The DLR Project "Quiet Air Traffic"

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Abstract:

Aircraft noise is the dominant environmental problem in the direct airport environment. Measures for its reduction at the source as well its mitigation around airports must take into account aspects of medicine and technical design as well as legal and land use planning aspects. So a project dealing with aircraft noise reduction must be of interdisciplinary nature to make sure that synergy effects between the different scientific fields are taken into account adequately. Within the project "Quiet Air Traffic" (German abbreviation "LFVK") and its successor "Quiet Air Traffic II" ("LFVK II") the DLR has made use of such an interdisciplinary approach which was integrated into national and international networks. This paper discusses the aspects of the multidisciplinary methodology used and presents some results obtained during the time period from 1999 to 2007.

Keywords

Aircraft Noise Reduction, Aircraft Noise Sources, Aircraft Noise Effects, Aircraft Noise Modelling, Noise Abatement Flight Procedures, Sound Propagation

Background

The straightforward and most efficient method to reduce noise in the airport environment is to reduce it at the source. But it must be noted that this measure can show effects only in the long term: Modern aircraft have lifecycles of about 30 years and hence the period between the availability of a new quiet technology and its significant penetration of the market can add up to some decades.

Measures which may be applicable in the short or medium term are noise abatement flight procedures (which are closely related to optimized air traffic management systems) as well as regulatory measures based on noise legislation and land use planning concepts. Both types of measures can be applied specific to an individual airport (in contradiction to the aircraft-specific technical ones described above).

However it is not very target-oriented to undertake any noise mitigation actions without a fundamental knowledge on the psychological and physiological human reactions to noise. It is no problem to quantify the physical phenomenon "sound" (e.g. in decibels), but "noise" is in the main a subjective experience. The relation between both phenomena is in practice described by quantities whose definition is a very ambitious task. They are called "noise descriptors" or "noise indices".

Finally one has to test or validate noise reduction concepts before they can be realised in practice. The development of suitable tools for these purposes is an important part of the work of aircraft noise modellers. Such tools are aircraft noise modelling systems which are realised as computer programs. Their principal field of application is the estimation noise indices based on a set of parameters usually denoted as “scenario”. A scenario may reach from a single aircraft operation up to a complex traffic situation describing a real airport. Noise models must be adapted to their specific field of application and hence cover a range from standardised and relatively simple models for planning purposes up to sophisticated models used for scientific investigations.

It should be pointed out that the multidisciplinary approach followed by the “Quiet Air Traffic” projects covers all the measures that were specified some years after the start of LFVK as the “Balanced Approach to Aircraft Noise Management” by the ICAO [1].

The project work packages

Considering this background situation the project LFVK was structured into five main work packages: l

WP 1: Goal was the definition of an improved und reliable index for nocturnal aircraft noise. Although aircraft noise during nighttime is the most serious noise problem in the vicinity of civil airports the actual noise indices in use at that time showed definitively deficits in describing its effects.

WP 2: On the technical side the target was the development of new noise reduction technologies. This work package was split up into two subtasks dealing with engine and airframe noise respectively. The work of this task was oriented towards the needs of the engine and aircraft industries.

WP 3: The improvement of currently used as well as the development of new noise abatement flight procedures was the focus of the third work package. These activities were addressed in particular to the airlines but as well to air traffic control organisations and airport authorities.

WP 4: Concepts for regulatory noise reduction measures were subject of work package four. Target was to derive them from transport research concepts. This work was addressed to legislators, land use planners and airport authorities.

WP 5: The last work package dealt with the definition of improved aircraft noise prediction models. It was split up into two subtasks. Subject of the first one was the definition of an improved model for sound propagation through the atmosphere, suitable for the integration into actual noise modelling systems. The improvement of a noise model based on partial sound sources was objective of the other subtask.

All these work packages built an interdisciplinary research system whose structure and internal cross linking is shown in figure 1.

