SUMMARY

Fourteenth Workshop on Measurement and Computation of Turbulent Flames (TNF14)

July 27-28, Dublin, Ireland

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INTRODUCTION

The objective of the TNF Workshop series is to provide a framework for collaborative experimental and computational research on fundamental aspects of turbulent combustion. The emphasis has been on measurement, DNS, and modeling of turbulence-chemistry interactions in flames that are relatively simple in terms of both chemistry and flow geometry. The workshop series was initiated in 1996 to address validation of RANS based models for turbulent nonpremixed jet flames. Although the TNF acronym has been retained, the word *nonpremixed* has been dropped from the title, and our scope has expanded over the past decade to address three challenges:

- Development and evaluation of modeling approaches that are accurate over a broad range of combustion modes and regimes (nonpremixed, partially-premixed, stratified, and fully premixed).
- Extension to more complex fuels (beyond CH_4) and fuel mixtures that are of practical interest.
- Establishment of a more complete framework for verification and validation of combustion LES, including quality assessment of calculations, as well as development of approaches for quantitative comparisons of multidimensional and time-resolved data from experiments and simulations.

Additionally, there has been increasing activity in the areas of flame-wall interaction (FWI) and combustion at elevated pressure. Our overall goal is to accelerate the development of advanced combustion models that are soundly based in fundamental science, rigorously tested against experiments and DNS, and capable of predicting flame behavior over a wide range of conditions.

One of the most useful functions of this workshop series has been to provide a framework for collaborative comparisons of measured and modeled results. Such comparisons are most informative when multiple modeling approaches are represented and when there has been early communication and cooperation regarding how the calculations should be carried out, particularly in the treatment of boundary conditions, and what results should be compared. Experience has shown that comparisons on new target flames can generate significant new insights, but also many new questions. These questions motivate further research, both computational and experimental, and subsequent rounds of model comparisons. Another important function of the workshop series is to provide overviews of new work on established target cases, as well as new burner configurations and emerging topics that are relevant to our overall goals and have potential to attract a critical mass of people interested in collaboratively investigating the new burner or topic.

Previous workshops were held in Naples, Italy (1996), Heppenheim, Germany (1997), Boulder, Colorado (1998), Darmstadt, Germany (1999), Delft, The Netherlands (2000), Sapporo, Japan (2002), Chicago, Illinois (2004), Heidelberg, Germany (2006), Montreal, Canada (2008), Beijing, China (2010), Darmstadt, Germany (2012), Pleasanton, California (2014), and Seoul, Korea (2016). Proceedings and summaries of all the workshops are available at tnfworkshop.org.

TNF14 engaged 98 registered participants from 16 countries. Additionally, with help from local organizers in Dublin, five satellite workshops of the International Symposium on Combustion were held at the Trinity College Conference Center. This allowed for combined sessions with the Premixed Turbulent Flames (PTF) Workshop and with the International Sooting Flames (ISF) Workshop on topics of mutual interest. Coordination among the organizers allowed researchers to participate in multiple workshops with minimal inconvenience.

The main TNF14 sessions addressed:

- Sydney Compositionally Inhomogeneous Flames
- Update on Cambridge Swirl Flames
- Modeling of CO in Turbulent Flames
- Highly Turbulent Premixed Flames (Joint PTF/TNF Session)
- Progress of Turbulent Sooting Flames (Joint ISF/TNF Session)
- Enclosed Flames and Flames at Elevated Pressure
- Flame-Wall Interaction
- Multi-mode Combustion

The complete TNF14 Proceedings are available for download in pdf format from tnfworkshop.org. The pdf file includes the list of participants, workshop agenda, summary abstracts of the technical sessions, presentation slides, and two-page abstracts of 30 contributed posters.

The move to this new web site follows termination of support for turbulent combustion research at Sandia by the U.S. Department of Energy, Office of Basic Energy Sciences. Most of the content from the old site has been moved, and we look forward to an easier process of adding content in the future.

