

PROJECT FINAL REPORT

Grant Agreement number: 255750

Project acronym: FLIGHT-NOISE

Project title: Advanced Turbofan-Equipped Aircraft Noise Model

Funding Scheme: Clean Sky SGO-02-003

Period covered: from 1 January 2010 to 31 August 2012

Name of the scientific representative of the project's co-ordinator¹, Title and Organisation:

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Project website address: N/A

¹ Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

4.1 Final publishable summary report

This section must be of suitable quality to enable direct publication by the Commission and should preferably not exceed 40 pages. This report should address a wide audience, including the general public.

The publishable summary has to include **5 distinct parts** described below:

- An executive summary (not exceeding 1 page).
- A summary description of project context and objectives (not exceeding 4 pages).
- A description of the main S&T results/foregrounds (not exceeding 25 pages),
- The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages).
- The address of the project public website, if applicable as well as relevant contact details.

Furthermore, project logo, diagrams or photographs illustrating and promoting the work of the project (including videos, etc...), as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

4.2 Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

▪ Section A

This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

▪ Section B

This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

Section A (public)

This section includes two templates

- Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers ² (if available)	Is/Will open access ³ provided to this publication?
1	<i>Validation Strategies for Comprehensive Aircraft Noise Prediction Methods</i>	<i>Filippone A.</i>	<i>AIAA/ATIO Conference</i>		<i>AIAA</i>	<i>Indianapolis, IN</i>	<i>2012</i>			no
2										
3										

² A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

³ Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Size of audience	Countries addressed
1	Conference	UNIMAN, Filippone	AIAA/ATIO Conference	17 Sept 2012	Indianapolis	Scientific Community	N/A	International
2	Workshop	UNIMAN		10 Jan 2012	Braunschweig	Scientific Community	40	International
3								

⁴ A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

⁵ A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible).

Section B (Confidential⁶ or public: confidential information to be marked clearly)
Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1 : LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights ⁷ :	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
N/A	N/A	N/A	N/A	N/A	

⁶ Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

⁷ A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground ⁸	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application ⁹	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
		NO		Software	Aircraft Operations, Aircraft Noise, Flight Mechanics		N/A	N/A

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

¹⁹ A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

⁹ A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

4.3 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when Grant Agreement number is entered.*

Grant Agreement Number:

255750

Title of Project:

Advanced Turbofan-Equipped Aircraft Noise Model

Name and Title of Coordinator:

Dr. A. Filippone

B Ethics

1. Did your project undergo an Ethics Review (and/or Screening)?

- If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports?

No

Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 'Work Progress and Achievements'

2. Please indicate whether your project involved any of the following issues (tick box) :

YES

RESEARCH ON HUMANS

• Did the project involve children?	no
• Did the project involve patients?	No
• Did the project involve persons not able to give consent?	No
• Did the project involve adult healthy volunteers?	No
• Did the project involve Human genetic material?	No
• Did the project involve Human biological samples?	No
• Did the project involve Human data collection?	No

RESEARCH ON HUMAN EMBRYO/FOETUS

• Did the project involve Human Embryos?	No
• Did the project involve Human Foetal Tissue / Cells?	No
• Did the project involve Human Embryonic Stem Cells (hESCs)?	No
• Did the project on human Embryonic Stem Cells involve cells in culture?	No
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No

PRIVACY

• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No
• Did the project involve tracking the location or observation of people?	No

RESEARCH ON ANIMALS

• Did the project involve research on animals?	No
• Were those animals transgenic small laboratory animals?	No
• Were those animals transgenic farm animals?	No

• Were those animals cloned farm animals?	No
• Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	No
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator		1
Work package leaders		1
Experienced researchers (i.e. PhD holders)		3
PhD Students		1
Other		

4. How many additional researchers (in companies and universities) were recruited specifically for this project?

Of which, indicate the number of men:	0
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D Gender Aspects

5.	Did you carry out specific Gender Equality Actions under the project?		No
6.	Which of the following actions did you carry out and how effective were they?		
		Not at all effective	Very effective
<input type="checkbox"/>	Design and implement an equal opportunity policy	<input type="radio"/>	<input type="radio"/>
<input type="checkbox"/>	Set targets to achieve a gender balance in the workforce	<input type="radio"/>	<input type="radio"/>
<input type="checkbox"/>	Organise conferences and workshops on gender	<input type="radio"/>	<input type="radio"/>
<input type="checkbox"/>	Actions to improve work-life balance	<input type="radio"/>	<input type="radio"/>
<input type="radio"/>	Other:		
7.	Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?		
<input type="radio"/>	Yes- please specify		
<input checked="" type="radio"/>	No		

