken mostly by the research partners (Universities and Technology Centres) and the publications cover several fields of the work performed within the project.

HYFLIERS honours the H2020 Mandate on open access to publications, and therefore provides ‘green’ or ‘gold’ open access to peer-reviewed journal and conference publications. The open access will be provided through the Zenodo repository when possible, and linked to OpenAIRE.

In the P1 period, the consortium has published papers in the following *journals*:

- Robotics and Automation Magazine
- IEEE Access
- IEEE Robotics and Automation Letters

In the next period, the number of publications in journals will be incremented substantially. The updated list of recommended journals is presented in Table 1.

Table 1: Updated list of recommended journal and magazines

No	Journal / Magazine
1	IEEE Transactions on Robotics
2	Journal of Field Robotics
3	IEEE Robotics and Automation Magazine
4	IEEE Access
5	IEEE Robotics and Automation Letters
6	Sensors
7	IEEE Multimedia
8	IEEE Transactions on Knowledge and Data Engineering

In the P1 period, the consortium has submitted and presented research papers at these *international conferences*:

- IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) - 2019.
- International Conference on Unmanned Aircraft Systems (ICUAS) - 2019
- Iberian Robotics Conference (ROBOT 2019)
- Workshop on Research, Education and Development of Unmanned Aerial Systems (RED-UAS) - 2019

In the next period, the number of publications and presentations in international conferences will be incremented. The updated list of recommended conferences is presented in Table 2.

Table 2: Updated list of recommended conferences

No	Conference
1	IEEE International Conference on Robotics and Automation (ICRA)
2	IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
3	International Conference on Unmanned Aircraft Systems (ICUAS)
4	IEEE International Conference on Mechatronics and Automation (ICMA)
5	IEEE International Conference on Automation Science and Engineering (CASE)
6	International Conference on Advanced Robotics (ICAR)
7	Robotics: Science and Systems (RSS)
8	Iberian Robotics Conference (ROBOT)

In the P1 period, the consortium members have presented HYFLIERS results in *public talks, keynotes and presentation in workshops* in the following events:

- European Robotics Forum (ERF) 2018, 2019
- International Symposium on Aerial Robotics (ISAR) 2018, 2019
- 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2018, keynote and tutorial
- IEEE International Conference on Robotics and Automation (ICRA) 2019, workshop.
- Robotics, Science and Systems (RSS) 2019, workshop

In the next period, the consortium will continue the public presentations of the HYFLIERS results in workshops and symposiums. The updated list of planned and recommended venues is presented in Table 3.

Table 3: Updated list of recommended venues for public presentations

No	Venues for public presentations (keynotes, workshops, ...)
1	European Robotics Forum (ERF)
2	Workshops in IEEE International Conference on Robotics and Automation (ICRA)
3	Workshops in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
4	Workshops in Robotics: Science and Systems (RSS)
5	International Conference on Unmanned Aircraft Systems (ICUAS)
6	International Symposium on Aerial Robotics (ISAR)

1.2.2. Dissemination to the Industry and End Users

Dissemination of HYFLIERS to the Industry and End-Users is being done through public presentations at industrial conferences and workshops, and industrial seminars. This task is being undertaken mostly by the industrial partners, and also by the other partners.

In the P1 period, the consortium has delivered the following public presentations in industrial seminars, workshops and conferences:

- SPRINT Robotics “World Conference for Inspection and Maintenance Robotics” 2018.
- European Robotics Forum 2018, 2019.
- Chevron Operational Excellence Forum 2019
- Chevron Unmanned Aerial Systems workshop 2019
- Total Annual Exploration & Technology Research & Technology Review 2018
- Total Annual Technology Group Committee Workshop on unmanned aerial vehicles 2018
- SPRINT Robotics Demonstration Event 2018
- Global Robot Expo 2019
- S-MOVING conference and exhibition 2018
- Congress of the NDT Association (AEND) 2019
- Conference “Drones and robots for mapping, inspection and maintenance” 2019
- Presentation to Navantia officials (Spanish ship builder company)

In the next period, the consortium will continue the public presentations of the HYFLIERS results at industrial conferences, workshops and seminars. The updated list of planned venues is presented in Table 4.

