Deliverable 3.1: Draft Innovation Strategy

Authors: Marina Papageorgiou, Jean Sciare, Ariane Dubost, Paolo Laj, Tuukka Petäjä, Hanna Lappalainen, Carmela Cornacchia, Silja Häme, Spyros Bezentakos

Work package no	WP3
Deliverable no.	D3.1
Lead beneficiary	CYI
Deliverable type	X R (Document, report) ☐ DEC (Websites, patent filings, videos, etc.) ☐ OTHER: please specify ....
Dissemination level	X PU (public) ☐ CO (confidential, only for members of the Consortium, incl. Commission)
Estimated delivery date	M24
Actual delivery date	28/12/2021
Version	Final
Reviewed by	Giulia Saponaro
Accepted by	Eija Juurola
Comments	

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

Contents

1. Introduction

This document is prepared in the context of the activities of the ACTRIS IMP project, in particular in Work Package 3 which provides strategic guidance and steering to enhance the relevance of ACTRIS to science, innovation and society, and monitors the impact and added value of ACTRIS. More specifically, it relates to Task 3.2, which is dedicated to building the strategy for innovation in ACTRIS.

Accordingly, this deliverable outlines a draft innovation strategy for ACTRIS to ensure that technologies in ACTRIS remain state-of-the-art, and align with the scientific mission of the RI, adopted by international standards and closely connected to the commercial market as a supplier, technology partner and user.

This deliverable also draws from, and feeds into the scope and tasks of WP9 "Positioning ACTRIS in the European innovation ecosystem", whose main objective is to foster the role of ACTRIS in the innovation landscape, by increasing the interest of the private sector towards ACTRIS as an innovation platform and by promoting actions for a more effective technology and knowledge transfer. More specifically, this deliverable provides the diagnostics and recommendations for building the ACTRIS innovation strategy, informed by WP9 existing results (MS9.2 Identification of collaboration models between ACTRIS and the private sector, and the ongoing D9.1 Progress Report on the position of ACTRIS in the European Innovation Ecosystem), and to be leveraged in associated actions (Task 9.2, 9.3, 9.4) throughout the implementation phase of ACTRIS (2020 – 2024).

It is the Consortium's expectation, that in order to maximize its relevance and impact, the draft innovation strategy outlined in this document, will be monitored, and refined as / if needed whilst ACTRIS moves towards reaching its operational phase (2025 – onwards), to become a reference service provider for short-lived climate relevant atmospheric constituents, offering a unique Catalogue of Services including open access to data and physical and remote access to high-quality Central and National facilities.

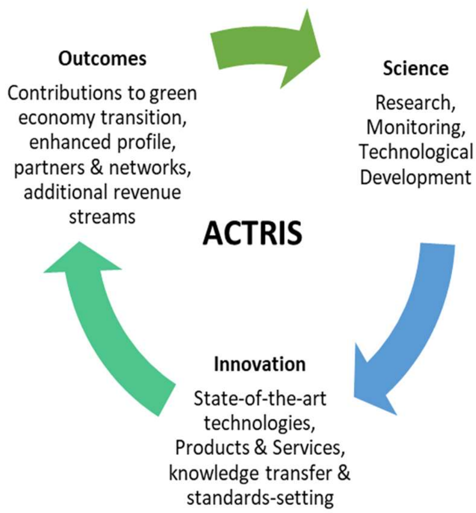
As per above, this document is structured in five (5) sections. Following this introductory section 1:

- **Section 2**, frames the draft innovation strategy's ambition, it evaluates the current positioning of ACTRIS within the innovation space, and it considers ACTRIS' "added value" proposition to be leveraged in reaching its innovation ambitions, as well as the key challenges that ACTRIS needs to address.
- **Section 3**, reports on how ACTRIS ensures that technologies in ACTRIS remain state-of-the-art. This is demonstrated through the use of case studies of innovative technologies (including low-cost), their applications in ACTRIS, and their links to the evolution of the ACTRIS data value chain included in the ANNEX.
- **Section 4,** summarizes ACTRIS's contributions in international standards-setting.
- **Section 5**, outlines the measures for ensuring that ACTRIS technologies and results remain closely connected to the commercial market as a supplier, technology partner and user: mapping opportunities across Europe for engaging with industry; laying out plans for strengthening links between ACTRIS and private stakeholders; and identifying effective actions for maximizing industrial engagement in ACTRIS and enhancing its impact.
- **Section 6,** grounds the ACTRIS innovation strategy ambitions within the timeframe and work programme of ACTRIS IMP.

2. Strategic Context

The draft innovation strategy outlined in this deliverable, and the innovation action that it lays out, aim to contribute to the long-term sustainability of ACTRIS and help maximize its impacts. The intention is for this to be done through efforts to enhance the innovation and technology development potential of ACTRIS to maximize private-user uptake of ACTRIS services and renewal of ACTRIS technologies, and to position ACTRIS at the heart of the international research and innovation landscape.

ACTRIS considers innovation an enabling force for maximizing its research, economic and societal impacts, promoting sustainability for the economy, society and the environment, and for contributing to the long-term sustainability of ACTRIS itself.



This is foreseen through a virtuous cycle (Figure 1) by which the scientific actions within ACTRIS (including research, monitoring and technological development), feed into innovation actions (relating to testing, monitoring and leveraging of state-of-the-art technologies, development of competitive products & services, knowledge transfer with industry and public bodies and the setting of international standards) and lead to positive outcomes for ACTRIS and the wider research & innovation landscape (including enhanced profile, visibility and reputation, partners & networks and the potential of additional revenue streams for ACTRIS, and contributions to green economy transition proving and strengthening the value and need for R&I actions), which then power back its scientific actions (e.g. as additional resources, support and opportunities) and long-term sustainability.

As already outlined in the context of ACTRIS IMP (GA section 2.1), this process contributes to maximizing the <u>long-term impacts of ACTRIS</u> in terms of:

- science (contributing to advancing scientific knowledge on atmospheric concentrations, trends, emissions, processes, etc.) & research (through new methodologies, tools, and instrumentations);
- the economy (including through creating new business opportunities and job creation);
- society (in helping to address challenges relating to climate change, air pollution and its impacts on human health, ecosystems, etc.);
- the environment (by actively contributing to standard-setting, policy-feedback and enabling a green economy transition in support of achieving the goals of the Paris Agreement and the European Commission low-carbon strategy).

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

As outlined in the GA (section 1) this links to all three Strategic Pillars (SP) framing the ACTRIS IMP project ambition and framing its implementation, but more specifically: **SP1 Securing the long-term sustainability of ACTRIS**, by defining and reinforcing the engagement of the ACTRIS community and stakeholders, securing the financial resources, consolidating the Business Plan and the Catalogue of Services, fortifying its user relationships, and addressing the ACTRIS relevance and societal impacts; and **SP3 Consolidating the position of ACTRIS in the national, European and international framework**, including the establishment of ACTRIS as a global research infrastructure contributing to the research and innovation landscape.