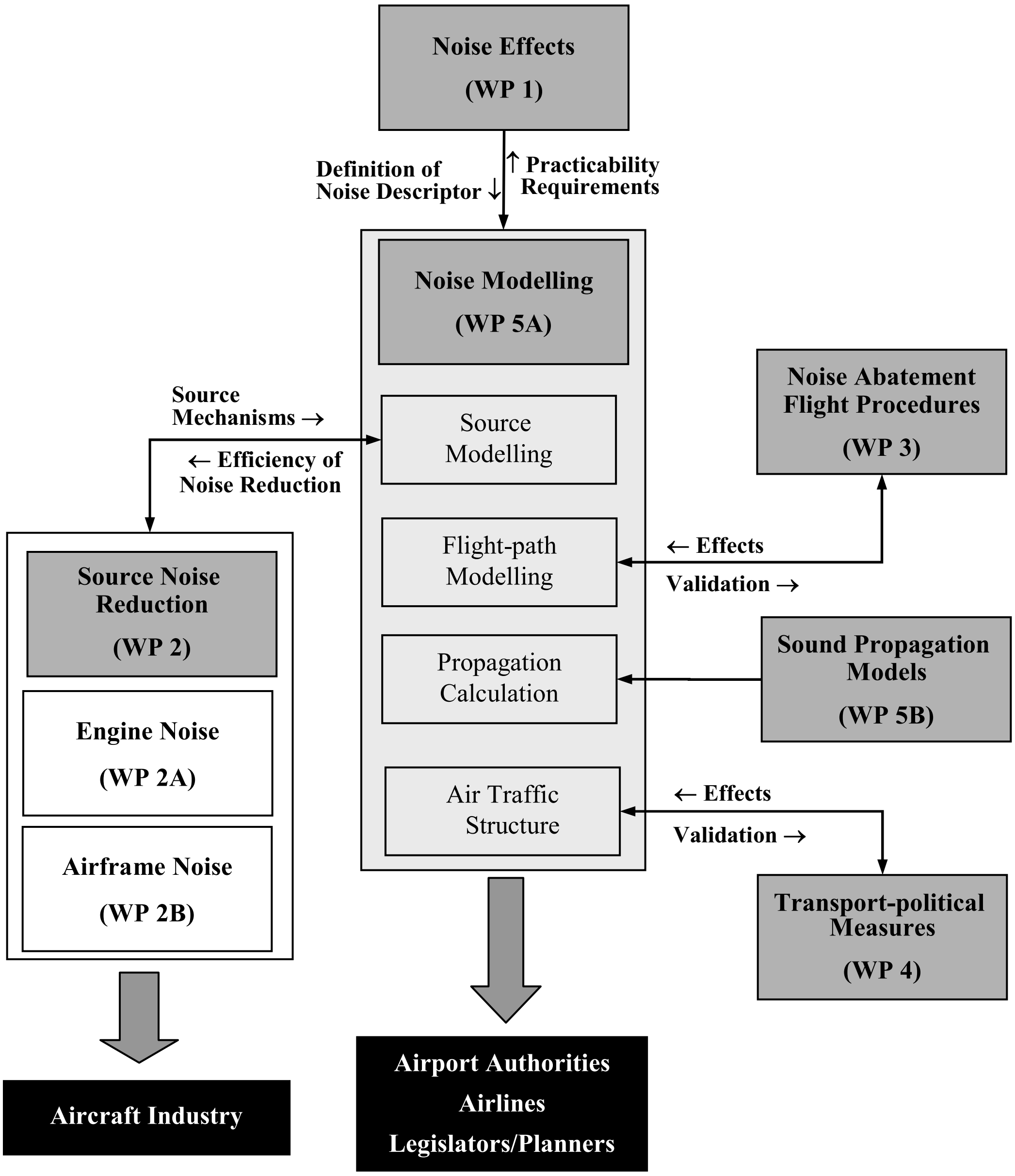


Figure 1: Structure of the project "Quiet Air Traffic"

The structure of LFVK II was identical except that (1) there was no work package 4 on transport research concepts and that (2) WP 3 was extended by a work package 3B dealing with air traffic management.

In the following sections more detailed information on these work packages is presented, although this can only be a very limited snapshot of the results of the particular tasks: The project LFVK and its successor spanned about 8 years with a budget of about 23 M€ and a total work amount of about 160 man-years. More detailed information as well as additional references can be taken from the final project reports [2,3]. But at first a brief discussion of figure 1 will give an overview on the interdependencies of the particular work packages and the special role of the noise modelling task.

The multidisciplinary approach and the role of noise modelling

The interdependencies between the work packages shown in figure 1 indicate a central role of the noise modelling task within the project structure. This is not astonishing since noise modelling is a highly interdisciplinary field of activity: the processes of developing and applying a noise modelling system require a more than rudimental knowledge of the particular scientific fields dealing with aircraft noise.

- The noise effect research provides to the modelling party the definition of a noise descriptor which should reflect suitably the human reaction on noise. But there are practical requirements in the opposite direction as well: A noise index should for example be measurable as well as predictable and stable to small changes of the underlying quantities. It makes no sense to define a sophisticated noise index which represents human reactions in a unique manner as long as he cannot be estimated in practice. So the noise modeller should be familiar with noise indices, their properties and specific fields of application.
- Any noise model is based on a source description whose particular form depends on the noise model structure. This requires that a noise modeller knows which mechanisms are generating aircraft noise and how they can be described. It is obvious that the major source for comprehensive information on noise generation are the engine- and aero-acousticians. On the other hand noise models may be used in an early stage of development to get an impression on the efficiency of the reduction measures at the receiver side (i.e. under practical sound propagation conditions and with respect to human reaction). So there is an information path in the reverse direction as well.
- The development of noise abatement flight procedures without noise modelling systems is in practice allmost impossible due to cost reasons. Using flight simulators procedures can be developed and tested for all aspects of flyability – but not for the noise they produce. The only way to avoid comprehensive and expensive flight tests to check the acoustic efficiency is an examination by noise modelling systems. These checks are usually based on the performance data generated by the simulator. Setting up a suitable modelling system and evaluating the effectiveness of noise abatement procedures requires at least fundamental knowledge on flight mechanics and operational practices.
- One standard business of a noise modeller is the preparation of expertises and reports for airport authorities or for governmental institutions dealing with transportation, environment or land use regulation. Hence an experienced modeller is usually familiar with aspects of noise legislation, land use and airport planning, sound insulation as well as with basic transport research concepts.

- The fundamental requirement for any noise modelling is of course a good knowledge on acoustics, especially on sound propagation through the atmosphere (and preferably some meteorological experiences). Comprehensive experiences in programming are mandatory if a focus of the activities is the development of noise modelling systems.

Hence an interdisciplinary project on aircraft noise ideally should be co-ordinated by someone from the noise modelling section to make sure that the communication between the different work packages is guided by a person that is familiar with all aspects of the problem to an adequate extent.