E Synergies with Science Education

8.	Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?		
<input type="radio"/>	Yes- please specify		
<input checked="" type="radio"/>	No		
9.	Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?		
<input type="radio"/>	Yes- please specify		
<input checked="" type="radio"/>	No		

F Interdisciplinarity

10.	Which disciplines (see list below) are involved in your project?		
<input type="radio"/>	Main discipline ¹⁰ :	<input type="radio"/>	Associated discipline ¹⁰ :
<input type="radio"/>	Associated discipline ¹⁰ :	<input type="radio"/>	Associated discipline ¹⁰ :

G Engaging with Civil society and policy makers

11a	Did your project engage with societal actors beyond the research community? (if 'No', go to Question 14)	<input type="radio"/>	Yes
		<input checked="" type="radio"/>	No
11b	If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?		
<input type="radio"/>	No		
<input type="radio"/>	Yes- in determining what research should be performed		
<input type="radio"/>	Yes - in implementing the research		
<input type="radio"/>	Yes, in communicating /disseminating / using the results of the project		

¹⁰ Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?		<input type="radio"/> <input checked="" type="radio"/>	Yes No
12. Did you engage with government / public bodies or policy makers (including international organisations)			
<input checked="" type="radio"/> No <input type="radio"/> Yes- in framing the research agenda <input type="radio"/> Yes - in implementing the research agenda <input type="radio"/> Yes, in communicating /disseminating / using the results of the project			
13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers? <input checked="" type="radio"/> Yes – as a primary objective (please indicate areas below- multiple answers possible) <input type="radio"/> Yes – as a secondary objective (please indicate areas below - multiple answer possible) <input type="radio"/> No			
13b If Yes, in which fields?			
Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid	Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport

13c If Yes, at which level? <input type="radio"/> Local / regional levels <input checked="" type="radio"/> National level <input checked="" type="radio"/> European level <input checked="" type="radio"/> International level										
H Use and dissemination										
14. How many Articles were published/accepted for publication in peer-reviewed journals?	1									
To how many of these is open access¹¹ provided?	0									
How many of these are published in open access journals?	0									
How many of these are published in open repositories?	0									
To how many of these is open access not provided?										
Please check all applicable reasons for not providing open access:										
<input checked="" type="checkbox"/> publisher's licensing agreement would not permit publishing in a repository <input type="checkbox"/> no suitable repository available <input type="checkbox"/> no suitable open access journal available <input type="checkbox"/> no funds available to publish in an open access journal <input type="checkbox"/> lack of time and resources <input type="checkbox"/> lack of information on open access <input type="checkbox"/> other ¹² :										
15. How many new patent applications ('priority filings') have been made? <i>("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).</i>	0									
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	0								
	Registered design	0								
	Other	0								
17. How many spin-off companies were created / are planned as a direct result of the project?	0									
<i>Indicate the approximate number of additional jobs in these companies:</i>		0								
18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project: <table border="0"> <tr> <td><input type="checkbox"/> Increase in employment, or</td> <td><input type="checkbox"/> In small & medium-sized enterprises</td> </tr> <tr> <td><input type="checkbox"/> Safeguard employment, or</td> <td><input type="checkbox"/> In large companies</td> </tr> <tr> <td><input type="checkbox"/> Decrease in employment,</td> <td><input type="checkbox"/> None of the above / not relevant to the project</td> </tr> <tr> <td><input checked="" type="checkbox"/> Difficult to estimate / not possible to quantify</td> <td></td> </tr> </table>			<input type="checkbox"/> Increase in employment, or	<input type="checkbox"/> In small & medium-sized enterprises	<input type="checkbox"/> Safeguard employment, or	<input type="checkbox"/> In large companies	<input type="checkbox"/> Decrease in employment,	<input type="checkbox"/> None of the above / not relevant to the project	<input checked="" type="checkbox"/> Difficult to estimate / not possible to quantify	
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<input type="checkbox"/> Safeguard employment, or	<input type="checkbox"/> In large companies									
<input type="checkbox"/> Decrease in employment,	<input type="checkbox"/> None of the above / not relevant to the project									
<input checked="" type="checkbox"/> Difficult to estimate / not possible to quantify										
19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs:	<i>Indicate figure:</i> 3									

¹¹ Open Access is defined as free of charge access for anyone via Internet.

¹² For instance: classification for security project.