Laying out a roadmap for consolidating a central positioning for ACTRIS in regards to innovation, needs to start with an auditing of ACTRIS' current positioning in that space. Building on existing work done by the ACTRIS Consortium (in ACTRIS IMP WP9, WP10 and ACTRIS PPP) a snapshot of ACTRIS current positioning, including the opportunities and threats foreseen in the process of evolving it, are outlined in the below SWOT analysis table.

SWOT ANALYSIS	
STRENGTHS	**WEAKNESSES**
Coordinator of a Pan-European network of RPOs operating National/Central Facilities with state-of-the-art technologies and access to innovative products and services. Single point of entry for access to long-term, quality-controlled measurement data and data services. Cultivated perception for technical quality in the sector. Reach to wide network (in Europe & beyond) of innovation stakeholders. Wide community of experts, lending ideal to knowledge-sharing, testing of innovation, and network partnerships.	Gaps in understanding between ACTRIS and industry that might hinder innovation collaborations (i.e. see "Challenges" below). Innovation capacity (including IP) located within RPOs. Not clear how / if ACTRIS ERIC could leverage IPR created within the framework of ACTRIS going forward. *(NB: though this could also be seen as a strength, leveraged to build further trust and capacity for ACTRIS to further support RPOS – see section 5).* Innovation products and services primarily developed / supplied directly by RPOs (*NB: this might also be leveraged as a strength - as above*).
OPPORTUNITIES	**THREATS**
The alignment of ACTRIS mission with the current European Commission (EC) and global priorities (e.g. Green Deal Strategy and its long-term low carbon strategy, WMO new air quality standards).	Industry bypasses ACTRIS in the process of engaging RPOs for innovation compromising its long-term sustainability.

Optimal time frame (establishment of ACTRIS ERIC) for strengthening and leveraging the current ACTRIS positioning as innovation facilitator to contribute to its long-term sustainability.	Loss of ACTRIS attractiveness for RPOs and EC Member states which are contributing financially to the ACTRIS ERIC annual membership fees.

To capitalize on its strengths and adequately address the weaknesses outlined in the above SWOT table for enhancing ACTRIS' innovation positioning, capacity and potential, the key challenges ACTRIS is faced with to reach its ambitions in terms of innovation, as well as an overview of the ACTRIS "added value" proposition to be leveraged in this regard, are examined below.

Challenges

Based on experience of existing collaboration of the ACTRIS consortium with industry, as well as insights from the wider Environmental Research Infrastructures (ENVRI) community, it has emerged that in advancing its innovation positioning, ACTRIS will need to address some broader challenges that relate to gaps of understanding between Research Infrastructures (RIs) and Research Performing Organizations (RPOs) and Industry on what constitutes successful and efficient innovation partnering. These include:

- **Information gap**: industry doesn't have the time or knowledge to understand the complexity of the distributed infrastructure landscape while the RIs could benefit from acquiring better knowledge of industry segments and the way with which industry operates.
- **Business model gap**: industry, for-profit companies prioritize profit and the financial implications of any given decision as these are vital to the sustainability and survival of their business. RIs and RPOs often do not share/understand this motivation.
- **Culture gap:** industry tend to value practical, solutions-oriented approaches, with clear IPR protection strategy while RIs and RPOs might put more focus on the soundness of methodology and advancing scientific knowledge within an Open Science environment.
- **Scale, pace and resource gap:** industry is driven by competitiveness, promoting fast-paced, scalable approaches for success. RIs and RPOs tend to operate at a different scale, in the framework of long-term atmospheric monitoring commitments, or grant funded collaborative research projects.

While it is clear that ACTRIS will not align its motivations to those of industry, as beyond the economic impacts of innovation, its vision is also dedicated to research and policy-feedback impacts, ACTRIS recognizes that it does need to work towards bridging the above gaps in understanding, in order to ensure more, mutually beneficial relationships with industry going forward, as suppliers, users and/or co-creators of innovation. The Consortium actively employs various means to bridge understanding between RIs / RPOs and industry in the context of ACTRIS IMP, including through organizing joint events with industry contacts operating in the atmospheric sciences, through knowledge-sharing and relevant community events as those organized in the context of ENVRI and other relevant communities, as well as in the context of activities outlined in WP9 and WP10 of the ACTRIS IMP work programme. These are further elaborated in section 5 of this document. Further, a possible solution to address these challenges would be to appoint facilitators at the RI level (e.g., an industry liaisons or contact officer) to bridge the gaps between the two worlds and enhance collaboration.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

Further to the above, and specific to ACTRIS, the Consortium recognizes that a distinct challenge to be resolved relates to clarifying on: i) the **added value proposition** and why ACTRIS should be preferred as a supplier and partner for innovation, and ii) the potential **innovation-related revenue streams** that could contribute to the long-term sustainability of ACTRIS.

In line with the ACTRIS knowledge management and protection strategy (GA, section 2.1) the knowledge created within ACTRIS IMP is aimed at directly benefitting ACTRIS members and users. Generally, ACTRIS IMP follows open access principles to enhance knowledge creation in the establishment of ACTRIS. Open access is not an obstacle for innovation, but protection of Intellectual Property Rights (IPR) may be necessary when working with industry and within technology transfer, as per the "as open as possible as closed as necessary" principles.

Further, based on the current model, new technologies, services and products are primarily developed and offered to external users directly by the ACTRIS network of RPOs. ACTRIS does not itself hold background IP and there is not currently a clear provision for how IPR of exploitable results developed in the context of ACTRIS, may be carried through or leveraged in the frame of an ACTRIS European Research Infrastructure Consortium (ERIC). As outlined in the SWOT table, this might be viewed as a weakness, in that ACTRIS would not have stake in IP or the potential to exploit it in any way. However, this could also be leveraged strategically as a strength for ACTRIS' positioning as an innovation facilitator, as it will allow ACTRIS to be wholly dedicated to furthering the innovation capacity and development of RPOs. This point is further elaborated on in section 5 of this deliverable.

Considering these questions is vital in paving the way for the future development of ACTRIS ERIC. They will be examined in depth in the context of ACTRIS IMP deliverables "D2.3 List of ACTRIS policies, internal rules and legal agreement templates" and "D2.4 Updated ACTRIS Business Plan" both due in M46. For the purposes of this deliverable, and to provide a framework for the ACTRIS draft innovation strategy, a collection of potential strategic approaches that may be deployed by ACTRIS are laid out, building on the ACTRIS added value for innovation, as this is outlined below.

Added Value

A distinct advantage of ACTRIS is that it is *more than the sum of its parts*, in that beyond leveraging the innovation activities and potential of its members, users, and partners, it can act as a connector and facilitator of innovation with a Pan-European reach.

This manifests into an added value proposition for ACTRIS in relation to potential innovation users, suppliers and partners, including ACTRIS members, RIs and RPOs, industry, government and other public entities. Namely, direct engagement with ACTRIS can bring:

- **Expertise:** to recommend, prioritize, guide, and possibly re-direct ongoing and/or future strategic research developments among its wide community of RPOs, hereby potentially influencing large markets (instrumentation, services).
- **Access:** to a large network of observational and exploratory facilities, RPOs, environmental data, state-of-the-art technologies and scientific knowledge relating to atmospheric sciences on a Pan-

European scale, as well as a wide network of technical experts and researchers that can legitimize and promote new instruments and technologies.