WP 1: Research on noise effects

The effects of aircraft noise during the night are different from those due to aircraft operations during the day. The latter are more or less related to the phenomenon of annoyance, which is mainly a psychological effect. Annoyance correlates quite good with equivalent continuous sound levels L_{eq} (i.e. with noise indices based on the average sound energy over a longer time period). In contrast the effects related to nocturnal aircraft noise are physiological ones. These usually manifest themselves in wake-up reactions which are determined by the maximum sound levels of single noise events rather than an energetic average. Nevertheless L_{eq}-based descriptors are established worldwide for the description of noise during the night whereas indices based on maximum levels are used only in a very limited number of countries. An example is Germany, where the so-called "Number Above Threshold (NAT)" criteria are in practical use since several years and they are now prescribed by the new Air Traffic Noise Act. But although the experiences made with NATs were satisfying, they do in principle not meet the fundamental requirements on a noise descriptor as e.g. specified in Volume 1 of ECAC Document 29 [4].

Between 1999 and 2004 extensive polysomnographic studies on the influence of noise on sleep were performed within the project LFVK. This included 4 laboratory as well as 2 field studies in the environment of Cologne airport. With about 192 participants aged between 19 and 61 years and 2240 investigated nights this study was the most comprehensive one worldwide by then.

The setup included the simultaneous recording of electrophysiological parameters (e.g. electroencephalogram EEG and electrocardiogram ECG) and noise events as well as the control of the nocturnal secretion rate of stress hormones (adrenaline, nor-adrenaline and cortisol). The studies were rounded off by additional questionnaires and performance tests of the participants.

Main result of these studies was the definition of dose-response-relationships between the maximum A-weighted sound pressure level of an aircraft noise event and the probability to wake up due to this event. These relationships are shown in figure 2 for the field and laboratory studies respectively. They are valid for noise-induced awakenings which occur additionally to the spontaneous awakenings (i.e. reactions which are appearing in the absence of noise as well). The difference between the laboratory and field results is remarkable but well known from earlier investigations. However from the practical point of view only the field result is of importance. The corresponding relationship makes it possible to define the number of wake-up reactions as a noise descriptor which fulfils the basic requirements of measurability, computability and stability. For the first time is now possible to establish noise protection zones which are directly related to human responses rather than being based solely on acoustical criteria.

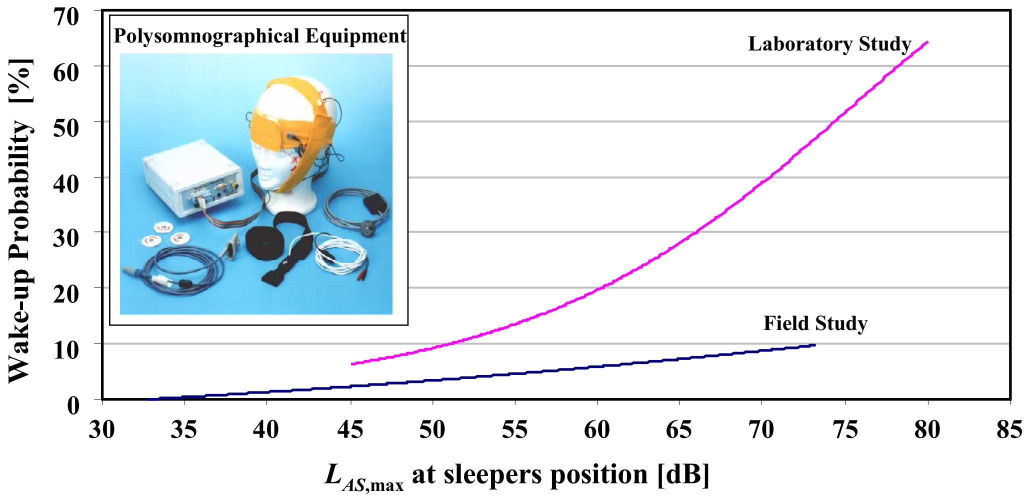


Figure 2: Polysomnographical equipment used for the studies and dose-effect-relationships for noise-induced wake-up reactions (results from field and laboratory studies).

Additional laboratory studies were performed during the successor project. They dealt with the effects of combined noise from AIRcraft, ROad and RAil traffic. Consequently the study was named AIRORA. The results indicated that the sleep quality is rated worst for rail traffic noise whereas the aircraft noise is assessed to be more annoying than noise from road and rail traffic. These results raise amongst others the question if the widely used noise bonus for rail traffic can be justified anymore.

Generally the differences in disturbance effects of the particular noise types are depending on the impact parameter (e.g. wake-up reactions or annoyance). The results of AIRORA indicate an urgent need for additional field studies as well as for more comprehensive fundamental research, especially with respect to cumulative effects of the different noise types (which could be identified to be not simply additive).

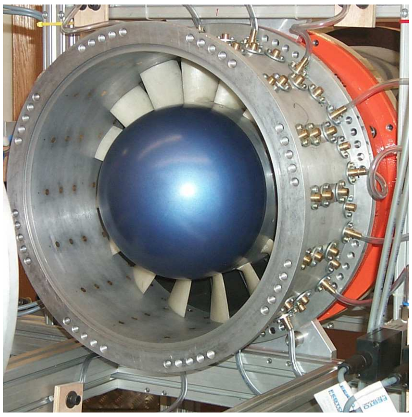
Finally it should be mentioned that the noise effect research done in both projects has provided an amount of data for the research community whose complete analysis and interpretation may be a longsome but fruitful process.

WP 2A: Engine noise reduction

The reduction of engine as well as of airframe noise is something that can only be achieved by a close co-operation between establishments dealing with fundamental research and the aircraft and engine industries. Hence all the activities related to source noise reduction were performed closely linked or as a part of large national or international research projects (e.g. European framework activities like SILENCER, AWIATOR or RAIN).