Difficult to estimate / not possible to quantify	<input type="checkbox"/>												
I Media and Communication to the general public													
20. As part of the project, were any of the beneficiaries professionals in communication or media relations? <input type="radio"/> Yes <input checked="" type="radio"/> No													
21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public? <input type="radio"/> Yes <input checked="" type="radio"/> No													
22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project? <table border="1"> <tr> <td><input type="checkbox"/> Press Release</td> <td><input type="checkbox"/> Coverage in specialist press</td> </tr> <tr> <td><input type="checkbox"/> Media briefing</td> <td><input type="checkbox"/> Coverage in general (non-specialist) press</td> </tr> <tr> <td><input type="checkbox"/> TV coverage / report</td> <td><input type="checkbox"/> Coverage in national press</td> </tr> <tr> <td><input type="checkbox"/> Radio coverage / report</td> <td><input type="checkbox"/> Coverage in international press</td> </tr> <tr> <td><input type="checkbox"/> Brochures /posters / flyers</td> <td><input checked="" type="checkbox"/> Website for the general public / internet</td> </tr> <tr> <td><input type="checkbox"/> DVD /Film /Multimedia</td> <td><input type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)</td> </tr> </table>		<input type="checkbox"/> Press Release	<input type="checkbox"/> Coverage in specialist press	<input type="checkbox"/> Media briefing	<input type="checkbox"/> Coverage in general (non-specialist) press	<input type="checkbox"/> TV coverage / report	<input type="checkbox"/> Coverage in national press	<input type="checkbox"/> Radio coverage / report	<input type="checkbox"/> Coverage in international press	<input type="checkbox"/> Brochures /posters / flyers	<input checked="" type="checkbox"/> Website for the general public / internet	<input type="checkbox"/> DVD /Film /Multimedia	<input type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)
<input type="checkbox"/> Press Release	<input type="checkbox"/> Coverage in specialist press												
<input type="checkbox"/> Media briefing	<input type="checkbox"/> Coverage in general (non-specialist) press												
<input type="checkbox"/> TV coverage / report	<input type="checkbox"/> Coverage in national press												
<input type="checkbox"/> Radio coverage / report	<input type="checkbox"/> Coverage in international press												
<input type="checkbox"/> Brochures /posters / flyers	<input checked="" type="checkbox"/> Website for the general public / internet												
<input type="checkbox"/> DVD /Film /Multimedia	<input type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)												
23 In which languages are the information products for the general public produced? <table border="1"> <tr> <td><input type="checkbox"/> Language of the coordinator</td> <td><input checked="" type="checkbox"/> English</td> </tr> <tr> <td><input type="checkbox"/> Other language(s)</td> <td></td> </tr> </table>		<input type="checkbox"/> Language of the coordinator	<input checked="" type="checkbox"/> English	<input type="checkbox"/> Other language(s)									
<input type="checkbox"/> Language of the coordinator	<input checked="" type="checkbox"/> English												
<input type="checkbox"/> Other language(s)													

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

- 1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
- 1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
- 1.3 Chemical sciences (chemistry, other allied subjects)
- 1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
- 1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2. ENGINEERING AND TECHNOLOGY

- 2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
- 2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
- 2.3. **Other engineering sciences** (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as

geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

- 3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
- 3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
- 3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

- 4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
- 4.2 Veterinary medicine

5. SOCIAL SCIENCES

- 5.1 Psychology
- 5.2 Economics
- 5.3 Educational sciences (education and training and other allied subjects)
- 5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary, methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

- 6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
- 6.2 Languages and literature (ancient and modern)
- 6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

