Deliverable D5.2: Documentation on technical concepts and requirements for ACTRIS Exploratory Platforms

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Contents

1 Introduction 2
2 Overview on ACTRIS Exploration Strategy 3
3 General principles for ACTRIS Exploratory Platforms 5
4 Technical concepts and requirements for ACTRIS Exploratory Platforms 6
4.1 ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms 6
4.1.1 Purpose and targets 6
4.1.2 Standards for instrumentation, operation and data provision 7
4.1.3 Requirements and recommendations 9
4.2 ACTRIS Mobile Platforms 10
4.2.1 Purpose and targets 10
4.2.2 Standards for instrumentation, operation and data provision 11
5 Organizational and strategic concepts and requirements for ACTRIS Exploratory Platforms 16
5.1 ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms 16
5.1.1 Scientific excellence 16
5.1.2 Uniqueness and diversity 16
5.1.3 Access capabilities 16
5.2 ACTRIS Mobile Platforms 17
5.2.1 Scientific excellence 17
5.2.2 Mobility 17
5.2.3 Access capabilities 18
5.3 Recommendations for national strategies 18
Annex A: References 19

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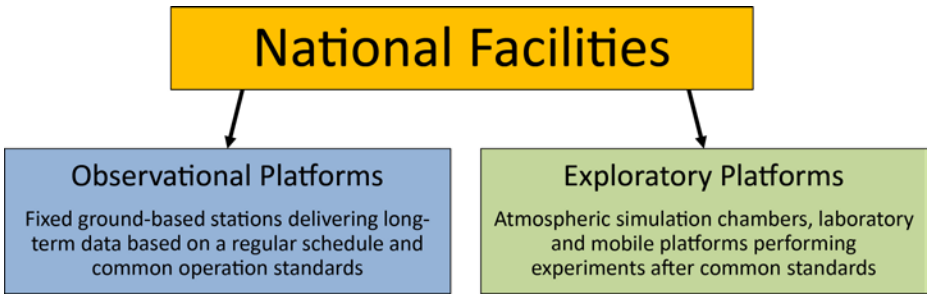
1 Introduction

The functionality of ACTRIS is based on a large number of **National Facilities (NFs)** widely distributed over Europe and also located at selected sites outside of Europe. NFs are developed, managed, and operated by the national **Research-Performing Organizations (RPOs)**. Decisions on the implementation and operation of NFs and respective funding solely fall to the member states. The major task of the NFs is the acquisition and delivery of quality-controlled data. NFs can also provide physical access, which will be centrally managed by the **Service and Access Management Unit (SAMU)** within the **ACTRIS Head Office (HO)**.

National Facilities within ACTRIS consist of Observational and Exploratory Platforms. **Observational Platforms** are fixed ground-based stations that deliver long-term data based on a regular measurement schedule and common operation standards. **Exploratory Platforms** are atmospheric simulation chambers, laboratory platforms and mobile platforms that perform dedicated experiments and contribute data on atmospheric constituents, processes, events or regions by following common ACTRIS standards.



This document aims at providing the description of technical concepts and requirements for ACTRIS Exploratory Platforms. It is complemented by the respective document on Observational Platforms (D5.1: *Documentation on technical concepts and requirements for ACTRIS Observational Platforms*). The concepts are outlined in sufficient detail to facilitate the substantiated estimation of all efforts and costs for implementation, long-term operation, and decommissioning of different kinds of Exploratory Platforms. The related data can be found in the *ACTRIS Cost Book* (D3.1). With the description of the technical requirements the document also sets the basis for the future labelling of ACTRIS Exploratory Platforms. The labelling principles are discussed in D5.3 (*Documentation on ACTRIS National Facility labelling principles*).

The document is structured as follows. After this introduction, in Chapter 2 an overview on the ACTRIS exploration strategy is given, highlighting the scientific case, user needs and the heritage of established structures and strategies. Chapter 3 outlines the general principles for ACTRIS Exploratory Platforms. Chapter 4 provides a comprehensive description of the technical concepts and requirements for ACTRIS Exploratory Platforms in all necessary detail. Chapter 5 gives further information on organizational and strategic concepts and requirements with a view to providing scientific excellence, uniqueness, mobility, and access capabilities. References and the link to the ACTRIS glossary are provided in Annex A.

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2 Overview on ACTRIS Exploration Strategy

The goal of ACTRIS is to provide highly reliable information on the four-dimensional distribution of aerosols, clouds and reactive trace gases and on the processes that control their life-cycles, with the grand challenge to reduce uncertainties in future-climate predictions, increase our knowledge on climate feedback mechanisms, evaluate air quality and related effects on health and ecosystems and address issues associated with climate–chemistry interaction. The atmospheric constituents investigated by ACTRIS comprise a multitude of species and types that exhibit a large variability in space and time due to the inhomogeneous distribution of natural and anthropogenic sources. The vast variety of complex formation, interaction, transport and removal processes result in relatively short constituent lifetimes of minutes to a few weeks.

The ACTRIS observational strategy (see D5.1) has been designed to provide long-term, standardized and quality-controlled data for the detection and understanding of trends as well as dedicated high-resolved, high-precision and synergistic data for the investigation and understanding of atmospheric processes. To complement this, the ACTRIS exploration strategy described here has been developed to support in particular the understanding of the mechanisms that drive the long-term trends and the variability of the atmosphere by applying two types of exploratory facilities:

1. **Atmospheric Simulation Chambers and Laboratory Platforms** producing well characterized gas and particle mixtures ('artificial atmospheres') under controlled laboratory conditions and equipped with sophisticated instrumentation to gain insight into atmospheric processes, obtain information on properties of short-lived atmospheric constituents, assess new-technology environmental impact or undertake measurement technique evaluation;
2. **Mobile Platforms** equipped with advanced atmospheric measurement techniques to study short-lived constituents and related atmospheric processes in targeted experiments and medium-duration campaigns under ambient natural conditions.