Table 4: Updated list of planned actions for dissemination to the Industry and End-Users

No	Venues for dissemination to the Industry and End-Users
1	European Robotics Forum (ERF)
2	SPRINT Robotics “World Conference for Inspection and Maintenance Robotics”
3	Presentations in Total worldwide meetings: Total E&P Inspection & Corrosion Seminar, Nov 2019 Total E&P EXP Field Operations Seminar, Dec. 2019 Total Annual Technical Orientation Committee 2020
4	Chevron worldwide meetings

5	Internal presentation to end-users
6	ORCA Hub Industry Workshop 2020

1.2.3. Dissemination to the Educational Community

The dissemination actions intended for the educational community consist of presentations to MSc and PhD students of robotics-related topics linked to HYFLIERS results, and also in summer schools. Actions in school and youth outreach programs are also included in this section. These actions are mostly accomplished by the academic partners, and also the rest of the partners for the outreach actions.

In this first period, HYFLIERS partners have done the following actions to disseminate the project to the educational community:

- Presentation to students of the Electrical Engineering MSc program (U. Seville) 2019.
- Presentation to students of the Automation, Electronics and Telecommunication Engineering PhD program (U. Seville) 2019.
- GE Girls Day 2019
- GE Tech Days 2019
- Summer course at UNIA (International University of Andalusia) 2018

In the next period, the consortium will continue the dissemination actions targeted to the educational community. The updated list of planned actions is presented in Table 6.

Table 5: Updated list of planned action for dissemination to the educational community

No	Planned actions for dissemination to the educational community
1	Participation in International Summer School of Automatic Control Grenoble 2020
2	Participation in aerial robotics summer schools
3	Presentations to MSc and PhD students (University of Seville, University of Oulu)
4	Participation in outreach programs (GEIR)

1.2.4. Dissemination to the General Public

Dissemination of HYFLIERS results to the general public is done through the project website (<https://hyfliers.eu>) and the partners' own websites, the social media, appearance in the media, and presentations and presence in events intended for the general public.

In the P1 period, HYFLIERS partners have done the following actions to disseminate the project to the general public:

- Maker Faire Rome 2018. Stand and presentations to the public.
- Interview in Kaleva Finnish newspaper 2018 (J. Röning, A. Ollero).
- Interview in Infodron Spanish magazine 2019 (A. Ollero).
- Project website (<https://hyfliers.eu>)
- Individual partners' websites
- Twitter accounts
- LinkedIn accounts

In the next period, the consortium will continue the dissemination actions targeted to the general public. The updated list of planned actions is presented in Table 6.

Table 6: Updated list of planned activities for dissemination to the general public

No	Dissemination to the general public
1	Articles/interviews in newspapers and magazines
2	Participation in general public events
3	Project website
4	Individual partners' websites
5	Twitter accounts
6	Linkedin accounts

2. Exploitation

The exploitation activities are designed to strengthen the position of Europe in the field, where HYFLIERS targets the following:

- Provision of HYFLIERS technology to the project's end user;
- Direct commercial exploitation and licensing of HYFLIERS technology to third parties;
- Generation of spin-off companies;
- Inspiration of new research in robotics;
- Further improvement of academic teaching offer in the field.

Throughout period P1, the project has to date focused on project end user need and risk mitigation particularly when a hydrocarbon release occurs.

2.1. Exploitation activities

2.1.1. Industrial Partners

Total / Chevron

The end users identified early in the project that the two proposed prototypes were too complex to certify for use in a potentially explosive atmosphere (ATEX). Instead, the approach decided for successful deployment of the HYFLIERS prototypes in an industrial oil and gas environment is to mitigate risk to a level that is as low as reasonably practicable.

