Case Study Template

1. Title of Case Study:

High-fidelity computational methods for development of advanced ignition technology.

2. Grant Reference Number:

EP/K024876/1 (UKCTRF computing time) & EP/L002698/1 (Staff time).

3. One sentence summary:

Clean transport and energy solutions depend on elimination of harmful emissions from combustion: this project develops advanced computational methods necessary for development of advanced ignition processes required for these applications.

4. One paragraph summary:

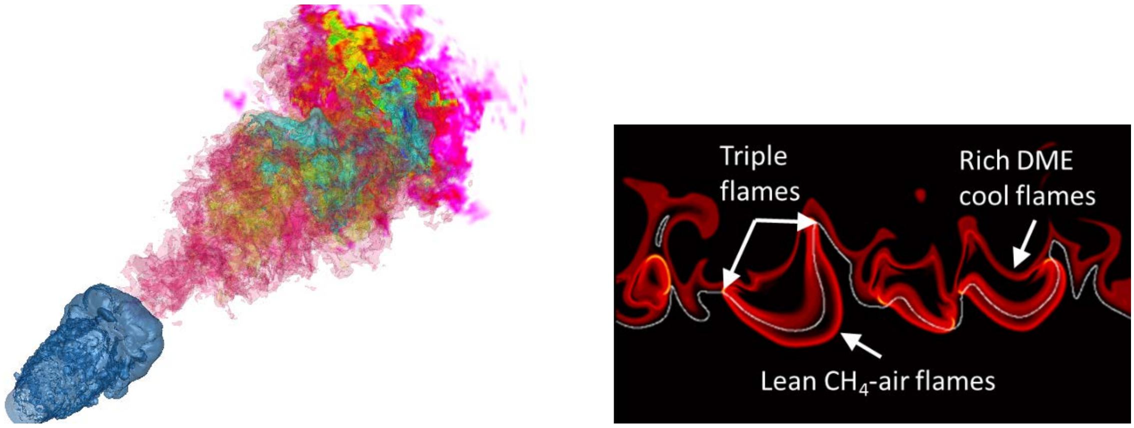
Advanced computational engineering methods have been developed to support development of propulsion and power systems exploiting novel ignition techniques. The research uses the UK's supercomputing capabilities to generate high-fidelity 'experimental' data that cannot yet be measured in the laboratory, and uses these data as the basis for rigorous development and validation of accurate but computationally-inexpensive engineering design tools. The engineering design tools and associated theory provide industry with insight into how different ignition concepts behave in their systems, and reliable predictions for how proposed technologies will perform – reducing the cost and time taken for development of next generation energy technology.

5. Key outputs in bullet points:

- User-friendly method for estimating the flow speed, residence time and concentration during unsteady fuel-injection.
- Advanced software for modelling chemical processes in unsteady fuel-injection.
- Benchmark simulation data for testing engineering models
- New collaborations across three academic institutions of the UK Consortium on Turbulent Reacting Flow, the University of Melbourne in Australia, and a leading UK Engine Technology business.
- Project participants have graduated into high-value computational engineering and into tenure-track academic roles, building directly on the expertise developed in this project.

6. Main body text

Pulsed fuel injection: Modern fuel injection systems are capable of delivering upwards of 8 distinct fuel pulses for each combustion event. This offers designers many degrees of freedom, however the mixing and fluid dynamics arising in pulsed jets are not well understood. Ignition of fuel is influenced by mixing rates and residence times. This project has provided a benchmark set of validation data for study of unsteady fluid injection, such as for the configuration shown in Fig. 1a involving interaction between two consecutive injection events. The data have served as a basis for developing robust theory that enables prediction of fluid concentrations and residence time during pulsed fuel injection using a very simple and insightful model [Shin, Sandberg, Richardson, Journal of Fluid Mechanics (2017), Shin Aspden, Richardson, Journal of Fluid Mechanics (2017)].



(a) (b)

Figure 1: (a) Volume rendering of jet fluid mass fraction from two consecutive injection pulses (first pulse shaded red-green, second pulse shaded blue). (b) Instantaneous heat release colour map from Direct Numerical Simulation of lean methane-air flame ignited by injection of the bio-derived diesel-substitute, dimethyl-ether.

Dual fuel pilot ignition: Modelling for pilot-ignited dual fuel combustion has been developed, using the national supercomputer to conduct highly-detailed simulations that provide an exact evaluation of the impact of alternative modelling choices. A simulation involving ignition of a fuel-lean methane-air mixture by pilot-injection of bio-derived diesel substitute dimethyl-ether (DME) is illustrated in Fig. 1b.

7. Names of key academics and any collaborators:

Dr. D-H Shin, University of Edinburgh, UK; Dr. Andrew Aspden, University of Newcastle, UK; Prof. Richard Sandberg, University of Melbourne, AUS; Dr. Edward Richardson, Dr. Tomas Matheson, Dr. Nabil Meah, Mr. Mark Picciani, Mr Bruno Soriano, current/former University of Southampton

8. Sources of significant sponsorship (if applicable): *EPSRC*

9. Who should we contact for more information?

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10. Please indicate if you would like this case study to be included on the Consortium's ARCHER web-page. Yes