Publishable Executive Summary

CONTRACT N°: AST3-CT-2003-502961

PROJECT N°: 502961

ACRONYM: INTELLECT D.M.

TITLE: Integrated Lean Low Emission Combustor Design Methodology

PROJECT CO-ORDINATOR: Rolls-Royce Deutschland Ltd & Co KG
Dr. Ralf von der Bank

PROJECT PARTNERS:

Rolls-Royce Deutschland	D
Rolls-Royce	UK
AVIO	I
SNECMA	F
Turbomeca	F
ONERA	F
DLR	D
CERFACS	F
CNRS	F
Universitet Lunds	SE
Universität der Bundeswehr München	D
University of Technology Czestochowa	PL
Imperial College	UK
Università degli Studi di Firenze	I
University of Loughborough	UK
University of Cambridge	UK
Universität Karlsruhe	D

REPORTING PERIOD: FROM 1.1.2004 TO 31.12.2009

PROJECT START DATE: 1.1.2004 DURATION: 72 months

Date of issue of this report: 18.06.2010

Project funded by the European Community's Sixth Framework Programme

Work package 1: Management

The project was implemented according to plan although two extensions had become necessary due to technical issues with highly complex test facilities.

The results of the project were reviewed by the EC Senior Project Officer Dr. Dietrich Knörzer and two independent experts (Prof. Dr. Johannes Janicka and Bryn Jones). The project was coordinated by Dr. Ralf von der Bank. The Final Meeting was hold from 2 to 4 December 2008 at the head office of the Helmholtz-Gemeinschaft in Berlin.

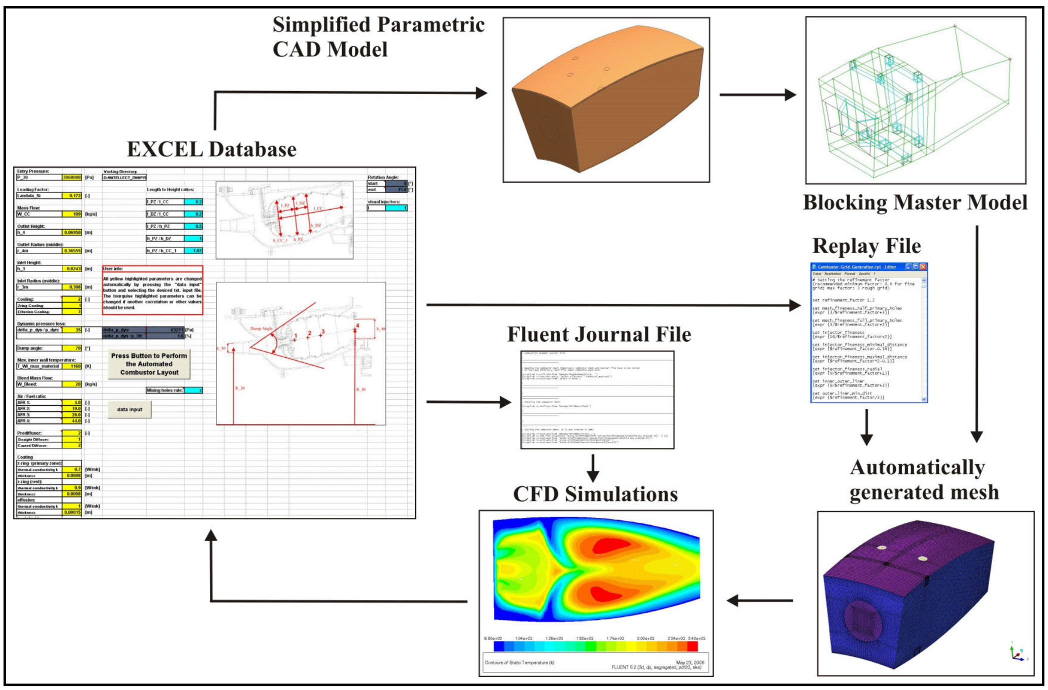
The Steering Committee unanimously agreed a prolongation of activities of DLR Task 4.2 by 12 month. The EC senior officer, Dr. Dietrich Knörzer approved, this request during the meeting. Task 4.2. was then reviewed separately by the EC in Brussels on 9 December 2009.
A liner for the exhaust gas of the Big Optical Single Sector combustion test facility of Task 4.2, which will be used to generate the results for deliverable report D4.2, needs to be installed to protect the concrete structure against water and water vapour from the throttle exhaust. Finally. a 6-month period has become necessary for the actual campaign with the largely untested new combustor hardware. Hence, DLR had to ask for a 12-month extension of the project to carry out the work planned for the Big Optical Single Sector.

All partners have completed the entire technical project work as planned successfully. This report represents a part of the Final Report.

Group photo of the INTELLECT D.M. team on 4 December 2008

Work package 2: Knowledge Based Combustor

The Knowledge Based Engineering (KBE) tool developed under this work package by Rolls Royce and Rolls Royce Deutschland will become the corner stone for capture and application of future lean low NOx design methodology.
This will provide an integrated environment, linked with design guidelines, predictive tools, to support efficient application of the combustor design process. Key design parameters and the models to be integrated have been identified, as well as the way they fit into the preliminary design process. All major data-flows driving the preliminary design have also been captured.
Work has been done to identify the combustion system module's interface. A 1D combustor aerodynamical model has been integrated into the system as well as an export into Unigraphics for automated meshing and an automatic tool for the simplification of technological details. This integration has been performed on the Technosoft platform and is based on AML language.