Fan noise has become more and more the major noise source of a modern aircraft engine because jet noise has been reduced significantly by introduction of high bypass engines. Since this dominance will increase with the introduction of engines of the 4th generation the focus of the engine noise reduction activities must have been the design of a quiet fan. This was main part of the work performed in WP 2A.

Since the fan is a rotating machinery its noise contains tonal components. These are usually perceived to be much more disturbing than broadband noise. However there exists a well-known technique for the elimination of tones – the active noise control ANC ("anti-sound"). The efficiency of the classical approach (loudspeaker-microphone-combinations) could be demonstrated using a newly developed controller technology. However a more practicable implementation of the ANC concept is the use of aerodynamic sound sources which can be realised by controlled injection of compressed air. Figure 3 shows the setup and the result of a corresponding model experiment. Since the fundamental technologies developed within LFVK were promising the research on this topic was continued in LFVK II.



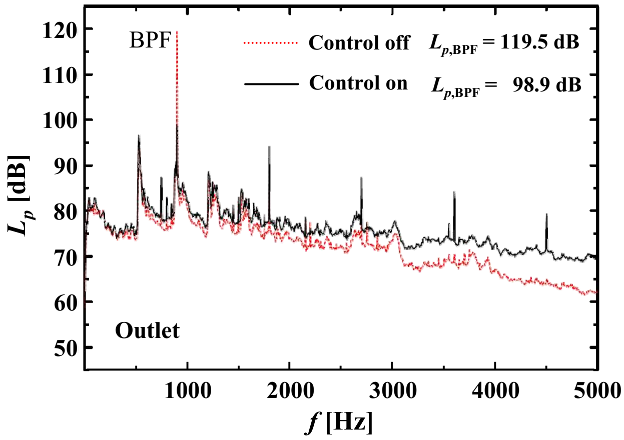


Figure 3: Experimental fan setup for active noise control by flow control at the fan blade tips (left) and resulting reduction of tonal levels for the blade passage frequency BPF (right).

Another focus of LFVK was the development respectively the improvement of numerical methods for a noise-optimised fan design. The improvement of the methods for sound field analyses was another goal of WP 2A.

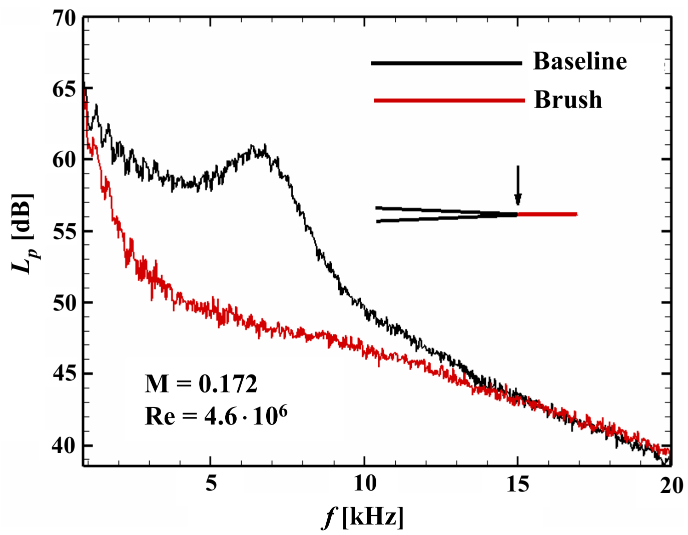
All these activities were continued in the successor project. The experimental validation of the results was performed together with SNECMA as a part of the SILENCER research project. The results indicated that a slowly rotating fan with ultra-high bypass ratio (UHBPR) will offer a high noise reduction potential.

Additional work was done with respect to the development of a quiet stator vane. Concepts like perforated leading edges as well as blowing out of microjets to reduce tonal components will be subject of further investigations in the EC framework project FLOCON. Further on WP 2A dealt with the reduction of broadband fan noise including the development and testing of an empirical model for this mechanism.

WP 2A: Reduction of airframe noise

The reduction of aerodynamic noise produced by the airflow around wings, high-lift devices and landing gears has become more and more important with the outcomes of the reduction of engine noise. Although airframe noise is up to now no problem for aircraft departures it cannot be neglected any longer during the landing of modern aeroplanes. Especially the development of noise optimised approach procedures with low engine power settings is strongly influenced by the generation of airframe noise.

Measures to reduce landing gear noise which are suitable for a retrofitting of landing gears of actual technology were designed and tested. An application of aerodynamically optimised fairings was shown to result in a noise reduction of 3 dB for gear noise. An empirical source model for this component was developed based on the results of wind tunnel experiments.



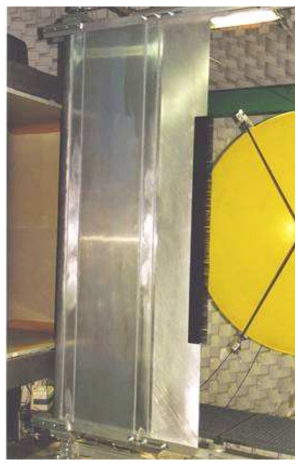


Figure 4: Aeroacoustic experiment for the reduction of trailing edge noise by brush edges performed in an acoustic wind tunnel.

The main sources of airframe noise could be identified - the dominant one is the slat. The mechanism of sound generation by it could not been clarified finally.

