

**LEC GETS**  
**LEC Green Energy and**  
**Transportation Systems**

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 Centers for Excellent Technologies

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## LEC LEAP – ENGINE SIMULATIONS MADE EASY

ADVANCED 3D CFD SIMULATIONS ARE ESSENTIAL FOR UNDERSTANDING FLOW, MIXTURE FORMATION AND COMBUSTION IN LARGE ENGINES, PARTICULARLY WITH NEW FUELS. LEC HAS DEVELOPED AN APPROACH THAT MAKES HIGH-FIDELITY ENGINE SIMULATIONS IN OPENFOAM MORE ACCESSIBLE, EFFICIENT, AND RELIABLE.

### The Challenge

The future development of combustion systems for large engines requires reliable 3D CFD methods for flow and combustion simulation. Simulating combustion in large engines is highly challenging due to moving geometries, complex boundary conditions, high velocities, coupled physical phenomena, and long computation times. The increasing use of new fuels further demands flexible adaptations of simulation models to account for changing fluid and gas properties. Proprietary simulation tools restrict direct modifications to the source code and provide only limited interfaces to the simulation models, which prevents extensive model adaptations and complicates detailed analyses of the phenomena. This would be possible with freely available open-source software; however, such software often lacks the capability to automate the execution of complex simulations at a reasonable effort, which is particularly important for engine simulations.

### The Innovation

To overcome the limitations posed by proprietary simulation tools, LEC employed the OpenFOAM Foundation software which offers full flexibility and extensive multiphysics capabilities. However, its operation is not very intuitive, requires extensive experience and effort on the part of the user, and lacks automated workflows for engine simulations. To make these complex processes practical for the user, a fully automated and standardized methodology was developed specifically for the simulation of internal combustion engines. This elevates OpenFOAM-based engine simulations to a level comparable to that of commercial computational fluid dynamics software, while granting unrestricted access and full control over the underlying models, thereby establishing a flexible workflow that is tailored for the users' needs.

### The implementation

The methodology has been implemented within the newly developed framework LEC LEAP, which extends

## SUCCESS STORY

the OpenFOAM Foundation software through Python-based interfaces, thereby making advanced CFD simulations significantly more user-friendly. The framework simplifies the preparation, case handling and execution of simulations, enabling users to perform complex engine simulations with reduced effort and increased reliability. LEC LEAP was developed in close collaboration with industry partners and meets high standards in terms of user-friendliness, documentation, and efficiency. Thanks to its modular design, it can be easily adapted to specific user requirements and, with only minor modifications, can also be used beyond traditional engine simulations, e.g., for simulating processes in spray and combustion chambers, as well as in rapid compression expansion machines. OpenFOAM's outstanding parallel computing performance enables the use of finer meshes and more detailed simulations, thereby increasing overall accuracy. Its virtually unlimited scalability and long-term availability make the approach future-proof.

### The impact

The application of LEC LEAP significantly simplifies the execution of engine simulations in OpenFOAM Foundation software and makes high-precision CFD simulations available for demanding research and development tasks. Unrestricted access to the source code enables targeted model modifications and in-depth analyses that are often not possible with commercial software solutions. Particularly when it comes to new fuels, the newly gained ability to flexibly adapt models and to identify, understand, and resolve problems offers a significant advantage. Successful validation using simulations of multiple test engines has demonstrated the practical applicability of this method. Ongoing simulations of two- and four-stroke engines with various combustion concepts underscore the great potential for practical application. In this way, the methodology bridges the gap between flexibility in research and industrial applicability.

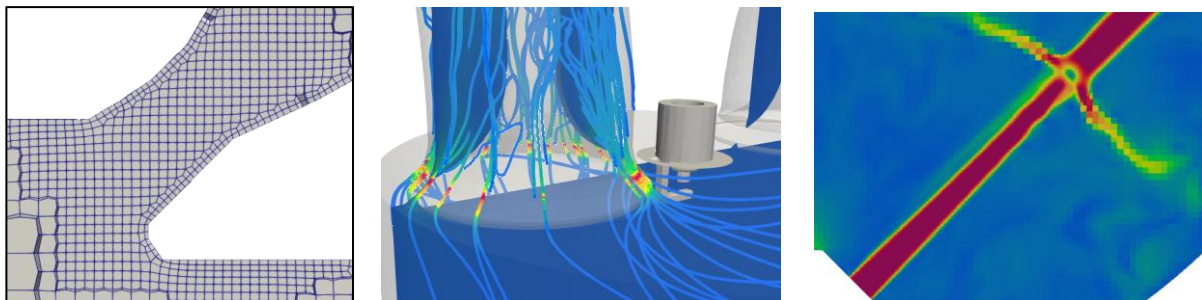


Fig. 1 LEC LEAP based on OpenFOAM Foundation software enables the complete workflow from advanced mesh generation (left) and CFD flow analysis of the engine (center) to high-resolution simulations of a free-jet collision (right) © LEC GmbH

### Project coordination

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