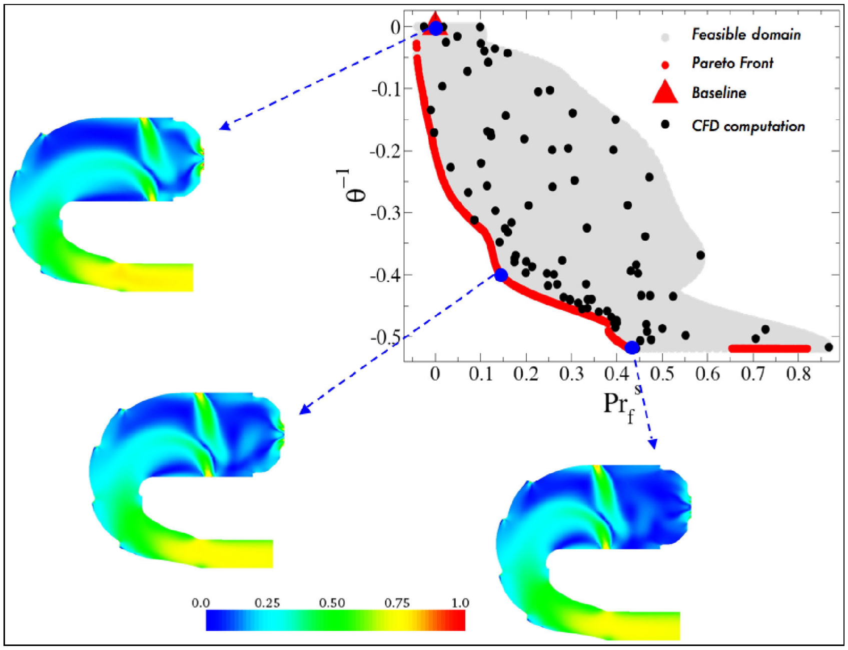


Automated design process (one example)

In parallel, a parametric injector has been added to the combustor CAD model by the University of the Bundeswehr in Munich and linked to the EXCEL database. The mesh generation in ICEM-CFD is automated via a replay file, which is generated and exported by the EXCEL database after every calculation.
CFD simulations are performed automatically. The CFD results are judged by an experienced design engineer and input parameters are changed within the EXCEL spreadsheet if necessary.

Concerning the optimisation strategies for CFD design, calculations of complex industrial configurations have been carried out with multi-objectives algorithms. Concerning the optimization strategies for CFD design, calculations on complex industrial configurations have been carried out with multi-objectives algorithms.

ONERA developed an optimisation method based on response surface model and applied it on the two-phase flow optimisation of a Turbomeca lean premixed prevaporized (LPP) injector. Because optimisation requires a lot of computations, the basic idea is to define a surrogate model reproducing the behaviour of the complex system with a short restitution time.
This response surface model (a multilayer perceptron neural network) is used in the optimisation process instead of the two-phase flow code to decrease CPU time. This chain was applied on a Turbomeca LPP injector optimisation computed in axisymmetrical two-dimensional. The results obtained have been exploited by Turbomeca to enhance the performances of Low NOx injection technologies for small gas turbines applications. CERFACS developed a fully automated optimisation loop based on the coupling device PALM. The main optimisation strategy adopted consists of a surrogate-based method. It allows treatment of mono and multi-objective problems with reduced clock time. This strategy was tested on simple 2D cases and then applied to the 3D optimisation of a Turbomeca combustor radial exit temperature profile.



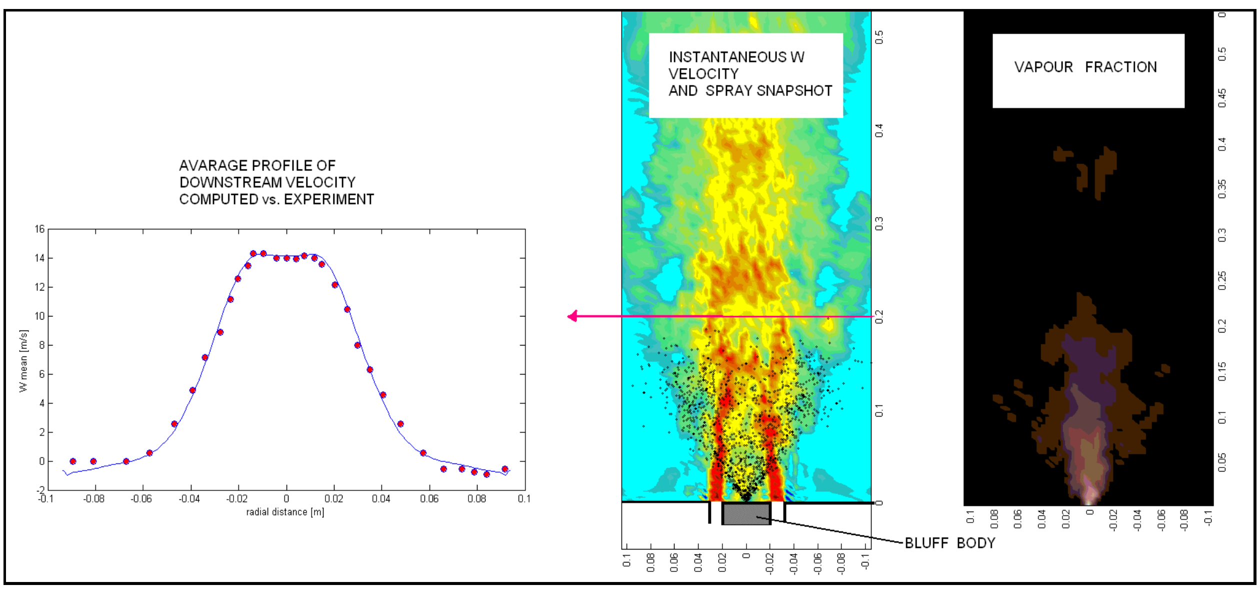
Potential candidates for an improved combustion chamber
(i.e. improved exit temperature profile and improved efficiency)