- **Reach:** to a growing network of innovation stakeholders in the atmospheric sciences across Europe and beyond, from academia, the public sector, and industry – including SMEs, planned to be further expanded through ACTRIS IMP WP10 actions.
- **Quality**: having cultivated a reputation of upholding high scientific, operational and technological standards, and through its success in securing competitive funding, association with ACTRIS can be perceived as an indicator of these traits amongst the atmospheric sciences community.
- **Breadth and depth:** of skills, expertise, resources and knowledge, which can be leveraged across Europe and its member states in a variety of innovation-relevant activities including consultancy, co-design / co-creation and training.
- **Facilitation, coordination and match-making:** capacity and capabilities for actors in the research & innovation ecosystem on a Pan-European scale, coordinated through the ACTRIS Head Office. Overall, the involvement of ACTRIS may yield several potential cost-benefits as the use of the existing infrastructure, resources, data, and knowledgebase established within ACTRIS could mean that innovation activities could be conducted by ecosystem actors at a fraction of the time and cost it would have taken for them to embark on it on their own (if at all able to proceed with their own means alone).

Potential approaches contributing to ACTRIS' long-term sustainability

Based on the above added value propositions, a number of initial proposals can be considered in terms of possible approaches for establishing revenue streams that may contribute to the long-term sustainability of ACTRIS. These are to be considered as **complementary to, or as "added value benefits" for, the revenue streams already outlined in the current version of the ACTRIS Business Plan** (ACTRIS PPP Deliverable D1.6 Business Plan), which in addition to Grants, Project Funding and Sponsoring, includes Member Contributions, Country Contributions, and Payments, based on the expectation that the value generated by ACTRIS will counterpart or exceed the investment sustained by the countries participating in ACTRIS ERIC as Members or Observers. Said additional revenue-streams, might include the following:

- **Innovation development support or co-creation services**: including acting as a facilitator or innovation platform/support hub for partnerships between actors in the innovation ecosystem, contributing to the design/co-design of instrumentation, equipment, procedures or observation techniques, and providing a platform for the testing/validating of new instruments or technologies. This could translate in the construction of an "*innovation pipeline*" that will engage RPOs into a well-defined step-by-step partnership framework with their industrial counterparts, facilitating technology transfer and fostering marketization while adhering to ACTRIS vision and mission.
- **Advisory services**: on developing innovation, leveraging ACTRIS data or technologies for innovation, research commercialization / related services relating to IPR and other legal issues.
- **Training services**: on building innovation capacity in ACTRIS' remit, using ACTRIS data and/or infrastructure for innovation purposes or in the use and applications of innovative techniques or technologies developed or operated through ACTRIS.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

- **Innovation capacity**: transforming its large network of RPOs into an innovative ecosystem through targeted training (e.g. business plan) and mentoring (e.g. with private investors).
- **Accreditation-adjacent services**: leveraging ACTRIS' reputation to develop a quality standard in terms of specific technologies, RIs or service-provisions.
- **Promotional services**: leveraging ACTRIS' reach and means established to cultivate this such as events and match-making activities on innovation in the atmospheric sciences (e.g. organization of specialized workshops, seminars, info days), as well as the ACTRIS website, mailing list and newsletters. Although revenue streams from annual membership of private partners may represent a marginal contribution to the overall ACTRIS budget, such a mechanism should be considered as it could have wider impacts.

Further, in addition to offering access to ACTRIS RIs through its TransNational Access (TNA) programmes, and building on the work being carried out to develop the ACTRIS Catalogue of Services (Task 6.3), ACTRIS may also consider the potential of consolidating a **catalogue of the products and services provided by its network of RPOs** (e.g. to be gathered through a survey), to better understand the capacity already present within the network and build on it to refine its own innovation strategy. This catalogue could highlight for instance competitive Facilities (e.g. workshops, labs, instruments, etc.) and technical expertise (hardware/software) that could be engaged in the co-development of relevant instrumentation and/or in the provision of specific services (e.g. data mining and visualization, upgrade/miniaturization of instrumentation, chemical analyses, etc.). This catalogue would allow identifying current gaps and help the positioning of both ACTRIS and RPOs. It may promote further integration and distribution of resources within the network. It would be built in such a way that direct competition is minimized while complementarity would be promoted. It could also benefit from the ENVRI-FAIR ongoing work in Task 3.4 on the Catalogue of services of ENVRIs for private sector (D3.5) and the lessons learnt from the CATRIS project[1].

The above proposals are to be further interrogated, tested and refined in the context of ACTRIS IMP (specifically through WP2, WP3 and WP9). If ACTRIS is to move forward with assuming the role of an innovation facilitator and integrator, as suggested in the above analysis, a revised stakeholder mapping exercise, including user and competitor research, will need to be taken forward to validate it, within the framework of preparing the next iteration of the ACTRIS Business Plan.

It should be restated here that beyond supporting commercialization actions and contributing to financial sustainability, ACTRIS' innovation ambition embraces a wider definition of innovation, also considering approaches for the assurance of state-of-the-art technologies and international standards to contribute to economic, scientific and social impacts, in line with sustainability principles and supporting green economy transition. These are addressed in sections 3 and 4 of this document.

3. Ensuring state-of-the-art technologies

ACTRIS has a proven record of successful developments and further integration of new technologies within the RI. New atmospheric parameters (to be monitored), new Central Facilities (the better qualify

[1] CatRIS - Catalogue of Research Infrastructure Services: https://project.catris.eu/

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

these new observations), new scientific instrumentation (e.g. on-line MS techniques), and new exploratory platforms (e.g. chambers, mobile platforms) are few examples that have shown the strong underlying dynamic that continuously feed ACTRIS with state-of-the-art technologies.

The procedures and methodologies employed by ACTRIS are geared towards continuing to advance science, technology development and RI services beyond the current state of the art. These procedures are demonstrated through the use of case studies which outline innovative monitoring technologies (including low-cost solutions), evaluating their potential applications within ACTRIS, and linking to the future evolution of the ACTRIS data value chain.

For the sake of keeping the focus on the strategic approaches ACTRIS may pursue in regards to innovation, ensuring flow within the document, and with the intention of treating this as a living document on which more information will be added to represent more aspects of the ACTRIS community work as the ACTRIS IMP project develops, case studies have been included in the Annex. Such case studies include, and relate to, the use of drone technology in atmospheric sciences and the use of drones as an innovative mobile exploratory platform in ACTRIS; the development and embedding of low-cost air quality sensors; as well as the development of nanoparticle instrumentation. To access the case studies, please refer to the Annex.

4. Informing international standards

ACTRIS' long and successful track-record of cooperation with innovation ecosystem actors, also includes activities that strongly promote standardization through partnerships with the private sector (from ACTRIS-2, ACTRIS PPP and predecessor projects ACTRIS I3, EARLINET, Cloudnet, and EUSAAR).

