# ORGANISATION OF EUROPEAN AERONAUTIC ULTRA-LOW $NO_X$ COMBUSTION RESEARCH

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## Abstract

*European companies are joining their research capabilities to promote the development of viable low emissions aero-engine combustion systems on a pre-competitive level.*

*The EC funded coordination action ELECT-AE[1] is bringing together the European key engine manufacturers and research establishments to enable this. The development of a concerted research strategy involves many complex interactions. The continuous improvement of the low NOx technology will finally bring the success.*
*Timescales for the development of aero-engine combustors are long. There is a clear vision and forecast of environmental needs. The ambitious ACARE[2] targets, especially the demand for 80% reduction of NOx emissions from aviation, require very well focused and balanced RTD♦ initiatives for the near future to prepare the technology for a successful implementation of a new generation of aero-engine combustors and therefore a highly integrated research strategy platform.*

*The Coordination Action (CA) "European Low Emission Combustion Technology in Aero-Engines" is in-line with the ACARE goals as formulated in their "Strategic Research Agenda II" to reduce the environmental impact of civil aviation with regard to emissions and thus generating economic and ecological benefits for the European and the global Society.*
*Therefore targets have been developed, designed to support the establishment of a pre-competitive research strategy consisting of actual measures and actions in the context of combustion system technology for low emissions of pollutants:*

- *Strategy on technology development*
- *Integration & strengthening of the European Research Area*
- *Enhancement of exploitation in Europe*
- *Dissemination of European research results and exchange of information in Europe*
- *Search and identification of Small-Medium Size Enterprises and new research partners in the EU25.*

*The global result will be an improvement of the efficiency of research, further increase of the rate of progress and innovation in the field of low-NOx aero-engine combustion technology in Europe. The total amount of emissions released during a flight mission is affected by a variety of factors. This includes combustor technology, aerodynamic efficiency of the aircraft, fuel efficiency and take-off weight, all of which cannot be strongly influenced by the engine combustor design.*
*The optimisation of the combustion process is an essential mean to reduce NOx production from aero-engines. It has to be noted that ultra-*

[1] European Low Emission Combustion Technology in Aero Engines, see for details: www.elect-ae.org
[2] Advisory Council for Aeronautics Research in Europe, see for details: www.acare4europe.org
♦ Research and Technology Development

*low NOx combustion technology contributes to fuel burn reduction by enabling cycles with higher pressures and bypass ratios, with higher turbine entry temperatures and by reducing cooling air and combustor pressure losses. Research on highly innovative architectures has to be carried out to reduce complexity, size and weight of ultra low NOx combustion systems.*

*Due to the extremely complex nature of this technological field and the fact that the development of ultra-low NOx technology has by far not yet reached engine-demonstrator readiness level, it will not be possible to down-select a combustion technology in the near future.*

## 1 Introduction

The ACARE goals have been set for efficiency improvement and emissions reduction for future aero-engine gas turbines.

The objectives are very challenging but represent probable best-case scenarios for the year 2020. This "Vision 2020" has been established by a group of personalities representing the European aviation industry.

These goals were also incorporated in the Work Programme of the Aeronautics and Space thematic priority of the 6th Framework. Some of the original and already very challenging ACARE goals are even stricter in respect of the emissions of pollutants. The timeframes set, refer to a medium term (5 to 10 years) and a long-term (15 to 20 years) perspective.

Based on experience from European funded research since the 4th framework, the development of low NOx combustion systems is very difficult and takes a long time.
A wide range of technological strategies has been investigated and a lot of effort was spent.
These programmes were very successful in identifying and assessing the potential of low emission combustion improvements.
Combustion requirements such as flame stability, operability, weight and costs still require further development.

Tools which help to close the gap between the extremely challenging ACARE and EC Work Programme on one side and the research projects on the other side are needed to clearly determine future strategies on How-To-Do low and ultra-low NOx combustion technology development. ELECT-AE is fully dedicated to closing this gap.

## 2 Objectives

The most important single measure for the implementation of the ACARE goals is the preparation of a short and intermediate term strategy for EU research and technology initiatives and to identify gaps in knowledge in the field of aero-engine combustion.

