EXC-SE^{2}A: Call for Research Proposals in Research Area ICA A

Assessment of the Air Transport System

1. Objectives of Call

Shaping the necessary transition pathways in order to achieve sustainable air transport solutions, high operational safety and reliability, as well as low cost and compatibility with existing infrastructure is a complex endeavour. It not only requires a sound understanding of the technological potential of future aircraft and their operation but also of the behaviour of the Air Transport System (ATS) itself. An ATS can be characterized as a socio-technical, socio-ecological, and socio-economic system including manifold actors, numerous interdependencies and close interlinks with road and rail transportation at the airport sites. Moreover, the development of the ATS is influenced by a multitude of external factors such as prices for fuels and electricity as well as CO_2 taxes or further legal and political regulations that frame the general conditions for the transition of the ATS. The uncertainties of the future development of these external factors shall be tackled by the development and formulation of alternative future scenarios which shall be basic for the transition of the ATS. This important field of research is where Research Area ICA A shall make its contribution.

The proposed research in ICA A shall explore the design, analysis and evaluation of alternative transition pathways in order to achieve long-term development goals for ATS. The assessment of effectiveness and efficiency of the complete ATS related to economic, ecological, and social goals as well as the health-related aspect of noise, shall be based on a scientifically sound development and application of a multi-method mix, integrating, amongst others, scenario analysis, multi-scale modelling and simulation, life-cycle engineering, noise assessment, as well as multi-criteria and robust optimisation. New technologies shall be assessed at different subsystem levels and at the overall ATS level to understand the system across different scales. The aim of the call is to set up a comprehensive research program along the following research hypotheses:

(1) Strong interdisciplinary collaboration between, for example, social sciences, economics, political science, or law will enable technology-based future research to analyse scenarios and promote sound understanding of the systems' behaviour and thus the determination of efficient and robust transition pathways.

(2) The external and cabin noise of future aircraft can be efficiently assessed using multifidelity approaches. These include **parametric component models for and sound propagation methods of different fidelity** that shall be utilized to ensure acceptance of new aircraft by stakeholders exposed to noise.

(3) The integration and automatisation of multi-scale modelling and **simulation of air traffic and airport management,** as well as the **multi-criteria evaluation of ATS~~,~~** enable new operational concepts, efficient and spatially sustainable structures, and concepts for integrating airports into **multimodal transportation networks**.

(4) **Sustainable assessment and life-cycle engineering** methods shall be applied to assess the influence of new aircraft on operation as well as maintenance, repair and overhaul of aircraft to avoid potential problem shifting.

The research work shall be structured into Research Units ICA-A1 to ICA-A4 as detailed below. Multi-scale modelling and simulation of air traffic and airport management as well as infrastructure are employed since they allow for the development of new concepts of operation, efficient and spatially sustainable structures and processes for airports, and the integration into multimodal transportation networks. The results from these analyses as well as those from ICA B and ICA C shall be integrated for further analysis at the aggregated system level. In particular, methods for the multi-objective and robust evaluation of transition pathways of the ATS shall be developed taking into account the different actors, their interdependencies, timeframes and delays, and links among the ATS and road and rail transportation at the airport site. The evaluation shall be based on future scenarios for transformation of the ATS integrating political, economic, social, ecological, and legal factors as well as use patterns and lifestyles.

2. Structure of Research Units

2.1 Analysis and Shaping of Future Scenarios (ICA-A1)

2.1.1 Objectives

The objective of this research unit is to establish a scientifically sound set of integrated tools based on scenario simulations and optimisation models for analysing and evaluating the ATS. These tools are to be fed with the knowledge and methods of very different disciplines such as social sciences, economics, political science and law. Scenario analyses shall provide instruments for integrating the heterogeneous findings from the Cluster into holistic images of alternative futures and transferring these 2050 vision(s) into credible contributions of knowledge regarding the potential transformation of the ATS at different levels of granularity. Transparently formulating and discussing design factors shall establish the use of a common terminology and thus facilitate communication, information flow, and decision-making within the Cluster. Moreover, the scenarios shall serve as input for the model-based assessment of the ATS.