EXECUTIVE SUMMARY

The Flight-Noise project dealt with aircraft noise from a modern turbofan-powered commercial aircraft. The strategic goal of the project was to develop and validate a comprehensive model to predict the noise at ground receivers. The project consisted in a first phase, in which we gathered the specifications; then we developed the comprehensive model at several levels, including aircraft configurations, engine/propulsion model, flight mechanics, and aircraft noise. In the second phase, the models were validated at all levels, starting from the airplane models, through to the engine performance, the flight mechanics performance, and finally the aircraft noise. The latter point was the real focus of the project. The noise model was broken down in parts: sources and propagation; the sources were modelled independently from the propagation and from each other. The noise sources were categorised as airframe (non propulsive) and engine (propulsive). We have provided account for noise from the lifting surfaces (wing, horizontal stabiliser, vertical tail), high-lift systems (flaps and slats) as well as landing gear. On the engine side, we have provided models that account for fan noise, compressor noise, combustor noise, turbine noise, jet noise, APU noise; we have then developed model to simulate interference effects, such as jet-by-jet shielding, wing/fuselage scattering, acoustic liners in a duct. The propagation models consisted of a pure propagation in the free atmosphere, according to ISO models, as well as the effects of wind, relative humidity, temperature shears, ground effect. The noise models have been validated at three levels: 1.) at the level of system component; 2.) at the level of integration onto the aircraft; 3.) at the trajectory level. For the latter part of the validation, we have used several types of analysis, from synthetic trajectories (comparison with INM V7) to real-life aircraft trajectories. For this purpose, we initiated a data gathering exercise and collected 4 trajectories for the Airbus A319-100 (thanks to the cooperation of DLR/Lufthansa, Germany), and 8 trajectories for the Embraer E195 (thanks to the cooperation of Manchester Airport/FlyBE). The data have been processed and prepared for the validation. Several exercises have been carried out, including (at the end of the project) a code-to-code comparison with DLR-Braunschweig. The validation was successful, and allowed us to make some fair comparisons and assess the overall accuracy of the methods developed under this initiative. The computer code Flight-Noise was delivered to Thales Avionics (Toulouse, France) at several stages of development. The final version of the code contained three airplane models: Airbus A139-100, Airbus A320-200, Embraer E195, and their respective engines. We conclude that the project was successful and was able to deliver the accuracy requested by the Call.

SUMMARY OF THE PROJECT

Strategic Aims. The Management of Trajectory and Mission branch of the Systems for Green Operations ITD aims at developing technologies to reduce emissions (CO₂, NO_x) and noise in the way the aircraft manages its trajectory. One of the main fields of research considered to reach these objectives is to improve in-flight 4D trajectories, including the overall missions profiles, through mathematical optimisation. Implementation of these optimisations is foreseen either on-board, in an avionics computer, or on ground, using computing tools in a laboratory or in an airline operations centre. In order to achieve this goal, the activities of this branch will bring these technologies to avionics systems demonstration platforms.

Improvement of environmental performance of aircraft needs to be based on a working knowledge of how aircraft contribute to emissions and noise. This knowledge will support the following MTM activities:

- Design better trajectories to reduce emissions and noise
- Assess the performance of technology for green missions and trajectories
- Enhance the representativeness of the simulations used for this assessment
- Provide airborne systems to perform trajectory and mission optimisation.

Since the systems developed for trajectory and mission optimisation need to be inserted in the overall economical model of the operators (the airlines), some knowledge needs also to be gained on how those economical models will influence operators choices when it comes to choosing between environmental impact and economical performance. This will enable to associate a “cost” to each generated trajectory.

Deliverables

Deliverable	Title	Description (if applicable)
D1	Model Technical Specification (TS)	Model requirements & interface specifications document. The Specification will then be refined, amended and completed during dedicated workshops for approval by the Topic Manager
D2	Model Definition and Justification Document (DJD)	Rationale for the chosen architecture of implementation, and analysis of compliance with requirements.
D3	Model Validation Test Plan (VTP)	
D4	First numerical Model Software Model User Manual Validation Test Report (VTR) Reference tests data files	Will be accepted through an acceptance review led by the topic manager.
D5	Problem report and model modification request	Compilation and analysis of problem reports and modification requests agreed in cooperation with the topic manager or his appointed representative.
D6	Model Technical Specification update (TS) Model Validation Test Plan update (VTP)	
D7	Final release of the numerical model software, with problem fixes. Model User Manual update Final Validation Test Report (VTR) Reference tests data files	
D8	Numerical model software and data package update for problem fixes or evolutions	

Results & Achievements

A comprehensive software system has been developed following the specifications of the project. The specifications were as follows:

Scope of Work

1. To identify the main parameters and propose the inputs/outputs parameters.
2. To adapt the turbofan and airframe model of noise emissions.
3. To provide evidence of model consistency through comparisons of estimated noise against experimental data, where available.
4. To deliver turbofan & airframe software and its associated documentation.
5. To provide post-delivery support up to the end of the project.

Key Requirements

1. Ability to model different commercial aircraft, engines and configurations.
2. Ability to model the effects of flight controls.
3. Ability to run off-line noise calculations.
4. Ability to model the effects of sound propagation through the atmosphere.
5. Ability to model the effects of the atmospheric winds.
6. Ability to model topographical details.

