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Assessing Continuous Descent Operations Using the Impact Monitor Framework †

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Abstract: The Impact Monitor Project is a European initiative designed to develop an impact assessment toolbox and framework, targeting the European aviation sector. The proposed framework is not only aimed at the environment, economics, and operations but also the societal impacts of new technologies and aircraft configurations. The toolbox works by setting out the key steps in the impact assessment cycle and presenting guidance, tips, and best practices. Led by DLR, the consortium includes research institutions and universities that have contributed their expertise and tools to develop the collaborative assessment toolbox and framework. The project defines three use cases by considering three assessment levels: aircraft, airport, and air transport system. This article focuses on Use Case 2 on continuous descent operations (CDOs) at the aircraft and airport levels. It describes the workflow proposal, along with the tools involved. The collaborative approach showcases integrating these tools and using collaborative strategies enabled by CPACS (Common Parametric Aircraft Configuration Schema) and RCE (remote component environment). The list of tools includes Scheduler (DLR; flight schedule simulation), AirTOp (NLR; TMA simulation), Dynamo/Farm (UPC; trajectory simulation and assessment), LEAS-iT (NLR; emissions simulation), Tuna (NLR; noise simulation), AECCI (ONERA; emissions simulation), TRIPAC (NLR; third-party risk simulation), and SCBA (TML; social and economic impact assessment). Interactions with other use cases of the project will be demonstrated via new aircraft configurations stemming from the use case at the aircraft level of the project. The results demonstrate the workflow's feasibility, the cooperation among the tools to obtain and refine the outcomes, as well as the analysis of the operational scenario of a generic airport, CAEPport, which has been extensively used in previous Clean Sky 2 projects.

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Keywords: Impact Monitor; airport; continuous descent operations; CDO; noise; emissions; third-party risk

1. Introduction

The Impact Monitor Project, funded by the EU, aims to develop an impact assessment toolbox and framework for European aviation. Focused on environmental, economic, and societal impacts, particularly greenhouse gas emissions, air quality, and noise, the toolbox details a working methodology by outlining the key steps in this cycle and presenting guidance, tips, and best practice, while the framework facilitates the integration of advanced design and evaluation tools. Coordinated by the German Aerospace Center (DLR), this initiative leverages digital technologies for collaborative engineering in the aviation sector, streamlining the assessment processes at the aircraft, airport, and system levels.

The project defines three use cases based on three assessment levels: the aircraft, airport, and air transport system levels. This paper presents the modeling and simulation of an impact assessment at the airport level, emphasizing the implementation of continuous descent operations (CDOs). It also aims to provide an interim demonstration of the capabilities developed by the Impact Monitor framework and the interactive dashboard application at the airport level. This demonstration will be completed in the final months of the project. This study describes the workflow proposal, along with the tools involved. The collaborative approach showcases integrating these tools and using collaborative strategies enabled by CPACS (Common Parametric Aircraft Configuration Schema) and RCE (remote component environment). The list of tools includes Scheduler (DLR; flight schedule simulation), AirTOp (NLR; TMA simulation), Dynamo/Farm (UPC; trajectory simulation and assessment), LEAS-iT (NLR; emissions simulation), Tuna (NLR; noise simulation), AECCI (ONERA; emissions simulation), TRIPAC (NLR; third-party risk simulation), and SCBA (TML; social and economic impact assessment).

The framework, along with the involved tools, allows for an assessment of the impacts of implementing the CDOs regarding emissions, noise, and third-party risk, which leads to an assessment of social benefit.

The following section describes the technical implementation of the Airport Use Case. Next, the set-up and results of the demonstration exercise are presented. The final section discusses the first conclusions that can be drawn from the exercise and the next steps that are still planned for this use case in the Impact Monitor project.

2. Technical Implementation

The Use Case aims to demonstrate the collaborative approach of the Impact Monitor project by integrating eight tools and using collaborative strategies enabled by CPACS (Common Parametric Aircraft Configuration Schema) and RCE (remote component environment).