The work performed by CERFACS and ONERA has been followed-up by Snecma and Turbomeca all along the INTELLECT D.M. project. Some of these developments have been implemented into Turbomeca's and SNECMA's design tools and used for low emission combustor applications. The first application is a demonstration of the 3D optimisation of a combustor's radial exit temperature profile using moving mesh techniques used as well by CERFACS and the second application deals with a full factorial design of experiment used to explore the flow structure of an air-blast swirler. SNECMA applied these methodologies on the automatic optimisation of an air-blast atomizer design.
AVIO has set up a design procedure based on Artificial Neural Net (ANN) coupled with a Genetic Algorithm (GA) to find out the effusion cooling air distribution that optimises the combustor liner life. The wall temperatures needed as input for a structural finite element (FE) analysis was provided directly from conjugate heat transfer performed during CFD main calculation.
The parameters to be optimised were the combustor outer liner permeabilities and the objective was to improve the life of the combustor liner. This optimisation predicted an improvement of the liner's life by a factor of 3.

Work package 3: Ignition Capability

The implementation of a Monte Carlo code for the simulation of the LEPDF spray equation was concluded by M14. The code is capable of simulating the Large Eddy behaviour of a gas flow in which a spray is injected. The LES equations for the gas-vapour mixture phase are coupled with a probabilistic description of the spray. A Monte Carlo integrator code for particles dynamics has been incorporated into the LES Boffin solver. The implementation includes droplet transport, droplet heating and vaporization, droplet break-up and a special treatment for Injector boundary conditions. The implementation allows both one-way and complete two-way coupling between the droplet and gas phases. It has been demonstrated that small droplets typically present in a spray may enhance the rotational strength of coherent structures. As a consequence these structures, which are the major cause of droplet dispersion, are responsible for droplet concentration and vapour fields that are highly discontinuous. These findings may be of use in combustion chamber design; atomizer diameter and fuel inflow directions may be tailored to minimize segregation effects and thus non vaporized and un-burnt liquid fuel.

The LES Boffin/Monte Carlo Spray has been fully parallelized using MPI. A version of the LES Boffin/Monte Carlo Spray was delivered to the University of Czestochowa. Modifications into the BOFFIN code to obtain PDF of diameters and PDF of flow velocity were done. In the latest version of BOFFIN code with spray and combustion/ignition models was delivered by Imperial College London. Also a Kerosine-air mechanism has been incorporated in this version of BOFFIN.
Before LES computations concerning ignition process in combustion chamber were started various tests were performed in simplified geometry, where two cases were analyzed: 1) ignition of gaseous kerosene only; 2) ignition of the liquid fuel (kerosene). Results obtained and analysis of stability of the code pointed out necessary modifications which were introduced into the BOFFIN code. Among the others the source term corresponding to the spark and the source term resulting from evaporating fuel were implemented in the code. Next, the computations for 1-sector configuration started. Ignition process for three different spark positions were analysed in ground ignition conditions. Results obtained show ability of the LES-BOFFIN code to correctly model these very complicated phenomena.

