Liquid fuels are commonly used in all types of engines (cars, planes, ships) and industrial devices (cauldrons, burners, combustion chambers, etc.) and therefore their usage constitutes a very important field of research both in academia and in industrial research institutions. Currently, the computational models (i.e. mathematical descriptions based on formulas and equations) used for simulation of combustion in gasoline and diesel engines and for gas turbines are often limited due to the approximate nature by which they include key physics of analysed phenomena. Analysis of the literature shows that this is particularly true for the ignition and flame extinction phenomena. The former is very important for aviation safety (jet engine relight at high altitude), for an industrial highly-efficient use of natural fuels (in reciprocating natural gas engines, for instance), and for achieving low emissions in diesel engines based on auto-ignition. The phenomenon of flame extinction is important for down-sized reciprocating engines and for low-emissions gas turbines.

The objective of this project is to analyse strongly unsteady phenomena in turbulent reacting two-phase (gas-liquid) flows. The project focuses on forced ignition (spark), auto-ignition, and extinction in sprays, phenomena that due to their insufficient understanding, are now limiting the establishment of low-emissions and safe industrial devices. Particular attention will be devoted to the flame generation and its propagation that are crucial from the point of view of reliability, environmental cleanliness and efficiency.

The two-phase combustion process involves the interactions between a turbulent gaseous flow field and liquid fuels additionally complemented by chemical reactions, therefore involving many non-linear processes such as chemical kinetics, turbulence, and phase change. Experimental analysis of these processes even though possible is extremely difficult and expensive, as it requires very sophisticated experimental apparatus. On the other hand there is a common belief that nowadays computers and available numerical tools enable modelling of these phenomena at reasonable time with acceptable accuracy. The research within this project will be based on applications of DNS (Direct Numerical Simulation) and LES (Large Eddy Simulation) methods combined with CMC (Conditional Moment Closure) and Eulerian PDF (Probability Density Function) models, which have been shown in the past to be the best candidates for capturing the difficult non-linear interactions between chemical kinetics, turbulence, and phase change. At present, DNS is used mainly in fundamental research while LES is being increasingly used in R&D across a very wide range of industries.

Because of large complexity of strongly unsteady ignition and flame development processes, numerous important questions still remain unanswered. Detailed numerical simulation methods with advanced combustion models will enable very deep insight into the physics of these phenomena. The key outcome of the project will be a better understanding of ignition phenomenon that was hidden so far, partially due to limited computer resources and lack of highly accurate numerical tools. The specific objectives of the present project are the following:

- to develop deeper physical knowledge on the processes associated with flame initiation and flame extinction, phenomena that are critical for the development of novel, efficient, and clean fuel use.
- to verify and develop turbulent two-phase reacting flow closures for the above processes, so that engineers have increased predictive capability and therefore produce innovative designs at lower cost than at present.