This section summarizes standard-making activities leveraged within the framework of ACTRIS IMP, for the assurance of international standards in ACTRIS's operation as well as the contribution towards the setting and monitoring of international standards for technologies, observations and methodologies emerging through ACTRIS.

ACTRIS holds a leading role in defining technical recommendations for the introduction of future standardization, and contributes to reinforcing the capacity of the European innovation ecosystem (specifically the private sector) to respond to the evolution of standardization protocols for monitoring the atmosphere.

Within the framework of ACTRIS, this has applied to its involvement in several CEN and ISO initiatives, its relationship with the International Bureau of Weights and Measures (*Bureau international des poids et mesures*, BIPM), as well as the development of internal measurement and calibration procedures for different instruments and techniques relevant to the consortium.

ACTRIS activities relating to standards-setting and upholding international standards have included:

- Development of CEN standard FprCEN/TS 16976 for ambient particle number concentration measurements (CPC). In this case, the technical committee for the standard development consisted mainly of ACTRIS and manufacturer members. ACTRIS sampling recommendation played a major role for the development of technical documents required for the standardization process.
- Ongoing CEN standardization for ambient particle number size distribution measurements (MPSS).
- ISO/TC 146/SC 5 Air quality -- Environmental meteorology: two lidar related standards (Visual range lidar and Doppler Lidar).

For an extensive record of ACTRIS historic participation in standard-setting activities, please refer to ACTRIS-2, "D4.1 Progress report on standard-making process" and "MS4.4 Final report on standard-making process".

Standard-setting and standardization activities are currently underway within the scope of ACTRIS IMP, including in relation to the Aerosol remote sensing data centre unit (ACTRIS DC-ARES). ACTRIS DC-ARES, operated by CNR, is the main responsible partner for the Single calculus cHain for Aerosol Remote sEnsing (SHARE), the centralized processing suite for the processing of aerosol lidar data. The Single Calculus Chain (SCC) is currently used by some of the EARLINET/ACTRIS stations, and it will become mandatory for the retrieval of ACTRIS aerosol profiling data in the operational phase. A TNA pilot action is foreseen (WP7) to offer the Single Calculus Chain use to external users for fostering international cooperation and standardization on the processing of aerosol lidar data.

5. Connecting to the commercial market

5.1. Opportunities for engaging with industry

ACTRIS has already identified and took advantage of a number of opportunities for engaging with industry, which will be further leveraged in the context of ACTRIS IMP.

A solid basis for efficient and successful engagement with private companies by ACTRIS had already been laid in previous projects (ACTRIS-2, EUROCHAMP 2020, ACTRIS PPP). While at the time of consolidating the ACTRIS IMP GA, ACTRIS has already put in place an established partnership with 25 private companies in Europe and worldwide representing suppliers, technology partners and users of ACTRIS (ACTRIS IMP GA, section 1.2), which will be further utilized in fostering the innovation potential of ACTRIS and enhancing its engagement with the private sector.

Further, as a tool to enhance its engagement with industry, ACTRIS has set up and is taking advantage of a transnational access (TNA) programme. A large potential market exists in Europe for improving air pollution control and monitoring, deploying technology, for developing cost-effective and innovative instrumentation or for designing new standard methodologies in conjunction with national metrology institutes (see section 3 and 4). By offering high level facilities for instrument testing and new technology assessments to industry and SMEs, transnational access (TNA) programmes, as implemented in the ACTRIS IMP or ATMO-ACCESS projects, are an asset to feed in the innovation strategy of ACTRIS. ATMO-ACCESS notably seeks at testing new access modalities and creating TNA pilots co-designed with private sector users. It is planned to combine the complementary capabilities of the various platforms and laboratories to provide enhanced services for innovators working in the development and application of atmospheric measurement techniques, which includes instruments, low-cost sensors, and other technologies.

ATMO-ACCESS also includes work on pricing and access fees which need to be asked for industrial users. This will help RIs involved in the project to better budget and invoice industrial users requesting a service be it at national or transnational level.

The TNA tool has some constraints notably regarding the administrative workload required for the users and regarding eligibility criteria. For instance, the user group and most of the users must work in a country other than the country where the installation providing access is located. This could be a barrier for private sector users as most of the collaborations with RI facilities are done at national or regional level. A tracking of Research Collaborations with private sector companies in complement of TNA projects involving industrial users should be envisaged as done in the EUROCHAMP 2020 project[2].

Furthermore, ACTRIS is involved in several projects and networks aiming at strengthening the links between Research infrastructures and the private sector:

· **ENVRI-FAIR**: ACTRIS is actively involved in ENVRI-FAIR WP3: Strategy for alignment with national and international stakeholders, community development and innovation activities. One of the aims of this WP is to develop targeted collaborative actions with the private sector to enhance the uptake of ENVRI data services. ACTRIS notably participated in the first ENVRI-FAIR workshop on innovation on 9 November 2021. The workshop aimed at discussing how to better unlock and exploit the innovation potential of Research infrastructures and how to boost ENVRIs cooperation with industry as providers of advanced services, procurers of leading-edge technologies and partners in the development of new data driven products and applications.

· **ENRIITC**: the ENRIITC project aims at building a permanent pan-European network of Industrial Liaison and Contact Officers and enable industry to become a full partner of RIs whether as a user, a supplier, or an innovation partner for co-creation. ACTRIS is an associated partner of the project and could benefit from this project experience for the establishment and operations of the ACTRIS Liaison Office.

These projects allow sharing experiences and best practices with RIs and try to find common ways to overcome the traditional challenges faced by RIs.

Some ACTRIS RPOs are also involved in projects aiming at developing operational pilots which showcase the capacity of the RI such as:

[2] See EUROCHAMP-2020 D4.6 Final Report on Engagement with the Private Sector: within the Eurochamp-2020 project 12 TNA involved industrial users, and 17 research collaborations were identified.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

· **ACTRIS CAMS contracts**: ACTRIS-CAMS are pilot contracts for the ACTRIS data provision to the Copernicus Atmosphere Monitoring Service (CAMS), with the main aim of demonstrating the feasibility of fully traceable and quality-controlled data provision and setting up the system of data provision in Near-Real-Time for the whole network. ACTRIS-CAMS comprises two contracts for the provision of ACTRIS observations: CAMS_21a for the provision of surface in-situ aerosol data and CAMS_21b for the provision of profile aerosol data.

· **e-SHAPE**: e-SHAPE showcases are operational services in the field of Earth observation research in Europe. This project is this regional GEO initiative aiming at improving user uptake of Earth Observation data in Europe. ACTRIS is notably involved in the EO4D_ASH - EO Data for Detection, Discrimination & Distribution (4D) of Volcanic ash pilot led by CNR.

Finally, ACTRIS plans to continue to align with EU strategies which aim to create more connected and efficient innovation ecosystems and plans to take advantage of innovative activities across Horizon Europe and other EU funding programs to improve the overall ecosystem for innovation in Europe. ACTRIS will also be able to leverage the European Policy on European Innovation Ecosystems (EIE) in complement and synergy with the European Innovation Council (EIC) and European Institute of Innovation and Technology (EIT).