A strategy for short and mid term RTD initiatives will be developed to tackle the long-term targets and challenges for 2020. Out of the variety of today's different low emission technology approaches there will be only a few having the potential to eventually meet future NOx reduction targets while offering the ability to maintain lean combustion stability, operability and safety with competitive cost and weight and airworthiness.

The successful implementation of ultra-low NOx combustion technology into aero-engines requires well-focused combustion RTD efforts. The definition of a technological roadmap to meet these targets by 2020 (EIS*) assumes the successful achievement of major RTD milestones.

Non-European and non-EU funded research activities will be monitored and summarised by a working group. The results will be fed back into the definition of RTD initiatives.

* EIS = Entry Into Service

A Patent Award will stimulate protection and exploitation of EU funded innovations generated in linked EC research projects.
In addition this CA aims at integration and strengthening of the European Research Area by promoting networking:

The consortium will offer to provide information regarding the latest combustion technology developments and relevant predictions of achievable emission reduction to both, ACARE and ICAO-CAEP[3] working groups.

A map of excellence will be developed to give direction to areas of scientific competence and existing test facilities available in European Union's 25 (EU25) member states.

There is also contact with the IP VITAL[4] sub-programme SP1, on Whole Engine Assessment, and to the IP NEWAC[5] sub-programme SP6, which deals with combustion system development.

The identification of Small and Medium Enterprises (SME) from the EU25 and their integration in future research initiatives, mainly in Specific Targeted Research Projects as contractor or subcontractor, will be promoted by creation of a link to AeroSME[6], which is a joint project of the AECMA[7] and the European Commission. Their database can be used to identify appropriate competences needed to perform specific scientific research work and/or manufacturing work relevant for combustion issues.
RTD results from linked European funded research projects will be assessed and disseminated to the public and to the aeronautics community through the organisation of work shops on specific topics for which expert lecturers will be invited when appropriate. There is an exchange of information and communication with networks such as CA AERONET III[8] and NoE ECATS[9].

Participation in international conferences (such as ICAS[10], ASME[11]-TurboExpo, ISABE[12] or the Aeronautics-Days[13]) and international exhibitions with posters or leaflets is taking place.
Public awareness regarding the current and future developments in the field of ultra-low emission technology will be raised by regular press releases (e.g. Parliament Magazine).
A semi-professional website (www.elect-ae.org) has been created and will be maintained throughout the project.

## 3 Project Consortium

The consortium is bringing together the European key aero-engine manufacturers with interests in low emissions combustion and the German and French aerospace research establishments (DLR and ONERA).

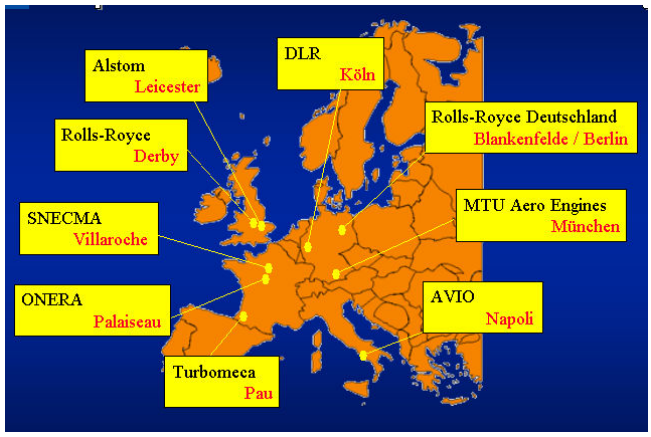


Fig.1: The ELECT-AE consortium

[3] International Civil Aviation Organisation – Committee on Aviation Environmental Protection www.icao.int
[4] Integrated Project VITAL "The innovative enabler to meet 2020 environmental goals"
[5] Integrated Project NEWAC "New Aero-Engine Concepts"
[6] The AeroSME-Project: Support for Aeronautical SMEs in Europe www.aerosme.com
[7] European Association of Aerospace Industries www.aecma.org
[8] Coordination Action on Aircraft Emissions and Reduction Technologies www.aero-net.org
[9] Network of Excellence on Environmental Compatible Air Transport System www.pa.op.dlr.de/ecats/
[10] www.icas2006.org
[11] www.asme.org
[12] www.isabe2005.com
[13] www.aerodays2006.org

Rolls-Royce Deutschland coordinates ELECT-AE. VOLVO Aero Corp. is also supporting the project and its future research initiatives.