2.1.2 Work content

What will happen? What can happen? And how can a specific target be reached? In order to answer these questions, exploratory and normative approaches, using state-of-the-art methodologies that integrate the quantitative predictions provided by the Cluster into holistic images of probable, possible, and desirable futures shall be applied. New business models aligned with sustainable development shall be developed, which can be used to change the ATS in the sense of energy efficiency and sustainability. The ATS is a complex system that cannot be sufficiently analysed only by disciplinary and structured models. It consists of technical, organizational, legal, social, economic, political subsystems that are complex in themselves.

In connection with the definition of the scenarios and development of new business models, the relevance of knowledge and non-knowledge in the context of sustainability transformation in aviation shall be considered. Qualitative, explorative regional studies based on interviews, quantitative, representative studies based on questionnaire surveys and qualitative studies at the international level using the method of Delphi studies shall support the scenario definition here.

An analysis of the macroeconomic impact of the current and future aviation sector shall support decision-making in future scenarios. To this purpose, the methodology of macroeconomic modelling (computable general equilibrium) and simulation is applied. This relies on comprehensive data sources (e.g., National Accounts by Feder Statistical Office Germany, IEA) for the representation of a country/region. The macroeconomic approach benefits from the technological perspective and know-how of the SE²A cluster. The techno-economic implications of the energy, aviation and related sectors as well as specific fuel value chains shall be integrated into the macroeconomic framework.

In a jurisprudential approach, an extension of the technological, economic and ecological factors by a legal dimension should be undertaken. Here, the question should be answered whether the currently applicable national and international air traffic law is at all capable of shaping the transition to a modern, sustainable and future-oriented air traffic system in a legally secure manner and sufficiently balancing the interests of all stakeholders. In the end, in addition to the legal doctrine of a contemporary air traffic law (including the licensing and liability rules), proposals should be made for the adaptation and further development of the currently applicable legal provisions in this area.

2.1.3 Estimate of resources within Research Unit

The overall personnel resources for establishing the Research Unit are 3-4 doctoral researchers.

2.1.4 Call coordination

The Call to establish Research Unit ICA-A1 is monitored by a Call Coordination Team composed of PI Jens Friedrichs, Sabine Langer and program manager Tatjana Szalkau. The team members will serve as points of contact for any question concerning this Call.

2.2 Noise Assessment (ICA-A2)

2.2.1 Objectives

Multi-scale and multi-fidelity noise assessments of new aircraft technologies shall comprise three levels of aggregation ranging from the effect of individual aircraft components (Level 1), to the overall aircraft impact during all phases of operation (Level 2), and finally up to multimodal traffic scenarios that consider airport apron operations and passenger transportation to and from the airport (Level 3). Both the airport scenario and the cabin-noise assessment shall be optimised by means of an iterative loop during the design process in ICA-B. Moreover, flight paths shall be optimised using minimisation of the ground noise immissions as a target function.

2.2.2 Work content

ICA A focusses on Level 2 and 3, while the components (Level 1) are investigated in ICA B. Further development and extension of the hybrid simulation chain (from sources to ground) is planned. This Level 1 work should deliver structural/acoustic loads, aircraft design details, and radiation patterns to ICA A. A software based on semi-empirical emission models shall be applied to calculate the radiation pattern of an entire aircraft along simulated take-off, flyover, and landing events, while a wave-resolving approach (e.g. based on the Finite Element Method) will be applied to calculate the details of cabin noise.

The sound radiation characteristics of the overall external aircraft noise emission shall be transferred to Level 3 using an approach that can take into consideration the noise from the airframe and the engine separately. Comparative studies with best practice approaches, among others, will provide insights into the modelling uncertainty and the robustness of the prediction. The emission data from Level 2a shall be assembled along simulated flight trajectories to yield a noise footprint over the course of a single flight event. Footprints shall then be integrated into a realistic scenario comprising comprehensive aircraft operation. The Level 1 noise on board a single aircraft (Level 2a) shall now inherently be considered part of an entire traffic scenario (Level 3). Here, a design-to-acoustics loop for flight operations will be implemented and aspects of inverse noise considerations will be addressed (e.g., modelling noise constraints and creating operations and trajectories maximizing constraints, optimizing procurements to maximize traffic throughput, extraction of noise emission requirements for operable aircraft). A wave-resolving software for Level 2 cabin noise takes into account structural and acoustic loads from Level 1 using high-fidelity models of the aircraft's coupled structure and cavities. The focus of vibroacoustic cabin noise prediction by deterministic models should be on the inclusion of stochastic sources and uncertain design parameters. The auralisation of resulting continuous frequency spectra and investigation of the effect of uncertainties within listening tests should lay the basis for the assessment of sound quality.