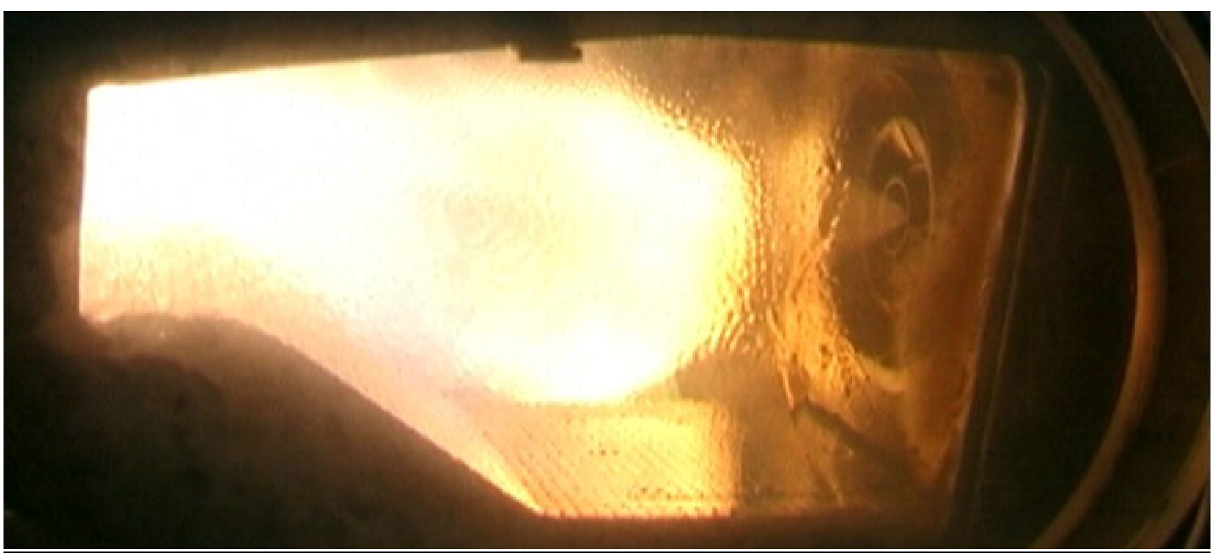


Results of a test case simulation with BOFFIN/LES

Two-phase flow computations in 3-sector configuration for ground ignition conditions were finished for both, RANS and LES using FLUENT. Computations with a spark ignition model in FLUENT were performed for simplified geometry and for single sector configuration. Results obtained with this model show that the flame extinguishes. The computations with BOFFIN code were delayed mainly because of problems with generation of 3-sectors mesh using ICEM CFD software. Many different meshes were prepared but none passed “quality test” implemented in BOFFIN code. Finally, the University of Czestochowa prepared the 3-sectors rotating the previously verified 1-sector mesh. Writing the mesh in BOFFIN format together with the input file for data exchange for parallel computations required preparation of an additional software. The computations concerning analysis of light across started. Because these computations are extremely time consuming they are still ongoing and were then finished by M60.

Lund University performed experiments observing ignition (pilot only) of the LP(P)4 injectors in the high pressure rig. The ignition process was observed by imaging chemiluminescent emission from the flame with a high-speed framing camera. For LP(P)4 a OH was also imaged in a planar arrangement using a multi-pulse dye laser system. Both conventional spark ignition and laser ignition were investigated. Two fuels were evaluated Jet-A1 and a Fischer-Tropsch-based jet fuel. The synthetic fuel required a longer ignition delay time before ignition occurred.

A clear advantage with the synthetic fuel there was the large reduction of soot deposition in the chamber compared to Jet-A1. The experiments showed that the ignition is a stochastic process dependent on e.g. local air/fuel ratio, local flow around the spark igniter, spark location and ignition method. Some common features can be identified between different ignition attempts where main features in dynamic pressure during ignition and in the high-speed camera pictures could be identified. The laser ignition tests shows that the technique is reliable and that the precise control of ignition time, ignition energy and position of ignition location can be advantages for fundamental ignition studies.



LNB1 flame after ignition and before light across

Three lean burner injector generations (e.g. LPX1, LPX2 and LN^{2}B) were tested (RRD) under simulated altitude conditions (25 and 30kft) in the sub-atmospheric relight–sector test rig (SARS). Ignition (light-up, light-across) and weak extinction experiments were performed using Jet-A1 Kerosene as fuel. It was found that the ignition and light across performance of the LPX2 configurations could not be improved relative to the LPX1 configuration.

The relight capability was limited to the low air speed domain where flame stabilization is not an issue. The LN^2B showed improved relight and weak extinction characteristics compared to LPX1 and LPX2, further improvements are regarded as possible.

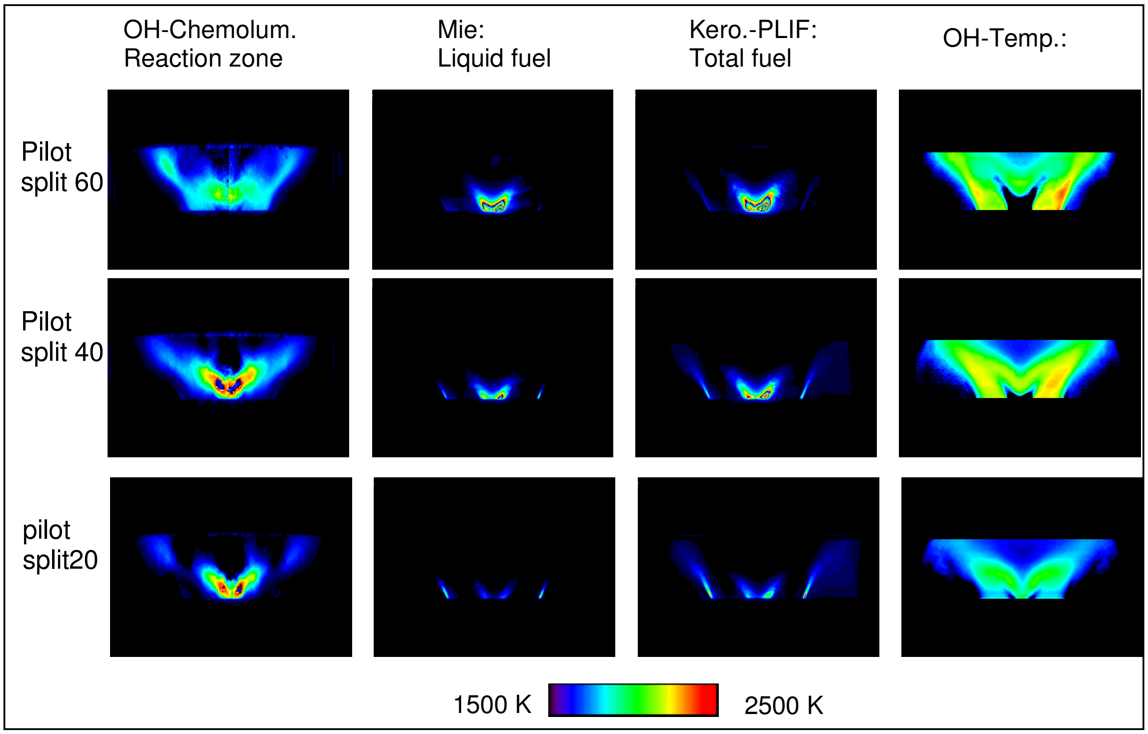
A full-annular test (FANN) has been carried out in the ILA University Stuttgart altitude relight test bed. Rolls-Royce Deutschland's single annular combustor was equipped with the RRD internally staged lean injector LN^2B. The test objectives have been to determine ignition and stability loops at three different combustor inlet pressures and temperatures representing different cruise altitudes and to determine ignition and stability at normal and cold day conditions.