TNF14 ORGANIZING COMMITTEE

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PLANNING

The 2020 TNF Workshop will be held in Adelaide, Australia prior to the 38th Combustion Symposium. It is likely that the schedules of the TNF, ISF, and PTF Workshops will again overlap on the Friday and Saturday before the Symposium, and it is expected that organizers will coordinate to make the combined event as informative and productive as possible.

HIGHLIGHTS OF PRESENTATIONS AND DISCUSSIONS

The sections that follow were condensed from session summaries in the full proceedings. Comments and conclusions given here are based on the perspectives of the authors and do not necessarily represent consensus opinions of the workshop participants. This summary does not attempt to address all topics discussed at the workshop or to define all the terms, acronyms, or references. Readers are encouraged to consult the complete TNF14 Proceedings and also the Proceedings of previous TNF Workshops, because each workshop builds upon what has been done before.

Sydney Compositionally Inhomogeneous Flames

Coordinators: Benoît Fiorina and Michael Mueller

The objective of this session was to compare recent simulations of the Sydney compositionally inhomogeneous piloted flames and survey progress since the last Workshop. Some key points are as follows: 1) An update on the experimental measurements was presented, including a comparison of previous datasets as well as new measurements at the University of Sydney for non-reacting flows made to directly address a number of modeling issues identified at the last Workshop associated with predictions of the mixture fraction field. 2) Analysis by the Princeton group revealed that the behavior of the pilot-coflow shear layer is very different for "cold" and "hot" configurations. All LES contributions underpredicted the breakdown of this shear layer in the reacting configuration. The influence of the predicted stability of the pilot-coflow shear layer on the variance between the computations and discrepancies with the experimental measurements for the mixture fraction remains an open question. 3) Analysis of the flame structure computed by all groups reveals difficulty in predicting the temperature field, especially downstream of the pilot-coflow shear layer. Identification of the cause of the discrepancies through a standard comparison between computed and measured scalar radial profiles is difficult. Post processing to compute the Wasserstein metric showed consistency among simulation results, and this approach should be further explored. 4) Some convergence among simulations compared to TNF13 is apparent, but difference between simulations and experiments remain. The next effort on this configuration should focus on analyzing existing results with the objective of writing a joint paper.

Update on Cambridge Swirl Flames

Coordinators: Benoît Fiorina, Andreas Kempf and Eray Inanc

The main objective of this session was to present new simulation results for the stratified swirl flames investigated at Cambridge and Sandia, with particular attention to CO modeling. New simulation results on the non-stratified, non-swirled SwB1 case were also compared with recently published flame-resolve simulations. For the swirled cases, five international groups contributed results based on their own established techniques. The results showed that the CO predictions in the swirled case are problematic close to the burner, unlike for the non-swirled variant. The Duisburg group demonstrated that the almost laminar flow in the large recirculation zone (RZ) in the swirl cases required a larger computational domain and longer run-time than for the non-swirled case. All groups applied adiabatic combustion models. While there is an effect of heat loss close to the bluff body surface, as demonstrated at TNF13 by the Paris group, the contributing groups showed that the main thermochemical properties of the fluid after three inner tube diameters were in good agreement when using an adiabatic solver. Generally, the computed Reynolds-averaged mean major quantities, such as momentum, equivalence ratio, temperature and mass fractions of CH_4, O_2, and CO_2, agreed well with the measurements slightly further downstream, whereas the spread angle of the swirled jet was under-predicted. Most of the deviations, however, occurred close to the bluff-body. Contributors came to the conclusion that the resolution and the settlement time of the RZ could cause these deviations. CO and H_2 mass fractions were over-estimated close to the burner. The closest agreement was obtained by a Monte-Carlo FDF method. The Duisburg-group also presented results using an ATF/FGM model with the same boundary conditions and computational grid, but the computationally more expensive Monte-Carlo technique provided a better agreement for most quantities. Larger deviations were observed for the stratified cases SwB7 and SwB11. However, results suggest that stratification can be predicted acceptably well by using FGM.