However all results of wind tunnel experiments indicate that the noise generation by the slat trailing edge is the most effective noise generating mechanism. A corresponding source model was developed and validated by flight experiments. Modifications for the reduction of slat noise (such as the application of brushes, see figure 4) provided a noise reduction potential of about 3 dB. Research on a quiet trailing edge was continued in LFVK II. The effect of combs or brushes could be quantified and scaling laws for the design of trailing edges could be developed.

Another important aerodynamic noise generator was identified to be the interaction between the extended landing flaps and the wake produced by the landing gear.

The improvement of the airframe noise model was one of the targets of the successor project LFVK II. Background was the need for tools suitable for a low noise airframe design already in the pre-design phase. Additional activities dealt with the definition and validation of a ray-tracing procedure applicable for the investigation of sound shadowing effects at future aircraft configurations (especially for over-wing-mounted engines).

WP 3: Noise abatement flight procedures and air traffic management

Noise abatement flight procedures (NAPs) are measures to reduce noise impact in the airport environment in the short or mid term. The fundamental approach is to optimize the following operational parameters:

- Flight altitude: Maximizing the distance to the ground allows damping effects to reduce the noise. Only for low altitudes and small elevation angles ground absorption effects may corrupt this effect.
- Engine power setting: It is obvious that noise decreases with engine power. But a power reduction may also be counterproductive in some situations occuring during departures since high power setting is related to good climb performance and hence a fast gaining of distance to the observer.
- Flight speed: It is mainly important for approaches since airframe noise depends strongly on aircraft speed. Lower speeds result in lower maximum levels. But concurrently noise duration and hence time integrated noise metrics (i.e. exposure levels) increase. However the effect of increased duration is in most cases overcompensated by the effect of decreased maximum level. The role of aircraft velocity is an indirect one for departures since the airframe gives only a marginal contribution. There is no significant influence on noise production but an increase in speed is usually related to a decrease in climb rate and vice versa. So speed effects become manifest in altitude effects.
- Configuration changes: Configuration changes (i.e. flap or gear deployment) are influencing the airframe noise directly due to the change of the flow geometry as well as indirectly due to the effects on power setting and aircraft speed. In principle airframe noise increases with increasing configuration

stage. The most distinct increases occur when the configuration is changed from clean to a particular flap setting.