The main results were that successful light-around was achieved at all test conditions with both igniters. The current test results translated into an engine windmill prediction indicate that the current combustor configuration would satisfy potential relight requirements, although the technology needs some more optimisation to show a stable result under all circumstances.

Work package 4: Stability and Extinction

The development of lean burn technology for single annular combustor architecture has been pursued. The emissions performance of the LP(P)5, the LPX1, the LPX2 and the LN^2B have been investigated. Two configurations of the LN^2B fuel injector have been investigated for their emission performance. The HPSS investigations were carried out applying an effusion cooled combustor liner, which was inserted in the test rig for the determination of realistic combustion efficiency. They feature V-shroud flame stabilisers for improved weak extinction capability, airfoil guide vanes for aerodynamic quality and effective area. The NOx emission performance demonstrated in the HPSS test rig was the best of all injectors investigated.
The C13 configuration achieved a NOx reduction of 77% (as measured) relative to the CAEP/2 emission certification standard. The C22 configuration achieved 74% NOx reduction. The cruise efficiency of 99.2% is lower than required.
For the first time ever a Fischer-Tropsch GTL has been investigated for its NOx performance and compared with emissions from conventional petroleum based Jet-A1 Kerosine. The investigated GTL contained special molecules.
In the context of the emissions results, it has to be noted that this fuel is just one example and is probably not representative for all GTL fuels available at the present time. It is recommended to gather more experience with the emissions performance of fully and semi-synthetic fuels in conjunction with lean burn modules.
However, the data which summarised the NOx performance, shows that the NOx emissions in terms of DP NOx,c / Foo increase by 18%. The cruise NOx is increased by 11%. Although there are virtually no aromatics in the GTL, the soot/particulate matter emissions seem to increase slightly for fuel staged conditions (i.e. +5% for cruise). For fuel rich pilot burner operation (e.g. 7% and 30% thust parameters) soot has been found to be 40 to 50% reduced compared to petroleum Jet-A1. The combustion efficiency of GTL at cruise was 0.2 %-points down compared to petroleum Jet-A1.

Computations for lean operating conditions using BOFFIN codev have been performed. The goal of these simulations was to investigate stability of the combustion for different AFR (Air to Fuel Ratio). The initial parameter of simulations (air mass flow/ fuel mass flow) corresponded to previously specified by RRD "idle conditions" with AFR=100. Next, decreasing the fuel mass flow the computations were for AFR=125, 150, 175, 200. Each case required preparation of different set of input files. Results obtained shows that the flame remains stable for very wide range of AFR, the length of the flame and the maximum temperature inside the combustion chamber decreases as the AFR increases.



Effect of fuel split variation at cruise condition (BOSS)

The test campaign in the BOSS optical single sector rig took place in November and December 2009. One full scale staged lean module by Rolls-Royce Deutschland with pressure swirl atomizer pilot and prefilmer main injector was tested using planar optical methods. The tests covered more than 30 test points, ranging from idle to simulated takeoff conditions. The corresponding pressure range was 5.7 bar to 12.9 bar.

Work package 5: Technology Assessment

The main objective of WP5 was to carry out an assessment of the technology improvements achieved within the physics-based work packages (WP3, WP4, WP6, WP7) with a view to formulating new design guidelines where possible. Considering the diversity of the combustion-related topics worked on within INTELLECT DM, WP5 aimed to collate the various contributions, highlight the progress made and identify remaining gaps.

According to plan, the assessment focused on three different topics: evaluation of progress with respect to

- state of the art of the emissions achievable with piloted lean burn design concepts,
- evaluation of progress made on the development of diffuser technology for lean burn and
- evaluation of effective calculation methods for cooling.

The delay affecting some of these deliverables simply reflected the need to wait for the physics-based tasks to complete before the assessment could be carried out.

Within INTELLECT DM, one of the key areas for development of combustion technology was the design and testing of piloted lean burn injectors. A number of different lean burn injectors have been developed by RRD, which allowed assessment of some key design features, like airblast vs pressure jet pilot, V-shaped flame holders and aerodynamically profiled swirler vanes.

The LPX1, LPX2 and LN2B injectors have been designed and then tested in a High Pressure Single Sector rig (TRL3). The assessment of the performance was based on NOx emissions corresponding to an ICAO LTO cycle as well as at cruise and allowed concluding that injector showing the best performance (LN2B) achieved 29.5% CAEP 2. This result has then put into perspective, by comparing the emissions to those of an optimised RQL as well as other lean burn concepts proposed by previous EU research programmes (e.g LowNOx III, LOPOCOTEP).

The comparison shows that the INTELLECT DM-developed LDI piloted lean burn Single Annular Combustor design offers a significant NOx reduction with respect to Double Annular Combustor solutions.

Furthermore, an initial assessment was carried out of the operability potentially achievable with this design concept, which suggested that no change to the current operating envelope would have to be invoked if lean burn was introduced in service. Of course, the development carried out in this research programme has been low TRL and a significant uncertainty affects the estimation of the performance deterioration likely to occur when moving to higher TRLs.