Atmospheric Simulation Chambers provide facilities for the determination of parameters needed for understanding chemical, physical and biological processes and for controlled simulation experiments under near-realistic environmental conditions. The research is focused on short-lived atmospheric constituents targeted by ACTRIS, and include a very wide field of applications dealing with, e.g., emissions from vegetation, vehicle exhaust and wood burning, transformations of combustion emissions, specific chemical reactions such as kinetic and mechanistic details of gas-phase oxidation processes, single or multi-phase chemical processes, air quality–health relations, cloud processes, plant physiology as well as interfaces and interactions between the atmosphere and other Earth system components such as water, snow, ice and soil. **Laboratory Platforms** provide high-technology instrumentation for dedicated investigations of ACTRIS-related atmospheric constituents and processes. The research at the Laboratory Platforms is concentrated on the provision of quality-controlled information on fundamental physical and chemical properties of short-lived atmospheric constituents that aid in our improved understanding of atmospheric processes and help developing new retrieval and exploitation methods.

Complementary, **Mobile Platforms** are constructed to study the various processes in the different environments and ecosystems where they occur. Mobile Platforms comprise land-based, shipborne and airborne facilities and thus allow for investigations under specific meteorological, climatic or topographic

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conditions. They can be moved to source regions of particles and gases such as deserts, active volcanoes and burning fires, operated in marine and polar environments as well as in industrial, agricultural or boreal areas and deployed in synergy with other instrumentation in dedicated field experiments.

Moreover, the **Exploratory Platforms** can be used for testing, comparing and calibrating instruments, for developing innovative concepts and methods, measurement techniques and novel equipment for use in remote-sensing and *in situ* applications and for exploring instrument synergies. In this regard, Exploratory Platforms play a strong role in the ACTRIS access strategy, since they help respond to a wide range of user needs, from scientific exploration to technological innovation.

The ACTRIS exploration strategy with respect to **Atmospheric Simulation Chambers** is already well established. The heritage evolves from a number of infrastructure projects related to the Integration of European Simulation Chambers for Investigating Atmospheric Processes (EUROCHAMP), which have supported the development of the most advanced European atmospheric simulation chambers into a world-class infrastructure for research and innovation in atmospheric science and related fields since 2004. The integration of EUROCHAMP and ACTRIS started with the common application for the ESFRI Roadmap in 2015. Since then, coordinated strategies aim at significantly enhancing the infrastructure's capacity for exploring atmospheric processes, substantially upgrading the services offered to users and developing an integrated system for atmospheric exploration in ACTRIS. While user access to Atmospheric Simulation Chambers has been well established in EUROCHAMP already, Laboratory and Mobile Platforms have been used by ACTRIS partners only sporadically, with very limited opportunities of data and physical access for users. The ACTRIS exploration strategy aims to close this gap by providing access to a) **Mobile Platforms**, which combine the potential of state-of-the-art measurement techniques as applied for long-term observations at the stationary ACTRIS Observational Platforms with the possibility to study atmospheric processes at key locations of interest, under natural conditions and with dedicated experimental approaches, and b) **Laboratory Platforms**, which are equipped with unique high-technology instrumentation to gain unprecedented data about ACTRIS-relevant targets and processes. Following this strategy, new exploratory facilities compliant with ACTRIS standards and requirements may be established in the future for process-related studies or the determination of parameters needed to evaluate or interpret ACTRIS observations, if respective gaps are identified and resources are provided by the member states. This concept facilitates renewal and further energizing of the ACTRIS infrastructure and enables new observational capacity to be developed to gap-fill future needs of the stakeholders.

ACTRIS Exploratory Platforms are part of a consolidated, sustainable, long-term research infrastructure and thus apply a strict Quality Assurance/Quality Control (QA/QC) strategy, even if, due to their innovative and explorative nature, they are less standardized than the ACTRIS Observational Platforms. The ACTRIS Topical Centres (TCs) and the ACTRIS Data Centre (DC) provide support to Exploratory Platforms and supervise the quality-assurance measures from instrumental setup to data delivery whenever possible. The present document describes the technical concepts and requirements for Exploratory Platforms, considering the heritage of previous developments as well as new aspects needed to improve and substantiate the capabilities of the research infrastructure.

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3 General principles for ACTRIS Exploratory Platforms

ACTRIS Exploratory Platforms provide key support to research projects and training activities for the atmospheric and climate science community. They allow users to study atmospheric processes, develop new techniques and observation capabilities or test and calibrate instrumentation by providing laboratory and mobile facilities. ACTRIS Exploratory Platforms follow common general principles listed hereafter. The compliance will be proven through the ACTRIS labelling process (see D5.3).

General Principles

ACTRIS Exploratory Platforms are high-technology and often heavy installations that require substantial investments from member states. Because of their outstanding nature, there is a high interest in their wide opening to the scientific community to gain the utmost scientific profit from these investments and to provide the user community with state-of-the-art, well-characterized and versatile facilities.