Modeling of CO in Turbulent Flames

Coordinators: Andreas Kempf and Benoit Fiorina

This session focused on issues related to prediction of CO in LES of turbulent flames. By comparison with the temperature or major species mass fractions, the CO prediction is more sensitive to the modeling of detailed combustion chemistry and subgrid scale flame wrinkling, due to the wide range of time scales in CO chemistry. CO formation/consumption is sensitive to three physical phenomena: i) the flame enthalpy (or heat losses); ii) the flame regimes (premixed, non-premixed, stratified, etc.); and iii) the subgrid scale flame wrinkling. Three target cases were selected to establish the state-of-the-art: Preccinsta combustion chamber (stable, $\phi = 0.83$); Cambridge swirl flame (SwB3); and Sydney inhomogeneous flames (Lr75-57 and Lr75-80). After a brief review of experimental issues, modeling challenges to CO prediction in turbulent flames were discussed, and then results from the target cases were presented and analyzed.

Comparison between numerical and experimental data for the Preccinsta combustor showed that temperature is well captured by non-adiabatic simulations, unlike adiabatic computations that over predict temperature in the near wall region. Heat losses have a strong impact on the CO formation, such that adiabatic simulations strongly overestimate measured profiles. A strong effect of the mesh refinement is also observed. This behavior is attributed to the lack of modeling of the impact of subgrid scale flame wrinkling on the CO mass fraction.

Simulations of the Cambridge SwB3 flame show significant variation in the mean CO profiles. In particular, the overestimation of the CO production by the Thickened Flame model for LES is evident. Simulations conducted using a filtered wrinkled flamelet table show that accounting for the impact of subgrid scale flame wrinkling on filtered species improves the CO prediction.

Discussion on the Sydney piloted inhomogeneous jet flames highlighted difficulties in predicting the mixing and temperature fields, especially downstream of the pilot-coflow shear layer. It is therefore difficult to draw clear conclusions on the origins of the CO deviation. However, the results appear sensitive to the flame regime assumption made to tabulate the chemistry. In particular, premixed flamelet based models tends to overestimate the CO profiles, whereas tabulation based on non-premixed flame archetype are more adapted to this jet flame configuration.

Highly Turbulent Premixed Flames (Joint PTF/TNF Session)

Coordinators: Adam Steinberg, Peter Hamlington, Luc Vervisch, Matthias Ihme, Evatt Hawkes, Jeff Sutton

This joint session was presented in three parts. The first provided an overview of recent observations made through experiments and DNS regarding the structure and dynamics of highly turbulent premixed flames. The second covered methods and issues in modeling of such flames. The third dealt with needs for further improvements in simulations and experiments to address knowledge gaps.

Observations on structure and dynamics (Steinberg, Hamlington):

Experiments in high Karlovitz number flames have primarily involved multi-dimensional imaging (PLIF, Rayleigh, PIV). The most prevalent configurations have been atmospheric-pressure methane/air jet- or Bunsen-flames issuing into a large coflow of combustion products. Imaging experiments consistently show broadened preheat zones (CH_2O), but results on the transition to broadened reaction zones has not been fully consistent. Discrepancies may be due to different definitions of Karlovitz number, the influence of geometry, or effects of mixing between main reactants and the hot coflow. Both DNS and experiments have shown significant stratification at the reaction zone in high-Ka flames having large differences in jet and coflow equivalence ratio.

The influence of combustion on turbulence has been a key area of interest, which has primarily been studied through DNS of isotropically forced turbulence. The flame influences the structure of the turbulence by suppressing small scales through increased temperature/viscosity, and by enhancing large scales through pressure-dilatation effects. The flame also induces anisotropy in the direction of the flame normal and changes the alignment of vorticity and strain rate. Both of these effects diminish with increasing Karlovitz number. Backscatter – viz. net up-scale transfer of kinetic energy – has been observed in DNS through analyses in physical space, Fourier space, and wavelet space. This process can lead to energization of large scale turbulent motions in some DNS.