To achieve this, Total and Chevron stated that a gas sensor must be included in the sensor payload of each prototype. Switching the power off is not enough as a residual current will exist in the batteries which are not designed to contain an ignition source (because of the non ATEX design). In this way, upon confirmed gas, each prototype is able to detect and fly away before reaching critical explosive limits.

The main issue that remains is in the event of a gas release once each prototype has landed, stabilised on a pipe and is clamped by some means, how to achieve the prototypes disconnecting from the pipe and taking off quickly enough.

To this end, USE has developed a mechanical bridge for the HRA prototype which acts as a quick release mechanism modular in design for various clamping methods. See Section 2.1.2.

GEIR

The exploitation goal of GEIR in HYFLIERS is to expand its product and technology portfolio as an inspection systems provider.

The technologies developed during the HYFLIERS can be, depending on the outcomes, exploited as follows:

- Industrialisation of the complete hybrid robot, most likely by transfer to a HYFLIERS spin-off whose business strategy is focused on inspection with aerial drones.
- Industrialisation of the satellite as a standalone product to expand GEIR's portfolio with a crawler suited for inspection of industrial piping and other smaller structures. Based on use-cases identified in cooperation with industrial partners in the HYFLIERS consortium representing asset owners (Total, Chevron), it seems feasible to extend the scope significantly towards "Could" requirements. This could be
 - min tube diameters 6"
 - inspection of elbows, T-joints, reducers and other piping complex elements
 - deployment under a hot work permit when operated without an onboard battery (ignition source); a safe shut-off can be implemented with already available ground stations that incorporate gas monitoring systems
 - integration of the satellite into the GEIR inspection software environment.
- The satellite may be further developed beyond the requirements and use-cases identified in the HYFLIERS project
 - adaptation to cover inner diameters of tubes and vessels
 - evaluation for suitability of ATEX certification
 - integration of other inspection technologies, such as eddy current.
- Use of the technical know-how gained in the HYFLIERS project, e.g. light-weight industrial design in other projects and products of GEIR, e.g. BIKE, FAST or TRIC system.
- Utilization of elements developed by other partners into GEIR products, such as
 - lightweight arm, circular arm
 - ultrasonic roller-probe
 - lightweight UT instrument
 - EMAT technology
 - small and lightweight EMAT instrument suitable for placement on robots.

DASEL

Dasel will focus on the development of ultrasound technology. Its main objective is to develop the necessary elements to have a small UT unit.

DASEL continues advancing in the integration of ultra-low weight ultrasound systems, concentrated in the following technologies:

- EMAT
- Roller probes
- Guided wave technology
- Multichannel system > 4 channels.

The objective of DASEL is not to exploit the complete solution of HYFLIERS, but to market UT's software and electronics.

2.1.2. Academic Partners

University of Oulu

As a consequence of the participation to the HYFLIERS project, UOULU targets at

- Widening their knowledge base;
- Strengthening and expanding their teaching offer in specialised courses;
- Activating related academic thesis topics;
- Raising UOULU academic profile;
- Sparkling new research in the field.

Academic theses work on HYFLIERS research topics is also progressing. The staff of UOULU research team is active in strategic planning at the University.

Moreover, UOULU will disseminate and promote results in euRobotics and SPARC, and thus feed them to the EC for possible use in future framework programmes.

University of Seville

The University of Seville is developing a modular concept for a hybrid robot that can fly, land on the pipe, and move over it to reach the different points that need inspection. This concept, which is presented in detail in deliverable D2.1 [D2.1], has an aerial platform, a magnetic linkage module and a landing gear add-on module which can have different designs with different specifications. The arm, developed by CREATE and described in deliverable D3.1 [D3.1], is attached directly to the magnetic linkage module.

The magnetic linkage module is designed so that in event of confirmed gas detection the lower part with the landing gear, the arm and the ultrasonic sensor can be detached, and the aerial platform with the upper part of the linkage and the batteries can take-off and move away from the dangerous area very fast. The different add-ons, the roller, the soft clamp and the crawler clamp are designed for different pipe configurations, i.e., isolated pipes, groups of pipes with a minimum lateral clearance, pipe racks with small or no lateral clearance, etc. These designs are included in two Spanish patents that are being filed by the University of Seville.