1. ACTRIS Exploratory Platforms must support research, development or training activities related to short-lived atmospheric constituents targeted by ACTRIS, i.e. aerosols, clouds and reactive trace gases, including the vast variety of related processes in the Earth system.
2. ACTRIS Exploratory Platforms are committed to long-term operation in order to support research, development and training activities continuously over the lifetime of ACTRIS.
3. ACTRIS Exploratory Platforms are operated by personnel with identified expertise in running experiments and complex platform instrumentation. Support for training of personnel in the use of ACTRIS instrumentation will be provided by the Topical Centres.
4. The instrumentation operated at ACTRIS Exploratory Platforms follows the ACTRIS recommendations, whenever applicable (see D5.1). Specific modifications of instruments necessary for exploratory purposes are documented and agreed with the associated Topical Centre. Instrumentation that is not supervised by any ACTRIS TC is applied following best practice and/or available international standards.
5. Measurement methodologies and procedures for operating instruments at Exploratory Platforms comply with the standards of calibration, operation and quality assurance defined and recommended by the Topical Centres, whenever applicable (see D5.1). Specific methodologies and operation procedures applied for exploratory purposes are documented and agreed with the associated Topical Centre. Methodologies and procedures that cannot be supervised by any ACTRIS TC follow best practice and/or available international standards and above all are subject to a very strict traceability process to make future reanalysis or correction of data possible.
6. Data from measurements performed for ACTRIS at Exploratory Platforms are made available to users through the ACTRIS Data Centre. Data are transferred to the ACTRIS DC following the procedures, formats and timelines described in Chapter 4 and in the Data Management Plan (D4.2).
7. ACTRIS Exploratory Platforms provide physical access for users following the specific requirements listed in Chapter 5, D2.6 and D6.3.
8. ACTRIS Exploratory Platforms follow the specific technical requirements outlined in Chapter 4.

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4 Technical concepts and requirements for ACTRIS Exploratory Platforms

4.1 ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms

4.1.1 Purpose and targets

ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms aim at providing ACTRIS users with the opportunity to perform experiments targeting detailed investigations of processes that control atmospheric composition, air quality and climate, including passive and reactive exchange processes at interfaces as well as the impact of air pollution on health, cultural heritage and ecosystems. ACTRIS Atmospheric Simulation Chambers are highly instrumented platforms that provide tools for the detailed investigation of atmospheric processes affecting the formation, transformation, fate and impacts of gaseous compounds, particles and clouds. Moreover, these facilities provide users with highly instrumented platforms as testbeds for novel instrumentation, evaluating the atmospheric impact of new technologies or the development and testing of new environmental technologies.

Atmospheric Simulation Chambers are often designed to address several scientific targets, but can nevertheless be sorted in the categories:

- Indoor chambers with artificial light sources,
- Large outdoor chambers,
- Cloud and aerosol-cloud-interaction chambers.

Laboratory Platforms are usually designed for specific purposes that do not require 'artificial atmospheres' as generated in chambers. They comprise assemblies of high-end instruments and installations to investigate smaller volumes of artificial and natural gas and particle samples.

The target research areas at the chamber and laboratory facilities can be divided into:

a) Radical chemistry, gas-phase compound transformation and photo-oxidant production;
b) Formation and transformation of aerosols, e.g., secondary organic aerosol, aerosol properties, particulate marker compounds, aerosol chemical composition, bio-aerosol interaction with atmospheric components;
c) Cloud microphysics and multiphase transformations;
d) Air pollution effects on human health and ecosystems;
e) Interface chemistry and physics including interactions between atmosphere and biosphere, ocean and cryosphere;
f) Fundamental physico-chemical properties of gas-phase and particulate systems and their interrelationships.

These detailed objectives of research enabled by the Atmospheric Simulation Chambers and Laboratory Platforms strongly couple and contribute to the overall objectives of ACTRIS. They are essential for the understanding of the 4D-variability of short-lived atmospheric constituents with regard to their physical, optical, chemical and biological properties. They help in the interpretation of cloud and aerosol-cloud interaction processes, and they provide means to study interfacial processes between the atmosphere

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and the cryosphere, ocean and biosphere. The description of the 4D-variability of clouds, aerosols and reactive trace gases and the interpretation of the observations that are carried out in the context of the field-oriented parts of ACTRIS require a proper system understanding. This understanding is achieved by the Atmospheric Simulation Chambers and Laboratory Platforms. These facilities also allow testing of hypotheses based on atmospheric observations and provide information on fundamental physical, chemical, optical and morphological properties of atmospheric constituents needed for the evaluation of atmospheric observations and the development of novel retrieval schemes.

The Atmospheric Simulation Chambers and Laboratory Platforms also strongly contribute to the ACTRIS objective of providing the means to more efficiently use the complex and multi-scale ACTRIS parameters, which serve a vast community of users working on models, satellite retrievals and analysis and forecast systems. They indeed support the understanding of long-term trends and variability of ACTRIS observables as process interpretation is required here. The process-oriented studies in Atmospheric Simulation Chambers and Laboratory Platforms provide important input to facilitate this, especially with regard to model development and validation. Continued model development and improvement aiding interpretation of complex atmospheric processes is an explicitly addressed part of the efforts at the Atmospheric Simulation Chambers and Laboratory Platforms.

All of the above-listed target research areas are subject to contribute to the ACTRIS overall objective to raise the level of technology used in the RI and the quality of services offered to the community of users, involving partners from the private sector. As outlined in the following, the strong interaction with users working in technology development is a key driver for the operation of Atmospheric Simulation Chambers and Laboratory Platforms. Furthermore, the objective of ACTRIS to promote training of operators and users and enhance the linkage between research, education and innovation in the field of atmospheric science is addressed.

4.1.2 Standards for instrumentation, operation and data provision

4.1.2.1 Instrumentation and calibration

ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms shall all be equipped with state-of-the-art devices. Two categories of instrumentation can be defined:

- Base instrumentation,
- Specific equipment.