Perspectives on modeling
(Vervisch) In the practice of real burners, it was discussed how high Karlovitz combustion actually goes with a drastic reduction of the Damköhler number. Two routes were examined to support the existence of low Damköhler combustion. First, the discrepancy between the enhancement in overall burning rate and the enhancement in flame surface area measured for high-intensity turbulence has been reported in the context of scaling laws for diffusivity enhancement from eddies smaller than the flamelet thickness. The factor quantifying this discrepancy is formalized as a closed-form function of the Karlovitz number. Second, basic scaling laws were presented which suggest that the overall decrease of the burning rate due to very fast mixing can be compensated by the energy brought to the reaction zone by burnt gases. The results confirm the possibility of reaching, with the help of a vitiated mixture, very high Karlovitz combustion before quenching occurs.

(Ihme) Three aspects were considered. First, a Lagrangian flamelet analysis was performed on three canonical DNS cases to identify whether these high-Ka flames retain an inherent flamelet character. This analysis showed the presence of an intact but weakened inner core flamelet structure that is well represented by 1D elongated flame-elements. Entrainment of hot combustion products by turbulent transport leads to mixing of the unburned reactants that can be well represented by a partially premixed reactor. Since the flame-structure and burning intensity is controlled by the upstream reactant mixture, it is unlikely that unstrained premixed flamelet methods are able to describe such flame regimes without taking into account the reactant mixing at the subgrid. Second, LES modeling efforts on vitiated flames were reviewed. It was concluded that current combustion models capture the main features of turbulent flame-structure at moderate Ka-regimes; in general, models were found to over predict the reactivity at higher Ka; and extensions of flamelet models show promise but lack key-physical aspects. Third, potential merits of combustion model adaptation and data assimilation techniques were discussed to improve predictions and take advantage of extensive measurements that are generated from high-speed, multi-dimensional measurements.

Needs for further improvement
(Hawkes) It was argued that the development of practical combustion models should be the primary objective of DNS work going forward. New opportunities were identified in conducting partial *a posteriori* tests, where some model inputs are taken directly from DNS, in order to focus attention of the performance of specific sub-models. Based on insights from very high-Re experiments, is was suggested that higher Re needs (somehow) to be accessed by DNS. The need to increase effort on cases with complex geometries (e.g., having recirculation zones, mean shear, etc.) was highlighted; these cases should have parametric sets and also preferably involve flows that can be computed straightforwardly with LES at resolutions where the models are actually doing some work.

(Sutton) Experimental needs were discussed in the context of current knowledge gaps, which include the understanding of configuration effects (i.e., geometry, pressure, turbulence generation, fuel type, etc.), characterization of the internal structure of turbulent flames, and the effects of turbulence-induced stratification. It was argued that specific measurement needs include

quantitative multi-scalar measurements, high-resolution velocity measurements, simultaneous velocity/scalar measurements, heat release rate measurements, and the coordination of new burner designs with modeling efforts. Mach number and compressibility effects were discussed; new measurements in turbulent, compressible flames have shown that turbulence is not attenuated through the flame, but rather flame-generated turbulence is observed. Finally, emerging capabilities to derive chemical mode and heat release rate from scalar measurements and to achieve high-spatial resolution in velocity measurements were highlighted.

