Modelling of Helicopter Noise in Arbitrary Maneuver Flight using Aeroacoustic Database

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Introduction

- Helicopter noise reduction
  - New helicopter design
  - Noise abatement procedures
- Activities for noise abatement procedure development, of the Helicopter Group of Technical Acoustics Division at DLR:
  - RONAP flight tests on BO105, 2001 (AHS paper 2003),
  - PAVE flight tests on BO105 and EC135 FHS, 2004 (AHS 2005),
  - Hemisphere2 for quasi-steady flight
  - PAVE-FRIENDCOPTER 2008 validation campaign on EC 135 FHS
- Objective of presented work: development of a method
  - able to design arbitrary flights (maneuvers included),
  - evaluate their flyability,
  - compute induced ground noise footprint.

Method used for noise abatement procedure design and OPTIMIZATION

Outline

- Method specifications
- Construction of an acoustic flight test data base
- Generation of flight procedures and simulation of their noise footprint
- Validation of a maneuvering flight simulation
- Conclusion and outlook

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Specifications of the method

- Should cover all noise sources of an helicopter: main rotor, tail rotor, engine, interaction and installation effects.
- Should be able to compute maneuver noise: acceleration can have a large impact on noise emission (about 15 dBA) and occur necessary in real flight.
- Should satisfy flyability constraints.
- Wind effects should be taken into account on flight conditions (for example aerodynamic slope change for a given geographic slope)

- Consequences:
  - Available purely numerical method excluded as they are not yet reliable for all noise sources and/or in the whole flight envelope.
  - Purely experimental method excluded as there would require to test too many different flights (cost ineffective).
  - A hybrid method is chosen.

The EC135-FHS

All the noise results shown are amplified by an unspecified factor, in order to consider the manufacturer interest in confidentiality.

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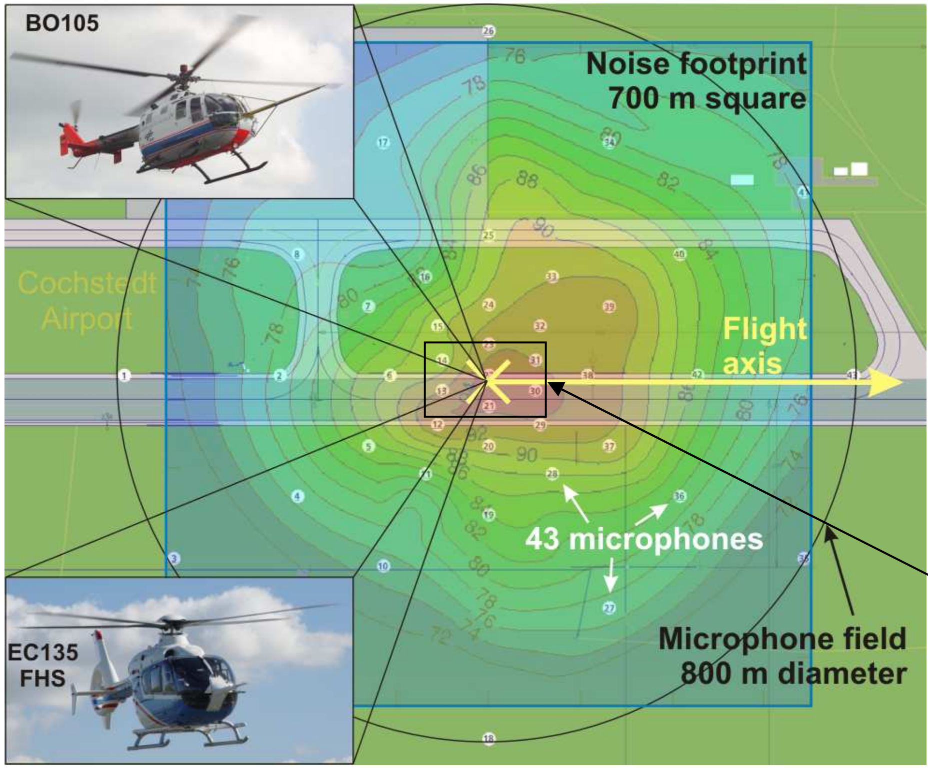
Generation of the acoustic data base: PAVE flight tests of 2004 (see AHS paper 2005)