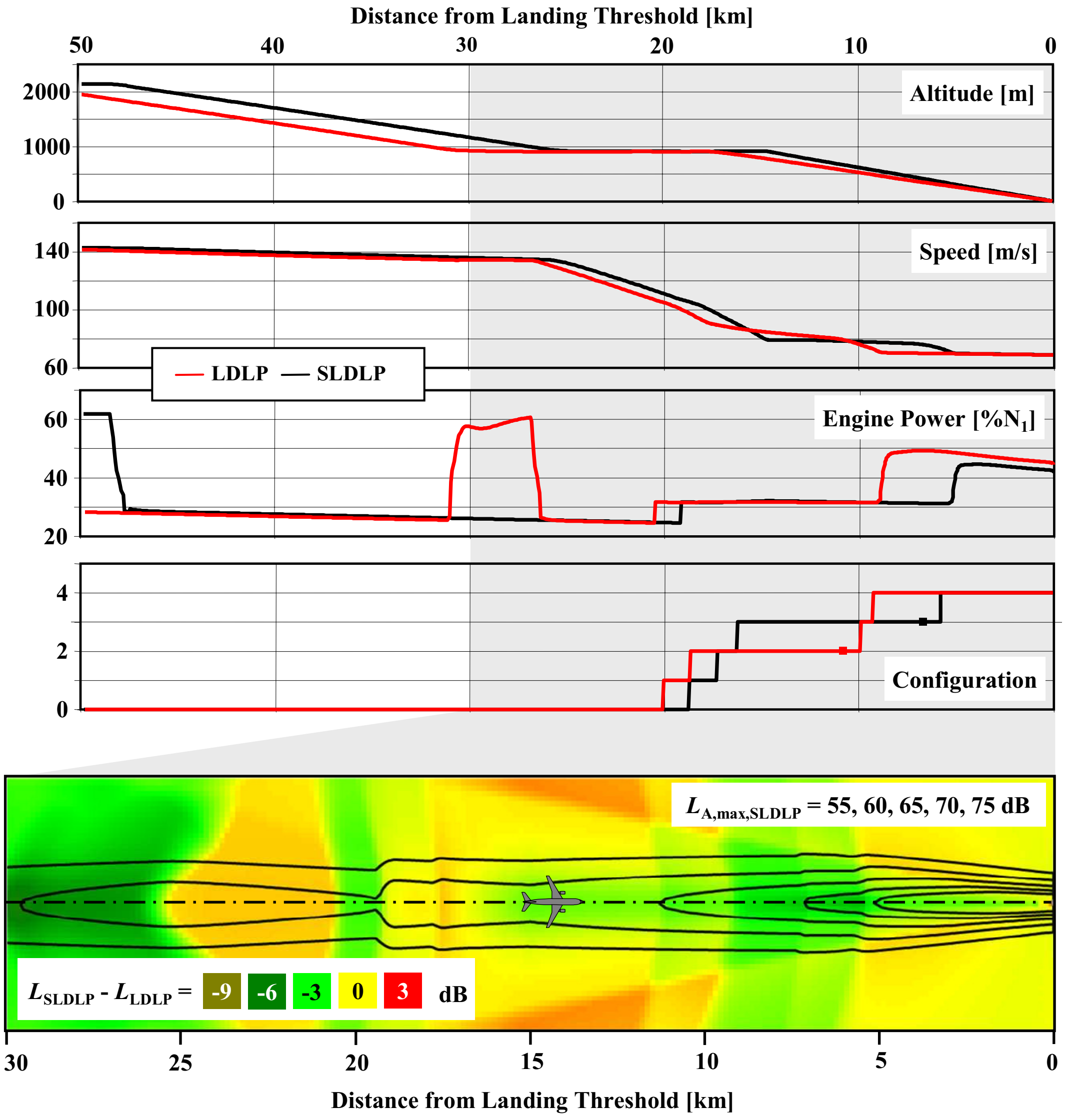


Figure 5: Comparison between standard (LDLP) and optimized (SLDLP) low-drag-low-power approach. The upper diagrams show performance parameters. The lower diagram shows contours of maximum A-weighted sound level for SLDLP and (colour-coded) the level differences to LDLP (calculation with DLR program SIMUL).

During the first project departure as well as approach procedures were investigated. It could be shown that the noise reduction potential of departure procedures is limited. This was expected: it needs a certain amount of energy to overcome the effect of gravitation and an amount of some hundredth of a percent of this energy is converted to sound. So optimisation of departure procedures is usually a problem how to distribute the noise to the ground ("far-out" or "close-in" departure procedures).

Approach procedures could be shown to offer a much higher potential on noise reduction. This is obvious since gravitation supports the process of descending and a great part of the flight path can be passed using idle power. So the development of noise optimised approach procedures is to a great extent related to the minimisation of airframe noise by optimising speed and configuration. This requires an adequate noise modelling tool.

Figure 5 shows as an example the comparison of the standard approach procedure used at German airports (low-drag-low-power procedure LDLP) with an optimised LDLP-procedure developed in WP 3. Compared are operational parameters as well as the maximum A-weighted sound level on the ground. The calculations were performed using the SIMUL program developed in WP 5A.

Finally NAPs are subject to a set of conditions which have to be fulfilled before the procedures can be implemented in practice. First one is safety; others are flyability and integrability into boardsided and groundsided management systems. These aspects, which are of special importance for the definition of noise abatement approach procedures, were treated in the successor project.

First step was the definition of requirements for the flight management (FMS) and flight control (FCS) systems. These could be met by development of an advanced flight management system (AFMS). The second step was a practicability test of this AFMS in a simulator environment as well as by flight experiments using DLR's flight test carrier ATTAS.

An essential problem of using noise abatement approach procedures in practice is their integration into the air traffic management (ATM) system. Such procedures can reduce the runway capacity so that their use is often restricted to the night. Within LFVK II a tool for trajectory-based arrival management (AMAN) was developed. Aim of this program is to supervise the arrival traffic and optimise it with respect to the noise impact on the ground. The program is a first approach to combine a trajectory and noise calculation in a fast-time simulation.

The activities of LFVK and especially those of WP 3 finally gave a spin-off for the comprehensive German project "Noise Optimized Approach and Departure Flight Procedures" (German abbreviation "LAnAb") [5] which was part of the German Research Network "Quiet Traffic". The validation of the source model for airframe noise as well as its application for the development of noise abatement approach procedures were major tasks of this project.

WP 4: Transport political concepts

Based on a comparative study on national and international regulatory noise mitigation measures these could be classified in the following groups:

- Direct – i.e. noise related – measures (noise-dependent landing fees, noise quotas, noise level limitations)

- Indirect – i.e. traffic related – measures (restrictions on operation time or number of aircraft movements, fleet mix modifications, airport co-operations, steering of modal split)
- Combined noise and traffic related measures (restrictions on operation time, noise/movement quotas)
- Procedures to force introduction of measures (mediation, incentives for carriers and other providers)
- Measures to increase the acceptance by impacted people (incentives for noise affected residents, noise information policy, efficient land use regulation)

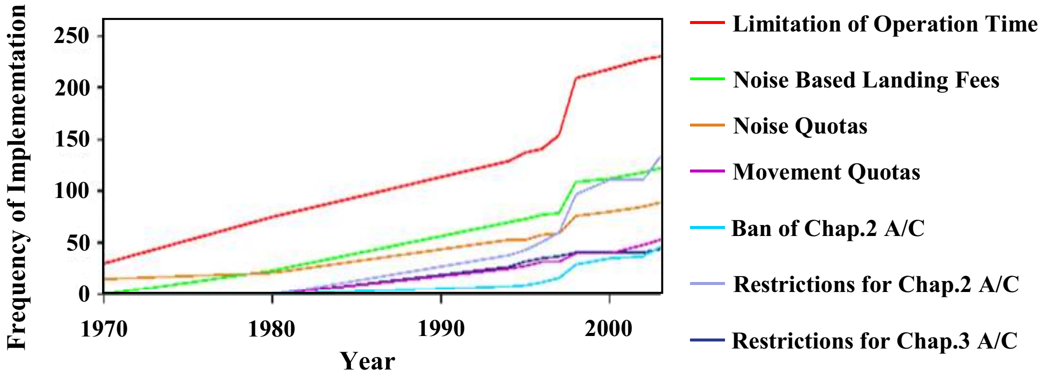


Figure 6: Development of the implementation of regulatory noise mitigation measures at 590 airports worldwide.