Industrial aero-engine technology projects co-funded by the Commission of the European Union are co-ordinated by an organisation called "Engine Industry Management Group" (EIMG). This group was formed in 1990 in response to a request from the Commission and consists of one representative from each of the 12 European aero-engine companies. Recently two new members from Czechia and from Poland (PSS and WSK) have joined. EIMG has the following objectives:

- To provide an European aero-engine industry view on the commission's Aeronautic Initiatives on research and technology
- To provide support to the Commission in preparing its relevant research programs
- To initiate any additional actions by the aero-engine industry which may be considered necessary to support these objectives
- To facilitate the research and technology activities of the parties and to improve or increase the results of those activities

The Low Emission Combustion (LEC) cluster being co-ordinated by Rolls-Royce Deutschland. Technology clusters are working groups under the supervision of EIMG. They are composed of specialists from the EIMG companies. Their role is to prepare the specialised research activities to be submitted in the European Commission funded Aeronautics Framework Programmes. They must ensure coherence between the projects submitted under the same cluster in order to give them the best chances to be accepted and to optimise the workload of all EIMG companies. Each cluster is co-ordinated by one of its members.

## 4 RTD Strategy Orientation

The first research strategy workshop was carried out on 8 and 9 March 2006 in Bois du Lys near Paris. Here, ELECT-AE brought together aero-engine manufacturers, research establishments and leading universities in the field in Europe.

### 4.1 Strategic drivers

Strategic drivers represent the key motivations for research. During the workshop the following drivers were identified:

- Environmentally friendly engine and sustainable air transport
- Economic benefits / reduced lifecycle costs
- Reduced development time and costs
- Reduced weight (parts count / complexity)
- Airworthiness / safety / certification
- Competitiveness on a global scale
- Customer demands

The relation between Research and Technology Development (RTD), which results in advanced technology and innovation and their stimulating effects on economic growth and finally on wealth was emphasised.

It has to be noted that an advantage in advanced knowledge and economic wealth is essential and that these advantages will steadily erode if the efforts are reduced.
Consequently, there is no choice for Europe but to avoid fragmentation and to increase efforts in order to remain competitive.

### 4.2 Research and Technology Development

The objective is to identify medium and long-term research goals to pro-actively support the ACARE target of 80% reduction of NOx emissions. The results are briefly summarised below:

- Combustion Technology

The workshop agreed that lean-burn technology is essential to achieve the low NOx targets and that it has to be driven towards higher

technology readiness. The development of lean combustion systems, featuring lean injection systems and single-annular combustor architecture has to be intensified.

The understanding concerning fuel-air mixture preparation, particulate matter formation and pressure oscillations driven by combustion instability has to be improved. Advanced models for the prediction of fuel atomisation, cooling and thermo-acoustics need to be developed.

New combustor concepts (10 years):

- internally piloted lean injection
- optimisation of lean staged combustors
- fuel-air mixing at low and high power
- better understanding of conventional ignition
- develop LASER ignition
- design for fuel efficient engines with high OPR, P30/T30 and ultra-high BPR

Radical combustor concepts (20 years):

- alternative combustion concepts
- porous combustor concepts
- actively cooled (liquid/steam/gas) combustor
- no-external aerodynamics combustor
- convective cooling
- catalytic combustion, ignition and flame stabilisation
- explore the influence and benefits of advanced cycle engines

New injectors (10 years):

- mixture optimisation
- fuel atomisation, dispersion, placement
- optimise thermal management (coking)
- ensure injector scalability

Radically new injection (20 years):

- circumferential array, multi-point injection with discrete jets
- explore external pre-vaporisation
- water injection at take-off
- identify improved concepts for advanced internal staging

• CFD Methods, Design Methodology and Life Prediction

Design methodologies and rules for lean combustion systems and lean injection systems focusing on operability and emission performance are urgently required.

The fundamental knowledge base and the understanding of processes concerning the fuel-air mixture preparation (fuel film / droplet break-up), particulate matter (soot) formation and pressure oscillations driven by combustion instabilities have to be improved.

Design tools have to comprise multi-physics incorporating heat-transfer and coupling with thermo-acoustics. Mechanical stress and lifing methods have to be integrated to better predict failure modes such as crack initiation and propagation.