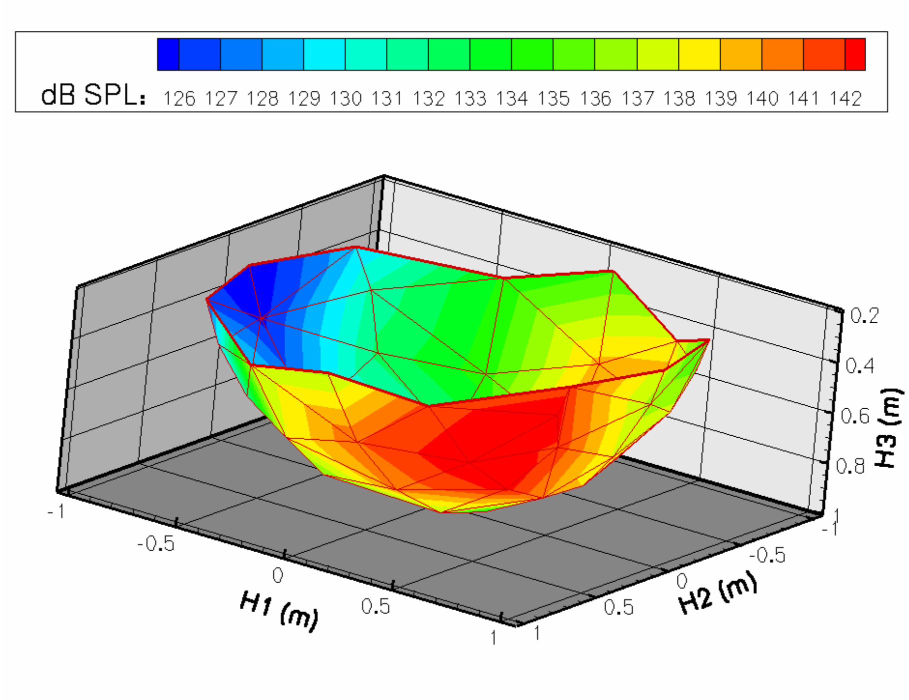
Microphone layout allowing noise directivity measurement for a given emission time

243 flyovers measured:

Measured flight conditions cover the steady flight envelope (with aerodynamic slopes up to 20 deg in descent). Many maneuver flights have been measured too (turns, accelerations, decelerations, transition to or from descent…)

For each flyover several emission times can be considered when the helicopter is close to the middle of the microphone array, especially for maneuvers : more than 3500 flight conditions are considered.

Backpropagation on directivity spheres



Sphere generated from the 43 microphones
for a given emission time during descent flight

<u>To be removed:</u>

- **Ground effect (can reach 10 dBA in grazing incidence) correction**
- **Spherical spreading**
- **Atmospheric absorption**
- **Doppler effect**