The different architecture of lean burn combustion systems also calls for development of novel external aerodynamic arrangements that have been thoroughly investigated within INTELLECT DM. Lean low NOx combustors call for a large percentage of the prediffuser efflux to enter the flametube through the fuel injector. As a result, flametube depth is usually larger in lean burn than in typical rich burn designs. Furthermore, the weight increase usually associated with lean burn systems emphasises the importance of minimising the length of the combustion system. An INTELLECT-DM integrated OGV prediffuser design (done by Loughborough and RR) driven by CFD has shown its potential for improved performance. Previous research has shown the beneficial effects of combustor blockage on prediffuser performance for rich burn systems. For lean burn systems characterised by as much as 70% of the prediffuser efflux going through the fuel injector the dump gap has to be integrated into the design to find an acceptable compromise between prediffuser performance and rotor forcing. An optimal dump gap range has been identified. Design guidelines have been derived and thoroughly assessed. From a modelling viewpoint, a relatively straightforward RANS approach has been shown to be able to drive the design in the right direction, even if accurate prediction of pressure losses is still a very challenging task.

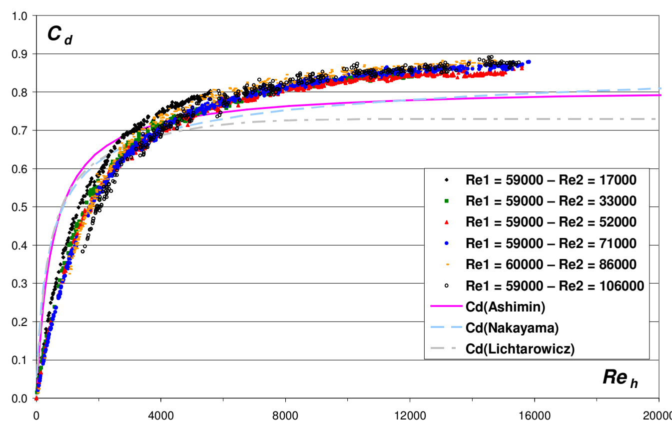
Due to the large amount of air required to achieve low NOx, lean burn combustor cooling flow has to be minimised. In order to do so, a combination of experiments and simulations can be used to analyse different designs. An assessment has been carried out by AVIO within WP5 on the methodologies for prediction of metal temperature. A comprehensive conjugate heat transfer approach has been proposed, which allows calculating metal temperature by accounting for radiation through a six-flux model and convection through an effusion cooling device via an effective heat transfer coefficient. The proposed method has been shown to offer a good trade off between accuracy and computational demand.

Work package 6: External Aerodynamics

All tasks in the Work Package have proceeded according to plan in this final year of the INTELLECT project. Only Task 6.1 has been operational. Deliverables (6.1.2 and 6.1.3) which were delayed slightly due to extra work being required in the extended optimisation methodology have now been completed. The work on the final Deliverable for WP6 (6.1.7), which was shifted to the last quarter of 2008 due to manufacturing delivery and availability of the experimental facility has now been completed. The analysis of the data and the writing of the report are planned to be complete and the Deliverable was submitted by M60.

Work package 7: Combustor Cooling Design

The assessment of combustor cooling aspects for lean burn systems is the key point of the activities carried out in this work package. The exploitation of results from other European projects has been done, as well as the validation of conjugate design procedure against experimental results and anisotropic CFD turbulence modelling implementation (University of Florence, SNECMA and CNRS).
The simulation of effusion cooling devices with RANS-CFD has been carried out by SNECMA. In the same Task CERFCAS developed and validated a LES based strategy to simulate an effusion cooling system in an isolated and controlled environment for a suitable generation of a numerical database from which models can be obtained to simulate such systems in real CFD-RANS solvers (experimental results were provided by Turbomeca).
The achievements are: the definition of a number of cooling devices, the evaluation of possible coupled solutions (impingement-pin fin, impingement- ribs), the evaluation of innovative effusion cooling geometries, the selection of innovative cooling devices for experimental studies (AVIO, University of Florence).
University of Florence exploited the modelling developed in previous European projects and selected an LPP combustor to be analysed for detailed heat flux evaluation by means of CFD. AVIO developed and validated a methodology for combustor wall temperature evaluation (conjugate heat transfer analysis) using a CFD in-house code. The experimental values used for validation have been taken from previous European projects.



Empirical correlations of the discharge coefficient in hot conditions

The reported achievements of Sub Task 7.3.3 are: two optimized cooling configuration manufactured by AVIO and the University of Florence (scale 1:5) and tested by means of TLC technique (impingement-ribs and effusion arrays samples). Another effusion array sample (shaped holes) was manufactured by AVIO and tested at CNRS. The measurements of discharge coefficient, adiabatic effectiveness and overall effectiveness of such devices is a very useful database for combustor applications. Finally a Monte Carlo radiation module to be linked to commercial CFD codes has been successfully developed and validated by the University of Karlsruhe, using RRD experimental results of an industrial combustion chamber.

The main results can be summarized as follows:
- development/improvement of CFD RANS/LES codes for wall temperature evaluation and
- great deal of experiments carried out to assess the best cooling configurations for lean-burn.

Following that new correlations design practises can be developed and used by industrial partners.

