aircraft design

conceptual design of new low-noise aircraft

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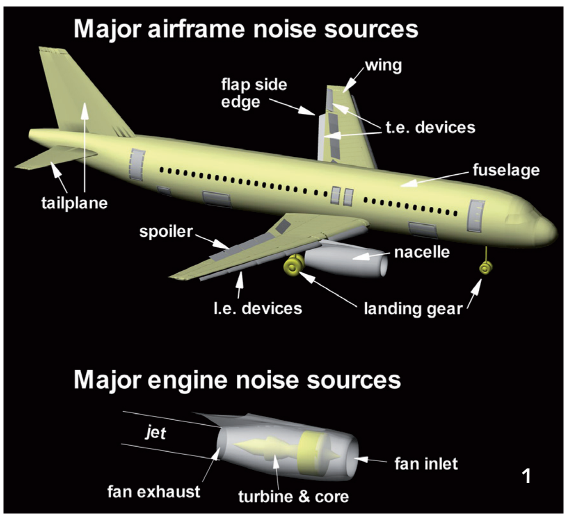
» Noise levels generated by aircraft (and rotorcraft) are among the loudest noise sources of our times. Sound pressure levels close to a jet aircraft engine under take-off conditions can reach the human threshold of pain with respect to noise. Aircraft ground noise levels comparable to a heavy truck passing by, i.e., maximum levels on the order of 70 to 80 dBA, can still be measured at large distances up to 20 km away from the actual airport premises. As a consequence, communities far from the vicinity of an airport can still be subject to significant aircraft noise perception and hence annoyance. Long-term exposure to relevant noise levels can have a negative affect on people's health and also decrease property and housing values.



1 The major noise sources on board a conventional turbofan transport aircraft are depicted. Major noise sources can be attributed to airframe or engine noise contributions.

Aircraft noise is generated by a variety of systems and components on board, so-called noise sources. The main focus of the presented activities lies on conventional turbofan transport aircraft due to their significant market share at most airports, meaning that they have a dominating influence on community noise annoyance. The major noise sources can be attributed to either airframe or engine contributions (see **Fig. 1**). The overall vehicle noise can be approximated by a summation of these major noise contributions which is referred to as a noise component breakdown. Adequate representation and superposition of each of these major noise sources can result in very good agreement with the overall vehicle noise.

Noise reduction measures. In order to fight aircraft noise, the International Civil Aviation Organization (ICAO) has defined four measures:

- modification of the noise source
- noise abatement flight procedures
- land-use planning and traffic routing
- operational constraints

These measures actively reduce noise generation or noise impact at a certain location. To maximize the overall noise-reducing effect, these measures have to be applied and accounted for simultaneously. Noise attenuation of ground-based noise sources can be excessive and on the order of tens of decibels. Therefore, these ground-based noise sources can effectively be reduced by passive protection measures. Instead of directly addressing the noise generation and propagation, these so-called passive measures will reduce perceived noise levels through constructive measures, e.g., special walls, hedges, or trees. But since maximum aircraft noise levels are perceived directly from above, aircraft noise is subject to only limited attenuation due to these measures compared to their impact on ground-based noise sources. Of course, certain passive measures such as soundproof windows can be applied and will have an effect.

In conclusion, the first two ICAO measures are the most relevant and effective because they directly affect noise generation at the source and ground noise distribution along the flight path. Therefore, the requirements for any low-noise aircraft are minimum noise generation directly at the source and a vehicle design tailored for flight performance to enable low-noise flight operation. In order to assess such new concepts and future technology, advanced simulation capabilities are essential. Based on these simulations, an aircraft designer can then select the most promising design trend or technology in order to reduce the community noise annoyance of the final vehicle. But significant changes to an aircraft design can only be applied and directly compared to other modifications early within the design process.

Aircraft design. The overall vehicle design and, consequently, the flight performance are defined and fixed in the conceptual design phase. Major design parameters and key settings are selected during this design phase, and later modifications

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For more information on aircraft noise visit: www.dlr.de/as to this initial selection should be avoided. Any changes would require revisiting the conceptual design stage in order to identify and assess any possible implications for other components and the overall system, i.e., evaluation of the so-called snowball effects. The conceptual vehicle layout is fixed within subsequent design phases, and only small and detailed modifications are still feasible. As a consequence, any larger low-noise measure and design modification has to be incorporated and accounted for as early as possible within the conceptual design phase.

