Professor Rutland’s research interests are in modeling and simulation of processes related to IC engines. He and his students work on projects that range from fundamental work in direct numerical simulation of turbulent reacting sprays, to large eddy simulation (LES) model development, to application of CFD modeling to engine topics such as HCCI mixing and control, to system level modeling of diesel emissions, aftertreatment devices, and combustion control.

Professor Rutland has a long term coordinated program to develop LES models for IC engine applications. This includes sub-grid modeling for turbulence, mixing, combustion, and sprays. These models are based on a new approach developed at the ERC called dynamic structure modeling. This approach provides a sound bases for complex LES models and works well in practical applications without significant computational requirements.

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LES Model Development

The next generation of CFD modeling for IC engines will use the LES approach. In LES modeling, local spatial averaging is used instead of time or ensemble averaging that is currently used. This means that more of the flow structures are represented on the computational grid. Thus, the flows are more accurately represented and the sub-grid modeling requires fewer phenomenological arguments. The figure on the upper left shows temperature contours in a mixing layer simulation. The direct numerical simulation (DNS) uses no turbulence or mixing models. The LES simulation of the same flow uses a coarser grid (8x smaller in each direction) and sub-grid models for turbulence and scalar mixing. These sub-grid models use the dynamic structure approach developed at the ERC.

The mixing layer simulations demonstrate how fundamental studies (e.g. DNS) are used to help develop and test LES models. This same concept is being used in developing sub-grid spray models. The figures in the lower left show a DNS spray simulation. The spray induces turbulent flow in the gas phase. Analysis of these results is used in developing sub-grid models for spray-turbulence interactions.

The image on the right shows an LES simulation of an axisymmetric valve flow in a simple, canonical flow. In the final process of LES model development, simulation results like these are compared to experimental data for validation.