Model Requirements

1. Airplane Geometrical Model & Design Limitations.
2. Engine Model & Design Limitations.
3. Engine Flight Envelopes.
4. Databases for Noise Theories (experimental data)

Input Parameters

1. Flight Altitude
2. Aircraft position (three coordinates)
3. Aircraft angles (attitude, heading, banking)
4. Indicated airspeed, true air speed, ground speed
5. Outside static air temperature, temperature and humidity.
6. Fuel flow (or net thrust)
7. Engine rotational speed
8. Aircraft mass at start of trajectory
9. Aircraft configuration (high lift devices and landing gear position)

Noise Metrics Provided

The software provides the following noise metrics and associated parameters:

1. Effective Perceived Noise (EPNL, integral metrics): total and by component.
2. Sound Exposure Level (SEL, integral noise metrics).
3. Equivalent Continuous Sound Level.
4. Maximum noise loudness over a flight trajectory.
5. Aircraft position at maximum noise level.
6. Noise sensitivity analysis (all components)
7. Noise breakdown by component, in the frequency domain (frame noise).
8. Noise breakdown by component, in the frequency domain (engine noise).
9. Noise levels above 70dB, 80dB, 90dB thresholds
10. Noise footprint calculations at take-off and landing (EPNL, SEL)

The verification and validation was carried out according to procedures discussed separately in the validation report (Deliverable D4). The validation addressed the issue of noise sources at the component level, at the integration level and at the trajectory level.

The Flight-Noise software provides only quantitative analysis in a deterministic scenario. It will be up to noise expert to judge the results of the analysis.

Further details are available in the project deliverables.

Main Results

Below, we show a final set of comparisons was carried out at the closure of the Flight-Noise project. Following extensive communications with DLR-Braunschweig (who provided reference data for this exercise), and further problem fixes (flap settings, flap installation angles, flap/slat directivity functions, fan noise directivity, acoustic liners and other details), we have been able to provide further improvements in the correlation between experimental data and simulated data for the Airbus A319-100 with CFM engines, both at departure and approach/landing. The results are shown below for microphones below the flight path and microphones on the sideline.

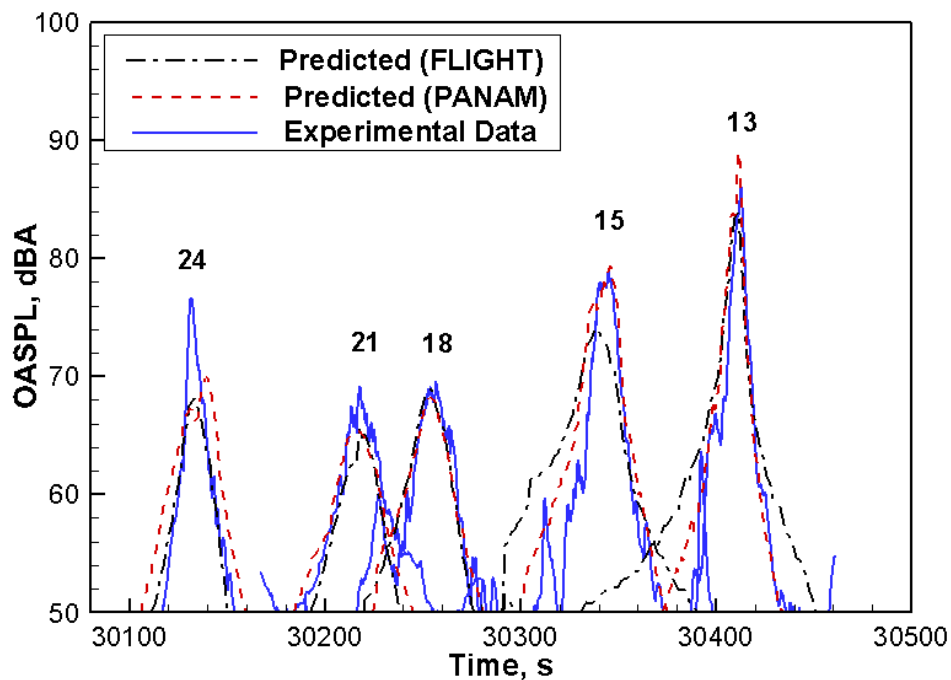


Figure 1: Approach/landing noise, trajectory rec002; comparison between experimental data, Flight-Noise and PANAM (DLR). Microphones below flight path.

In the final part of the project we produced a database of experimental data, including flight-data recorder (FDR), noise measurements and atmospheric data. The airplane was an Embraer E195 (E95) flown by the airline FlyBE to/from Manchester Airport. FlyBE provided raw data from the FDR, including about 30 flight parameters. These parameters included the position of the aircraft (latitude, longitude, altitude), the airplane angles (roll, pitch, heading), the air speed, the engine conditions (rpm and fuel flow), landing gear status, flap and slat setting, wind speeds, and other parameters. Manchester airport, Dept. of Environment, took the measurements, which included raw OASPL(dB) data for about 20 seconds duration, corresponding to airplane overfly, as well as integral noise metrics (EPNL, SEL, LAeqT). The atmospheric data corresponding to these flights were gathered from the UK Meteorological office. These data included barometric pressure, air temperature, wind speed, wind direction, maximum wind gust intensity, relative humidity, visibility and other parameters not relevant to the work carried out in the Flight-Noise context.