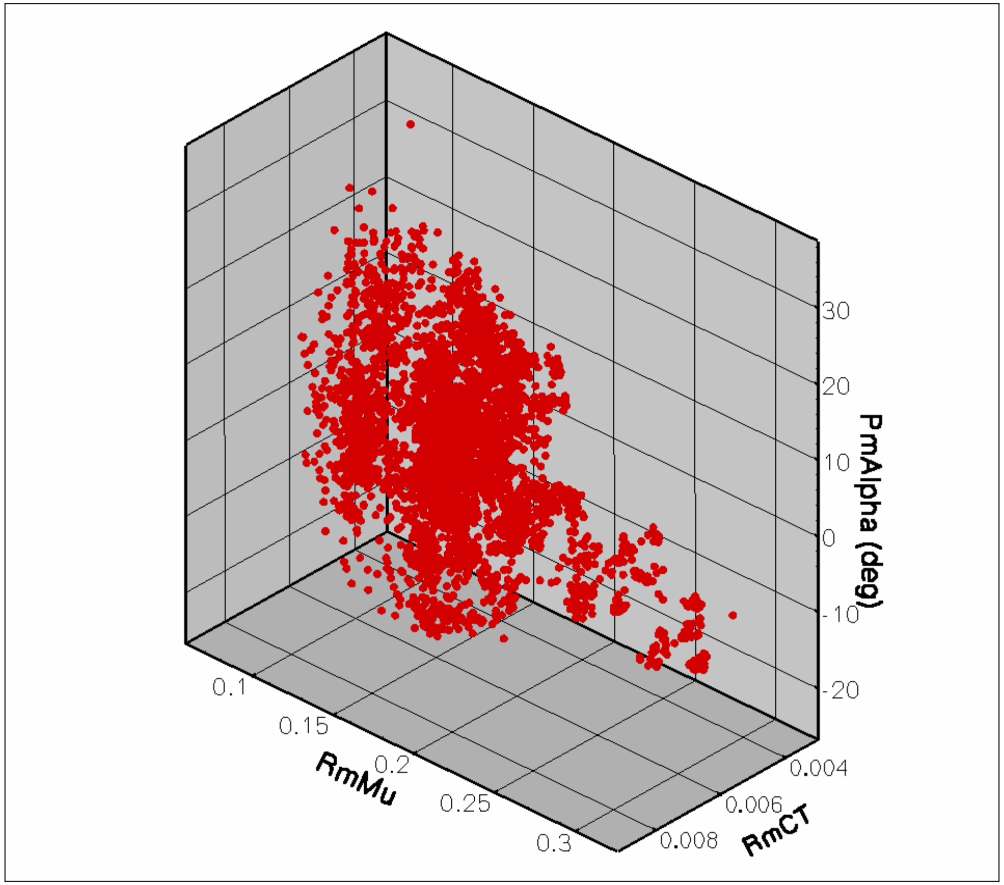
Selection of noise emission parameters

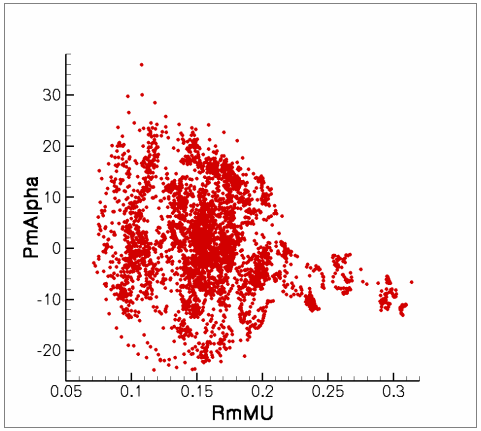
HOST (flight dynamics tool from Eurocopter) inverse simulation of the flights allows to *calculate flight dynamics of the measured trajectories. Each sphere is then associated to flight dynamics of the corresponding emission time, and stored in the database according to:*

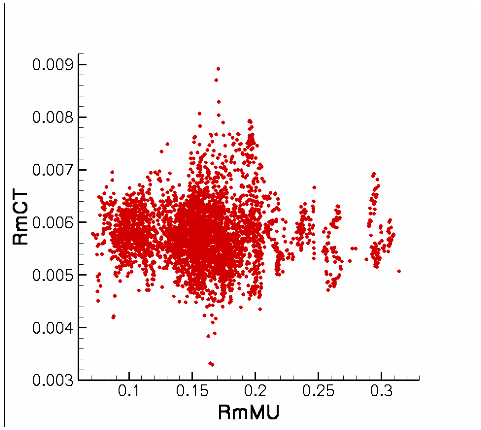
- *PmAlpha* : tip path plane incidence angle of the main rotor
- *RmCT* : thrust coefficient of the main rotor
- *RmMu* : advance ratio of the main rotor

- It is assumed that the noise emission is only determined by the value of the triplet (*PmAlpha, RmCT, RmMu*).

Correlation of the spheres with noise emission parameters







36 deg

PmAlpha

-24 deg

0.009

RmCT

0.0034

0.07 RmMu 0.31

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

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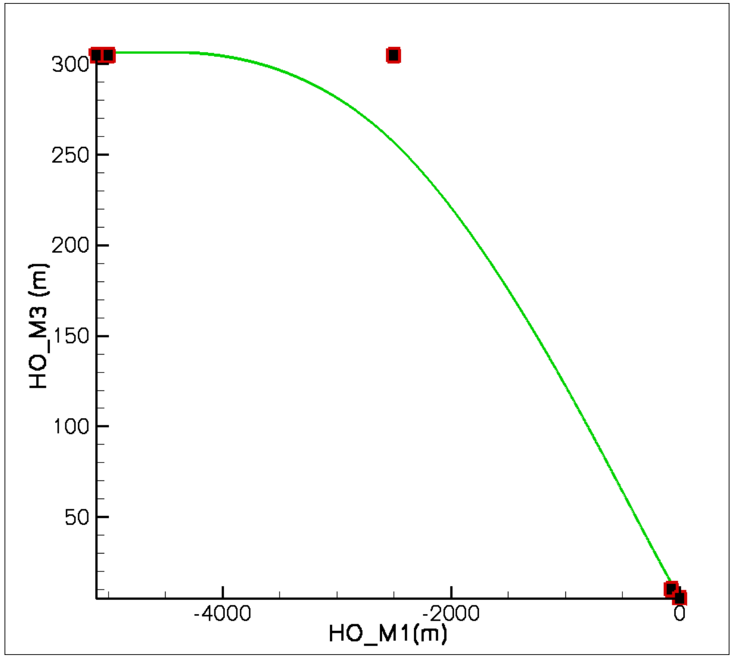
Generation of simulated procedures

- The flight procedures are defined by a set of control points for which the coordinates and the velocity relative to the ground are given and must respect given initial and final conditions.
- An inverse HOST simulation (flight dynamics) is performed. It allows to determine (*PmAlpha, RmCT, RmMu*) all along the flight procedure.
- Flyability checks are performed (autorotation, HV diagramm, VRS...)



