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Gas-Turbine Combustion using Hydrogen Enriched Fuels

- Gas turbines are one of the world’s most important sources of industrial and domestic power, they are also the driving force behind aviation.
- Currently hydrocarbon fuels dominate since they are safe and well understood.
- Alternative fuels are an increasing issue and Hydrogen is one of the most important.
- Hydrogen offers large reductions in CO_2 and the elimination of CO and UHCs. Low NOx technologies are applicable to H_2 to minimise NOx emissions.

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Hydrogen Enriched Fuels - a First Logical Step

- Complete re-design of current machines may not be desirable and, in any case, may delay the adoption of H_2 fuels.
- Pure H_2 presents several problems for flame stability due to its very high flame speed when premixed, and its high temperatures when non-premixed.
- Tailoring a fuel of hydrogen-hydrocarbon allows for a more progressive transition of fuels while still affecting a reduction in carbon dioxide emissions.
- Tailored fuels may assist the operation of combustors near their lean limit and encourage the use of biomass fuels.

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Technical Challenges for Hydrogen Enriched Fuels

- The behaviour of multi-component fuels is a complex issue for both the mixing and the combustion cycles.
- Whilst the behaviour of both hydrogen and hydrocarbon flames is relatively well understood, from fundamental to applied configurations, multi-component fuel mixtures require a great deal of fundamental investigation before being applied.
- This proposal is an effective way to gain this knowledge through a joint program of kinetics, modelling and supporting experimental work.

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Technical Programme Summary

- This programme will demonstrate an effective way to gain the essential basic knowledge through a joint program of kinetics, modelling and supporting experimental work.
- The program will develop a fundamental understanding of hydrogen mixtures, progressively apply it to more applied geometries and finally apply it in realistic gas turbine systems.
- The activity will comprise of two stand-alone programmes (1 EU and 1 US) which can interlock to maximise mutual benefit.

Programme Partners & Roles

- **The EC project would have 3 main elements:**
- Kinetics managed by *Warnatz*, Heidelberg,
- Modelling managed by *Janicka*, Darmstadt
- Diagnostic Experiments managed by *Hutchinson, & Greenhalgh,* Cranfield.

- **The US project:**
- Complementary activities on all three fields above managed by *Gallagher & Keller*, CRF, Sandia National Labs., Livermore US.

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Key Technical Aspects

- **Kinetics** (building on experience from past EC projects)**:**
- *Automatic reaction generation (LISP) and mechanism reduction, ignition & extinction modelling, coupling to flow through pdf modelling.*
- **Modelling:**
- *LES modelling with specific SGS combustion sub-grid model development.*
- **Experiments:**
- *Validation experiments for SGS model development and model validation (e.g. scalar dissipation and differential diffusion effects).*
- *Progressive validation data from more realistic geometries.*

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Advantages of Combustion-LES

- The sub-grid-scale (SGS) model improves with finer grids. Thus, a good balance can be achieved between computational effort and accuracy of results
- LES has the potential to correctly describe unsteady phenomena. This becomes important for gas-turbine combustors where thermo-acoustic instabilities need to be resolved.
- The classical problem of LES (description of wall effects) becomes irrelevant here since in Combustion-LES, all important aspects are bound to regions off the walls (reaction, heat release, pollutant formation, radiative heat loss).
- Although combustion happens within the sub-grid and still has to be modelled, it can be described much more accurately because sub-grid fluctuations are small (30% of those in RANS) and unsteady information is available.

Simultaneous Imaging of fuel, T & OH

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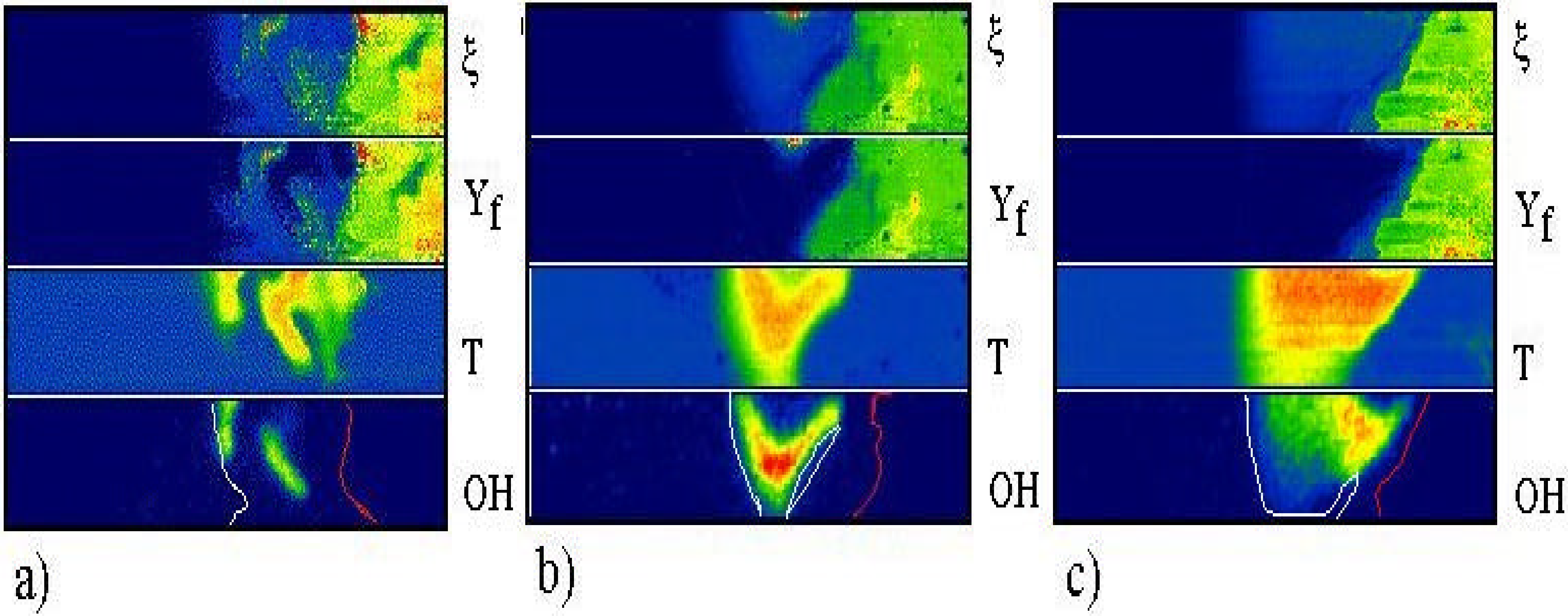

3 instantaneous series of images (a-c) of mixture fraction (?, black-red, 0-0.3), fuel mass fraction (black-red, 0-0.3), temperature (black-red, 0-2200K) and OH concentration (black-red, 0-6.9E+16 molecules/cc) in a lifted turbulent methane diffusion flame. Lean reactive limit: (? = 0.02) white, rich reactive limit: (? = 0.12), red