2.2.3 Estimate of resources within Research Unit

The overall personnel resources for establishing the Research Unit are 3 doctoral researchers.

2.2.4 Call coordination

The Call to establish Research Unit ICA-A2 is monitored by a Call Coordination Team composed of PI Jens Friedrichs, Sabine Langer and program manager Tatjana Szalkau. The team members will serve as points of contact for any question concerning this Call.

2.3 Simulation and optimisation of ATS (ICA-A3)

2.3.1 Objectives

The aircraft and the ATS are strongly interlinked through the design of operations within the regulatory landscape. Additionally, the strong need for interoperability of conventional aircraft and future in the ATS will require full compatibility of present technologies and operations as well as those of future aircraft over several decades. Consequently, requirements in the operational domain will have a strong impact on the design of the vehicle and vice versa. Therefore, this research topic shall bridge this gap between the present and future and link research related to design of operation (ICA A) with research in the area of flight physics (ICA B) and energy provision (ICA C). To take this strong dependency between operational and vehicle design into account on a practical basis, an existing air traffic simulation environment shall be employed and enhanced to facilitate the assessment of future air traffic participants. Profound integration and automation of simulation modules should open up the possibility of what-if investigations for ATS stakeholders. Simulation and optimization should include ground and handling operations.

The simulation strives to achieve a deeper understanding of the mechanisms by which the development of the ATS can be steered in order to facilitate formulation of recommendations on its future design and operation. This in turn shall facilitate the successful transition towards sustainability and energy efficiency both at the level of single technologies or actors and at the system level.

2.3.2 Work content

To assess the future aircraft defined and modelled in high fidelity within ICA B in the context of an air traffic scenario as defined by SESAR 2020, an existing air transport simulation environment shall be extended by relevant operational scenarios built on assumptions regarding future air transport demand. In addition, future aircraft configurations shall be modelled and integrated into a fleet of conventional aircraft. Therefore, the high-fidelity physical flight model as developed in ICA B shall be scaled down to ensure fast computational times for simulations. This scaling process needs to be accompanied by indications about the loss of fidelity and confidence of the models and the impact of this degradation at ATS level. Robust optimisation techniques shall be applied to minimise potential degradation of models. Extensive implementation work has to be invested in the deep integration and automation of simulation modules. Optimisation problems arising in simulations of airport infrastructure planning and operations involving variables of location, capacity, and complex scheduling shall be studied and solved. Feeders from transportation modes such as rail and road need added flexibility to accommodate the more rigid aircraft flight schedules if four-hour door-to-door transport is to be achieved. The design of transportation services in multimodal transportation networks can offer seamless integration of different transportation modes, provided that an efficient infrastructure to connect these modes exists and that the services are carefully and robustly scheduled.

Modelling uncertain future developments of the most relevant external factors shall be basic for the transition of the ATS System. Dynamics and Agent-Based models to analyse the behaviour of the overall ATS as well as Multi-criteria optimisation models for the selection and temporal allocation of measures shall be enhanced.

Specifically, for example, strategies could be developed to optimally manage aircraft fleet renewal. An optimization model to be developed for this purpose could build on existing simulation software for feasibility testing in terms of routing, range, etc., and then develop an automated approach to test different scenarios in terms of aircraft type availability. Optimised use of different aircraft types over time will allow a better understanding of potential economic and environmental impacts.

Detailed system dynamic modelling of all parts of the potential future ATS with new aircraft types and systematic testing of parameters across all areas of the ATS for the target value of cumulative emission reductions and their respective interaction will provide a systematic representation of sensitivities. This is the basis for identifying the most influential parameters for emission reductions in a future ATS and provides a clear picture of which parameters should be closely monitored and, if possible, positively influenced.

2.3.3 Estimate of resources within Research Unit

The overall personnel resources for establishing the Research Unit are 3-4 doctoral researchers.