2.1. Brief Description of CDOs

CDOs allow aircraft to follow an optimum flight path that delivers major environmental and economic benefits, resulting in engine-idle continuous descents that reduce fuel consumption, pollutant emissions, and noise nuisance (cf., e.g., [1–4]). Figure 1 illustrates this concept and the reduced noise footprint when following a CDO strategy.

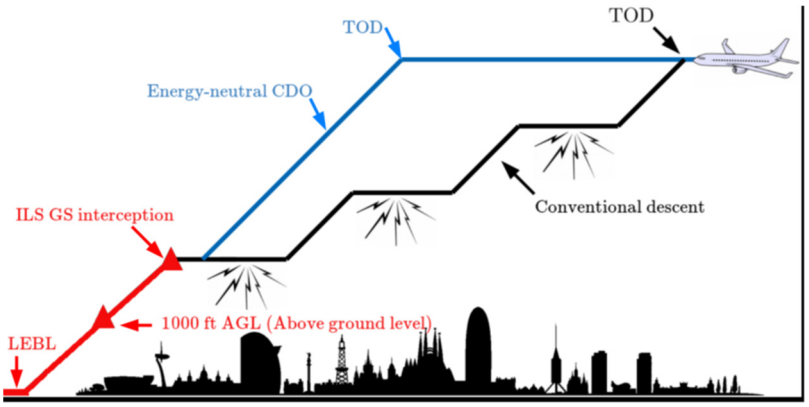


Figure 1. Illustrative comparison of a CDO and a conventional descent operation (Source UPC).

CDOs have been on the research desk for a while but have not been fully deployed. The CDO use case will explore the impacts of this ATM strategy on the sustainability of these operations. To demonstrate the Impact Monitor framework capabilities about CDOs, two assessment levels will be considered due to integrating several models, enabling the analysis of CDOs' impact at the aircraft and airport levels. Aspects of investigation include the following: (a) at the aircraft level, the impact of CDOs on emissions and operations will be analyzed using deterministic aircraft trajectory prediction; (b) at the airport level, starting from a one-day flight schedule, the environmental impact assessment of CDOs will be performed, comparing the environmental performance in cases with and without CDOs for the selected airport and flight schedule. Here, noise impact (e.g., L_{den} and L_{night} contours, along with the population exposed/annoyed/sleep-disturbed) and emissions impact (e.g., the total amount of emissions below 3000 ft) will be quantified. In addition, the effect of introducing CDOs on airport capacity at the airport level will also be addressed. In conclusion, a social cost–benefit analysis approach will be applied to evaluate the costs and benefits of CDOs.

2.2. Workflow

Use Case 2 is based on the tools listed in the previous section. These tools are arranged on the workflow shown in Figure 2. It has been updated and adjusted along with the project discussions, and the one shown here is the latest version.