Progress of Turbulent Sooting Flames (Joint ISF/TNF Session)

Coordinators: Bassam Dally and Michael Mueller

The objective of the session was to bring together the TNF and ISF turbulent flames communities to discuss common problems and strategies for addressing experimental and computational challenges in turbulent sooting flames. Overviews were presented on current experimental capabilities for turbulent sooting flames (time resolved LII, CARS, two-line atomic fluorescence for temperature, and krypton PLIF for mixture fraction) as well as target flames and computational comparisons. The two types of targets accentuate different aspects of soot-turbulence-chemistry interactions, with jet flames stressing small-scale interactions including slow PAH chemistry, and recirculating flows stressing large-scale interactions, notably the residence time at different mixture fractions where different growth mechanisms dominate. For comparisons with experimental measurements, progress between consecutive ISF Workshops has been rapid with decreasing variance between models with detailed model improvements being made based on insights from limited experimental measurements and DNS data. However, the fundamental challenge in understanding the underlying physics and uncovering the source of discrepancies is a lack of data, particularly (simultaneous) data on flame structure, combining temperature and speciation with soot measurements. These overviews were followed by comments from three panelists: Simone Hochgreb discussed experimental configurations, measurement techniques, and experimental challenges; William L Roberts highlighted recent progress at KAUST in making high-pressure measurements in turbulent sooting flames; Venkat Raman discussed the differences in the modeling challenges between jet flames and recirculating flows with respect to small-scale and large-scale intermittency. The importance of history in soot evolution was also discussed and the need to identify canonical configurations that match the history of soot evolution in technical combustion systems. Fundamental differences between detailed, PAH-based soot models and semi-empirical, acetylene-based soot models were also highlighted with a suggestion to design experiments to stress each class of models.

Enclosed Flames and Elevated Pressure

Coordinators: Christoph Arndt and Wolfgang Meier

Recent experiments and simulations of enclosed flames and flames at elevated pressure, as well as associated experimental and computational challenges, were discussed. In the first part of the session, contributions on experiments and simulations of swirl combustors at atmospheric and elevated pressure as well as a test case of a jet flame at elevated pressure were presented, including: “Experimental study on dynamics of lean premixed swirl flames” from Shanghai Jiao Tong University; “Experimental and numerical investigation of the response of a swirled flame to flow modulations in a non-adiabatic combustor” from Centrale Supélec; “SFB 606 Gas Turbine Model Combustor” from DLR Stuttgart; “LES studies on enclosed swirl flames in laboratory combustors” from the University of Cambridge; “High-pressure syngas jet flames (CHN)” from KAUST; and “LES studies on enclosed swirl flames in industrial combustors” from the University of Cambridge. The second part of the session focused on FLOX® and MILD combustion with contributions on: “Flameless combustion in a lab-scale furnace” from TU Delft; “Confined and pressurized jet in hot and vitiated coflow burner” from Adelaide and Sydney; “High-pressure enclosed jet flames” from DLR Stuttgart; and “Investigation of a high pressure jet flame with heat losses using tabulated and finite rate chemistry” from University Duisburg-Essen.

Flame Wall Interaction

Coordinators: Andreas Dreizler and Johannes Janicka

Flame-wall interaction (FWI) was introduced as a TNF topic in 2014, and a first target case of side-wall quenching (SWQ) was introduced at TNF13. FWI leads to flame quenching related to heat losses and incomplete combustion causing primary pollutant formation such as carbon monoxide (CO) and unburnt hydrocarbons (UHC). A deeper understanding of turbulent flames in the vicinity of walls is needed to improve combustion modelling for practical systems.

The experimental portion of this session introduced a Forced Laminar Axisymmetric Quenching (FLAQ) burner developed by the University of Melbourne to study FWI and the interaction of cooling jets with flames. An overview of experimental progress by TU Darmstadt to significantly enlarge the data base of the SWQ target flames was presented. Discussion focused on selected issues with the following conclusions: 1) Quenching distance is decreased for increasing wall temperatures causing an enhanced heat transfer rate within the FWI zone. 2) For a fixed wall temperature CO/T scatter plots for stoichiometric methane/air flames show an impact on CO-formation for wall distances below 0.2 mm whereas CO-oxidation at high temperatures (T > 1500 K) is influenced already for wall distances up to ~1 mm. These effects were attributed to differences in chemical time scales in relation to time scales for heat transfer. 3) Correlations of normalized heat release and curvature of premixed flames in the near-wall region indicate an influence of Lewis-number.