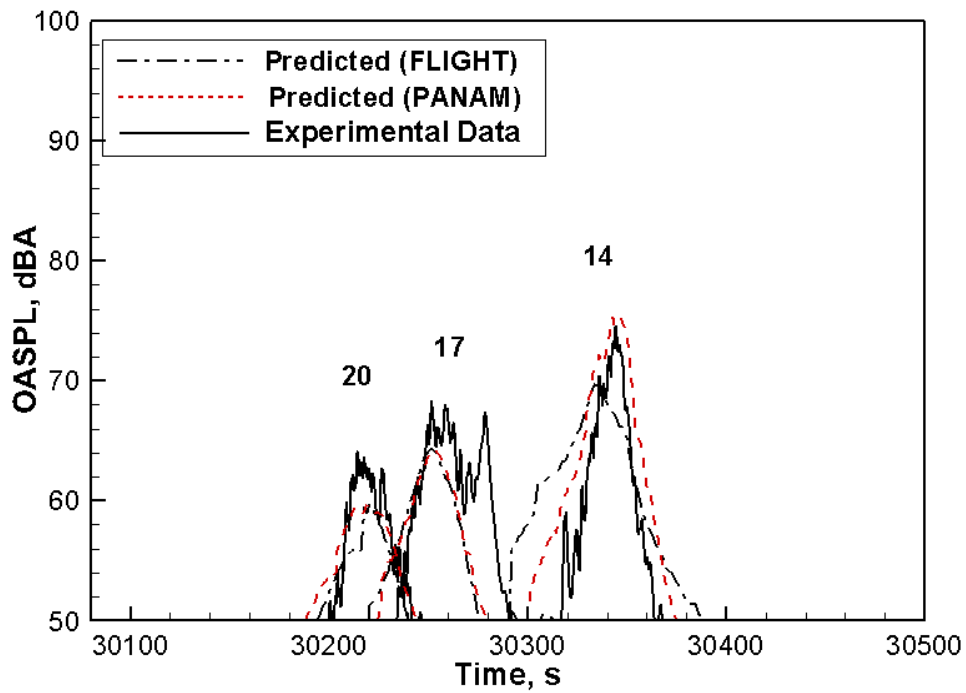


Figure 2: Approach/landing noise, trajectory rec002; comparison between experimental data, Flight-Noise and PANAM (DLR). Microphones on the sideline.

