Heat release modeling

1D heat release model

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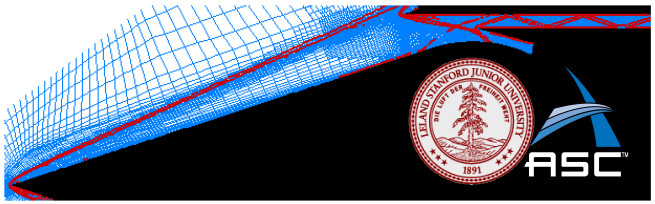
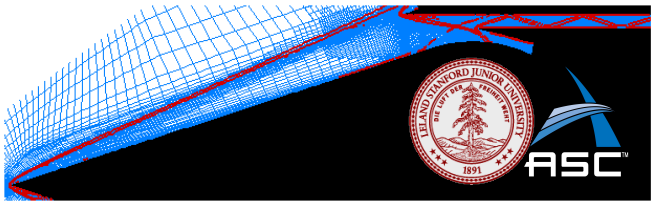


1D heat release model

Assumptions

- Combustion is modeled as simple source term in energy equation
- Heat release is homogeneous across cross-area, only depends on streamwise coordinate x
- No mass addition considered
- No mixing, i.e., properties do not change
- No flame-lift off (assumption can be relaxed with additional parameter)
- Distribution of heat release controlled by function with 2 parameters
- Parameters require calibration



Analytical formulation of model

Model

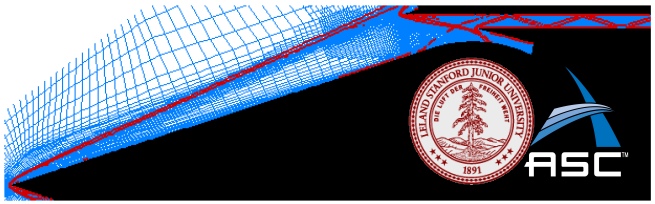
Cumulative heat release* [J/s]: $\mathbf{Q = \phi\, f_{st}\, H_f\, m_{air}\, \eta(x/L_c)}$

Source term [J/s]: $\mathbf{q = \phi\, f_{st}\, H_f\, m_{air}\, A^{-1}(x)\, d\eta/dx(x/L_c)\, dV}$