Required simulation capabilities. In order to evaluate the noise generation of new vehicles within the conceptual design phase, special simulation capabilities are required. The two required main simulation capabilities are an aircraft design synthesis process and a vehicle system noise prediction. An aircraft design synthesis process is required in order to assess the specific vehicle concept and its corresponding flight performance, including detailed flight paths. In order to evaluate the ground noise impact, a parametric noise prediction tool is essential. In this context, the noise simulation has to be parametric with respect to both the aircraft design and the corresponding flight operation. Such a prediction tool can be realized based on the concept of the componential modeling of the main individual noise sources as depicted in **Fig. 1**. Each of the depicted noise sources can then be modeled with a dedicated source model. Superposition of these individual contributions then yields a good approximation of the overall vehicle noise.

In a joint research activity, the German Aerospace Center (DLR) and the TU Braunschweig have developed the required simulation capabilities. A new conceptual aircraft design process with integrated noise prediction capabilities has been established [1].

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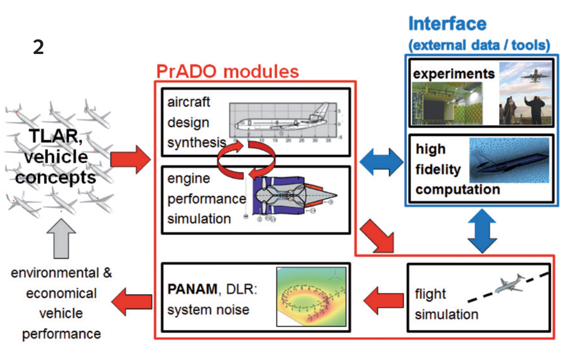

2 The simulation process is depicted as developed by DLR and TU Braunschweig. Aircraft design and flight simulation are carried out with TU Braunschweig's PrADO tool. Aircraft system noise is predicted with DLR's PANAM tool. Interfaces to external data enable the incorporation of high-fidelity simulation results or experimental results.

Simulation process. The new design process is depicted in **Fig. 2**. The process comprises the aircraft design synthesis code PrADO from the TU Braunschweig and the aircraft noise prediction tool PANAM from DLR. Furthermore, interfaces to experimental data or other high-fidelity simulation tools are available, e.g., an interface to the DLR noise shielding tool SHADOW. Based on a preselected basic layout and a design mission, all relevant disciplines and their interactions can be evaluated. Certain design parameters can be modified and adapted in the process until the main design and mission constraints are met. At this point, the multidisciplinary and iterative process yields a feasible aircraft design. This aircraft is then simulated along prescribed approach and departure flight procedures in order to evaluate the precise flight path, including configuration changes such as deployment of the high-lift system. Finally, the aircraft ground noise impact can then be evaluated along these approach and departure flight paths. With this new process, the aircraft designer can directly evaluate and compare the vehicle performance and the noise characteristics of widely varying aircraft concepts [1].

Application example. The process has been applied to reduce the ground noise impact of a conventional transport aircraft similar to an Airbus A319. A very promising and effective approach to this goal is the reduction of engine noise through structural shielding. A recently developed simulation tool from DLR known as SHADOW enables the evaluation of engine noise shielding. This tool is incorporated into the process via dedicated interfaces [2] as depicted in **Fig. 2**.

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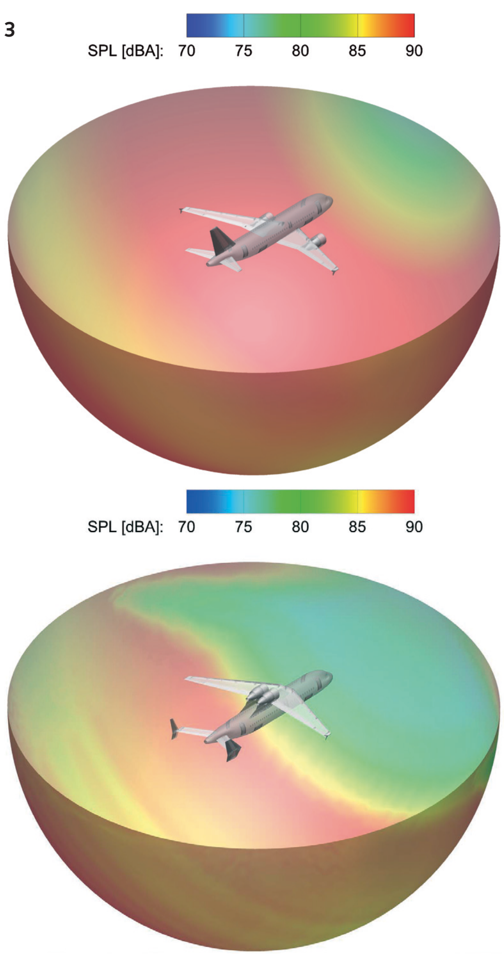
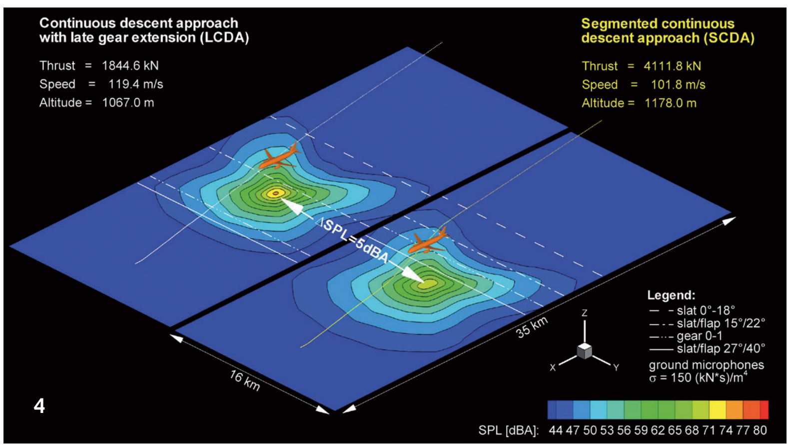


