HPC IN DEN INGENIEURWISSENSCHAFTEN – VON DER GRUNDLAGENFORSCHUNG BIS HIN ZUR ANWENDUNG
LIGHHOUSE PROJECTS

Clean Circles
Iron as carbon-free energy carrier in a circular energy economy
Interdisciplinary cluster project aiming for Excellence Initiative
Partners: KIT, HDA, JvGU, RKU, DLR, MPI (total volume 15 M€)
HPC is key to understand the fundamental processes, e.g. in iron-air flames

Turbulent pulverized iron-air flame

Experiment, Reactive Flows and Diagnostics
Prof. Dreizler

Simulation, Simulation of reactive Thermo-Fluid Systems
Prof. Hasse
The CRC/TRR 150 teams up researchers from TU Darmstadt and Karlsruhe Institute of Technology.

They aim to advance the fundamental understanding and modelling of chemical kinetics.

At STFS, Flame-Wall Interaction and Boundary Layer Flames are investigated.

The CRC/TRR 129 combines the experience of TU Darmstadt, RWTH Aachen and Ruhr-Universität Bochum.

The focus is on homogeneous gas and heterogeneous biomass combustion.

At STFS, the objective is modeling and simulation of the complete Oxy-Fuel combustion system.

TU Darmstadt is one of four University Technology Centres (UTC) in Germany.

In Darmstadt, the collaboration between institutes and Rolls-Royce works on Combustor-Turbine Aerothermal interaction.

At STFS, the focus of the UTC is modeling of aero-engine combustion.
FROM COMPLEX TO SIMPLE
BUILDING A DIGITAL HPC TWIN

FULL-ENGINE CONFIGURATION
Global performance metric
Point measurements

ENGINE-LIKE CONFIGURATION
Point measurements
Microphone probes

LAB-SCALE MODEL COMBUSTOR
Detailed laser measurements
Microphone probes

GENERIC ACADEMIC CONFIGURATION
Analytical models
Two-dimensional modeling
$u(t) = u_0 + u'(t)$

$$\text{FTF}(\omega) = \frac{\dot{Q}'}{\bar{Q}} \frac{u'}{\bar{u}}$$
GENERIC ACADEMIC CONFIGURATION

RIJKE TUBE

YouTube, NightHawkInLight (2021), Acoustic Energy & Surprising Ways To Harness It. [Link to Full Video]
POSSIBLE MODE SHAPES

[1] YouTube, NightHawkInLight (2021), Acoustic Energy & Surprising Ways To Harness It. [Link to Video]
[2] YouTube, NightHawkInLight (2021), Fire Driven Sound Waves in a Quartz Tube. [Link to Video]
LAB-SCALE MODEL COMBUSTOR

SFB606 GAS TURBINE MODEL COMBUSTOR
LAB-SCALE MODEL COMBUSTOR

SFB606 GAS TURBINE MODEL COMBUSTOR

HPC Digital Twin
lab-scale, atmospheric burner

Gas Turbine Model Combustor at DLR Stuttgart
© DLR

ENGINE-LIKE CONFIGURATION

SCARLET
ENGINE-LIKE CONFIGURATION

SCARLET

HPC Digital Twin
real injector, engine-like conditions

Typical number of cores: 200-1000
Total runtime: ~1 million core hours per acoustic excitation per OP
ENGINE-LIKE CONFIGURATION

SCARLET

HPC Digital Twin
real injector, engine-like conditions

Acoustic Energy
Temperature
Source Term
CHARACTERISTICS OF SOOT


[1] Normalized Number Density

Particle Diameter (nm)

[2]

[3]
IMPORTANCE OF SOOT PREDICTION

EXAMPLE n\textit{v}PM EMISSIONS AT ZURICH AIRPORT

Fleuti (2018), Presentation, Ultrafeinstaubstudien Flughafen Zürich, Flughafen Zürich AG, [Link]
FROM COMPLEX TO SIMPLE
BUILDING A DIGITAL HPC TWIN

FULL-ENGINE CONFIGURATION
Global performance metric
Point measurements

REAL COMBUSTOR CONFIGURATION
Point measurements
Different operating conditions

TURBULENT SOOTING FLAME
Detailed laser measurements
Particle size distribution

GENERIC ACADEMIC CONFIGURATION
Analytical models
Low-dimensional modeling
Temperature

Soot number density

BR710 AERO-ENGINE COMBUSTOR
BR710 AERO-ENGINE COMBUSTOR

Typical number of cores: 200-1000
Total runtime: ~1 million core hours per OP
HYDROGEN COMBUSTION
BUILDING A DIGITAL HPC TWIN

Launch of hydrogen-powered engines until 2035

HYDROGEN COMBUSTION

CHALLENGES

Boundary Layer Flashback

Thermo-Diffusive Instabilities

[1] [2] [3]
HYDROGEN COMBUSTION

BOUNDARY LAYER FLASHBACK
HYDROGEN COMBUSTION

CHALLENGES

Boundary Layer Flashback

Thermo-Diffusive Instabilities
HYDROGEN COMBUSTION

THERMO-DIFFUSIVE INSTABILITIES

ACKNOWLEDGEMENT

THERMOACOUSTIC

SOOT

HYDROGEN