• Diagnostics & Test Rigs

Diagnostics and test rigs have to enhance capability at realistic engine operation conditions. Optical access is a main issue for large scale testing of combustion devices and the application of advanced LASER techniques. Simultaneous multi-parameter measurements and the development of new techniques to explore optically dense regions of sprays must have high priority to reduce test time, costs and to increase testing value.

• Alternative Fuels

Alternative fuels could play an important part in reducing emissions but needs global coordination. Safety of supply and costs are decisive. Fischer-Tropsch synthetic kerosene, which can be produced from natural gas, coal and biomass, and blends thereof with Jet-A1 kerosene, is in the focus of interest. At present these kerosenes are regarded as the only realistic alternative aviation fuel. Assessment of their combustion, emission performance, controls and whole engine impact should be initiated.

The participants unanimously agreed that the workshop was successful and opted for an annual update to extend and to refine the research strategy developed. The vision developed will be used to align and to focus future European research and development initiatives.

The results were reported to [1] ICAO's Task Group on Long-Term Technology Goals during their review meeting on 20 to 24 March at UK's Department of Trade and Industry, London, to [2] the Aeronautics Days 2006 (19-21 June 2006) in Vienna and [3] widely disseminated by an advertorial in Parliament Magazine.

A summary of the results was given to the EIMG board for forwarding to ACARE.

A European research and technology strategy on low emissions combustion in aero engines was initiated. Perspectives were developed covering combustion technology, CFD methods, design methodologies, diagnostics and test rigs and alternative fuels.

Lean combustion systems (single annular architecture) with lean injectors were identified as the only viable approach for the time being with some rather radical technologies slowly emerging.

The lean burn technology development has to be strongly supported by enhanced capabilities in the field of CFD methods & design methodologies and diagnostics and test rigs.

Organisations supporting the workshop are listed below:

| | |
|---|---|
| Air BP | (UK) |
| ALSTOM | (UK) |
| AVIO | (IT) |
| CERFACS | (FR) |
| CNRS (IMFT / EM2C) | (FR) |
| DLR (Stuttgart/Köln) | (DE) |
| IFP (Paris) | (FR) |
| MTU Aero-Engines | (DE) |
| ONERA (Palaiseau/Toulouse) | (FR) |
| Rolls-Royce Deutschland | (DE) |
| Rolls-Royce UK | (UK) |
| Shell Aviation | (UK) |
| SIEMENS | (SE) |
| SNECMA | (FR) |
| Turbomeca | (FR) |
| VOLVO Aero | (SE) |
| Universität der Bundeswehr München | (DE) |
| University Cambridge | (UK) |
| Universität Darmstadt | (DE) |
| Universität Karlsruhe (TH) | (DE) |
| University Loughborough | (UK) |
| Universitet Lunds | (SE) |
| University Oxford | (UK) |
| University Sheffield | (UK) |
| University Southampton | (UK) |

Fig.2: The workshop participants

## 5 Future Research and Technology Initiatives

The planning of preliminary actions for new RTD initiatives is underway. Based on the expectation that Framework 7 will have improved but still similar tools for specific research actions to Framework Programme 6 the intended initiatives are considered to take a similar form.
Themes for Framework Programme 7 with relevance for ELECT's work scope were published by the EC:

- Greening of air transport

Reduction of emissions and noise disturbance, incorporating work on engines and alternative fuels, structures and new aircraft designs, airport operations and air traffic management

- Improving cost efficiency

Reduction of costs associated with product development, manufacturing and operating costs focusing on the zero maintenance aircraft and the increased use of automation and simulation.

- Pioneering the air transport of the future

Addressing the long-term challenges of aviation with more radical, environmentally efficient and innovative combinations of technologies, which would lead to significant steps forward in air transport.

## 6 Networks (European Research Area)

ELECT-AE is a forum where information, experience and views can be exchanged between the organisations inside and from outside.

It supports the forging of future RTD initiatives, strategies and help to integrate and to strengthen the European Research Area. It assesses and disseminates results from its linked RTD projects to acquaint the public and the aeronautics community with the latest achievements in low emission technology in aero-engines.