These different measures were evaluated based on a literature analysis as well as on a survey among the environmental divisions of the 18 German international airports (see figure 6). Criteria for the assessment of the suitability and the noise reduction potential of the particular measures were the effects on air traffic, economy, acceptance by the people affected and practicability. The resulting ranking was as follows:

1. Introduction of landing fees according to ICAO noise certification levels
2. Individual prosecution of violation of local noise regulations
3. Introduction of landing fees based on locally measured noise levels
4. Incentives for noise affected people
5. Manipulation of modal split
6. Incentives for providers
7. Mediation
8. Land use regulation

However the evaluative analysis indicated that the requirements for the particular design of these measures are partly not realisable. This is mainly a consequence of the requirement that a balanced approach between ecology (i.e. noise reduction) and economy has to be followed for any noise mitigation activity. Furthermore noticeable implementation deficits of individual measures could be identified.

Additional investigations dealt with theoretical approaches on the effects of regulatory noise mitigation measures, especially with the effects of air transport market structure on the development of noise charges and their implementation.

Overall it could be stated that the realisation of regulatory measures at German airports is higher than the world-wide average. This is obvious since German airports are generally located in densely populated areas. Nevertheless there is additional potential for optimisation. Especially the problem of land use regulation – which was out of the scope of the project activities – has to be tackled in future in a comprehensive and intensely manner.

WP 5A: Noise Modelling

As pointed out in the introduction noise modelling systems are an essential tool for most noise mitigation measures. Bu it must be accounted for the dependency between the structure of an aircraft noise model and its field of application:

- "Conventional" models – like the Integrated Noise Model INM [6] or ECAC Doc.29 [4] – are designed for the investigation of complex air traffic scenarios, usually for land use planning or noise legislation purposes. These models have to estimate the average noise immission over longer time periods. They are usually based on simplifying assumptions on sound generation and propagation mechanisms. Conventional models have to be robust and reliable and they must set up on comprehensive underlying databases. These models are only of limited use for purposes like the development of noise abatement procedures or other scientific problem.
- On the other hand there are the "scientific" noise models. They offer a great flexibility in source as well as propagation modelling. Consequently these models need high computation times as well as very detailed databases. The latter is the crucial problem: to derive a comprehensive source model from measurements is nearly impossible due to the amount of money and manpower needed. The alternative approach of a fully analytical source modelling is up to now an unrealistic one as well: although the fundamental mechanisms of sound generation by an aircraft are identified and partly well known there remains a lot of missing knowledge.

An intermediate approach was developed by the author in the late 80s [7]. It was based on the fact that different aircraft noise sources are influenced in a different way by the aircraft speed: In most cases it is only a kinematic effect (i.e. amplification in direction of movement and reduction rearwards) but for airframe noise and jet noise the sound production itself is a function of aircraft speed. So the SIMUL model developed was based on partial sound sources. The original version of this model used only jet and turbomachinery noise sources. Target of LFVK was to implement a source module for airframe noise. Based on the results of WP 2B additional source components for gear and high-lift devices were added to SIMUL. Additionally an enhanced propagation model was implemented which accounts for the effects of wind and temperature gradients. It was derived from the AKUMET model developed in WP 5B (see below).

Goal of LFVK was the improvement and testing of the SIMUL model. Application of SIMUL was performed during the successor project as well as within the LAnAb research project. A special focus of LFVK II was the use of SIMUL as a tool for the validation and improvement of conventional models.

By a comprehensive analysis of long-term weather influence on noise immission it could be proved that the simplifying assumptions of an isotropic atmosphere used by conventional models provide reasonable results for the long-term calculation of aircraft noise – in particular a little overprediction of immission levels.

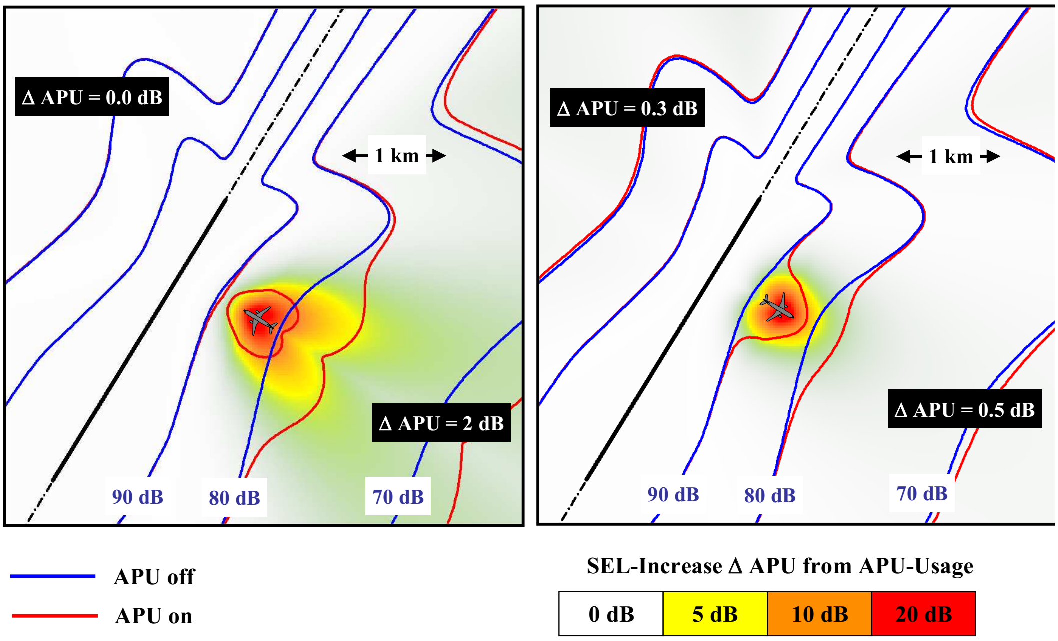


Figure 7: Modelling of APU-noise with SIMUL – effect of aircraft orientation on SEL-contours (calculation for a LTO-cycle of an A320 and 30 minutes APU-operation).