Base instrumentation covers the tools necessary to monitor the physical and chemical conditions prior and during an experiment. It concerns fundamental environmental parameters such as temperature, pressure, relative humidity and irradiation levels. It concerns also any instrumentation or variables that are covered by an ACTRIS TC, e.g., concentration–time profiles of various species such as VOCs as well as basic atmospheric contaminants including NO_x, aerosol number concentration and size distribution. The related instruments will be thoroughly calibrated following procedures recommended by the TCs and/or using TC services. This approach shall allow comparison of the key parameters of experiments and their main results.

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Specific equipment and instrumentation is often developed in-house, is oriented toward very specific targets and tests of novel ideas and concepts and/or covers extremely low concentration ranges, rare but atmospheric-relevant substances and detection limits. Typically, there is no common calibration method provided by the TCs for these techniques. ACTRIS Atmospheric Simulation Chamber and Laboratory Platform staff will have to implement protocols enabling internal consistency of the measurements for a posteriori validations/reanalysis of the data produced by these high-technology instruments. In this context, full traceability of the methodologies, calibrations, algorithms and software versions shall be implemented by the RPO operating the facility.

4.1.2.2 Operation and data processing

Atmospheric Simulation Chamber experiments shall be conducted in suitable installations following standard protocols defined in the Handbook for Atmospheric Simulation Chamber Studies (see E2020-D3.11), whenever this is possible.

In any case, simulation experiments and fundamental studies on physical, chemical, optical and morphological properties shall be carried out together with related blank and control experiments, if necessary for the interpretation of results. The control data shall be stored at the ACTRIS Data Centre and linked with the experiment data themselves so that possible future reanalysis can take them into account. All data should be provided with information on accuracy and precision for realistic error estimates of results.

Data processing will benefit from the tools evaluated in the framework of EUROCHAMP-2020 and distributed through the Atmospheric Simulation Chamber pillars of the ACTRIS Data Centre. Additional tools that are specifically needed for the Laboratory Platforms will be distributed through the DC as well.

4.1.2.3 Data provision and quality control

The ACTRIS Data Centre will provide scientists with free and open access to data from Atmospheric Simulation Chamber and Laboratory Platform experiments as well as mature data products and tools that support activities related to atmospheric observations and modelling. The Data Centre shall comprise three databases.

- **The Database of Atmospheric Simulation Chamber Studies (DASCS):** This database provides a compilation of experimental and modelled data obtained from experiments in Atmospheric Simulation Chambers as well as the necessary technical details of the involved chamber which are needed to re-analyse or re-use these data. These experiments can be used for a better understanding of the atmospheric processes involved in air pollution and climate change, as well as their impact on health, global food supply and cultural heritage. These data are highly useful for the development and the validation of atmospheric models.
- **The Library of Analytical Resources (LAR):** During experiments in Atmospheric Simulation Chambers, a large suite of analytical techniques is typically used to monitor the chemical composition of the gas and particle phases. Quantitative chemical analysis of these complex mixtures requires access to standards for the calibration of instruments (IR spectra, UV spectra

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or mass spectra). To make these rare resources freely available to the scientific community the Library of Analytical Resources has been developed.

- **The Library of Advanced Data Products (LADP)**: This database provides different types of mature and high-level products of experiments, which are especially useful for researchers working on atmospheric observations as well as atmospheric model development and validation. It includes products for the development of chemical mechanisms in atmospheric models (e.g., rate coefficients, photolysis frequencies, secondary organic aerosol yields, vapour pressures, etc.), high-level products for active and passive remote-sensing applications and for radiative transfer modelling (e.g., mass extinction coefficients, backscatter and extinction cross sections of aerosols; UV, IR, Raman and fluorescence spectra; Raman, fluorescence and absorption differential cross sections; hygroscopic, polarization and other electromagnetic properties of aerosols) and tools to generate oxidation schemes which are very useful to interpret field measurements as well as laboratory studies.

The submission of data to the DASCS will be mandatory. Thus the ability to provide the variables to this database as defined and implemented within the EUROCHAMP projects will be a minimum requirement for any Atmospheric Simulation Chamber as well as for Laboratory Platforms aiming at being an ACTRIS National Facility. The contribution of users to the latter two databases will remain optional and can be considered as an optimal capability. ACTRIS will hence take incentive action in this direction. On the contrary, except for specific non-disclosure agreements (e.g., for private-sector studies), the submission of data to the DASCS will be mandatory within a period of one year. If a longer period of time is required to produce coherent and meaningful set of data, an extension of one year can be granted upon thorough justification. The submissions will have to comply with the ACTRIS quality requirements, i.e. they will have to comply with the EDF format (EUROCHAMP data format, Alvarez et al. 2008), and be fully documented with the relevant protocol detailed description, chamber and laboratory characteristic information as well as related calibration and traceability information.

4.1.3 Requirements and recommendations

Via its Exploratory Platforms, ACTRIS will offer **hands-on access to world-class Atmospheric Simulation Chambers and Laboratory Platforms** in Europe. Above all, Atmospheric Simulation Chambers and Laboratory Platforms selected as National Facilities must provide a significant amount of physical access for the greater benefit of the user community. The research facilities shall hence be selected based on their uniqueness within Europe and their ability to constitute an ensemble that offers a wide range of experimental capabilities at the forefront of research advances in atmospheric simulations and related studies. Each of these National Facilities will have to demonstrate the interest for access of a large number of users and the ability to provide the expected services. These two critical requirements will have to be evaluated by effective records (such as past TNA records) as well as quantitative impact studies.

Due to the diversity of topics that can be addressed by Atmospheric Simulation Chambers and Laboratory Platforms, they all exhibit a high degree of specialized emphasis and thus do not allow for neither defining a common minimum configuration nor an optimal setup. Nevertheless, the ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms shall all be equipped with the state-of-the-art equipment

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required for reaching their main scientific targets (see 4.1.1). In particular, the operation and calibration principles of their base instrumentation (see 4.1.2.1) shall be compliant with the recommendation of the related TCs when available.

