PSAAP III
INTEGRATED SIMULATIONS USING EXASCALE MULTIPHYSICS ENSEMBLES

Visualization of Ignition Kernel Dynamics

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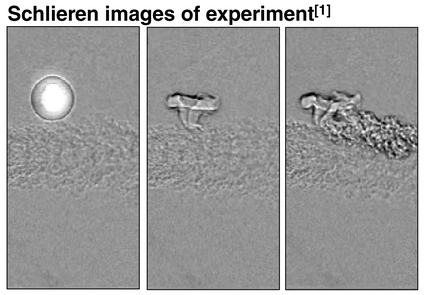
I. Motivations and Significance

One of the main objectives of PSAAP-III is to perform numerical simulations of laser-induced ignition of a rocket combustor. 2D visualizations of these simulations provide evidence of ignition success and clarify features seen in experiment. However, **3D effects are expected to be critical** when identifying ignition kernel dynamics and subsequent propagation of the flame front.

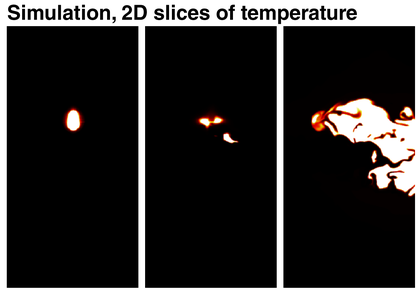
Schlieren images of experiment[1]



Energy kernel deposited | Heated gas interacts with shear layer | Ignition observed

Similar behavior

Simulation, 2D slices of temperature



Energy kernel deposited | Out-of-plane interactions occur | Ignition observed

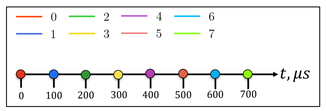
? → **3D CFD**

An important component to establishing the credibility of these numerical simulations is to understand the uncertainties which affect ignition. **3D visualizations** of interactions between the ignition kernel and non-premixed turbulent flow **can provide insight into ignition sensitivities**.

II. Methodology

ParaView, running on the Lassen Cluster in batch mode, was used to visualize a series of combustor simulations in 3D. In total, 6 TB of data were processed to generate 400 images.

8 simulations were visualized. All initial conditions except the time of energy deposition were equal across simulations. Energy deposition was delayed in increasing increments of 100 μs in the series.

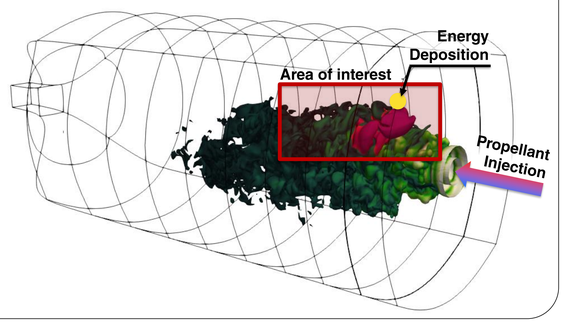


Energy Deposition Delay

The area of interest was injection flow adjacent to and downstream of the location of energy deposition.

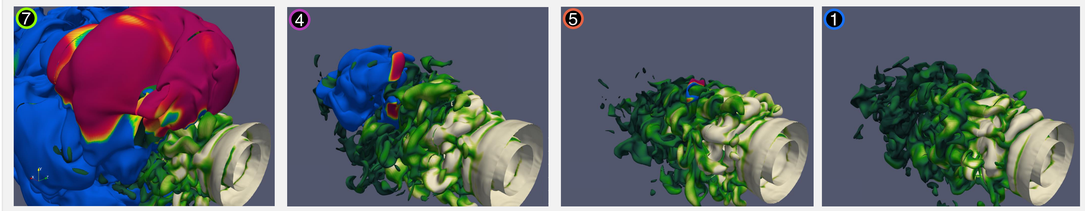
Two isosurfaces were generated for each image:
- Equilibrium mixture fraction ( )
- Temperature at 2000 K ( )

Observations were made on the series of images.



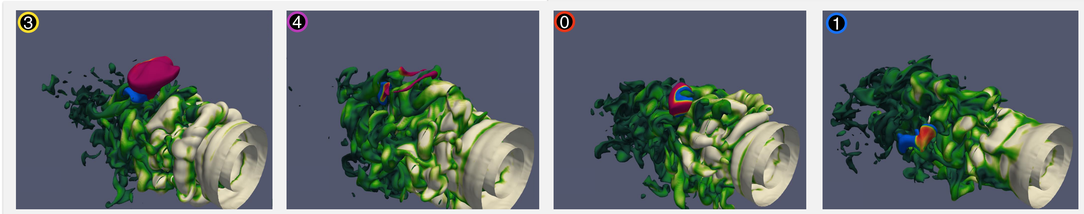
III. Results

Stochastic variations in background flow influenced ignition success, ignition delay, and propagation of the flame front. Visualizations allowed for observation of out-of-plane interactions contributing to ignition. Interactions seen in experiments between the heated gas and shear layer were clarified by the images.



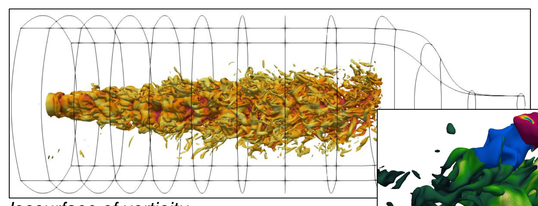
Images at same time relative to laser deployment. Disparity shown in progress of ignition.

Images of early-stage ignition. Variance shown in flame topology and time of ignition relative to laser deployment.

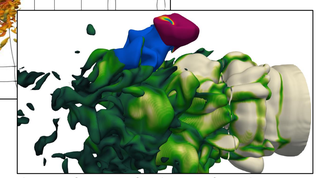


IV. Ongoing Work

ParaView is being used to generate visualizations of quantities of interest in the combustor. These images will be used in attempts to gain further insight into flow characteristics, clarify experiments, and understand ignition behavior.



Isosurface of vorticity



Isosurfaces of mixture fraction and temperature

V. Conclusions

The images generated and the observations they allow indicate a first step towards building understanding of the physical mechanisms that lead to successful ignition. Additionally, the sensitivity observed confirms the challenges associated with non-premixed turbulent combustion.

References:
[1] Schlieren images by Slabaugh Group, Purdue University

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