List of publications

A. Boguslawski, W. Elsner
The activity of Institute of Thermal Machinery Czestochowa University of Technology in the field of aeroengine research
International Conference Cooperation with the New EU Member States: Aeronautics Research, DLR, 15.05.2005, Berlin, Germany

A. Boguslawski, S.Drobniak, A.Tyliszczak
Application of LES and RANS-LES methods for modeling of flow and combustion in combustion chamber of aeroengines
Symposium on Hybrid RANS-LES Methods, 14.-15.07.2005 Stockholm, Sweden

S. Mendez, F. Nicoud, P. Miron
Direct and Large-Eddy Simulations of a Turbulent Flow with Effusion
DLES 2005, 12.-14.09.2005

S. Mendez, F. Nicoud, T. Poinsot
LARGE-EDDY SIMULATIONS OF A TURBULENT FLOWAROUND A MULTI-PERFORATED PLATE
Complex Effects in Large Eddy Simulation, Limassol, Cypress, 20.-24.09.2005

F. Duchaine, L.Y.M. Gicquel, D. Bissieres, C. Berat, T. Poinsoit
Automatic Design Optimization Applied to Lean Premixed Combustor Cooling
INCA Workshop 2005

N. Pegemanyfar, M. Pfitzner
ERSTELLUNG EINES PARAMETRISCHEN BRENNKAMMERMODELLS FÜR DIE AUTOMATISIERTE AUSLEGUNG VON FLUGZEUGTRIEBWERKSBRENNKAMMERN
DGLR Deutscher Luft- und Raumfahrtkongress 2005, Friedrichshafen, Germany, 26.-29.09.2005

A.D. Walker, J.F. Carrotte, J.J. McGuirk
ENHANCED EXTERNAL AERODYNAMIC PERFORMANCE OF A GENERIC COMBUSTOR USING AN INTEGRATED OGV/PRE-DIFFUSER DESIGN TECHNIQUE
ASME Turbo Expo 2005, Power for Land, Sea and Air, 08.-11.05.2006, Barcelona, Spain

N. Pegemanyfar, M. Pfitzner, R. von der Bank, R. Eggels, M. Zedda
DEVELOPMENT OF AN AUTOMATED PRELIMINARY COMBUSTION CHAMBER DESIGN TOOL
ASME Turbo Expo 2005, Power for Land, Sea and Air, 08.-11.05.2006, Barcelona, Spain

R. von der Bank, N. Savary, M. Linne, M. Zedda, J.J. McGuirk, G. Cinque
Integrated Lean Low Emission Combustor Design Methodology - Project Overview
5th Community Aeronautical Days, 19.-21.06.2006, Wien, Austria

O. Brunn, F. Wetzel, P. Habisreuther, N. Zarzalis
INVESTIGATION OF A COMBUSTOR USING A PRESUMED JPDF REACTION MODEL APPLYING RADIATIVE HEAT LOSS BY THE MONTE CARLO METHOD
ICAS 2006, International Council of the Aeronautical Sciences, 03.-08.09.2006, Hamburg, Germany

A. Andreini, J.L. Champion , B. Facchini, E. Mercier, M. Surace
ADVANCED LINER COOLING NUMERICAL ANALYSIS FOR LOW EMISSION COMBUSTORS
ICAS 2006, International Council of the Aeronautical Sciences, 03.-08.09.2006, Hamburg, Germany

N. Pegemanyfar, M. Pfitzner
DEVELOPMENT OF A COMBUSTION CHAMBER DESIGN METHODOLOGY AND AUTOMATION OF THE DESIGN PROCESS
ICAS 2006, International Council of the Aeronautical Sciences, 03.-08.09.2006, Hamburg, Germany

F. Duchaine, L. Y. M. Gicquel, T. Poinsot
OPTIMIZATION LOOP BASED ON A CFD RANS CODE
ICAS 2006, International Council of the Aeronautical Sciences, 03.-08.09.2006, Hamburg, Germany

F. Scheel, S. Gashi, C. Kaminski
STUDY OF FLAME RESPONSE TO SELF EXCITED AND FORCED ACOUSTIC PERTURBATIONS USING LASER DIAGNOSTICS
DGLR Deutscher Luft- und Raumfahrtkongress 2006, Braunschweig, Germany, 06.-09.11.2006

T. Otten, M. Plohr, R. von der Bank
GEGENÜBERSTELLUNG DES EMISSIONS-VERBESSERUNGSPOTENTIALS VON BRENNKAMMERTECHNOLOGIEN UND ANDEREN WEITERENTWICKLUNGEN AM LUFTTRANSPORTSYSTEM
DGLR Deutscher Luft- und Raumfahrtkongress 2006, Braunschweig, Germany, 06.-09.11.2006

P. Klotz, N. Bartoli, L. Cornez, M. Samuelides, P. Villedieu
Database enrichment for optimization with artificial neural networks
SMSMEO-2006, SURROGATE MODELLING AND SPACE MAPPING FOR ENGINEERING OPTIMIZATION, TU Denmark November 9-11, 2006

S. Mendez, J. Eldredge, F. Nicoud, T. Poinsot, M. Shoeybi, G. Iaccarino
Numerical investigation and preliminary modeling of a turbulent flow over a multi-perforated plate
Center for Turbulence Research Proceedings of the Summer Program 2006

F. Scheel, S. Gashi, C. Kaminski, A. Dowling
Investigation of Self Excited and Acoustically Forced Combustion Instabilities with Laser Diagnostics
45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, USA, 08.-11.01.2007

H. Seyfried, C. Brackmann, A. Lindholm, M. Linne, M. Alden, F. Barreras, R. von der Bank
Optical Investigations of the Combustion Characteristics of a Gas Turbine Pilot Burner
45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, USA, 08.-11.01.2007