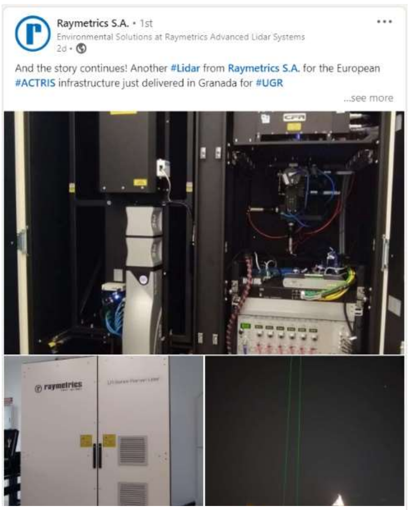
ACTRIS will also engage with the community and partners, and pursue participation in events and networking opportunities of EIT Climate - KIC, Europe's largest public-private innovation partnership focused on climate innovation to mitigate and adapt to climate change. A large number of ACTRIS participating RPOs are already active members of the EIT Climate-KIC community which can help highlight the added value ACTRIS can bring to relevant initiatives and collaborations.

5.2. Strengthening links between ACTRIS and private stakeholders

Further to the above, ACTRIS employs a suite of communications means to strengthen links with private stakeholders.

On 18 May 2021, ACTRIS successfully co-hosted the 1st Innovation in Atmospheric Sciences Virtual Workshop (https://www.actris.eu/innovation-workshop). The workshop was also a Partner Event of the 2021 EU Green Week. Through a full day of sessions, talks, and activities the workshop brought together atmospheric science communities to discuss the latest innovations in the sector. Participants had the opportunity to find out about and discuss the latest technologies, products, services, and instrumentation. The Workshop Programme included 30 Oral Presentations reporting on the main innovations in the field of atmospheric sciences and a selection of 23 virtual PICO presentations with recent relevant advances in the field. Presenters came from universities, research institutions and private companies from across Europe and beyond. Details of the programme are accessible on the ACTRIS website. The Workshop brought together nearly 400 participants from 45 countries, and created a unique platform for networking and knowledge-exchange between key contacts from academia, private companies, the public sector and NGOs.

In addition, targeted communication actions have been put in place in the frame of WP10 (see e.g., ACTRIS IMP Milestone 10.3: Guidelines for communication and public relations). A specific section of the website has been set up to inform the private sector about the different opportunities offered by ACTRIS. Besides, a dedicated private sector mailing list was created by the ACTRIS Head Office (under WP9 activities) on the ACTRIS website. This allows the HO to send targeted mailing campaigns to individuals interested in innovation via *mail chimp* notably and monitor its successes.



LinkedIn post by Raymetrics

To further engage with private sector users, ACTRIS could build up on Eurochamp "Success Stories" which highlight successful collaborations between EUROCHAMP-2020 partners and the private sector.

Efforts are also put in developing and maintaining a high level of activity on social media to promote ACTRIS: to date the ACTRIS accounts have 1400 followers on Twitter and 175 on LinkedIn. These communication actions are part of the recommendation measures detailed in the RI Innovation and Industry Liaison Preparedness Roadmap[3] developed in the ENVRI-PLUS project.

5.3. Maximizing industrial engagement

As already outlined in section 2 of this document, ACTRIS aims to maximize its engagement with industry to help secure the long-term sustainability of ACTRIS and consolidate the position of ACTRIS in the national, European and international research and innovation landscape.

To bring this ambition to life, ACTRIS has identified, and will capitalize on the potential of offerings that do or can meet, the key industry needs that can be addressed through the remit, activities and resources of ACTRIS. On the market-side, these needs primarily relate to access to high-quality long-term monitoring data, research infrastructure, technologies, and expertise to assess, adapt, and develop solutions for the monitoring of atmospheric composition and the improvement of air quality. They are strongly motivated by initiatives aimed at addressing the climate crisis and promoting a sustainable economic recovery from the impacts of the ongoing COVID-19 pandemic, requiring continuing monitoring and compliance towards emissions-reduction goals set at the national (NECPs), EU and international levels, in line with the goals of the Paris Agreement. Relevant capacity of ACTRIS in response to these needs includes improving air pollution control and monitoring, deploying technology for developing cost-effective and innovative

[3] ENVRIPLUS, D18.5 RI Innovation and Industry Liaison Preparedness Roadmap

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

instrumentation or for designing new standard methodologies in conjunction with national bodies, and providing consultancy and training services in strengthening capacity in these remits.

Depending on the strategic direction(s) ACTRIS chooses to pursue in terms of its innovation positioning, the markets that may be addressed may include the following, relating to ACTRIS positioning as:

- **Facilitator**: building and expanding on the notion of ACTRIS as Innovation Platform, and as outlined in section 2 of this document, ACTRIS is well-positioned to operate as a facilitator for innovation, connecting and providing innovation support services (including providing unique insights into new or existing products, help resolve technical uncertainties), training and access to data and facilities to RPOs, industry (including SMEs) and other organizations directly involved, or aiming to take advantage of opportunities relating to, innovation in the atmospheric sciences.
- **Supplier or partner**: this relates to the potential of ACTRIS having direct involvement in the provision and/or co-creation of new products and innovative services in the environmental field. A potential large market exists in Europe for improving air pollution control and monitoring, use of renewable energy, and developing cost-effective and innovative instrumentation.

Moreover, the use of ACTRIS data has a potential impact in different sectors in terms of services, including food security, tourism, water access, agriculture and farming, public health, protection from risks related to climate change, and resilience of territories.

The market potential of the above options will be further examined to inform the consolidated positioning for ACTRIS to be crystalized in the context of relevant work conducted within ACTRIS IMP, primarily relating to WP9, and within the framework of updating the ACTRIS Business Plan (WP2).

Input in this process will also be provided by the ongoing consolidation of the ACTRIS catalogue of services, as this was reported in "MS6.2 Detailed description of the ACTRIS Service Catalogue" (M13) and MS6.4 "1st Release of the ACTRIS Catalogue of Services" (M18) and, its part classified as "innovation services", included in the ongoing MS9.4 Draft ACTRIS Innovation offer portfolio. Complimentary to this work, and if deemed valuable by the Coordination, ACTRIS may also conduct an exercise to gather information on the existent capacity of the RPOs in its network for the provision of competitive products and services to industry.

In maximizing ACTRIS industrial engagement, all potential collaboration models between ACTRIS and the private sector will be considered, as these have been identified in ACTRIS IMP "MS 9.2 Identification of collaboration models between ACTRIS and the private sector" (M16), relating to a. the upstream business model (industry as a supplier), b. the downstream business model (industry as a user), and c. the co-creation business model (RIs and industry acting as innovation partners).

Recommendations will also be taken forward from the European Commission's independent Expert Report "Supporting the Transformative Impact of Research Infrastructures on European Research". The report acknowledges ACTRIS' efforts in implementing the Innovation Platform and services that are being used by industry. It also states that "ACTRIS still needs to put the ensemble of these activities as a central part of the RI governance structure". Key recommendations include that ACTRIS:

- Seeks project-based resources to initiate innovation activities and recruit the necessary expertise;
- Widens the user community also exploiting the huge innovation potential of technology development via co-design and co-creation projects with industry, so as to provide market-driven services to the private sector.