Cubic Bézier splines:

Curve does not cross the control point: not a problem for optimization. Steady flight only achieved approximately using proper choice of control points.

Noise emission

- Emission times are set every 1 s along the synthesized flight procedure.
- For each emission time a directivity sphere is constructed starting from the four closest spheres from the database in terms of distance in *PmAlpha, RmCT, RmMu*. A Delaunay 3D triangulation/interpolation is then applied which permits to find the closest spheres and their weighting factor.
- The found spheres are then interpolated in direction so that their new nodes correspond to the emission direction to the simulated ground microphones. This is performed with a Delaunay 2D triangulation.
- The noise is then propagated to ground from the interpolated sphere from the 4 selected spheres. Symmetric corrections compared to the back-propagation already presented are used.

Schematic representation of the computation chain

Blade pressures

WT tests

Flight tests

Computation

DATA BASE of noise directivities on hemisphere ordered vs (PmAlpha, RmCT, RmMu)

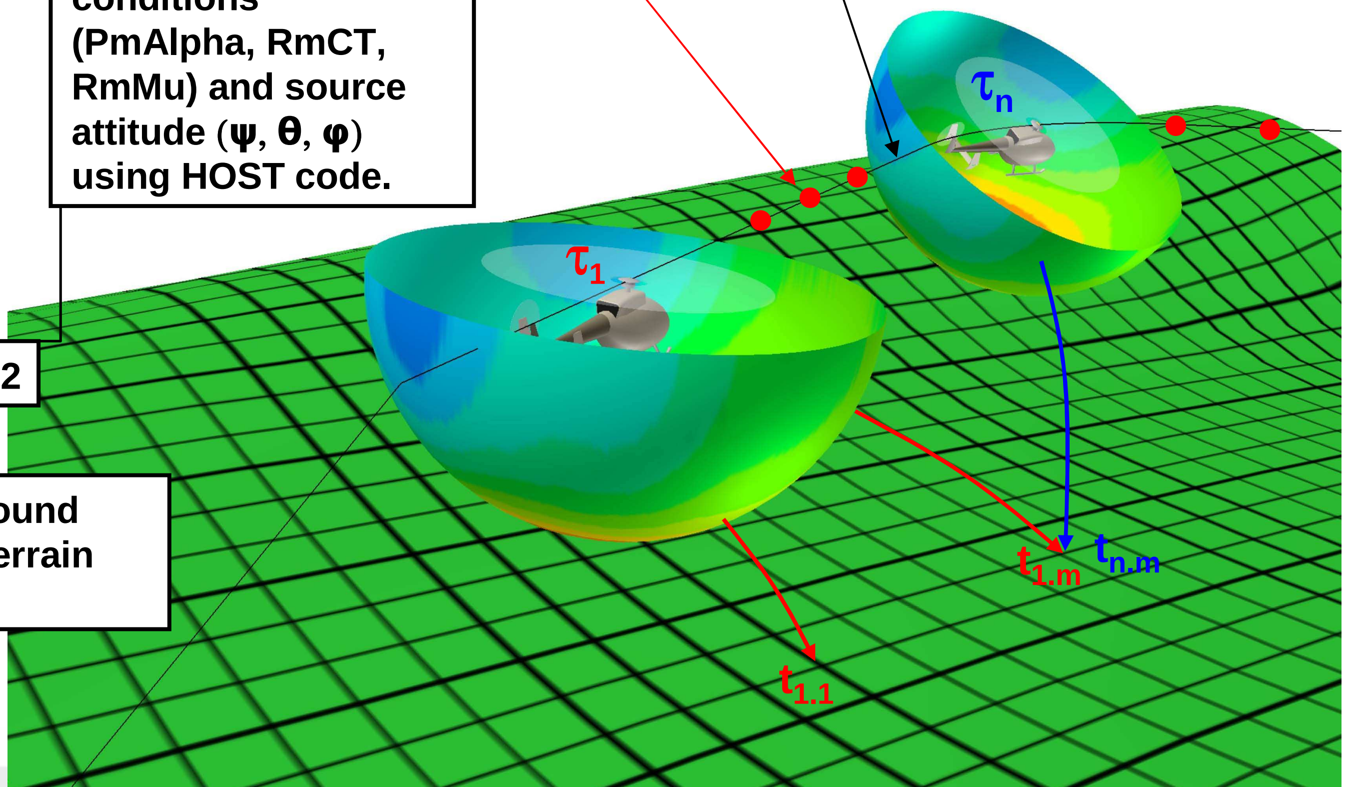
Loop of following steps on selected noise emission times τ_i