With $\mathbf{\eta(x/L_c) = 1 - \exp(-(kx/L_c)^d)}$

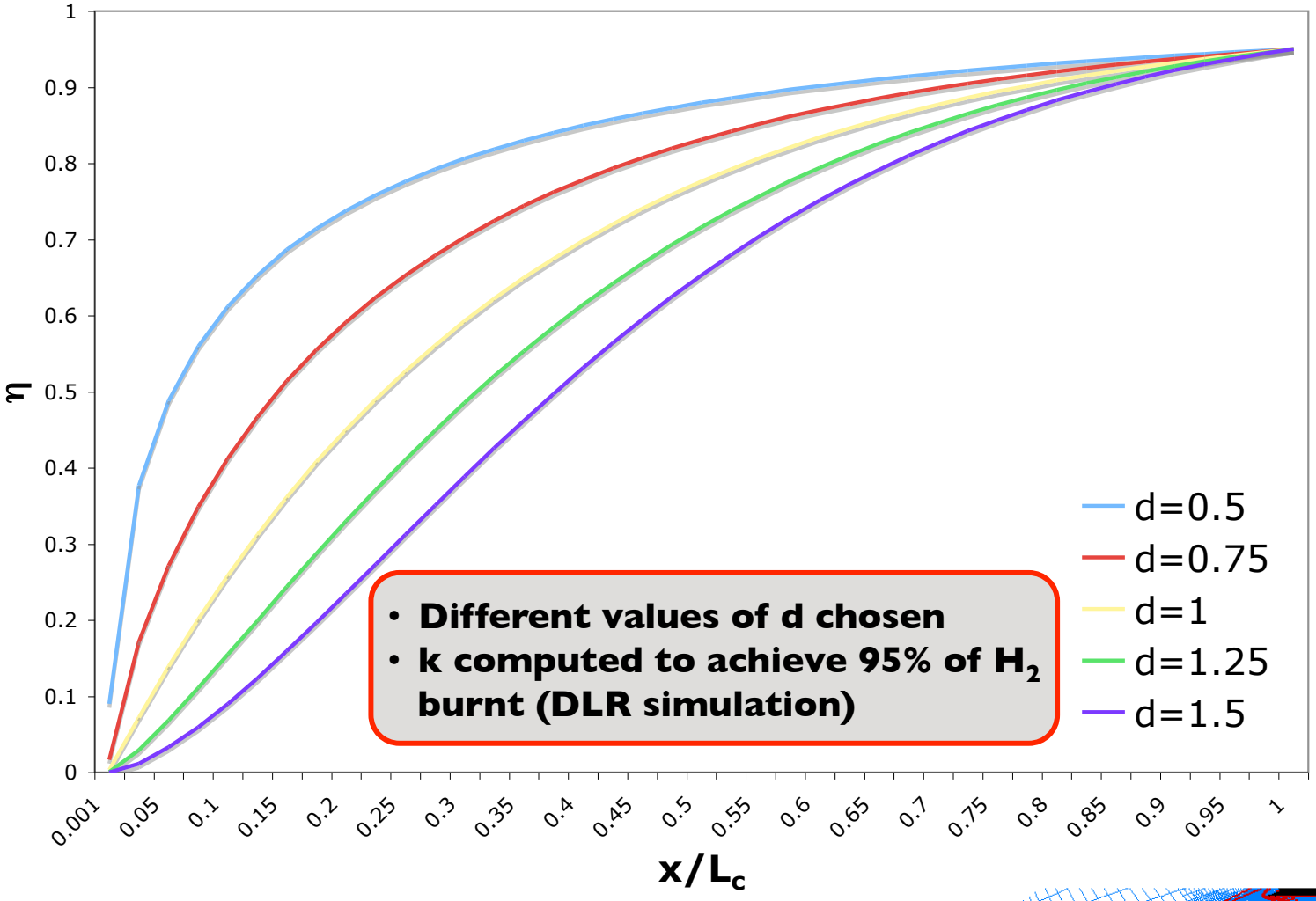
- ϕ : equivalence ratio
- $\mathbf{F_{st}}$: stoichiometric fuel/air ratio (=0.028 for H_2/air)
- $\mathbf{H_f}$: fuel heating value (= 120 MJ/kg for H_2)
- $\mathbf{m_{air}}$: mass flow rate of injected air
- $\mathbf{A(x)}$: cross-area of combustor
- $\mathbf{L_c}$: combustor length
- $\mathbf{dV}$: volume of control volume
- $\mathbf{\eta(x/L_c)}$: heat release distribution function ($\eta(0)=0$ and $\max(\eta)=1$)
- $\mathbf{k}$: free parameter controlling amount of fuel burnt
- $\mathbf{d}$: free parameter controlling shape of heat release

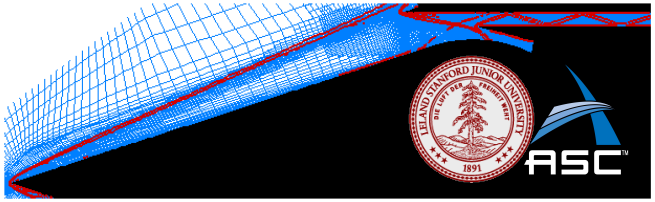
* Based on C. Doolan and R. Boyce, AIAA 2008-2603