During the construction and implementation phase of ACTRIS, there have been strong indications for the potential demand from industry in using RI services as well as the interest in supplying instrumentation for this purpose. Indicatively, the study in ACTRIS PPP WP8[4] , showed that the funds attracted within R&D projects commissioned by the private sector in utilizing ACTRIS facilities amounted to c.16 M€ in the period 2008-2016, with an estimation of additional 12 M€ for 2017-2019. The same data analysis shows that cooperation with private sector companies led to the creation of 9 start-ups/spin-offs in the period 2008-2016, and 3 more expected for 2017-2019.

In line with this ambitious strategy, ACTRIS community is currently involved in taking the advantage of the Horizon Europe call dedicated to Next generation of scientific instrumentation, tools and methods (2022) (HORIZON-INFRA-2022-TECH-01) with the aim to focus on Research and development of new scientific instrumentation, their technology validation and prototyping, as well as new tools and methods taking into account the industrial exploitation of the solutions and/or for the benefits of the society.

To exploit this potential, dedicated mechanisms, guidelines and procedures are being put in place to define the framework through which legal issues, including confidentiality, IPR and licensing will be handled within ACTRIS, to provide clarity and further facilitate and encourage industrial engagement. These will be reported on as part of ACTRIS IMP "D2.3 List of ACTRIS policies, internal rules and legal agreement templates" (M48) and referenced in the updated ACTRIS Business Plan (D2.4). Care will be taken to ensure that in the relevant frameworks to be developed the ambition of ACTRIS for the development of its data value chain is complementary to its ongoing commitment to Open Access and Horizon Europe Open Science principles.

Finally, summarized below are additional actions to be undertaken within ACTRIS IMP aimed at maximizing industrial engagement in ACTRIS and enhancing its impact, in the context of WP9 - Positioning ACTRIS in the European innovation ecosystem, and specifically:

- Task 9.2 ACTRIS modalities for technology transfer: which will provide the framework for sound interactions and networking with the private sector in all possible models of technology/knowledge transfer (upstream, downstream, co-creation).

[4] ACTRIS PPP, D8.1: Report on KPIs for the quantification of ACTRIS direct impact

- Task 9.3 Addressing current and future innovation demand from the private sector: which will provide an assessment and analysis of private sector user needs, and produce a list of findings, recommendations and actions for how ACTRIS can best address these.
- Task 9.4 Fostering partnership with the private sector in ACTRIS: which will set the frame of actions to generate an enabling environment for new opportunities of cooperation in innovation with the ACTRIS community and the private sector.

6. Grounding the strategy

The innovation work of ACTRIS and the implementation of the innovation strategy will be supported by WP9 in which the technical work for innovation and industry involvement will be tackled (as per the tasks outlined in section 5.3 of this deliverable). Most innovation-related actions are foreseen to take place in ACTRIS CFs and NFs, being the focus of ACTRIS IMP WP4 and WP5, respectively. Actions relating to setting the legal framework for innovation will be executed within WP2, whilst engagement with industry will be further supported by WP10. The innovation implementation actions taking place within the context of ACTRS IMP WPs are planned to be concluded by the project planned end-date, though the strategy and actions that it sets out will be carried forward within the context of ACTRIS ERIC (2025 - onwards).

The innovation management of ACTRIS IMP will be overseen by the ACTRIS IMP Executive Board together with the ACTRIS RI committee, National Facility Assembly, which will also be accountable for ensuring the appropriate refining of the ACTRIS innovation strategy, its implementation within ACTRIS, and the setting and monitoring of innovation KPIs to support progress towards the strategic direction for innovation to be solidified in the Updated ACTRIS Business Plan (D2.4). Further, a more concrete framework for implementation will be defined through the definition of the ACTRIS liaison office, relevant means and recommendations for which will be reported as part of “D9.2 Means and recommendations for the operation of the ACTRIS liaison office (M36)”.

The innovation strategy in itself, the first draft of which has been laid out in this deliverable, will be treated as a “living” document, to be reviewed, discussed and revised by the Consortium throughout the duration of the ACTRIS IMP project, under the coordination of the ACTRIS Head Office. Within that framework, additional innovation case studies will be collected and updated from across the ACTRIS community.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

7. References

ACTRIS-2, D4.1 Progress report on standard-making process

ACTRIS-2, MS4.4 Final report on standard-making process

ACTRIS IMP, MS 9.2 Identification of collaboration models between ACTRIS and the private sector

ACTRIS PPP, D1.6 ACTRIS Business Plan

ACTRIS PPP, D8.1: Report on KPIs for the quantification of ACTRIS direct impact

Bezantakos, S., Costi, M., Barmpounis, K., Antoniou, P., Vouterakos, P., Keleshis, C., Sciare, J. and Biskos, G., 2021. Qualification of the Alphasense optical particle counter for inline air quality monitoring. Aerosol Science and Technology, 55, 361-370.

Borrego, C., Coutinho, M., Costa, A.M., Ginja, J., Ribeiro, C., Monteiro, A., Ribeiro, I., Valente, J., Amorim, J.H., Martins, H., Lopes, D., Miranda, A.I., 2015. Challenges for a new air quality directive: the role of monitoring and modelling techniques. Urban Climate 14 (Part 3), 328–341.

CatRIS - Catalogue of Research Infrastructure Services: https://project.catris.eu/

CITI-SENSE, 2016. Development of citizen observatories for improvement of quality of life in cities. In: Project Summary, Deliverable D9.16.

ENVRIPLUS, D18.5 RI Innovation and Industry Liaison Preparedness Roadmap

EUROCHAMP-2020 D4.6 Final Report on Engagement with the Private Sector

GAW report No. 227, 2016

Jovašević-Stojanović, M., Bartonova, A., Topalović, D., Lazović, I., Pokrić, B., Ristovski, Z., 2015. On the use of small and cheaper sensors and devices for indicative citizenbased monitoring of respirable particulate matter. Environ. Pollut. 206, 696–704.

Kezoudi, M., Tesche, M., Smith, H., Tsekeri, A., Baars, H., Dollner, M., Estellés, V., Bühl, J., Weinzierl, B., Ulanowski, Z., Müller, D., and Amiridis, V.: Measurement report: Balloon-borne in situ profiling of Saharan dust over Cyprus with the UCASS optical particle counter, Atmos. Chem. Phys., 21, 6781–6797, https://doi.org/10.5194/acp-21-6781-2021, 2021.

Morawska, L., Thai, P. K., Liu, X., Asumadu-Sakyi, A., Ayoko, G., Bartonova, A., Bedini,A., Chai, F., Christensen, B., Dunbabin, M., Gao, J., Hagler, G. S. W., Jayaratne, R., Jumar, P., Lau, A. K. H., Louie, P. K. K., Mazaheri, M., Ning, Z., Motta, N., Mullins, B., Rahman, Md. M., Ristovski, Z., Shafiei, M., Tjondronegoro,

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

D., Westerdahl, D., Williams, R., (2018). Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? Environ. Int.,116, 286-299.