2.3.4 Call coordination

The Call to establish Research Unit ICA-A3 is monitored by a Call Coordination Team composed of PI Peter Hecker, Imke Joormann, and program manager Tatjana Szalkau. The team members will serve as points of contact for any question concerning this Call.

2.4 Sustainable aircraft system (ICA-A4)

2.4.1 Objectives

The objective is to develop an integrated computational life-cycle engineering and sustainable assessment approach consisting of multi-scale physical, environmental, and cost models. Special attention should be paid to the socio-ecological interaction of the Air Traffic System. Addressing social and environmental issues is central to an accurate holistic assessment of the air transportation system (ATS). This provides the basis for designing an effective and efficient transition to a sustainable system.

One requirement of the approach is that it provides life-cycle-oriented analysis and evaluation of engineering leverage in the early stages of aircraft development. This requires the development of lifecycle-oriented system models for different aircraft configurations (concerning powertrains and aircraft architecture) as well as alternative supply chain and usage scenarios. This includes the consideration of new handling requirements during operation and maintenance that emerge from new technology demands such as battery replacement. Additionally, the research shall perform environmental and economic assessment of a set of defined aircraft configurations as part of aircraft fleets. The results of these assessments shall serve as an input for the evaluation of the ATS. The integrated computational life-cycle approach shall coherently combine multi-scale models and shall offer several advantages. First, the approach shall allow for a comprehensive life-cycle costing and life-cycle assessment analysis. Second, the impact of new systems and subsystems on the aircraft and its related life-cycle processes shall be assessed and existing trade-offs shall be identified. Third, product development and design shall be supported at an early phase by an environment- and cost-oriented analysis including a contribution analysis. This shall provide important insights regarding the environmental and economic impact of specific materials, parts, and components. Fourth, the evaluation of individual aircraft, aircraft generations, and aircraft fleets shall provide crucial information and insights for the analysis and evaluation of the complete ATS.

2.4.2 Work content

One task is to refine environmental and socioeconomic sustainability indicators that quantify the contribution of new aircraft concepts to achieving higher-level sustainability goals (e.g., sustainable development goals and planetary boundaries). Furthermore, relevant airframe-level sustainability indicators would have to be provided for overall system assessment as well as the engineering of aircraft components and configurations.

Furthermore, a methodology and data & coordination platform demonstrator for the monitoring of life-cycle data from components and modules of future aircraft systems should be developed. Sustainable life cycle strategies should be identified through a System of Systems Engineering approach with special focus on electric aircraft operation, MRO and end-of-life from an operational and System of Systems perspective. Data monitoring combined with environmental assessment of aircraft components within emerging electrified powertrains for sustainability-oriented coordination of actors via a platform approach have to be built up, combined with environmental assessment of daily operations of novel aircraft concepts. This includes providing relevant metadata structures for the integration of data resources from various systems and stakeholders in aviation industry.

In general, of key importance for the future of aviation is what basket of technological, operational and political measures should be deployed over time in order to cut down emission by a significant extent despite rocketing air travel demand while ensuring safe, seamless and cost-effective operation. Especially against the background of disruptive global changes, it is essential to consider social and ecological interactions. These would have to find their way into a model-based assessment of the ATS. Such a holistic assessment shall be developed by the **Junior Research Group "Socio-ecological Interaction of Air Traffic System"**, which will be comprised of the lead and 2 doctoral researchers. The JRG should strive to achieve a thorough understanding of the mechanisms by which the development of the ATS can be steered in order to derive recommendations on its future design and operation. The JRG's methods and research should support and enrich system dynamics and agent-based models for analysing the behaviour of the entire ATS, as well as multi-criteria optimisation models for selecting and allocating actions over time.

This call addresses only the research field of the life-cycle and sustainable assessment. The Junior Research Group is addressed in a different call.

2.4.3 Estimate of resources within Research Unit

The overall personnel resources for establishing the Research Unit are 4-5 doctoral researchers (2 of them belong to the JRG) and one JRG lead position.

2.4.4 Call coordination

The Call to establish Research Unit ICA-A4 is monitored by a Call Coordination Team composed of PI Christoph Hermann, Sabine Langer, and program manager Tatjana Szalkau. The team members will serve as points of contact for any question concerning this Call.