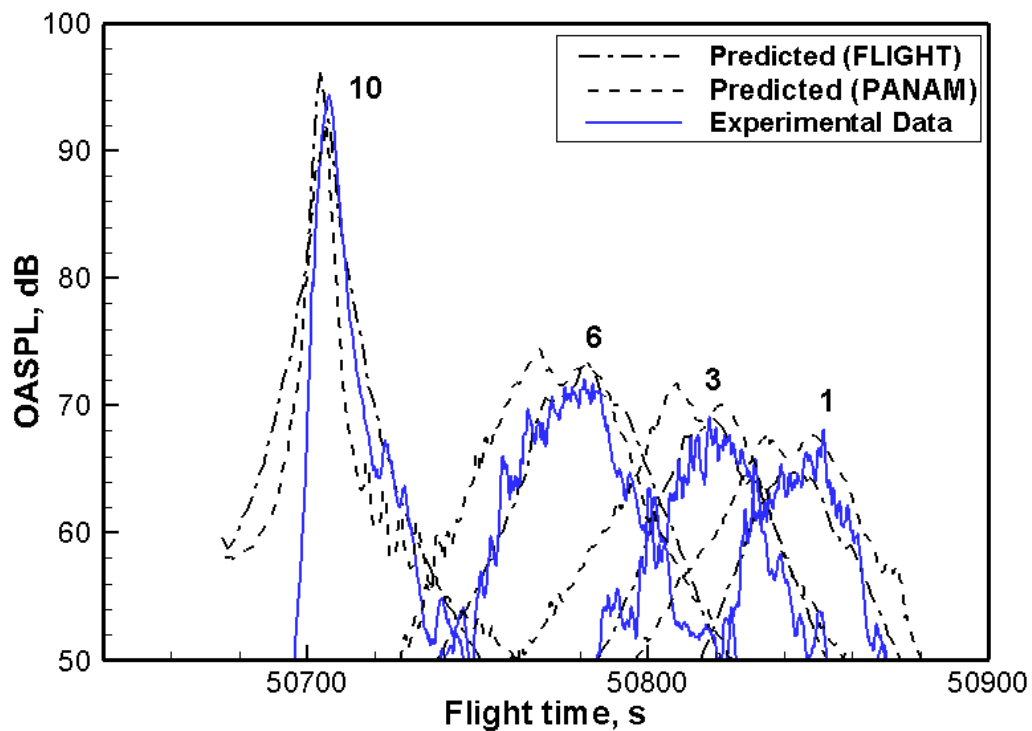


Figure 3: Departure noise, trajectory rec013; comparison between experimental data, Flight-Noise and PANAM (DLR). Microphones below flight path.

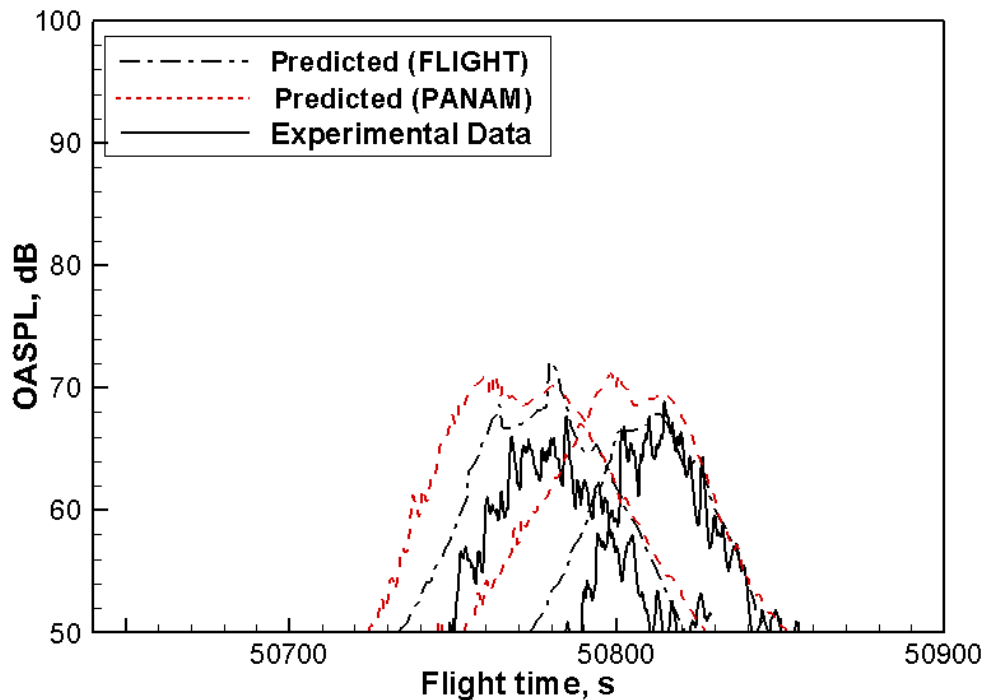


Figure 4: Takeoff/departure noise, trajectory rec013; comparison between experimental data, Flight-Noise and PANAM (DLR). Microphones on the sideline.

E-195 Measurement Data Spread

The spread in the EPNL data obtained at each of the microphones for the E-195 aircraft is shown in Figure 5, where only those measurements rated as “good” or “fair” have been included. Measurements rated as “poor” or worse are assumed to be unusable. On the arrivals side the spread in the data becomes generally larger with increasing distance from the airport and with increasing distance between the microphone and the flight path. Overall however the spread in EPNL values on the arrival side is low, having a maximum variation in measurements of 3.5dB at microphone 7. On the departures side the spread in measured EPNL data is significantly larger. This, however, is generally due to the larger variation in trajectories on takeoff.

