SUMMARIES:

Pablo SALAS: Modern pollutant emission regulation has led to the use of lean premixed combustion in gas turbine combustors, a technology which is prone to develop thermoacoustic instabilities. This phenomenon is the result of a resonant feedback between combustion, acoustic waves and flow dynamics in confined combustion chambers. In this work, combustion instabilities are studied using a Helmholtz equation with a reactive term that takes into account the coupling between combustion and acoustics. The discretization of the resulting Helmholtz equation on unstructured meshes leads to a large sparse non-symmetric complex nonlinear eigenvalue problem of size N (N is equal to the number of nodes in the mesh), whose solution provides the frequencies and growth rates (complex eigenvalues) and the structure (eigenvectors) of the resonant modes of the combustor. Since dangerous combustion instabilities occur mostly at low frequencies, the nonlinear eigenvalue problem must be solved in order to obtain the smallest magnitude eigenvalues.The nonlinear problem is linearized using a fixed point iteration procedure. This leads to a sequence of linear eigenproblems which must be solved iteratively in order to obtain one nonlinear eigenpair. Therefore, efficient and robust parallel eigensolvers for the solution of linear problems are investigated, and strategies to accelerate the solution of the sequence of linear eigenproblems are also proposed. In modern gas turbines with annular combustors,the most dangerous resonant modes often take the form of azimuthal waves, making their study of first importance. This work focuses on azimuthal modes in annular combustors: their stability and nature (standing, spinning or mixed) are investigated as a function of the symmetry of the configuration. Thanks to the efficiency of the algorithms for the solution of the thermoacoustic eigenproblem, the 3D Helmholtz solver AVSP is used for the study of thermoacoustic instabilities of an annular industrial combustor.

Emmanuel MOTHEAU: Virtually all combustion chambers are subject to instabilities. Consequently there is a need to better understand them so as to control them. A possibility is to simulate the reactive flow within a combustor with the Large-Eddy Simulation (LES) method. However LES results come at a tremendous computational cost. Another route is to reduce the complexity of the problem to a simple thermoacoustic Helmholtz wave equation, which can be solved in the frequency domain as an eigenvalue problem. The coupling between the flame and the acoustic is then taken into account via proper models. The main drawback of this latter methodology is that it relies under the zero-Mach number assumption. Hence all phenomena inherent to mean flow effects are neglected. The present thesis aims to provide a novel strategy to introduce back some mean flow effects within the zero-Mach number framework. In a first part, the proper way to impose high-speed elements such as a turbine is investigated. The second part focuses on the coupling between acoustics and temperature heterogeneities that are naturally generated at the flame and convected downstream by the flow. Such phenomenon is important because it is responsible for indirect combustion noise that may drive a thermoacoustic instability. A Delayed Entropy Coupled Boundary Condition (DECBC) is then derived in order to account for this latter mechanism in the framework of a Helmholtz solver where the baseline flow is assumed at rest. In the last part, a realistic aero-engine combustor that feature a mixed acoustic/entropy instability is studied. The benefit of the methodology developed in the present thesis is tested and compared to LES computations. It is shown that computations with the Helmholtz solver can reproduce a complex combustion instability, and that this latter methodology is a potential tool to design new combustors so as to predict and avoid combustion instabilities.

Ignacio DURAN: Combustion noise is increasing its relative contribution to aircraft noise as other sources are being reduced and new low-NOx emissions combustion chambers are built. Two mechanisms are responsible for this noise source: direct noise in which acoustic waves are generated by the flame and propagate to the outlet of the aero-engine, and indirect noise, where entropy waves generate noise as they are accelerated and decelerated in the turbine stages. In this work the analytical models used for the propagation of waves through non-homogeneous flows, including the generation of indirect noise, are revised and extended. First, the quasi-1D case is studied, extending the analytical method to non-zero frequencies and validating the results with numerical methods and experimental data. In the second part the 2D method for the case of compact turbine blades is studied and validated using numerical simulations of a rotating blade and of a complete turbine stage. Finally, these models are combined with reactive and compressible large eddy simulations of combustion chambers to build a hybrid approach, called CHORUS, able to predict combustion noise.