S. Mendez, F. Nicoud
Numerical investigation of an anisothermal turbulent flow with effusion
Conference on Turbulent Shear Flow Phenomena, 2007, Munich, Germany

R. von der Bank, T. Otten, M. Plohr (presentation)
Evaluation of technological progress in NOx reduction relative to the state of the art
ELECT-AE Mid-Term-Meeting, 25/26 January 2007, DLR-Office Brussels

P. Klotz, N. Bartoli, L.Cornez, P. Villedieu and M. Samuelides
Database enrichment for multi-objective optimization
42 eme colloque d'aerodynamique appliquee. Couplage et optimisation multidisciplinaire. Nice, les 19,20 et 21 mars 2007

N. Pegemanyfar, M. Pfitzner, M. Surace
AUTOMATED CFD ANALYSIS WITHIN THE PRELIMINARY COMBUSTOR DESIGN SYSTEM PRECODES UTILIZING IMPROVED COOLING MODELS
ASME Turbo Expo 2007, Power for Land, Sea and Air, 14.-17.05.2007, Montreal, Canada

A.D. Walker, J.F. Carrotte, J.J. McGuirk
COMPRESSOR-DIFFUSER-COMBUSTOR AERODYNAMIC INTERACTIONS IN LEAN MODULE COMBUSTORS
ASME Turbo Expo 2007, Power for Land, Sea and Air, 14.-17.05.2007, Montreal, Canada

M. Bini, W.P. Jones
Particle acceleration in turbulent flows: a class of non-linear stochastic models for intermittency
Physics of Fluids, 2007, Vol.19, ISSN 1070-6631

Schavan, A. (Editor, EC publication)
Success Through Research – Germany's Contribution to European Research Projects (INTELLECT D.M.)
CORDIS Focus – Thematic Supplement, iss. 24, June 2007, EU Publications Office, Luxemburg

R. von der Bank (presentation)
Alternative Fuels in Lean Burn Combustion - Perspective 2020
2nd RTD Strategy Workshop, ELECT-AE, ONERA-Toulouse, 6 September 2007, Toulouse

O. Brunn, P. Habisreuther, N. Zarzalis
Numerische Berechnung der Wärmebelastung von Brennkammerwänden unter Berücksichtigung von Russ- und Gasstrahlung
23. Deutscher Flammentag, VDI-GET, TU-Berlin, 12/13 September 2007, Berlin

R. von der Bank, N. Savary, M. Alden, M. Zedda, J. McGuirk, G. Cinque
On the development of combustion systems and their design methodologies for the reduction of pollutant emissions from aero-engines
DGLR-CEAS2007-398498, Deutscher Luft- und Raumfahrtkongress DGLR 2007
European Air and Space Conference CEAS 2007, 10-13 September 2007, Berlin, Germany

S. Mendez, F. Nicoud
An adiabatic model for the flow around a multi-perforated plate
AIAA Journal Publication (submitted)

A.D. Walker, J.F. Carrotte, J.J. McGuirk
THE INFLUENCE OF DUMP GAP ON EXTERNAL COMBUSTOR AERODYNAMICS AT HIGH FUEL INJECTOR FLOW RATES
ASME Turbo Expo 2008: Power for Land, Sea and Air, June 9-13, 2008, Berlin, Germany, GT2008-50271

N. Pegemanyfar, M. Pfitzner
STATE-OF-THE-ART COMBUSTOR DESIGN UTILIZING THE PRELIMINARY COMBUSTOR DESIGN SYSTEM PRECODES
ASME Turbo Expo 2008: Power for Land, Sea and Air, June 9-13, 2008, Berlin, Germany, GT2008-50577

A. Andreini, M.Cerutti,B. Facchini, L. Mangani
MODELING OF TURBULENT COMBUSTION AND RADIATIVE HEAT TRANSFER IN A OBJECT-ORIENTED CFD CODE FOR GAS TURBINE
ASME Turbo Expo 2008: Power for Land, Sea and Air, June 9-13, 2008, Berlin, Germany, GT2008-51117

N. Pegemanyfar, R. von der Bank, M. Zedda, M. Pfitzner, N. Savary (presentation)
Design methodologies and CFD methods for the development of low emission combustion systems in aero-engines
8th World Congress on Computational Mechanics (WCCM8), June 30 – July 5, 2008, Venice, Italy
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)

P. Klotz, N. Bartoli and R. Lecourt
LPP optimization using response surface method
Second colloque INCA, CORIA - UMR 6614, Rouen, France 23-24 Octobre 2008

Andreini, C. Bianchini, A. Ceccherini, B. Facchini, L. Mangani, G.Cinque and S.Colantuoni
INVESTIGATION OF CIRCULAR AND SHAPED EFFUSION COOLING ARRAYS FOR COMBUSTOR LINER APPLICATION - PART 2: NUMERICAL ANALYSIS
ASME TURBO EXPO 2009: Power for Land, Sea & Air, June, 8-12, 2009, Orlando, Florida, USA, GT2009-60038

L. Toni
Gas Turbine Aero-Engines effusion cooling systems
Ph. D. Thesis, Università degli Studi di Firenze, Dipartimento di Energetica, 2009

R. von der Bank
EU-Forschungsprojekt INTELLECT D.M. erfolgreich abgeschlossen
FanPost, January / February 2009, vol. 80, p.11, Rolls-Royce Deutschland