Compared to TNF13 a large group contributed FWI simulations, including both DNS and modelling studies of various configurations. Only a few of the many results and conclusions documented in the proceedings are mentioned here. The quenching distance for turbulent conditions decreases and the magnitude of the maximum wall heat flux increases in comparison to the corresponding laminar HOQ values for cases with Le<1. All the modelling assumptions associated with high Damköhler number (Da≫1) and presumed bi-modal PDF of c are rendered invalid close to the wall. Both conventional flame surface density (FSD) and scalar dissipation rate (SDR) closures for mean reaction rate break down in the near-wall region. Flame velocity seems to be the governing parameter in the turbulence-chemistry interaction more than flame thickness vs. turbulence length scales. Based on DNS studies, a modified FSD-based closure for mean reaction rate in terms of flame-wall interaction has been proposed. LES of the SWQ target case using detailed chemistry and FGM-based tabulated chemistry showed similar wall-normal temperature profiles but strongly different CO profiles due to large diffusion effects close to the wall that are not reflected in the FGM tabulation.

Multi-mode Combustion

Coordinator: Rob Gordon

This session follows from discussions in TNF13 on combustion regime indicators and reaction progress markers. Key information from TNF13 was briefly reviewed, then highlights were presented on recent progress in four areas: 1) Extention of chemical explosive mode analysis (CEMA) to include diffusion as well as local chemistry, allowing greater refinement in the identification of local combustion modes, including assisted ignition, auto-ignition, and local extinction in DNS of a high-Ka jet flame. 2) New applications of the gradient free regime identification (GFRI) method to derive chemical mode and heat release rate from experimental data. 3) An approach for selecting the most approprate models for local conditions within a simulation, based on a Combustion Model Compliance Indicator. 4) Development of a modeling approach based on Generalized Multi-Modal Manifolds.

Last Experiments at Sandia

Coordinator: Rob Barlow

This brief session outlined a series of visiting experiments conducted from March to July 2018 to take maximum advantage of the unique diagnostic capabilities of the Turbulent Combustion Laboratory before termination of DOE funding for experimental research on turbulent combustion at Sandia.

KEY CHALLENGES AND PRIORITIES

Multi-mode combustion continues to be a challenging area for fundamental understanding and for model development. There has been some convergence in simulations of the Sydney inhomogeneous flames. However, the sensitivity of these piloted flames to boundary conditions in experiments as well as simulations, particularly with respect to stability of the pilot-coflow shear layer, has complicated detailed comparison of measured and modeled results. Organizers have proposed a joint publication on the current state of understanding, and they have encouraged further analysis based on the Wasserstein metric to help quantify and interpret comparisons. One future goal in the context of multi-mode combustion might be to apply one modeling framework across regimes, which could be a single burner or multiple burners. A new multi-mode or Multi-Regime Burner (MRB), with well-controlled and characterized boundary conditions, has been developed by TU Darmstadt, and a first set of Raman/Rayleigh measurements has been conducted at Sandia (see posters by Butz et al. and Hartl et al.). Meanwhile, PIV/PLIF of the same configurations have been performed at Darmstadt. This burner could be a target case for TNF15.

Simulations of the Cambridge stratified swirl flames focused mainly on SwB3 (highest swirl number, 0.75 equivalence number in both streams). The high swirl cases exhibit a large, open recirculation zone that transports diluted products from far downstream all the way to the bluff body surface. This leads to a requirement for long run times to initialize the flow and scalar fields. Results for SwB11, (highest swirl, highest stratification) were inconclusive, due to the need for longer initialization. The highest stratification cases have and inner flow equivalence ratio of 1.125, and there appears to be some influence of Lewis number going to these cases. Further work to address these issues could be done. The new Darmstadt MRB cases also include stratified reaction zones that cross lean and rich mixture fraction values, so those flames may allow for investigation of these same issues without the complication of a very large recirculation zone.