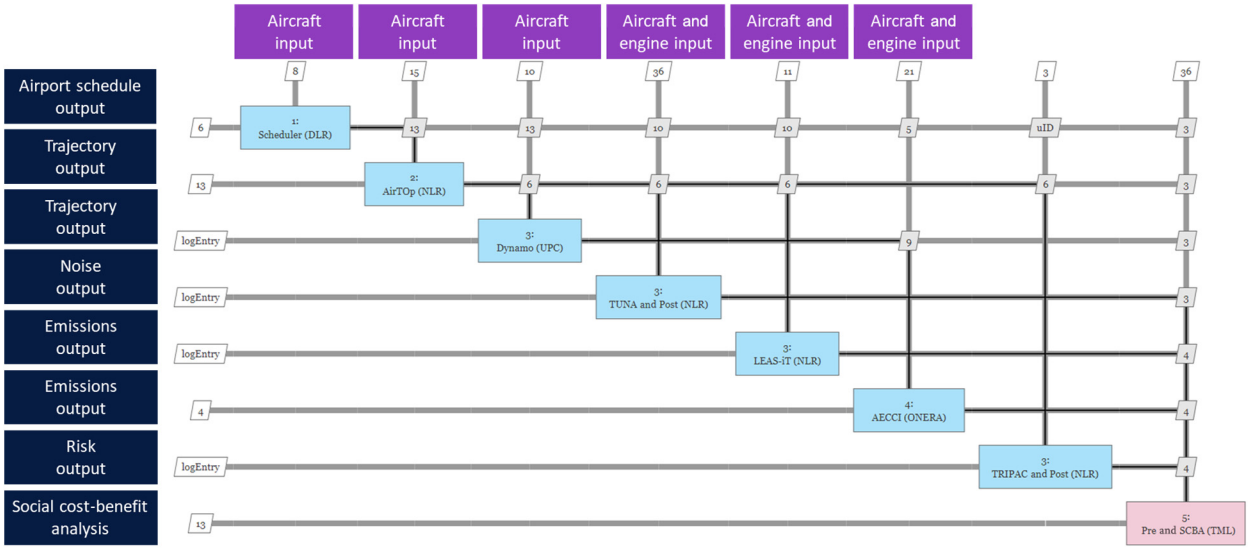


Figure 2. Use Case 2 workflow with labeled inputs and outputs.

Associated with this workflow, the CPACS file schema requires fulfilling a few relevant items:

- Flight schedule: SCHEDULER will fill CPACS with the information about flight schedule, namely the OD (origin–destination) pair and the arrival and departure times.
- Airport: Information about the airport (CAEPport) will be included for AirTOp and DYNAMO.
- Aircraft information for new configurations will be included, providing the path to the OPF (the EUROCONTROL BADA file about aircraft operational performance (Aircraft Performance Operational File)) file, which will reproduce the BADA data, and some parameters will also be inserted directly at CPACS, such as engine reference. Aircraft information for standard and existing configurations will be defined via the BADA database. A nomenclator list has already been used to verify the definition of the aircraft models.
- Trajectories: A single set of trajectories will be available. AirTOp will provide a first output, which will be refined by DYNAMO. Using its FARM module, DYNAMO will add information about fuel consumption, flight time, thrust level, and weather conditions, among others.
- DYNAMO also enables incorporating weather data into the CPACS file, which will later be used by AECCI tool to calculate emissions.
- Three alternate branches are available for this workflow. The first and the main one is to use the whole set of proposed tools since they are complementary. The second and third branches use either Leas-iT, TUNA, and TRIPAC tools or DYNAMO (and its FARM module) and AECCI. Tools like AirTOp and DYNAMO, as well as Leas-iT and AECCI, can complement the results of the other tool. This is why the two secondary branches can be proposed.
- The final step in the workflow is social and economic impact assessment. The SCBA tool by TML is used to compare and compute the impact (considering delays, operational costs, emissions, noise, and risk) associated with the implementation of CDO with respect to a non-CDO scenario.

2.3. Integration of the Tools in CPACS, RCE, and the Dashboard Application

In order to run the workflow, an RCE framework with UPLINK and BRICS connection is established. The framework enables the creation of a network, which can be later used to connect and communicate the tools while running the simulations.

Data sharing is based on CPACS, which conforms to the low-level communication language between the tools. While RCE manages the interaction between tools, CPACS is the data container used to share data. Both the partial and the outcomes of each tool can be visualized using the Impact Monitor dashboard. To store all of these outputs, a Next-Cloud repository is provided. The dashboard takes the data from the repository to provide results visualization (see Figure 3).



Figure 3. Integration of Use Case 2 tools in CPACS, RCE, and the dashboard application.

To conduct the case study, the CPACS data model is extended in several ways.

3. Demonstration Exercise: Scenarios and Preliminary Results

The Impact Monitor assessment for Use Case 2, at the airport level, is based on comparing two scenarios. The first one is the reference baseline. It considers the null application of continuous descent operations. The second one already considers CDO. More specifically, the operation of interest is the approach, so the scenarios focus on continuous descent approaches (CDAs).