More critically, making the greater profit out of the work carried out within the networking activities of EUROCHAMP-1, EUROCHAMP-2 and EUROCHAMP-2020, the ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms shall be very well characterized and shall implement traceability of the experiments (documentation, protocol, calibration, reference experiments, etc.). They shall provide comprehensive user services, good conditions of access and the capacity to provide high-quality, research-driven training of young scientists and new users. Consequently, qualified dedicated technical staff shall be available to welcome, train and assist users.

As an additional key requirement, Atmospheric Simulation Chambers and Laboratory Platforms will have to exhibit exemplary data submission records to the Database of Atmospheric Simulation Chamber Studies (DASCS). These records will concern not only the number and the quality of the studies open to the virtual access but also the necessary ancillary information (facility characteristics description, traceability information, blank experiments, auxiliary mechanisms, dedicated models, etc.).

These characteristics shall be ascertainable and traceable based on records of successful previous transnational access demonstrating also the attractiveness of the installation. For Exploratory Platforms that a) develop novel ground-breaking concepts with regard to simulations of atmospheric processes and investigations of fundamental physico-chemical properties and b) cannot present a track-record due to the nature of being novel, these characteristics shall be defined on the basis of their uniqueness of equipment and expertise of staff, a science-based identification/justification of attractiveness and a thorough quantitative assessment of the existence of a wide community of users.

4.2 ACTRIS Mobile Platforms

4.2.1 Purpose and targets

ACTRIS Mobile Platforms aim at investigating processes related to aerosols, clouds and reactive trace gases in dedicated experiments, specific regions and with focus on particular scientific questions. In principle, Mobile Platforms apply the same technologies as ACTRIS Observational Platforms described in D5.1 and thus contribute to:

- Aerosol remote sensing,
- Cloud remote sensing,
- Reactive trace gases remote sensing,
- Aerosol *in situ* measurements,
- Cloud *in situ* measurements and
- Reactive trace gases *in situ* measurements.

ACTRIS Mobile Platforms perform front-line research and thus require state-of-the-art equipment. Naturally, they operate newest and best-available technologies. The number and combination of instruments, and thus the amount of produced variables and their level of synergy, is flexible and science-

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driven. In order to access different atmospheric environments, three types of Mobile Platforms are considered in ACTRIS:

- **Land-based Mobile Platforms**: For the application in field campaigns on land, instruments are usually set up in containers, trailers or other robust housings that can be easily shipped and set up in remote locations. Observations may also be performed on moving platforms (e.g., vans).
- **Shipborne Mobile Platforms**: For research in maritime environments, instruments are deployed on research or commercial vessels, either as fixed setup or in removable seaworthy housings or containers.
- **Airborne Mobile Platforms**: Certain light-weight instruments can be flown on airborne platforms, including unmanned aerial vehicles (UAV) and balloon-borne or helicopter-borne platforms.

ACTRIS does not aim at observations on research and commercial aircraft, because these are covered by other RIs. However, if required for specific ACTRIS purposes and when supported at national level, heavy-weight instruments developed in ACTRIS for airborne application may be flown on selected research aircraft designated for ACTRIS by the respective member state.

4.2.2 Standards for instrumentation, operation and data provision

In general, the configuration of ACTRIS Mobile Platforms and their deployment in field experiments must be agreed with the associated Topical Centres and the Data Centre in order to assure that specific quality assurance tools are available and respective campaign data can be processed, quality-controlled and published. The submission of data collected by users during access to ACTRIS Mobile Platforms is mandatory, except for specific non-disclosure agreements (e.g., for private-sector studies). In general, data obtained with Mobile Platforms must be submitted to the Data Centre within six months after acquisition, if not prohibited by technical limitations at remote field sites. If a longer period of time is required to produce a coherent and meaningful set of data, an extension of one year can be granted upon thorough justification.

4.2.2.1 Aerosol remote sensing

ACTRIS Mobile Platforms for aerosol remote sensing apply high-power aerosol lidars and sun/sky/polarized and moon photometers according to the requirements outlined in Sec. 4.1 of the *Documentation on technical concepts and requirements for ACTRIS Observational Platforms* (D5.1).

The involvement of aerosol remote-sensing instrumentation in campaigns aims at providing standard Level 1 and 2 aerosol variables, including also joint photometer and lidar retrievals,

1) At a new fixed location (new temporary station) and
2) At any time when a mobile platform is moving (ship, van, aircraft, etc.).

In addition to national mobile facilities, backup instrumentation for mobile deployment may also be provided by the Centre for Aerosol Remote Sensing (at least a mobile sun/sky/polarized and moon photometer) and shall be ready to be shipped to a specific location in case of extreme events relevant and of interest for the community (e.g., volcanic eruptions).

For the application in campaigns, the following specific requirements apply in order to maintain instrument calibration and data quality.

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High-power aerosol lidars

- The internal check-up procedures defined by the Centre for Aerosol Remote Sensing have to be applied after each transport and before acquiring data at a new location. The results have to be submitted to the Centre for Aerosol Remote Sensing.
- In agreement with the lidar unit of the Data Centre, a campaign entry for the Single Calculus Chain (SCC) has to be created and data transfer and processing capabilities have to be tested.
- If possible, data should be transferred in near real-time (NRT) to the SCC. If the campaign location does not allow immediate transfer, data must be transferred within six months after acquisition.