Distribution function

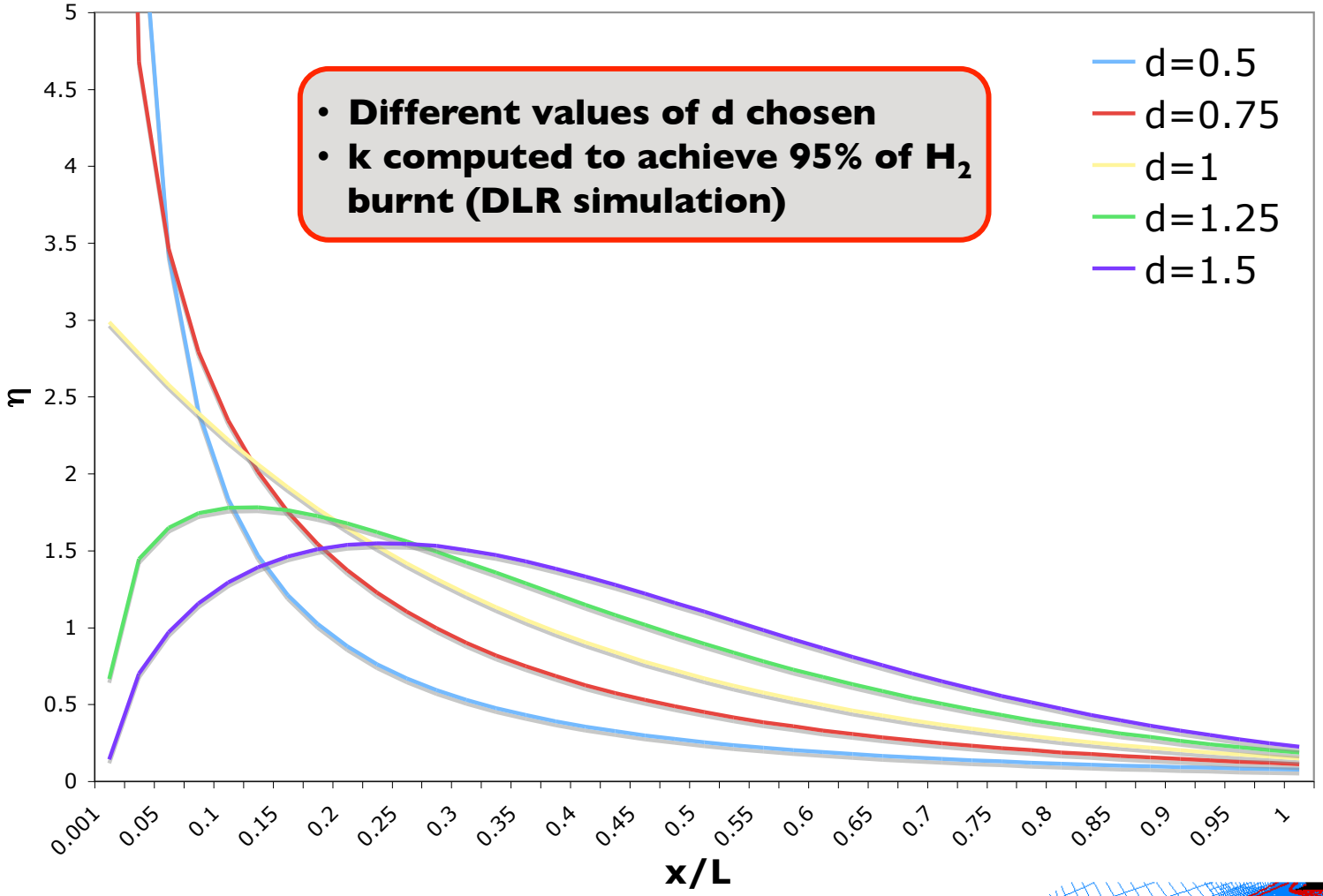
Heat release distribution function η along the combustor