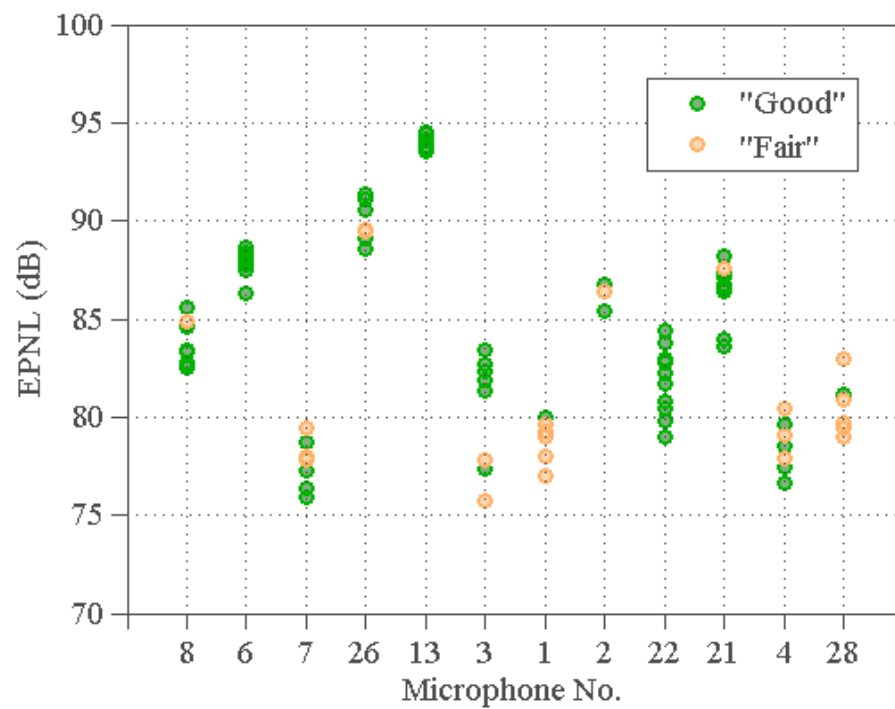


Figure 5: Spread in measured EPNL values for the E-195 aircraft, including measurements rated "good" and "fair" only.

Potential Impact

The Flight-Noise software developed under this research program has a large number of engineering applications. With specific reference to “aircraft noise”, the software can be used in a variety of scenarios, including, but limited to:

1. Flight path optimisation.
2. Effects of ground topography on noise propagation,
3. Effects of atmospheric conditions, including winds, humidity and temperature shear.
4. Noise analysis at airports, specifically noise footprints at landing and takeoff, noise stacks (noise levels from multiple aircraft movements).
5. Analysis of a variety of integral noise metrics (SEL, EPNL, LAeqT).
6. Parametric analysis to investigate the effects of each noise source.

There is clearly a vast impact, both on society, on the economic impact of aviation. This software can be used by trained professional to help in the formulation of environmental policies, to advice on airport expansions and operations, on the engineering analysis of aircraft noise at a very high technical level. Furthermore, there is potential for further exploitation by continuing the development of the software, and its validation with relevant data. Current areas of work include: acoustic liners, fan noise, fuselage external noise, fuselage internal noise, propeller noise, trajectory optimisation, sensitivity analysis and validation across all the disciplines. An example of noise footprints is shown in the figure below. Details of this type of analysis are shown in the project deliverables.

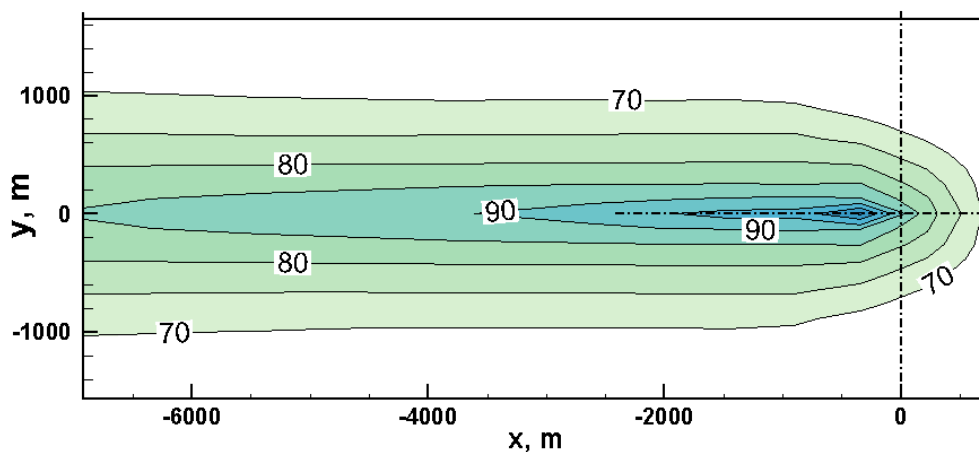


Figure: Noise footprint on approach/landing of an Airbus A320-200-CFM, calculate by Flight-Noise.

Project's Website

There is no specific website for this project, but the software developed under this research programme is accessible (in demo format) from the website: www.flight.mace.manchester.ac.uk. All contact details are found there.