Automatic sun/sky/polarized and moon photometers

- All calibration and maintenance procedures have to be performed at the Centre for Aerosol Remote Sensing before the beginning of the campaign. They have to be performed again immediately at the end of the campaign.
- In agreement with the dedicated units of the Centre for Aerosol Remote Sensing, a campaign entry for data processing has to be created and data transfer setup and processing capabilities have to be tested. In case of a moving platform (ship, van, etc.), all technical information on navigation parameters must be provided to the TC.
- NRT instrument status and data processing are mandatory for the campaigns, therefore data must be submitted to the TC as soon as they have been acquired.
- Data quality control and minimum local maintenance that guarantees operational reliability are mandatory during the campaign.

4.2.2.2 Cloud remote sensing

ACTRIS Mobile Platforms for cloud remote sensing deploy a cloud radar, lidar/ceilometer, microwave radiometer and preferably also a Doppler wind lidar according to the requirements outlined in Sec. 4.2 of the *Documentation on technical concepts and requirements for ACTRIS Observational Platforms* (D5.1).

Similar to aerosol remote sensing, the aim is to deploy cloud remote-sensing instrumentation capable of providing the standard Level 1 and 2 cloud variables,

1) At a new fixed location (new temporary station) and
2) At any time when a mobile platform is moving (ship, van, aircraft, etc.).

Campaign deployments must respect the following specific requirements to maintain instrument calibration and data quality. All instruments should follow internal monitoring and quality control procedures as defined by the Centre for Cloud Remote Sensing, with the results from calibration activities submitted to the Centre for Cloud Remote Sensing. In addition:

Cloud radar

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- Where external calibration cannot be performed during the campaign (e.g., drone overflight restrictions), then external calibration or intercomparison with a reference instrument should be performed prior to and after the campaign.
- For moving platforms, an inertial measurement unit (IMU) or similar mechanism is necessary for a Doppler cloud radar instrument to report potential departures from vertical-pointing operation.

Microwave radiometer

- At least one external load (liquid N_2) calibration procedure should be performed during the campaign.

Processing

- In agreement with the associated unit of the Data Centre,
  - Campaign location details should be submitted ahead of the campaign to enable provision of auxiliary meteorological profiles from modelling centres. For moving platforms, this may not be possible in NRT since the model vertical column extraction service provided by modelling centres is not dynamic and cannot be updated in NRT.
  - A campaign entry for the Cloudnet processing chain and instrument identifiers should be created, and data transfer and processing capabilities tested.
  - If possible, data should be transferred in NRT to the associated unit of the Data Centre. If the campaign location does not allow immediate transfer, data must be transferred within six months after acquisition.

4.2.2.3 Reactive trace gases remote sensing

Use of standard ACTRIS FTIR, UVVIS and O_3 DIAL instruments on Mobile Platforms

ACTRIS Mobile Platforms for remote sensing of reactive trace gases shall apply FTIR, UVVIS or O_3 DIAL instruments according to the requirements outlined in Sec. 4.3 of the *Documentation on technical concepts and requirements for ACTRIS Observational Platforms* (D5.1), if the mobile facility can accommodate this kind of instruments, taking into account their size, weight, power consumption, etc. Typically, ACTRIS FTIR, UVVIS or O_3 DIAL instruments for reactive-trace-gas remote sensing require a container or van if they are to be deployed as Exploratory Platform.

Use of alternative instruments for remote sensing of reactive trace gases

On many Mobile Platforms, like aircraft or UAV, the standard ACTRIS FTIR, UVVIS and O_3 DIAL instruments cannot be deployed because of size and weight constraints. However, less performant, more compact and light-weight instruments have been developed (or are in the stage of development). These instruments can provide some of the ACTRIS target reactive trace gases, with less precision and/or accuracy, but are still useful in certain cases and for specific research purposes (e.g., Kille et al. 2017, Merlaud et al. 2018).

For any proposal of mobile deployment of such an alternative instrument for remote sensing of ACTRIS target reactive trace gases, the ACTRIS Centre for Reactive Trace Gases Remote Sensing will evaluate the proposal and instrument performances based on technical specifications and – if available – peer-reviewed reference publications to be provided by the proposer. The Centre for Reactive Trace Gases Remote Sensing will establish the requirements for Level 0 and Level 1 data QA/QC, data processing (Level

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1 → Level 2), Level 2 data QA/QC and submission, in agreement with the instrument owner or user and the ACTRIS Data Centre.

4.2.2.4 Aerosol *in situ* measurements

Measurements of the ACTRIS aerosol *in situ* variables on Mobile Platforms can often be conducted with the same instrumentation that is used for the Observational Platforms. There are, however, additional requirements and challenges imposed by Mobile Platforms, such as limited space, limited weight, reduced operating pressure or vibrations and other environmental factors. These requirements often lead to miniaturized, unique instrument versions of commercial instruments usually found at the Observational Platforms. Accordingly, the QA/QC tools (calibration procedures, measurement guidelines, traceability of standards, etc.) are identical for Mobile and Observational Platforms and thus should be applied accordingly. Deviations from the absolute data quality objectives are allowed by way of exception when required by the operating conditions on the Mobile Platform. However, data quality has to be known and documented in the same way as for Observational Platforms. Additional issues need to be considered, in order to accept aerosol *in situ* data from Mobile Platforms as ACTRIS data:

- A quality assurance program for the period of application has to be jointly developed by the RPO operating the Mobile Platform and the Centre for Aerosol In Situ Measurements, as the responsible Topical Centre.
- Quality control must be documented by the respective RPO, and this documentation must be provided to the Centre for Aerosol In Situ Measurements, following the same procedure as required for data from Observational Platforms.
- In particular, aerosol inlet systems (inlet plus sampling line) might cause larger uncertainties of data collected on Mobile Platforms compared to Observational Platforms. In order to meet the high ACTRIS data quality standards, the particle size-dependent sampling efficiency of inlet systems must be determined and be accounted for in the Level 1 and Level 2 data that are submitted to the ACTRIS DC.
- The instrument calibrations, being part of the QA/QC program, have to take account of and be performed under the full range of conditions encountered by the instruments during operation.
- Quality-assured data must be submitted to the ACTRIS DC within a period of six month after the measurement.