1. Generation of flight path and velocity evolution

2. Flight dynamics calculation of flight conditions (PmAlpha, RmCT, RmMu) and source attitude (ψ, θ, φ) using HOST code.

3. HEMISPHERE 2

Noise propagated on ground including atmospheric/terrain effects



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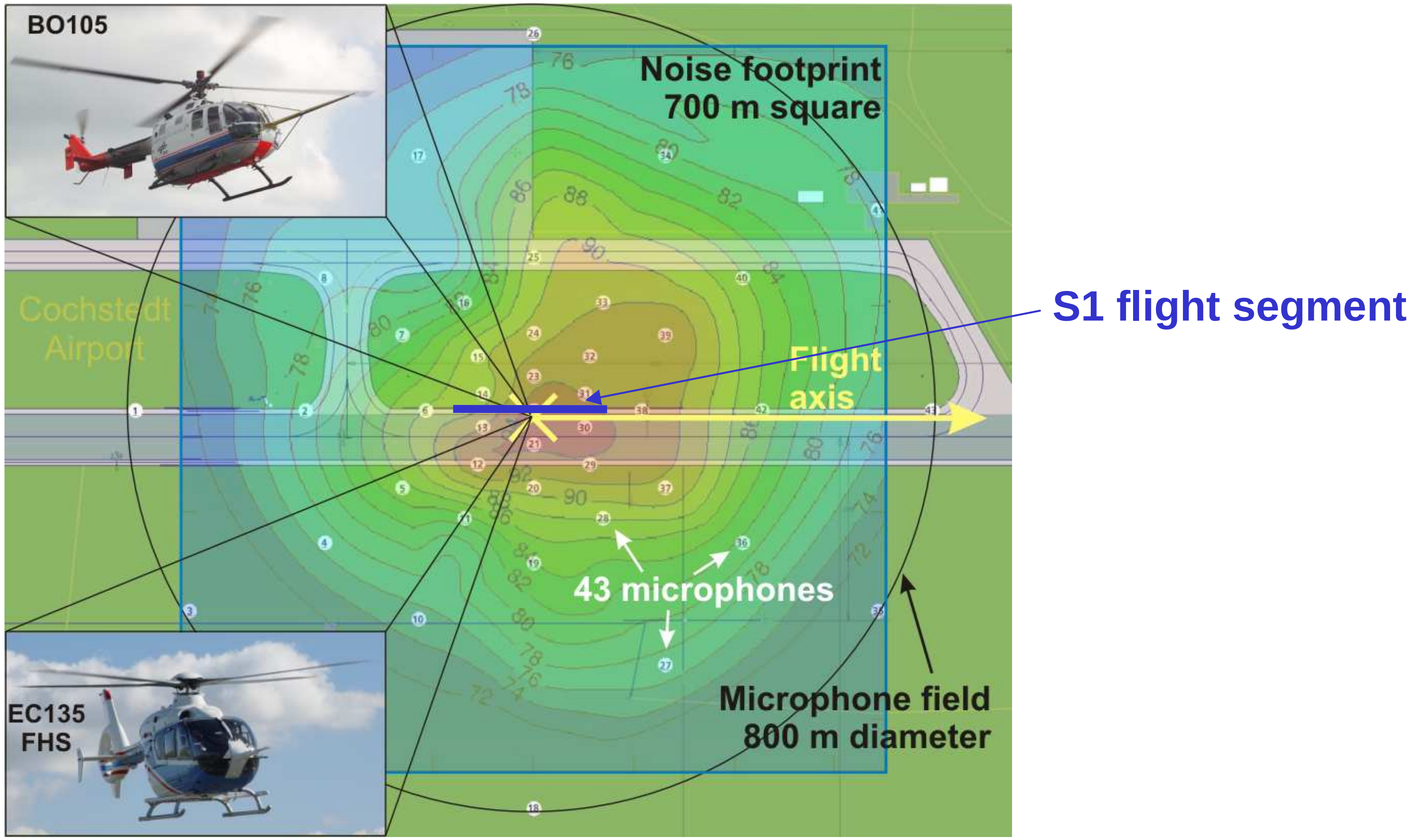
Complete chain validation on a tested flight segment