3.1. Scenario Definition: Baseline Scenario and CDO Scenarios

Both scenarios are initially defined by a flight schedule, regardless of whether CDO is implemented or not. The scheduler tool provides the arrival and departure times of a set of flights, linked to its origin–destination (OD) pair. The AirTOp tool uses the scheduled flights to simulate the arrival and departure trajectories while assessing air traffic management criteria, such as capacity or conflicts. The generated trajectories are later used by each of the two branches of the workflow to obtain the emissions and fuel consumption (the branch that incorporates DYNAMO/FARM and AECCI tools, by UPC and ONERA, respectively), or to obtain emissions up to 3000 ft, namely noise and risk (the branch that incorporates Leas-IT, TUNA, and TRIPAK, by NLR). The final step in the workflow is the final social and economic impact assessment, which is performed by the SCBA tool of TML.

AirTOp is the tool which manages the implementation of CDO. It enables the activation or deactivation of CDO but does not enable selecting the implementation level. This means that the CDO will be implemented based on the capacity of the airspace to accept a larger or lower number of such operations.

The SCBA requires computing two scenarios: the baseline design and the CDO design. The baseline design does not include any continuous descent approaches (CDAs), while the CDO scenario does. The number of flights considered in the scenarios is crucial to ensure that when requesting the implementation of CDO, it is feasible, and at least some flights adhere to this procedure. A continuous increase in the number of flights will increase the CDO implementation to a certain level. At some point, the air space structure and the airport capacity will limit the CDO implementation, and the number of flights using CDA could begin to decrease.

3.2. Scenario Results

Partial results demonstrate the connection and data transfer among the workflow tools. A dashboard to visualize all the available results, including partial and final ones, has been developed as a project outcome. The dashboard has already been tested and is under further development to refine and upgrade the amount and quality of the results and its visualization.

In the particular case of Use Case 2, readers should consider the large number of tools involved in the workflow. Having partial results for all of them and enabling the dashboard user to visualize all of them is a challenge.

The user can expect the following:

- Scheduler output: Scheduler only offers output in a text format, following CPACS rules, as well as a list of flights. CPACS stores the flight schedule generated by Scheduler. It contains a description, information about the date and time of all the flights, and the type of aircraft.
- AirTOp output: AirTOp takes the list of flights and simulates all of them to obtain the best trajectories according to the airspace structure and airport characteristics. The trajectory is stored in the CPACS file, creating a node belonging to the flight node,

which relates this information to the schedule. Figure 4 is a graphical representation of a set of trajectories obtained by AirTOp. These trajectories fulfill ATC regulations.

- DYNAMO/FARM postprocesses the AirTOp trajectories to achieve refined and additional data related to the trajectories. DYNAMO/FARM deals with individual trajectories, simulating each trajectory from an individual point of view, without considering the effects from other trajectories. The postprocess adds data such as distance, speed CAS and mach, thrust level, fuel flow, and weather data for each trajectory point. DYNAMO/FARM can easily calculate the CO_2 emissions for the fuel flow.
- AECCI takes the DYNAMO/FARM trajectory as the input data and complements the emission calculation. AECCI calculates the amount of NOx, CO, H_2O, SO_2, and HC. In this case, the calculation also provides the total final values. Figures 5 and 6 are two examples of CO_2 and NOx analysis calculated by AECCI.
- TUNA calculates the noise footprint of the approach section of the trajectory. An example of this output is shown in Figure 7.
- LEAS-it provides the calculation of emissions below 3000 ft. A footprint, similar to the one about noise, can also be obtained
- TRIPAC calculates the third-party risk footprint of the approach section of the trajectory.
- SCBA is the last step in the social and economic assessment analysis. It aims to compare. Using the outputs of the above-mentioned tools (such as delays, fuel consumption, emissions, noise, and risks) for the two scenarios, it aims to assess the economic and societal benefits or costs of CDO. Results by SCBA include the effect on passengers, airlines and operators, as well as the costs related to emissions, air pollution, noise, and accidents as shown in Figure 8.