Accurate modeling of CO remains a challenge, such that comparisons on three different target flames showed significant variation in CO predictions.

The joint PTF/TNF session on highly turbulent premixed flames provided an excellent overview of the current state of knowledge. One key point, taken from recent DNS of the Lund flames and recent experiments on the HiPilot burner, is that the highest Ka cases, which are generated at laboratory scale by surrounding a very lean reactant flow by combustion products of a more robust mixture, actually burn as stratified flames. That is, significant mixing between jet and coflow occurs before heat release, such that heat release occurs at intermediate values of mixture fraction and in the presence of a mixture fraction gradient. Creating a truly premixed flame, with uniform equivalence ratio across the flame brush, at laboratory scale remains a significant challenge. Further work is will be needed to explore the high-Ka regime of uniformly premixed flames. That said, the high-Ka stratified flames are very interesting in themselves and could be a good topic for further collaborative research. Emerging diagnostics for very-high-resolution velocity measurements and simultaneous velocity-scalar measurements show significant potential to provide new insights and valuable data on highly turbulent flames.

For turbulent sooting flames, the fundamental challenge in understanding the underlying physics and uncovering the source of discrepancies is a lack of data, particularly simultaneous data on flame structure, combining temperature and speciation with soot measurements. Filtered Rayleigh scattering combined with PIV and LII might be fruitful diagnostic direction. Raman scattering is challenging even in blue, upstream regions of sooting flames, so it is not obvious that detailed multi-scalar comparable to those acquired in TNF flames can ever become available for sooting flames. However, benefit can be gained by using the same burner geometries with non-sooting and sooting flames, that have as many parameters in common as possible.

The side-wall-quench (SWQ) flame is proposed as a future TNF target configuration. Priorities for experimental work are to measure more scalars, measure wall temperature and heat transfer, and conduct parametric variation of such things as wall temperature, surface coatings, fuel, and effusion cooling.

Important progress has been made in developing regime indicators for both simulation (CEMA including both chemistry and diffusion effects) and experiments (application GFRI methods to lifted flames and to DNS of premixed and mildly stratified flames). These and similar regime identification tools can provide insights on variations in local reaction zone structure and might be included as metrics in future comparisons between experiments and simulations.

Consideration of more complex fuels, specifically DME, took a pause for TNF14, although there work on these flames was presented at the Symposium. Repeating comments from TNF13: It is important to continue working with fuels more complex than methane. Goals should comprise computations of the entire piloted DME jet flame series (Sandia DME D-G') with focus on the accurate prediction of the degree of localized extinction. We should also seek clarification of the predictions' dependencies on the chemical mechanisms. This may include the need for a quantitative comparison of formaldehyde, as this is the measured species with the most pronounced differences for all flame and flow conditions. Quantitative LIF of formaldehyde remains a challenge. Direct measurements of intermediate species by Raman scattering have proven difficult, and no further work in this area will be possible at Sandia.

In addition to new measurements in the Darmstadt multi-regime burner (MRB), experiments have been conducted on a new version of the Sydney hot-coflow burner, which includes thermal insulation around the central jet to minimize heat transfer to the jet fluid upstream of the exit. Two types of flames have been measured: 1) Lean premixed CH_4/air jet flames into hot H_2/air products with temperature matching the adiabatic equilibrium temperature of the jet; 2) Rich CH_4/air jets, producing lifted partially-premixed flames. The first cases are analogous to the Sydney PPJB flames (Dunn et al.) but with only two streams rather than three. The lifted flame conditions were selected to emphasize either flame propagation or auto-ignition as the primary stabilization mechanism. These data sets may be available before the next workshop.