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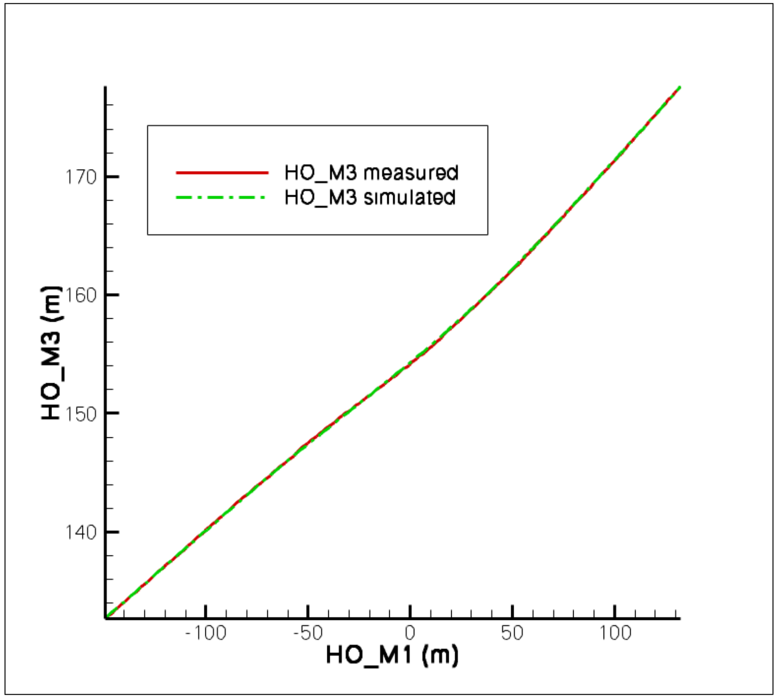
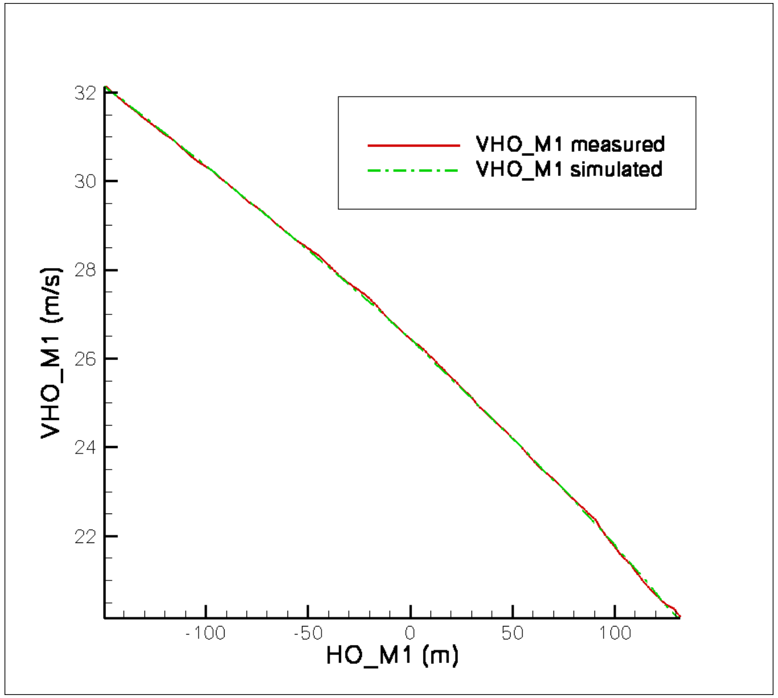