4.2.2.5 Cloud *in situ* measurements

Similar to aerosol *in situ* measurements, ACTRIS Mobile Platforms for cloud *in situ* measurements will often apply the same or similar instrumentation that is used at the Observational Platforms. If the same type of instrumentation is used, the QA/QC requirements defined by the Centre for Cloud In Situ Measurements for Observational Platforms apply to their mobile application as well. If instrumentation needs to be modified or newly developed to overcome limitations of Mobile Platforms (e.g., available space and payload), instrument performance needs to be documented and a quality assurance program for the period of application needs to be provided to the Centre for Cloud In Situ Measurements. Acceptance as ACTRIS data can then be granted, even if performance of mobile instrumentation does not meet the standards defined for Observational Platforms.

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4.2.2.6 Reactive trace gases *in situ* measurements

For VOCs, both on-line and off-line measurement techniques can be used on Mobile Platforms. For NO_x, only on-line measurements should be applied. The quality assurance procedure (calibration, traceability of standards, etc.) is basically identical for Mobile and Observational Platforms. The additional procedures described below account for the special conditions that occur during on-line sampling by instruments on Mobile Platforms. For off-line sampling only the first three bullet points have to be taken into account.

- The whole sampling line has to be cleaned (e.g., by flushing with zero air or ambient air) and tested before starting the measurements.
- A significant timespan has to be considered before the start of the measurement campaign so that a stabilized set-up can be attained. This step is especially essential when adsorptive substances such as oxidized VOCs are analyzed.
- The expected level of concentrations may need some specific parameter adjustments for the sampling as well as the analytical parts.
- The instrument has to be calibrated against the working standard before and after the usage on a Mobile Platform. Intervals of calibration have to fulfill the requirements for Observational Platforms, but consider potentially higher requirements due to more challenging operation conditions of the instrument on Mobile Platforms. Special care has to be taken for substantial change of environmental conditions, e.g., pressure, temperature, humidity. Another issue is associated with artefacts caused by changing positions and potential damages due to forces acting on analytical systems during mobile operation. In principle, calibrations have to take account of and be performed under the full range of conditions encountered by the instruments during operation.
- During the use on the Mobile Platform, a target gas has to be regularly measured for quality control reasons.
- Immediate quality control using the tools prepared by the Centre for Reactive Trace Gases In Situ Measurements is highly advised.

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5 Organizational and strategic concepts and requirements for ACTRIS Exploratory Platforms

5.1 ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms

5.1.1 Scientific excellence

ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms will allow the users to perform front-line research on atmospheric processes related to aerosols, clouds and reactive trace gases under conditions that are controllable, reproducible and relevant to the ambient atmosphere. In particular, they shall allow the understanding of the key drivers of the processes investigated. The platforms must therefore be well equipped and will involve state-of-the-art instrumentation, which might be exploratory itself.

ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms shall be well characterized so that the unavoidable artefacts related with, e.g., wall reactivity, volume limitation, irradiation, and radiation characteristics of light sources, are well known and quantified. The impact and consequences of these artefacts on the study of the main scientific target shall be known. Up-to-date model codes and instrument characterization shall be available every time possible, e.g., in specified time intervals or when upgrades have been made.

5.1.2 Uniqueness and diversity

In the objective of providing the user community a versatile range of facilities and hence to allow a wide range of research to be carried out, ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms will form a coherent ensemble of complementary installations at the cutting edge of technology. The installations are highly instrumented and versatile. Large indoor and outdoor chambers are especially suited to investigate process studies performed under realistic atmospheric conditions. Chambers are also rapidly developing into useful tools for investigating atmospheric transformations of real-world emissions, such as those from vegetation, vehicle exhaust and wood burning, and for studying processes at the interfaces and/or in clouds. The large-scale chamber facilities are complemented by smaller units, which are typically used to investigate very specific chemical processes, such as kinetic and mechanistic details of gas-phase oxidation processes, often as a function of temperature and pressure, and by sophisticated laboratory facilities, which focus on the investigation of fundamental physical, chemical, and optical properties of short-lived atmospheric constituents.

5.1.3 Access capabilities

ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms will be open for physical access to users. They can also be used for the need of the research infrastructure (e.g., comparison campaigns, calibration and validation experiments, new methodology and technology testing, etc.). The suitability for physical access will depend on uniqueness of equipment, available logistics, expertise, desired simulated conditions and controllability of the experimental setup during a campaign. Physical access to ACTRIS Atmospheric Simulation Chambers and Laboratory Platforms may also include commitment of the entire

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facility on user request for specific campaigns and the development and testing of ground-breaking new concepts. In general, suitability of a simulation platform for physical access requires:

- Possibilities to set up and run the platform together with other instruments of the user, including respective local capacities for the supply of power, water, technical gases, internet connection, etc.;
- Resources to host users including working (offices) and storage space and all necessary auxiliary facilities;
- Capabilities to train and support users by experienced staff;
- Possibilities to use the platform on user request for specific investigations, in specific modes and under specific technical conditions;
- Data storage space and secure network design for the curation of the Level 0 and Level 1 data.