Rai, C. A., Kumar, P., Pilla, F., Skouloudis, A. N., Di Sabatino, S., Ratti, C., Yasar, A., Rickerby, D., 2017. End-user perspective of low-cost sensors for outdoor air pollution monitoring. Science of the Total Environment 607-608, 691-705.

USEPA, 2016. Air Pollution Monitoring for Communities Grants.

Villa, T. F., Gonzalez, F., Miljievic, B., Ristovski, Z. D., and Morawska, L. (2016). An Overview of Small Unmanned Aerial Vehicles for Air Quality Measurements: Present Applications and Future Prospectives. Sensors, 16(7), 1072.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

ANNEX

CASE STUDIES: TECHNOLOGICAL DEVELOPMENT AND INNOVATION WITHIN ACTRIS

Case Study #1 Low-cost air quality sensors

Recent developments in the field of micro-electronics, material sciences and manufacturing processes have been utilized towards reducing the dimensions (i.e., miniaturization) and cost of air quality (AQ) sensors. These technologies and their outcomes promise a revolutionary advance in both outdoor and indoor AQ monitoring by vastly increasing the spatiotemporal resolution of the observations, which in turn can be utilized for: i) supplement existing AQ monitoring infrastructure(i.e., reference sites), ii) provide additional and much needed data for relating pollutant exposure and human health, iii) improve emergency response management, iv) enhance source compliance monitoring, v) increase citizen awareness and engagement towards better AQ, sustainable environment and healthy living[5]. Mixed networks, consisting of reference/standard instruments and low-cost/miniature sensors, have been recommended in the USA[6], since a few years ago. In addition to that, low-cost and most importantly miniature/lightweight sensors are excellent candidates for AQ observations on-board Unmanned Aerial Vehicles (UAVs), due to their small size, low weight and low energy consumption[7].

Due to the numerous low-cost sensors, emerging mainly from the private sector, which do not undergo under extensive performance testing and characterization[8], both the US and EU have funded projects for the evaluation of the performance of low-cost AQ sensors and AQ networks based upon them (e.g., USEPA, 2016[9]; CITI-SENSE, 2016[10]). Low-cost AQ sensors cover a wide range of sensors that provide measurements of AQ relevance, including particulate matter (PM) sensors (e.g., PM number/mass concentration, PM size distribution, PM physicochemical properties in general) and/or gas sensors (e.g., NOx, SOx, O_3, Volatile Organic Compounds; VOCs, etc.). It should be noted that the term "low-cost" is rather ambiguous, covering a range from a few to some thousand Euros, depending mostly on the scope/application and user. For instance, while a 5k Euro PM sensor can be considered as a "low-cost" sensor for a governmental authority, in comparison to a 50k Euro reference instrument, the same is considered as a high cost sensor for a person/community and/or a small business.

---

[5] Rai, C. A., Kumar, P., Pilla, F., Skouloudis, A. N., Di Sabatino, S., Ratti, C., Yasar, A., Rickerby, D., 2017. End-user perspective of low-cost sensors for outdoor air pollution monitoring. Science of the Total Environment 607-608, 691-705.

[6] Borrego, C., Coutinho, M., Costa, A.M., Ginja, J., Ribeiro, C., Monteiro, A., Ribeiro, I., Valente, J., Amorim, J.H., Martins, H., Lopes, D., Miranda, A.I., 2015. Challenges for a new air quality directive: the role of monitoring and modelling techniques. Urban Climate 14 (Part 3), 328–341.

[7] Villa, T. F., Gonzalez, F., Miljievic, B., Ristovski, Z. D., and Morawska, L. (2016). An Overview of Small Unmanned Aerial Vehicles for Air Quality Measurements: Present Applications and Future Prospectives. Sensors, 16(7), 1072.

[8] Jovašević-Stojanović, M., Bartonova, A., Topalović, D., Lazović, I., Pokrić, B., Ristovski, Z., 2015. On the use of small and cheaper sensors and devices for indicative citizenbased monitoring of respirable particulate matter. Environ. Pollut. 206, 696–704.

[9] USEPA, 2016. Air Pollution Monitoring for Communities Grants.

[10] CITI-SENSE, 2016. Development of citizen observatories for improvement of quality of life in cities. In: Project Summary, Deliverable D9.16.

Current commercialized low-cost sensors include: i) PM sensors that are mostly based on the optical detection of aerosols in order to determine their mass concentration and/or size distribution and ii) metal-oxide-semiconductor (MOS) and electrochemical (EC) sensors for measuring the concentration of AQ-relevant gases, operating on the basis of induced measurable changes on their sensing material(s) due to the absorption of a specific gaseous species (e.g., conductivity). Based on the available scientific literature the performance of the commercially available low-cost sensors in comparison to standard/laboratory-grade instruments varies significantly, especially under real-life conditions, exhibiting coefficients of determination (i.e., R^2) ranging from ca. 0.1 to ca. 0.91. Causes for the observable discrepancies between the low-cost sensors and laboratory-grade/standard counterparts are related to their design, operating principle, materials and peripherals, data processing and sampling methods.[11] For example, the non-straight path design of a low-cost PM sensor can induce significant losses of super-micron aerosols (i.e., due to impaction losses), compromising its performance at this size range. In addition, a fan-based sampling flow system, which is common to most PM low-cost sensors, is inadequate for their connection with PM pre-treatment/drying lines, prohibiting sampling of aerosols at a dry state, which would mitigate sampling artefacts and increase data quality according to the suggestions of WMO/GAW[12]. On the other hand, the performance of the low-cost gas sensors can be compromised by the cross-sensitivity of the sensing material to other gases, temperature and relative humidity (RH) conditions, which may alter the properties of the sensing material independently of the gas concentration, and on the accuracy of measuring electronic circuit.[13]

Despite the observable discrepancies between the low-cost sensors and reference/laboratory- grade instruments, efforts for their improvement and their development beyond the current state of the art are conducted. Such efforts are materialized upon the recognition of the high potential of low-cost sensors for conducting/complementing AQ observations and atmospheric research and on the rapid and continuous evolution of the associated technologies. For instance, some of the low-cost PM sensor limitations can be overcome by targeted modifications (e.g., a more adequate/standard complying sampling flow system) and their implementation on low-cost instruments.[14] The latter combine one or more low-cost sensors with all the needed peripherals and modifications for its autonomous operation, while offering increased applicability and improved performance in most of the cases, while maintaining

[11] Morawska, L., Thai, P. K., Liu, X., Asumadu-Sakyi, A., Ayoko, G., Bartonova, A., Bedini,A., Chai, F., Christensen, B., Dunbabin, M., Gao, J., Hagler, G. S. W., Jayaratne, R., Jumar, P., Lau, A. K. H., Louie, P. K. K., Mazaheri, M., Ning, Z., Motta, N., Mullins, B., Rahman, Md. M., Ristovski, Z., Shafiei, M., Tjondronegoro, D., Westerdahl, D., Williams, R., (2018). Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? *Environ. Int.,*116, 286-299.