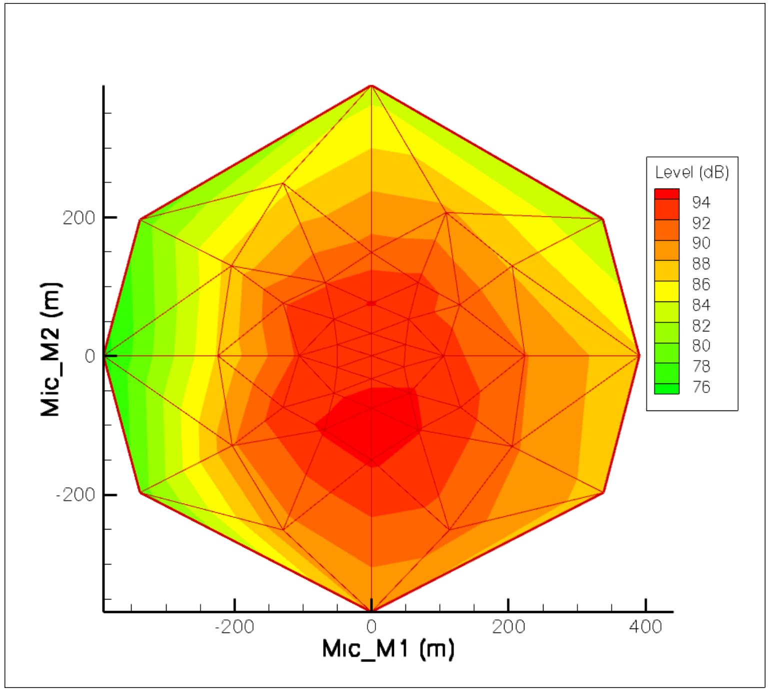
Position

Velocity

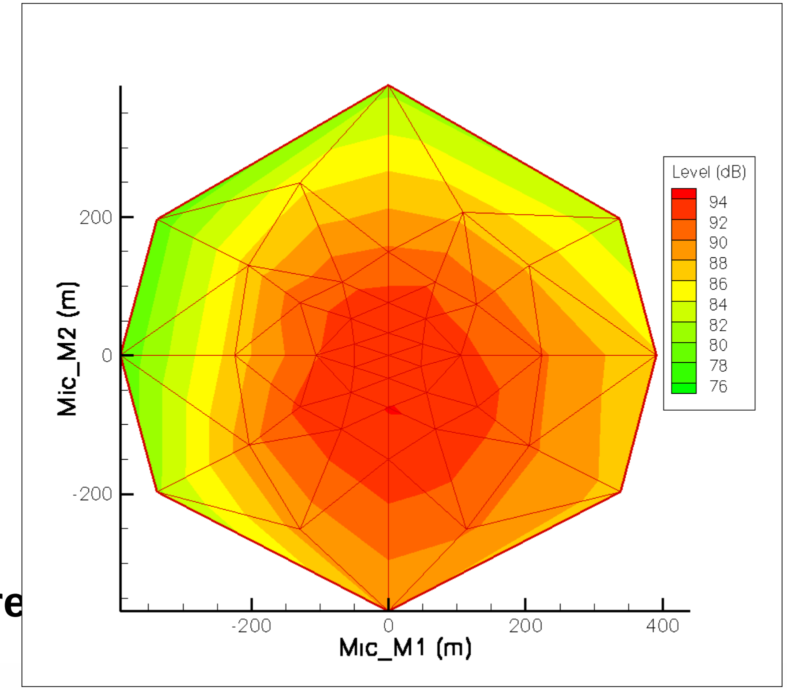
Comparison of the measured S1 and S1 simulated with the Bézier curve interpolation and 16 control points picked on measured S1

Deceleration: 1.04 m/s2 = 0.11g

Complete chain validation on a tested flight segment. Noise footprints (SEL).



Measurement



Simulated flight segment, with fully automatic sphere selection in the data base and interpolations.

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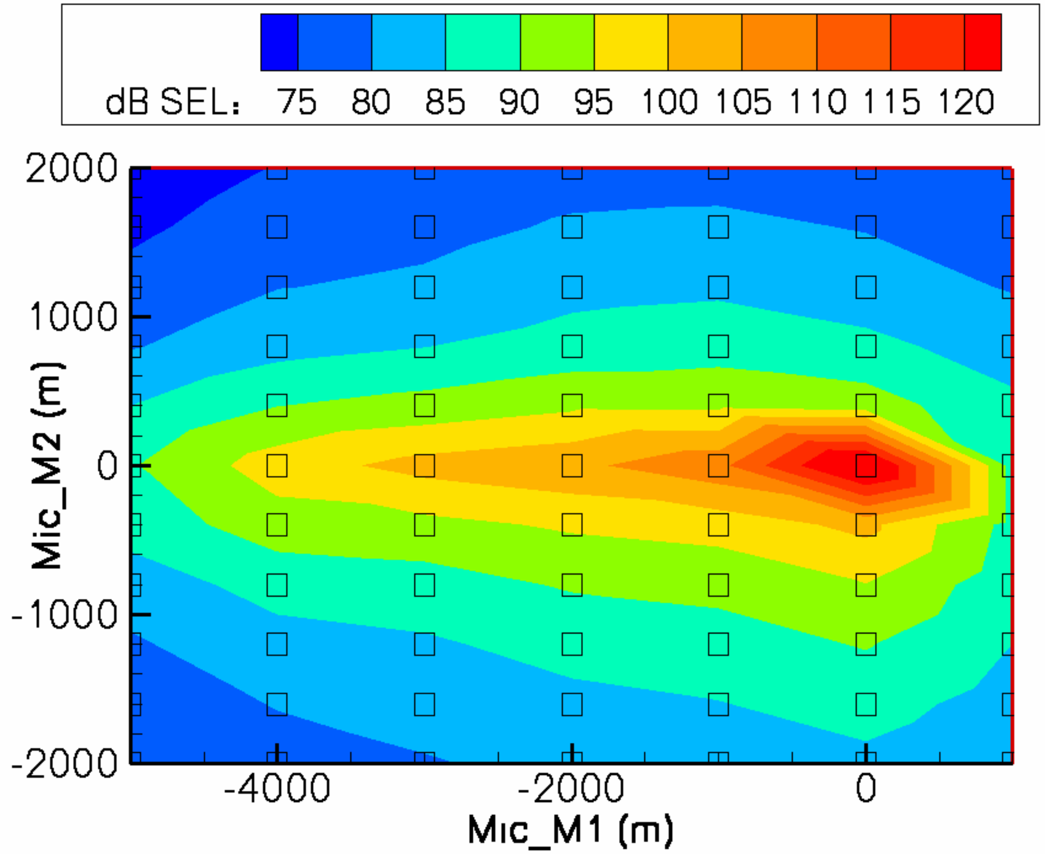
Conclusion