Physical access to Atmospheric Simulation Chambers and Laboratory Platforms will be managed by the SAMU. Next to the general suitability of a platform for physical access, which can be identified in the labelling process, the campaign-dependent actual abilities have to be proven case by case. Details are specified in D6.3 and D2.6.

5.2 ACTRIS Mobile Platforms

5.2.1 Scientific excellence

ACTRIS Mobile Platforms will perform front-line research on atmospheric processes related to aerosols, clouds and reactive trace gases at locations that are not covered by ACTRIS Observational Platforms. In particular, they shall allow dedicated investigations of specific processes, constituents and/or interactions in the natural environment. The platforms must therefore be well equipped and capable of being applied in remote locations under the respective ambient conditions. ACTRIS Mobile Platforms shall apply state-of-the-art instrumentation, which might be exploratory itself. In order to assure data quality, instruments and standard operation procedures have to be supervised by the associated ACTRIS Topical Centre.

5.2.2 Mobility

ACTRIS Mobile Platforms shall be designed such that they can be applied in field campaigns across the world. Depending on the platform type, the application requires that the platform

- Can be transported to and set up at different locations with reasonable effort in adequate time;
- Is ready to be operated under different climatic and geographical conditions;
- Is adaptable to local conditions regarding required supply of power, water, technical gases, internet connection, etc.;
- Is compliant with local safety regulation laws;
- Is adequately configured for international transport and possesses respective customs documents.

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5.2.3 Access capabilities

ACTRIS Mobile Platforms shall collect and deliver experimental, quality-controlled data for provision to users via the ACTRIS Data Centre. In addition, physical access to ACTRIS Mobile Platforms shall be offered to users. The suitability for physical access will depend on equipment, available logistics, and actual conditions during a campaign. Physical access to ACTRIS Mobile Platforms may include:

- Commitment of the entire facility on user request for specific field campaigns;
- Access during campaigns for scientific or training purposes, e.g.,
    - By hosting instrumentation of the user for dedicated observations,
    - By running the Mobile Platform in specific observation modes on user request,
    - By training users in the operation of Mobile Platforms.

In general, suitability of a Mobile Platform for physical access requires:

- Capabilities to apply the platform on user request for specific investigations, in specific modes, or at specific sites, under consideration of the applicable safety operation criteria;
- Possibilities to set up and run the platform together with other instruments of the user, providing the necessary capacities of power, water, technical gases, internet connection, etc.;
- Resources to host users, including working and storage space and all necessary auxiliary facilities;
- Data storage space and secure network design for the curation of the Level 0 and Level 1 data;
- Capabilities to train and support users by experienced staff.

Physical access to Mobile Platforms will be managed by the SAMU. Next to the general suitability of a Mobile Platform for physical access, which will be identified in the labelling process, the actual campaign-dependent abilities have to be proven case by case. Details are specified in D6.3 and D2.6.

5.3 Recommendations for national strategies

The provision of Exploratory Platforms by ACTRIS member states is not mandatory, but welcome. It is recommended to examine at national level, whether

1. Existing atmospheric simulation chambers, laboratory platforms and mobile platforms are suited for ACTRIS;
2. Capacities to develop new exploratory facilities, which can fill gaps in the ACTRIS strategy, are available; and
3. National research strategies are consistent with ACTRIS and thus long-term commitment of existing and development of new exploratory platforms is feasible.

The implementation of new Exploratory Platforms shall be discussed with other countries in order to use the available resources in the most effective way.

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Annex A: References

A.1 Applicable ACTRIS-PPP Documents

ACTRIS Glossary: https://www.actris.eu/About/ACTRIS/ACTRISglossary.aspx

D2.3: ACTRIS Data Policy

D2.6: ACTRIS Access and Service Policy

D3.1: ACTRIS Cost Book

D4.1: Concept document on ACTRIS Central Facilities structure and services

D4.2: ACTRIS Data Management Plan

D5.1: Documentation on technical concepts and requirements for ACTRIS Observational Platforms

D5.3: Documentation on ACTRIS National Facility labelling principles

D6.3: Report on access rules and modalities and recommendations for ACTRIS access policy

A.2 Applicable EUROCHAMP-2020 Documents

E2020-D3.11: Summary report on standard protocols – Handbook for Atmospheric Simulation Chamber Studies

A.3 Publications

Alvarez, E. G., Vazquez, M., Muñoz, A., Hjorth, J., Pilling, M., Saathoff, H., and Brauers, T., 2008: The Eurochamp Chamber Experiment Database: Goals And Uses. Present And Future Potential Benefits, in: *Simulation and Assessment of Chemical Processes in a Multiphase Environment*, edited by: Barnes, I., and Kharytonov, M. M., Springer Netherlands, Dordrecht, 71–82.

Kille, N., S. Baidar, P. Handley, I. Ortega, R. Sinreich, O.R. Cooper, F. Hase, J. W. Hannigan, G. Pfister, and R. Volkamer, 2017: The CU mobile Solar Occultation Flux instrument: structure, functions and emission rates of NH3, NO2 and C2H6, Atmos. Meas. Tech., 10, 373–392, doi: 10.5194/amt-10-373-2017.

Merlaud, A., Tack, F., Constantin, D., Georgescu, L., Maes, J., Fayt, C., Mingireanu, F., Schuettemeyer, D., Meier, A. C., Schönardt, A., Ruhtz, T., Bellegante, L., Nicolae, D., Den Hoed, M., Allaart, M., and Van Roozendael, M., 2018: The Small Whiskbroom Imager for atmospheric compositioN monitorinG (SWING) and its operations from an Unmanned Aerial Vehicle (UAV) during the AROMAT campaign, Atmos. Meas. Tech., 11, 551–567, doi: 10.5194/amt-11-551-2018.

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