Additional work was done related to the revision of the German Air Traffic Noise Act. Based on measurements performed at Munich airport a model for the noise of auxiliary power units (APU) was developed (see figure 7). This model was integrated into the revised German aircraft noise calculation model. Furthermore some fundamental research on the practicability of noise indices was carried out.

WP 5B: Sound propagation models

Goal of work package 5B was the development of a system for the consistent modelling of meteorological and topographical influences on sound propagation. The approach was to couple an existing meteorological model to an acoustical model to be developed. The resulting model should be suitable for practical applications but nevertheless describe the physics of sound propagation as exactly as possible. This demand was met by development of a modelling system of graduated complexity.

The fundamental and comprehensive physical model developed within WP 5B is a linearised Euler model denoted AKU3D. It accounts for the effects of reflection, refraction, diffraction, scattering and absorption. AKU3D is very time consuming and hence not practicable for complex air traffic scenarios – it is used primarily for special investigations or for the improvement of simpler models.

A less complex model is AKUMET which is a Lagrange model based on the tracking of sound particles ("phonons") along sound rays. AKUMET needs less computation time than AKU3D but is not capable to model diffraction effects. This mechanism must be parameterised based on results from the Euler model.

The AKUMET model was used to derive the simplified AKUFIX model. AKUFIX was used to introduce an additional meteo-attenuation into the SIMUL propagation scheme. SIMUL used by then a conventional approach describing absorption only by geometrical spreading and atmospheric attenuation. The new meteo-attenuation is pre-calculated for octave bands and stored in lookup-tables. These tables are parameterised by meteorological stability class, source altitude, wind speed, wind direction and lateral distance to the observer. This approach has the advantages of fast execution time and the capability of being integrated into any noise model based on octave bands.

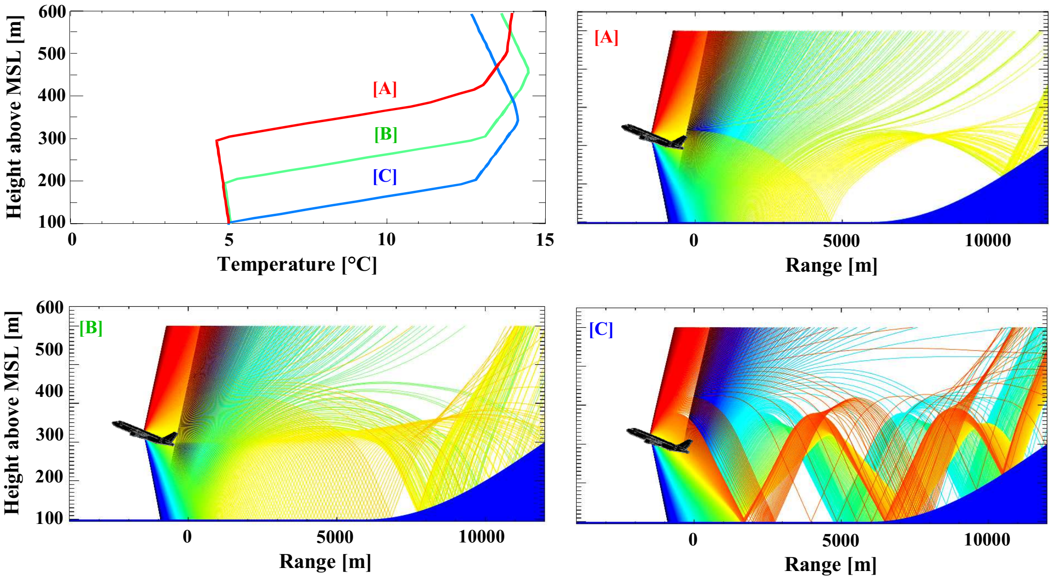


Figure 8: Propagation of sound from a departing aircraft along a hillside for three different types of temperature inversions. Colours are indicating the vertical emission angle.

Activities within LFVK II were – as within the modelling task – mainly related to validation and first practical applications. As an example figure 8 shows some results from an investigation on the audibility of aircraft over longer propagation distances for weather conditions with temperature inversions. The calculations were performed using AKUMET.

Résumé

The "Quiet Air Traffic" was – at least for German circumstances – the first approach to deal with the aircraft noise problem in a comprehensive and cross-disciplinary way. Accordingly one should question if this approach was a successful one and especially if use was made of the synergy potential pointed out in figure 1. Generally speaking this question can be affirmed (otherwise the successor project would not have been authorised at all). The direct connections between the particular work packages have been used to a great extent.

But beside these problem-related direct interfaces the interdisciplinary structure provides a more general advantage: Scientists of completely different research areas can (and should) be forced to meet regularly to describe their status of work as well as their actual problems. During the yearly meetings the LFVK team has made the experience that non-specialised colleagues sometimes interpret problems from another point of view – and hence provide solutions which are unobvious for the expert but nevertheless helpful.

So a project plan for a multidisciplinary project should allow for such technical meetings. In many cases regular meetings are only planned for the work package co-ordinators. This is mandatory for any project – at least twice per year for interdisciplinary ones. But beside that once a year an opportunity for an extensive scientific discussion should be provided – and that for the people doing the scientific work, not only for the co-ordinators.

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The following list of references is only a short one. More comprehensive citation lists can be taken from the final reports for the projects LFVK, LFVK II and LAnAb.

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