3 The effect of engine noise shielding due to structural elements is depicted. On the left side, noise emission for a conventional vehicle layout is simulated. The picture on the right shows the noise emission for a radical new vehicle concept. The engine locations are specifically optimized for maximum noise shielding. Both vehicles are simulated under similar operating conditions, i.e., a flight speed of 130 m/s and with clean configuration (high-lift system and gear retracted).

Fig. 3 shows a comparison of two engine installation locations, i.e., conventional and above the main wing/fuselage junction [2]. The different noise emission due to the engine noise shielding is depicted. As expected, the noise emission can be significantly reduced for the advanced shielding. At the same time, the resulting flight performance along the design mission can be evaluated for both vehicles with the overall process. At this point, the aircraft designer has access to physics-based information with respect to the noise and performance of both vehicles. Now environmental and economic performance can be evaluated and weighted, and the most promising design can be chosen. Identification of the most promising concept from a large solution space ends the conceptual design phase. Subsequent and more detailed design phases can be initiated in order to get a detailed analysis of the selected vehicle.

Various other application areas are feasible for the new process. For example, the process can be applied to prepare flyover noise measurements of existing vehicles. **Fig. 4** depicts a simulation of two common approach procedures. The direct comparison enables the selection of the most promising observer locations in order to measure the differences between the two procedures.

Furthermore, newly developed technologies or components can be simulated on board a reference vehicle in order to evaluate the overall impact on environmental and economic performance; for example, the effects of a new high-lift system have been studied in detail. Other applications that are not yet realized include real-time noise analysis for ground-based flight simulators or auralization purposes.



4 Real-time noise footprints along two different approach procedures are depicted. The reference aircraft is operated along both flight procedures in order to directly compare the difference in ground noise impact. Both procedures can be directly evaluated and compared to each other. If both procedures are selected for a fly-over noise measurement, the most promising microphone locations can be selected in order to measure the differences between both procedures.

Future challenges. In order to fight aircraft noise, both the aircraft itself and the way it is operated have to be improved at the same time. So far, the new simulation process has mainly focused on the aircraft design [1, 2]. According to the individual flight performance of the specific aircraft design, a standard approach and departure have been analyzed. The next step would be to develop aircraft designs that enable radical low-noise flight procedures in order to maximize the ground noise reduction. Exploitation of new design ideas in combination with radical flight operation promises significant community noise reduction. Furthermore, the simulation process will be updated with recent findings and new noise source models to account for circulation control high-lift systems, for example [3].

Currently, a promising new approach to low-noise vehicle design is under investigation at DLR. The basic idea is to derive design constraints and tailored specifications for a certain noise source depending on preselected noise constraints on the ground. Up to now, a variety of parameters have had to be evaluated for their noise impact in order to identify the most promising design for the noise source. The new approach could directly provide the most promising source design based on the preselected ground noise limitation, thus enabling a "noise-to-design" process [4].

Within DLR, these activities are assigned to the Institute of Aerodynamics and Flow Technology in Göttingen. The Aircraft Noise working group develops and applies aircraft noise calculation models. The different tools currently in use cover everything from best-practice models like the INM of the FAA or the German AzB, to sophisticated parametrical models. Consequently, the field of application is very large – ranging from classical aircraft noise prediction tasks for land-use planning, to low-noise conceptual aircraft design as described in the article. «

References

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