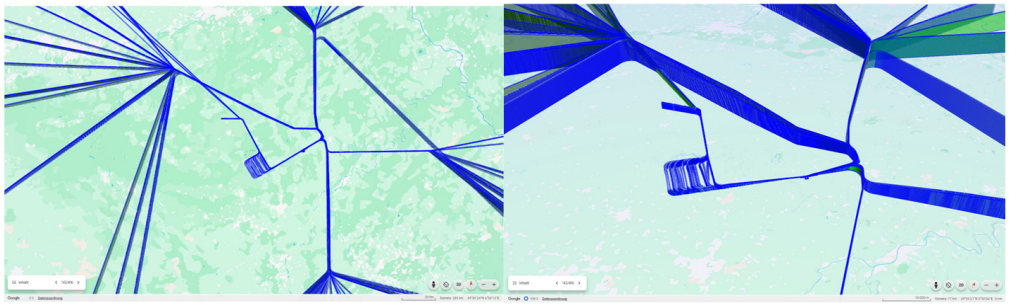


Figure 4. Graphical representation of all AirTOp trajectories. General view (**left**), close-up view (**right**).

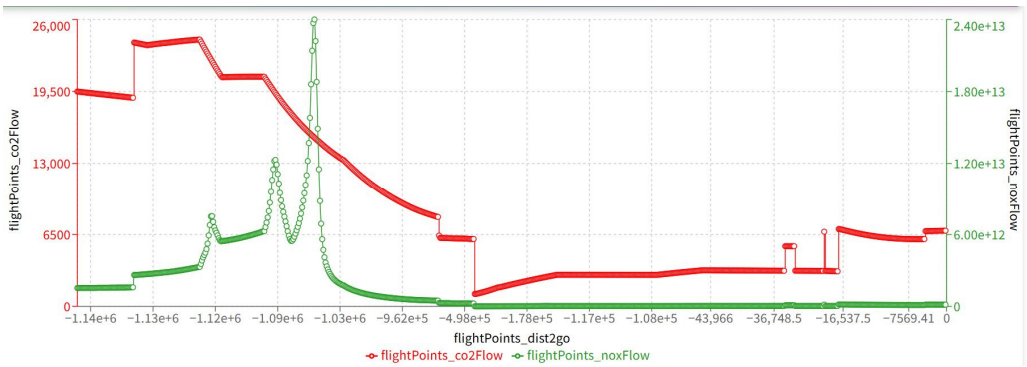


Figure 5. CO_2 and NOx emissions by AECCI.

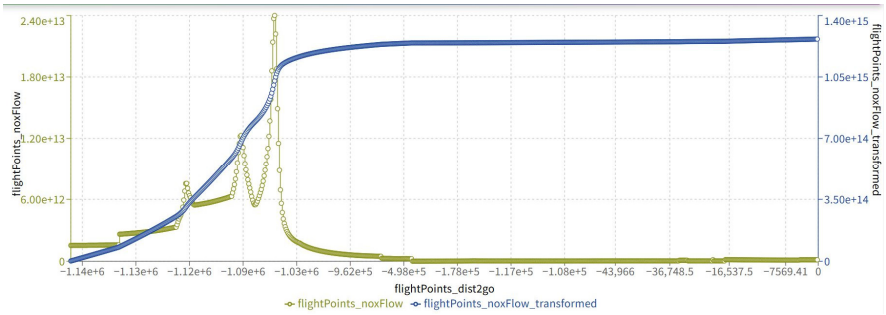


Figure 6. NOx and accumulated NOx values by AECCI.