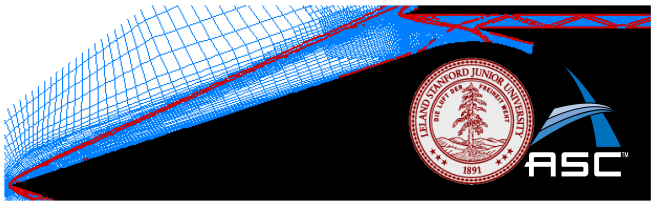




Distribution function

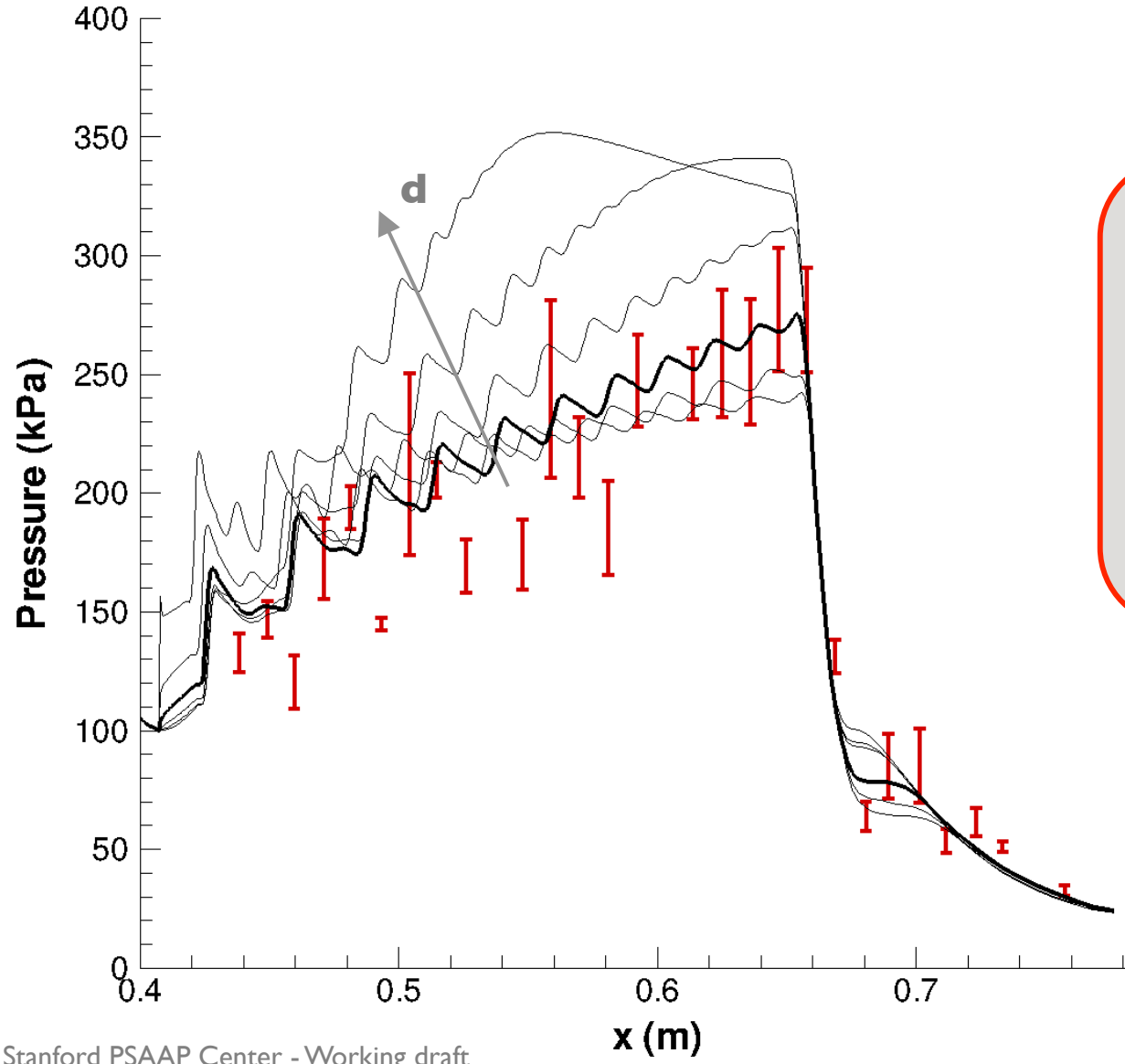
Derivative of heat release distribution function dη/dx along the combustor





Calibration – HyShot II ground experiment

Pressure in combustor in [kPa], comparison with experimental data from DLR



- **Different values of d chosen from 0.25 to 1.5 by 0.25 increments**
- **k computed to achieve 95% of H_2 burnt (DLR simulation)**
- **Best fit with d=0.75 (black line)**