2.1.3. Research and Technological Centres

CREATE

A new start-up company has been founded on 05/10/2018 by prof. Vincenzo Lippiello to exploit the outputs of the HYFLIERS project with the name NEABOTICS srl. The development and commercialization of advanced service robots are the main statutory objective of this new company.

CREATE and the new company stipulated a scientific collaboration agreement. Moreover, a specific agreement has been also signed specifically for the exploitation of the results of the HYFLIERS project. As a tangible result, in few months the start-up has deposited two Italian patent requests, which are extendable at European/World level in one year after the formal acceptance by the patent office:

- number 102018000010184 (08/11/2018)
- number 102019000006875 (15/05/2019)

The latter is a direct result of the HYFLIERS project (the new concept of rover that can move and stabilize on pipes, even if not magnetic). A third patent, which is directly related to the project results (specialized tools and drone robotic arms for NDT inspection), is being written.

FADA-CATEC

The main objective of FADA-CATEC is transferring technology to companies that will market them. Therefore, it is expected that some of the technologies developed in this project, and that will be demonstrated in a realistic scenario, will be of interest of the UAS/robotics industry. Then, the exploitation scheme will be based on licensing the technology for its industrialization and production.

2.2. Update of the Exploitation Plan

The exploitation plan of the project was presented in deliverable D7.2 in month M6 [D7.2]. The actions implemented by the consortium in the P1 period of the project have been presented in the previous section. This section presents an updated overview of the exploitation activities and plans of the partners of HYFLIERS.

2.2.1. Value Chain in Maintenance and Inspection

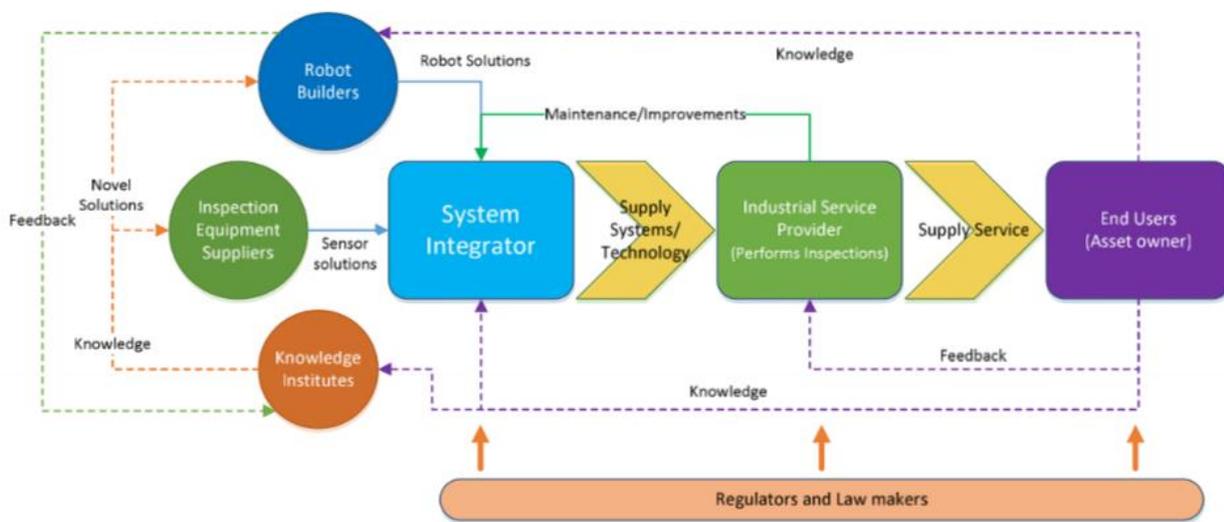


Figure 4: Value chain and stakeholder in robotics in the maintenance & inspection industry domain (see SPRINT Robotics Strategic Roadmap [ROADMAP2018]).