### 6.1 RTD projects

The coordinators of on-going low-NOx relevant RTD programmes (including FP5 and FP6) are linked to ELECT-AE. The coordinators are represented in the so-called Project Liaison-Support Team.
During FP6 four EIMG led projects were approved by the EC. Two are mainly dealing with technology development and design methodologies (INTELLECT D.M. and TLC), the third one is focused on combustion prediction methods (TimeCop-AE). The fourth project is devoted to the development of remote emissions sensing techniques (AEROTEST).

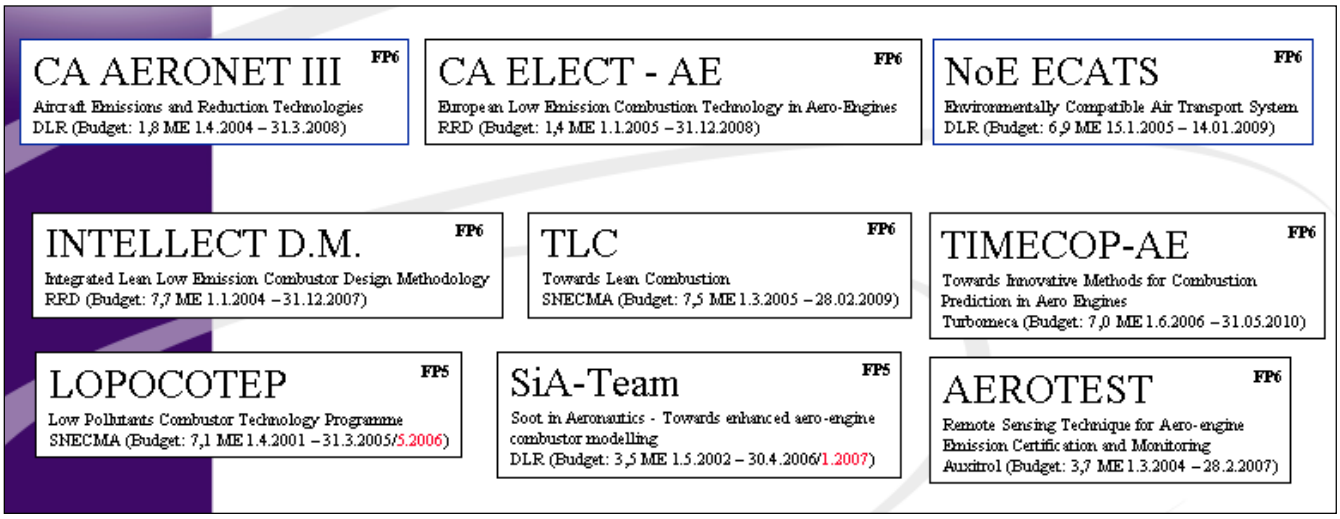


Fig. 3: ELECT-AE's Network

Both, LOPOCOTEP (on lean combustion technology in axially staged combustors) and SiA-Team (fundamental knowledge on soot mechanisms) were approved in FP5 and are now reaching the final phase.

Please refer to Fig.3. for acronyms, budget figures and timeframes. The projects are described in brief below:

MUSCLES

This project was recently completed. It was focused on gaining extra understanding of the unsteady combustion phenomena that occur in combustors, and the limitations they present in the development and deployment of lean-burn technology.
This has been achieved through carefully constructed experiments and numerical simulations to gain insight into the mechanisms that lead to instabilities.
At the completion of the project a great deal of progress in the understanding of the underlying physics of the unsteady phenomena has been made and this will be a major bonus in the design of low emissions combustors. In addition new experimental techniques were developed, which can give greater information on the processes involved in droplet evaporation.

LOPOCOTEP

The end of the programme LOPOCOTEP has been extended and was completed by end of May 2006. (This programme's objective is for a 80% reduction for large and 70% for medium size fan engines relative to CAEP/2) RR UK successfully completed multi-sector tests with so-called Lean Direct Injection (LDI) systems in support of ANTLE. RRD developed the advanced LP(P)5 module with centarlly integrated pilot atomiser, which was investigated in a high-pressure multi-sector combustor.
Turbomeca and AVIO tightly teamed their efforts and manufactured a small reverse flow combustor. A FANN (Full ANNular combustor) test was carried out. MTU have manufactured a small Rich-Quench-Lean (RQL) combustor, which was tested at atmospheric conditions. At SNECMA a multi-point injection system with radial air inflow and centrally integrated pilot fuel injection was developed and the emission performance was successfully tested.