- A method able to predict automatically complete helicopter noise in an arbitrary flight (including in quasi steady maneuver) and using a flight test data base has been developed.
- The flight test data base has been constructed from EC135 PAVE 2004 tests and covers well the steady and maneuver flight envelope.
- The method simulates continuous flights starting from control points meant to become optimization parameters. The flight dynamics are computed all along the procedures.
- The method comprises flyability and comfort checks.
- Wind profile is taken into account in the computation of noise relevant flight parameters.
- The method has been validated using the EC135 PAVE 2004 flight test data base, in particular for decelerated flight.
- The method is ready to be used for designing complete, flyable and comfortable flight procedures minimizing the ground noise footprint.

Noise simulation of a complete landing procedure.

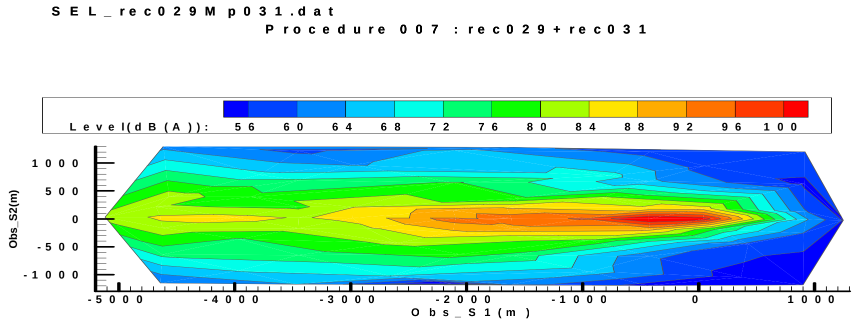


Computation time of a complete flight procedure time for the whole computation chain and for 77 microphones: 10 min on a home PC.

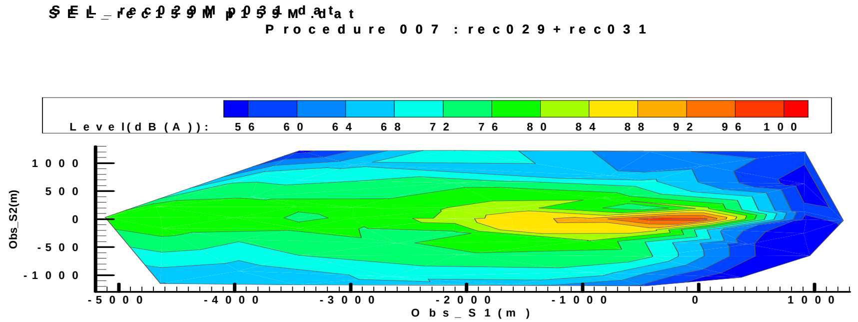
The computation chain works fully automatically starting from the control point setting and can be used in an optimization loop.

Outlook

- Footprint minimization work for various wind conditions and masses for the EC135 performed in 2008.
- Optimized procedures validated in flight.



The reference procedure contains briefly the 6 deg 65 kts condition and is easy to fly. Optimization performed for a 5 km long procedure with light wind.



The optimized procedure shows a gain of about 10 dB 2 km for the landing point, as predicted by simulation.

Thank you for your attention