Figure 4 shows the general organization of the value chain in robotics in the maintenance and inspection industry. HYFLIERS consortium partners and their role in the value chain are the following:

- Asset Owner: CHEVRON, TOTAL
- Industrial Service Provider: GE Inspection Robotics (GE Oil&Gas Advanced Inspection Services)
- System Integrator: FADA CATEC, GE Inspection Robotics, Dasel
- Inspection Equipment Suppliers: GE Inspection Robotics, Dasel
- Robot Builders (GEIR);
- Knowledge & Research Institutes: FADA CATEC, University of Oulu, CREATE, University of Sevilla

The industrial consortium partners have reached out to peers to cross-check and benchmark the use cases. CHEVRON, TOTAL and GEIR as SPRINT robotics participants have involved the SPRINT robotics community. The project approach was presented, discussed and benchmarked within in the

SPRINT robotics community. The results are reflected in the project work, in particular in the specification, system design and exploitation.

2.2.2. Industry and Market Characteristics

The spending on maintenance and repair services in the petrochemical and oil&gas plants is significant (see Table 7). The share of maintenance and repair services for pipes is around 5%, which means ca. 1.1 USD billion per year.

The share of pure inspection service work is around 10% - 15%. The addressable market in the hydrocarbon processing domain can be estimated to 112 – 160 USD million per year.

Table 7: Yearly spending for maintenance and inspection [HPI2012]

Sector	U.S.	O.U.S.	Worldwide
Petrochemical/chemical	\$ 6.700.000.000	\$ 20.300.000.000	\$ 27.000.000.000
Oil	\$ 5.700.000.000	\$ 17.500.000.000	\$ 23.200.000.000
Gas processing	\$ 1.300.000.000	\$ 4.500.000.000	\$ 5.800.000.000
Total	\$ 13.700.000.000	\$ 42.300.000.000	\$ 56.000.000.000

Table 8: Split by asset type [HPI2012]

%	Item	U.S.	O.U.S.	Worldwide
5	Piping	\$ 274.000.000	\$ 846.000.000	\$ 1.120.000.000
8	Vessels	\$ 383.600.000	\$ 1.184.400.000	\$ 1.568.000.000
6	Boilers	\$ 328.800.000	\$ 1.015.200.000	\$ 1.344.000.000
10	Heat exchanges	\$ 548.000.000	\$ 1.692.000.000	\$ 1.568.000

Other industries in which similar type of pipe inspection is of relevance are

- Power Generation
- Pharmaceutical
- Basic Chemistry

The addressable market in Power Generation and Pharma, Pharmaceutical and Basic Chemistry are in the same or even slightly larger magnitude as hydrocarbon processing each.

The overall addressable market is estimated at around 0.5 – 0.75 USD billion (inspection services) per year.

The addressable market volume for system sales and system-related support & maintenance (HYFLIERS technology-related systems) is estimated to around 100 – 150 USD million per year (ca. 20% of the inspection service business).

2.2.3. Exploitation related project activities

The basis for an exploitation has been set up with setting up a spin-off and the protection of research and development results by patents which is regarded as an extremely strong position at this point of time in the project. The roles and function of the consortium partners for the exploitations are defined. Each partner is pursuing the defined plan by itself, which is regarded as being important for a success. Additionally, the partners are collaborating in different relationships (customer – supplier relationship, joint industrialization and exploitation set up etc.).

References

- D2.1 Rönning J, ed. (2018) Project presentation. HYFLIERS project deliverable D8.1. 31 Jan.
- D3.1 Rönning J, ed. (2018) Data management plan. ORDP. HYFLIERS project deliverable D8.2. 29 Jun.
- D7.2 Ollero A, ed. (2018) HYFLIERS Dissemination and Exploitation Plan. HYFLIERS project deliverable D7.2. 31 Jan.
- HPI2012 Hydrocarbon Processing Industry Market Data (2012)
- ROADMAP2018 Wim van Hoorn et al. (2018). SPRINT Robotics Roadmap.
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