SiA-Team

Its objective is to further develop aero-engine combustion models for the prediction of the formation, agglomeration and destruction of soot (particulate matter).

These essential models were developed and devised and then verified against experimental findings produced within the frame of the project.

TLC

The project comprises 4 work packages on Advanced Experimental Techniques, Numerical Diagnosis, the experimental evaluation and the design and optimisation of lean burn systems.

The committed objective that has been set is to achieve a NOx target of between 60 to 70 % reduction relative to CAEP/2 regulations for medium and large turbofan engines.

INTELLECT D.M.

This project is focused on operability (stability & weak extinction in adverse weather conditions), ignition capability (cold start, light across and light around), external aerodynamics and combustor cooling design. Design rules and guidelines will be fed through an assessment process into knowledge based engineering tools for parametric and inverse design. The NOx objective agrees with the ACARE goals, which requires a reduction of 80% relative to CAEP/2 by 2020.

The combustion technology pursued by all partners is now based on single annular combustor architecture. Different types of next generation lean burner are under development.

Some feature centrally integrated pilot injector and so-called V-shroud flame stabiliser and with airfoils aerodynamically profiled guide vanes in the air duct's swirl generators.

At AVIO an axially staged combustor is used as reference for their investigations.

Highly efficient cooling technologies are now becoming very important because of the air-feed requirements of the lean burn modules, where the fraction of combustor air flowing through the lean module has to be maximised.

AeroTest

The focus is on sensing techniques for aero-engine emission certification and monitoring. The project addresses quality and standardisation issues regarding requirements for regulations and certification authorities.

The application of emissions measurement instruments for ICAO gases (CO, NO, NO2, UHC, CO2 and moisture) will be explored by FTIR spectroscopy. LII (laser induced incan-descence) is used to measure soot particles.

TimeCop-AE

A highly innovative initiative, which builds on already successfully completed projects on CFD modelling (MOLECULES).

Large Eddy Simulation (LES) CFD will be extended to partially premixed combustion and two-phase modelling. This is regarded as an essential step towards the application of LES methods on the design of ultra-low NOx aero-combustors. Further development of LES is required for better predictions concerning operability issues (ignition, relight, weak extinction).

The 2-phase flow models will be extended to kerosene evaporation, micro-mixing and improved turbulence-droplet interaction. Kerosene chemistry (reduced schemes and turbulence coupling) will be experimentally validated and implemented.
A link to the automotive spray combustion has been established.

MENELAS

The MENELAS project (Minority Effluent measurements of aircraft eNgine Emissions by infrared LAser Spectroscopy) ended in spring 2005 already with much progress in the developments of two novel optical instruments (an Optical Parametric Oscillator and a Pico-second LIDAR) for probing in the infrared spectrum minority species like CO, NO, CO2, H2O and UHC. There were two important field experiments to test the possibilities of LASER infrared absorption spectroscopy with setups using diode LASER targeting CO, NO, CO2, H2O and CH4.
The first campaign was carried out at the DLR-Köln to probe an Atmospheric Primary Zone combustor prototype. The second one was in the NLR test site at Amsterdam Airport Schiphol probing the aircraft engine exhaust gases of a Cessna Citation II aircraft. The results obtained clearly showed that spectroscopic measurements of trace gases in a combustor or at the exhaust of an aircraft engine are feasible on ground and that temperature and pressure can be measured non-intrusively with spectroscopic techniques.

## 6.2 ECATS

ECATS is a so-called network of excellence, which has no direct involvement of the aero-engine manufacturers.
The objective of this project is the restructuring and reorganisation of research organisations on the environmental compatibility of aviation in Europe in a cost effective manner by creating a virtual institute.
The project has 13 partners from 7 EU member states. The project is split in 3 thematic areas.

The first thematic area is on engine technology, near field plumes and alternative fuels.

The second thematic area is on local and regional air quality, while the third area covers green flight and scenarios.

Capability enhancement will address 5 separate tasks, such as an Aviation Fuels Centre and airport air quality measurements.
Research initiatives on 5 topics are planned for the same period, including sustainable fuels for use in aviation and on measurement methods for nano-particles formed by nucleation and condensation in gas turbine exhaust.