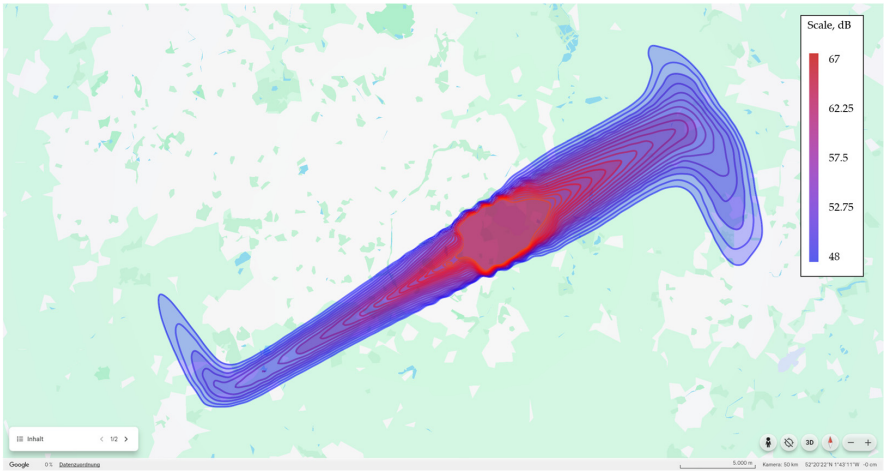


Figure 7. Noise footprint.

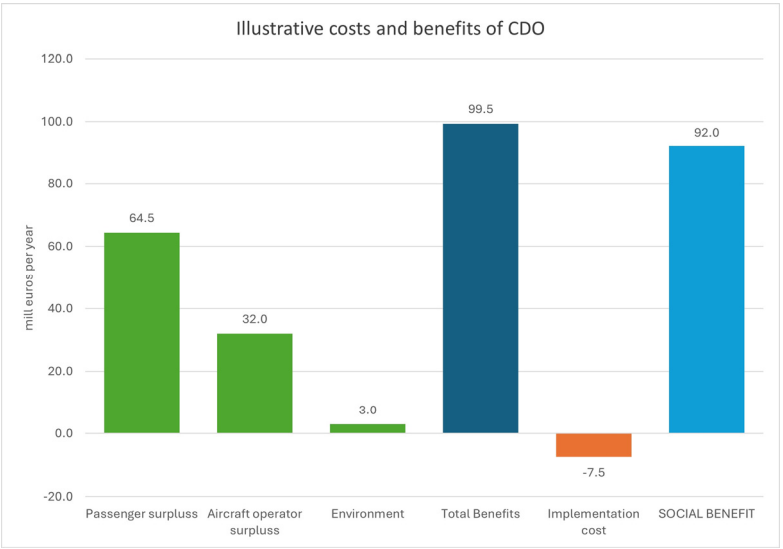


Figure 8. Illustrative costs and benefits of CDO.

4. Conclusions for the Impact Monitor Framework

This paper describes the effort of the Impact Monitor consortium to define and apply a collaborative assessment framework at the airport level. This effort led to defining a specific Use Case, the so-called Use Case 2 (UC2). UC2 integrated several tools from DLR, NLR, ONERA, TML, and UPC. The results presented are preliminary results that demonstrate the feasibility of the workflow. The challenge to make a long list of tools working together has proven to be significant, but it finally works smoothly and seamlessly, as shown in

this study. The use of CPACS provided a common language for all the tools, implying the simplification of the format of the input and output files.

The results presented are preliminary and aim to demonstrate the communication of the complete set of tools involved in the use case workflow. This communication is managed using the RCE tool by DLR, representing a cooperative environment. All the tools in the use case have been successfully integrated in this environment. Two scenarios have been tested, one with no CDO at all, and a second one with CDO. The level of CDO implementation in this second scenario depends on the number of flights and the potential congestion produced with the level of demand. The results may be inaccurate or show unfeasible outcomes because scenario refinement is still required.

The way forward demands refining the workflow connections and scenarios. Fully automating workflow execution is the main issue left to solve and has already been addressed.

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