[12] GAW report No. 227, 2016

[13] Rai, C. A., Kumar, P., Pilla, F., Skouloudis, A. N., Di Sabatino, S., Ratti, C., Yasar, A., Rickerby, D., 2017. End-user perspective of low-cost sensors for outdoor air pollution monitoring. Science of the Total Environment 607-608, 691-705.

[14] Bezantakos, S., Costi, M., Barmpounis, K., Antoniou, P., Vouterakos, P., Keleshis, C., Sciare, J. and Biskos, G., 2021. Qualification of the Alphasense optical particle counter for inline air quality monitoring. Aerosol Science and Technology, 55, 361-370.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

the favourable characteristics of cost-effectiveness, high energy efficiency and of compact dimensions/portability.

It is important to highlight, that most of the low-cost sensors and instruments are tested following various, custom protocols, while only a small minority of studies have followed and/or reported their results based on national (e.g., U.S EPA) or European protocols, thus a direct comparison between all their published performance results is difficult and laborious. Low-cost sensors/instrument developers can be benefited by the know-how of the ACTRIS members/associates, the proposed standardization/protocols, and the vast network of observational sites. Access to these sites and most importantly to the high quality, easy accessible data offered by ACTRIS, is essential for evaluating the performance of low-cost sensors/instruments under diverse real-life conditions, thus complementing laboratory studies, while highlighting aspects for improvements and further development. End users of low-cost sensors/instruments can be benefited from the involvement of ACTRIS in low cost-sensor evaluations, by being able to locate in a centralized database all the key information (e.g., scope of use, cost, performance, available technologies, evaluation of operation under different conditions/locations) necessary for selecting the most suitable sensor for the scope. On the other hand, ACTRIS network can be mainly benefited by the significant increase of the spatiotemporal resolution offered by adopting accurate, standardized, low-cost sensors and by their unique capabilities for performing mobile observations (e.g., on-board UAVs). By exploiting both these advantages, studying diverse micro-environments, and/or rapid evolving procedures with a quasi real-time resolution (due to the networking capabilities of the low-cost sensors) would be facilitated, in a wide pan-European network.

Case Study #2: Drone technology in atmospheric sciences

Potential: Unmanned Aircraft Systems (UAS) comprise of an unmanned aircraft platform, its payload, control station, Ground Control Station (GCS), and the aircraft launch and recovery sub-systems. UAS operation has become more frequent over the past decade, enabling low-cost routine observations targeting the investigation of gases and aerosols properties and their evolution within the Earth's atmosphere. One of the benefits of the UAS is their ability to fly over regions where no manned aircraft is allowed to fly, for example, close to a fire, a volcanic eruption, or a nuclear accident. UAS can sample aerosols at relatively low air speed (which manned aircraft can hardly perform) with high collection efficiency and minimal disturbance of the environment. They have the potential to fly close to the ground (which is critical for better documenting the vertical dispersion of ground-based emissions), and they can provide very dense atmospheric operations (high spatial resolution). As such, they can fill the gap of observations between ground-based in-situ and remote sensing observations, both being performed within ACTRIS. Another advantage is that one can easily and safely recover the UAV-payload after the flight; something that is not always easy with balloons. UAS have the great potential to complement relatively low-cost ground-based measurements with an airborne in-situ component and contribute to various diverse atmospheric applications, especially over regions where surface measurements are impossible or hard to perform on a regular basis, for example over oceans. Some of them deal with (1) the calibration/validation of lidar and satellite aerosol products, e.g., of the Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS), (2) in-situ cloud sensing, (3) the representation of ground-based observations (e.g., of new particle formation), (4) the mapping of ground-based emissions for Integrated Carbon Observation System (ICOS), and (5) the detection and mapping of air pollution episodes. UAS can also be valuable tools for hyperspectral or multispectral monitoring of ecosystems and hence contribute to the understanding of land-atmosphere interactions.

Challenges: Challenges to integrate drone technologies into ACTRIS are enormous. Among obstacles, the lack of well-established training programmes for pilots and Ground-control station operators following the recently updated EC regulation on drones (European Union Aviation Safety Agency, https://www.easa.europa.eu/), and the lack of critical mass of end-users in ACTRIS if we exclude the ISARRA (International Society for Atmospheric Research using Remotely piloted Aircraft, http://www.isarra.org/) community, which is mostly devoted to meteorological research. Although availability of lightweight sensors is increasing fast with more and more robust technologies and better quality measurements, the number of sensors remains limited. Hence, integration of sensors into UAVs may require additional technical skills and knowledge as the number of fully integrated UAS solutions remains extremely limited. The added value of UAS within the long-term monitoring strategy of ACTRIS remains also open and most of the current applications of UAS remain limited to intense deployments of several weeks. Last but not least, companies selling lightweight sensors are not those proposing UAS solutions for atmospheric observations, creating a gap in the supply chain.

Drones as an innovative mobile exploratory platform in ACTRIS: Nevertheless, and despite all these obstacles, the community of UAS end-users within ACTRIS is constantly increasing (ca. >15 RPOs), and it has appeared necessary to account for this mobile platform as a new means of observation and ensure it meets adequate requirements (precision, accuracy) for atmospheric parameters relevant to ACTRIS (e.g. total aerosol number concentrations, absorption). In this respect, ACTRIS IMP is testing, for the first time, the provision of TNA within a UAV facility (USRL, https://usrl.cyi.ac.cy/ and Kezoudi et al., Atmosphere, 2021), and lessons learned will certainly allow the provision of more adapted services. At the same time, ACTRIS Central Facilities are expected to play a major role here in organizing specific workshops, training, and intercomparison studies for targeted UAS lightweight sensors, define appropriate Standard Operating Procedures (SOPs), and develop new tool kits for the data visualization and uploading them into the ACTRIS (ebas) database.

It is envisioned here that integrating UAS into ACTRIS will further boost Innovation capacities of a growing number of RPOs which will further develop new UAS solutions (beyond the current mission of ACTRIS), and raise the overall reputation and visibility of ACTRIS in this specific field.

Case Study #3 Development of nanoparticle instrumentation

Potential: Recently the importance of nanoparticles has been recognized in air quality, climate change and industrial applications, such as in clean rooms. On one hand, aerosol number concentration measurements for larger than 10 nm in size are standardized as a part of CEN-activity as underlined above. In this action, ACTRIS aerosol in-situ CF is heavily involved. On the other hand, there is a scientific need to explore concentration measurements below the CEN standardized aerosol sizes of 10 nm and below. This is particularly critical for the understanding and quantifying the gas-to-particle conversion at the molecular level.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115

Challenges: The reliable measurement of sub-10 nm number concentration and size distribution has many physical and chemical challenges. For example, the high diffusivity of the particles and their loss to the inlet structures during the measurement process is a considerable technological challenge.

ACTRIS IMP (www.actris.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-INFRADEV-2019-2, Grant Agreement number: 871115