### 6.3 AERONET III

The Coordination Action AERONET III is linked to ELECT to report on the various atmospheric and fuel related issues discussed in that community and receives information about the perspectives and strategies being developed.

Aeronet III's starting date was 1 April 2004. They have 25 partners from 9 countries including a member from Russia.

The goals are to initiate communication in the aeronautic community and with atmospheric science, to facilitate exchange of information and experience, to foster and support cooperation.

It is organised in work packages covering policy, aircraft and engine technology aspects of emissions reduction, airport air quality and the air transportation environmental reference system.

ELECT-AE participated in AERONET III's workshop on Aircraft Emissions and Reduction Technology [4]. This workshop identified a number of future research topics, which are briefly summarised below:

- Low NOx combustion in aero-engines

Lean-burn technology is essential to achieve the low NOx targets. Technology has to be driven towards higher technology readiness levels and application in aero-engine gas turbines. Operability issues (such as flame stability, altitude relight, oscillations etc.) have potential to significantly compromise NOx reductions.

- Alternative aviation fuels

Designed synthetic kerosene (Fischer-Tropsch) has to be assessed. There is a need to develop a comprehensive strategy for identifying and introducing technically and economically viable alternative fuels.

- Contrails and cirrus cover and climate impact

The impact of contrails and aircraft induced cirrus cover needs to be clarified as this is a necessary background information for the future ATM and potential aircraft development.

- Noise and airport air quality

Airports may become the most critical bottleneck for future air transport growth. Besides runway and air space capacity shortage, noise and airport air quality may be the limiting criteria.

- Aviation scenario capability and requirements

A durable prediction for the development up to 2050 is not possible. But high quality scenario work and quality in Europe can support industry.

## 7 Patent Awards

ELECT-AE is promoting the development of European technologies supporting and enabling low and ultra-low NOx combustion in aero-engines.

The objective of the Patent Awards is to award individuals or teams for their outstanding contribution in the field of low and ultra-low NOx combustion covering advancements in the development of combustion technology, fuel preparation, mixing, combustion, cooling, fundamental knowledge, theoretical and

experimental methods, modeling and design methodologies.

Individuals and teams from all partner organisations actively participating in low NOx combustion related specific targeted research projects from Framework 5, 6 and 7 directly linked to ELECT-AE are entitled to submit applications. The patent and its know-how must have been generated in a work-package, task or subtask in one of these projects.

The awarding ceremony will take place during the Final Meeting of ELECT-AE in autumn 2008.

The evaluation of submitted applications will consider the following items:

- Topicality and creativity
- Degree of innovation, competitiveness and spin-off effects
- Applicability (license, prototype, series)
- Potential contribution to growth
- Sustainability

The submitted patent applications had to be filed to at least one National Patent Office of one of the member states of the European Union (EU25) or to the European Patent Office.

In this case the Award will be limited to the certificate issued by ELECT-AE, which will be given to this inventor/representative.

## 8 Conclusions

ELECT-AE is supporting the implementation of the ACARE objectives (80% NOx reduction).

A pre-competitive RTD strategy was initiated.

The first strategy workshop on future research and technology development was carried out.

Aero-engine manufacturers, research establishments and leading universities in the field in Europe were brought together. The following important fields have been identified for further initiatives:

- Combustion Technology
- CFD Methods, Design Methodology and Life Prediction
- Diagnostics & Test Rigs
- Alternative Fuels

Lean-burn technology is essential to achieve the low NOx targets and has to be driven towards higher technology readiness. The development of lean combustion systems, featuring lean injection systems and single-annular combustor architecture has to be intensified.

The work and the objectives of the EIMG, ACARE and ICAO's WG 3 were supported. The results of the strategy workshop were reported and disseminated.
Links have been established to ECATS and AERONET III. The ECATS' Scientific Advisory Board is and AERONET's emissions reduction workshop was actively supported.
Regular communication and exchanges of information between ELECT and the directly linked EC co-funded research projects has been established.

A call for submissions to a patent award was issued to enhance exploitation of low NOx research results in Europe.

## Acknowledgements

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The authors would like to thank all organisations and personalities who were supporting ELECT's 1st RTD Strategy Workshop at Bois du Lys near Paris.

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