Simulation of transport, evaporation, and combustion of liquids in large-scale fire incidents

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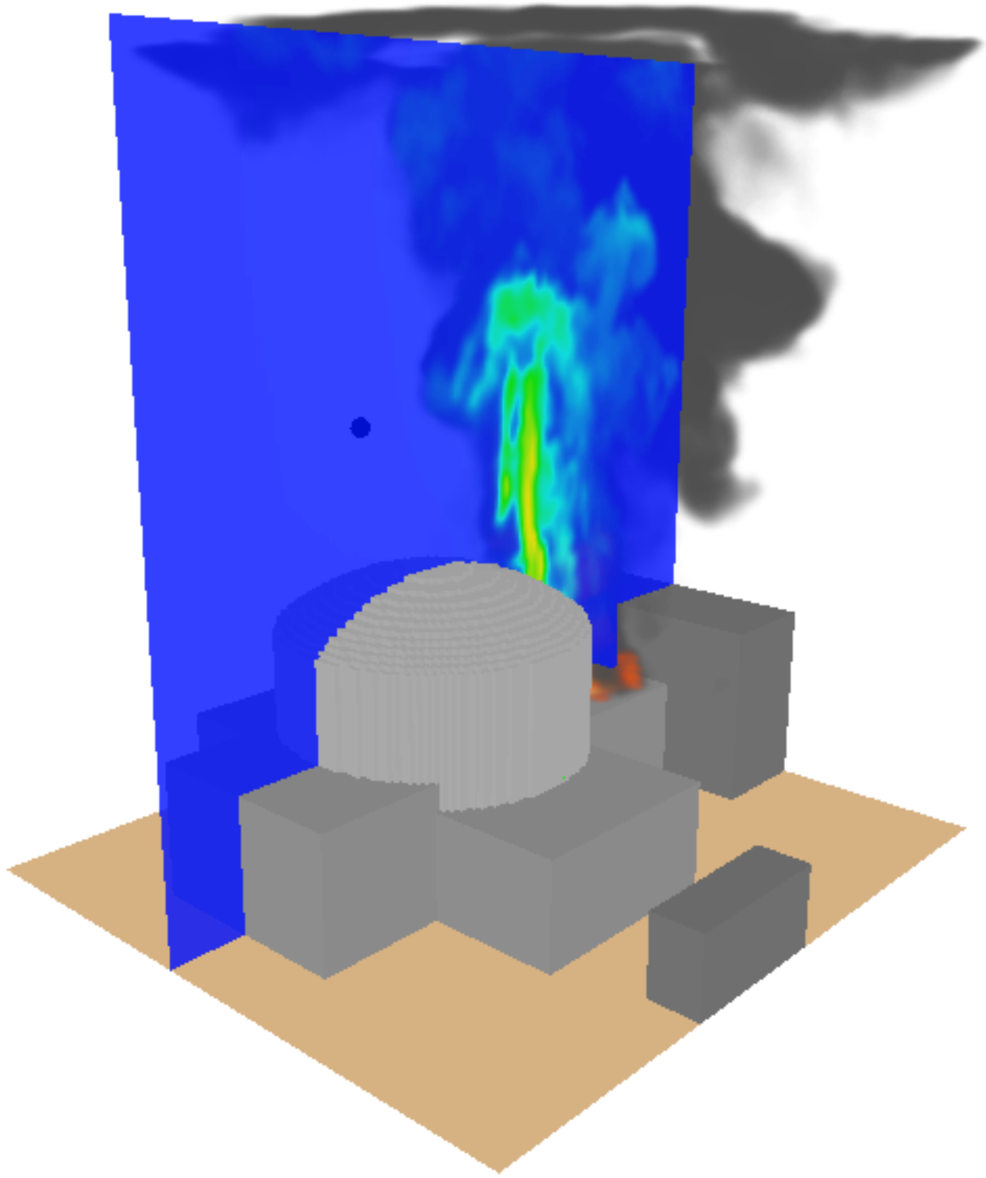
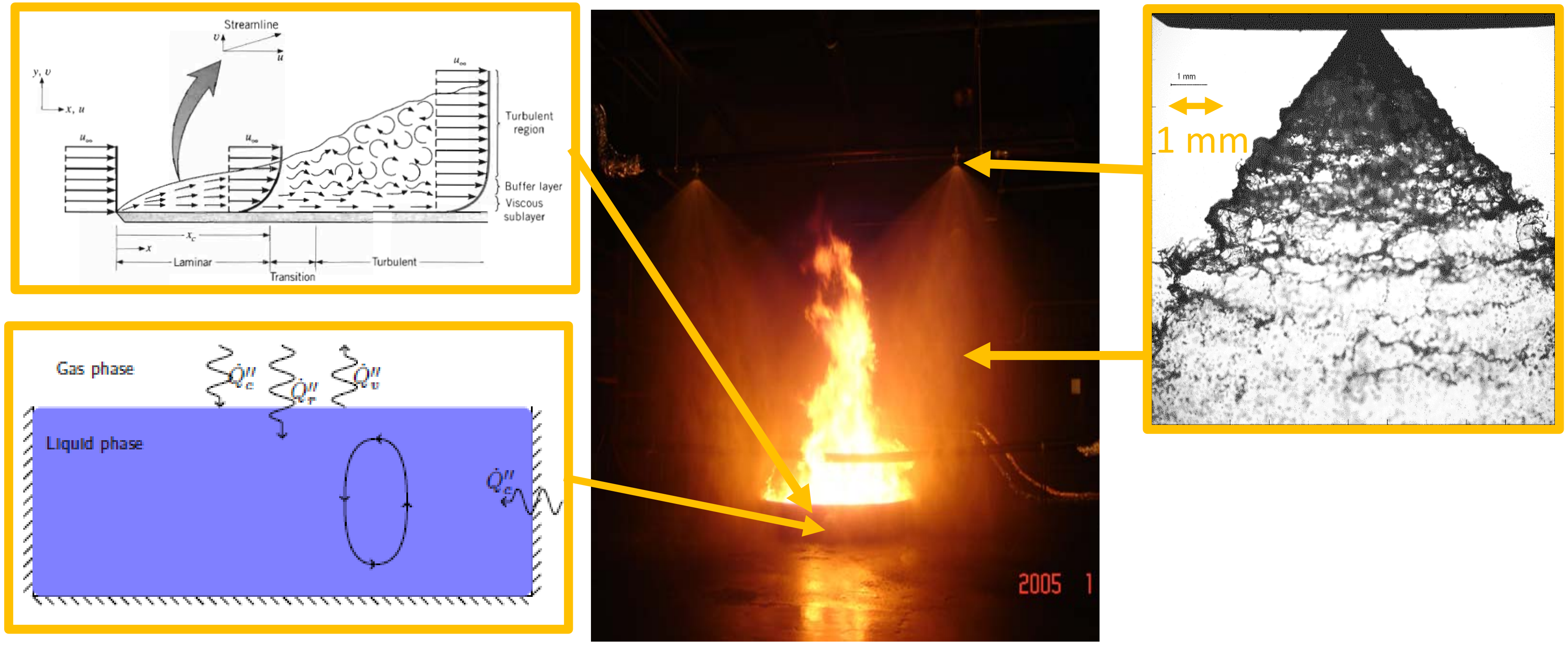
19^{th} International Water Mist Conference in Berlin, Germany, on 23rd & 24th October 2019

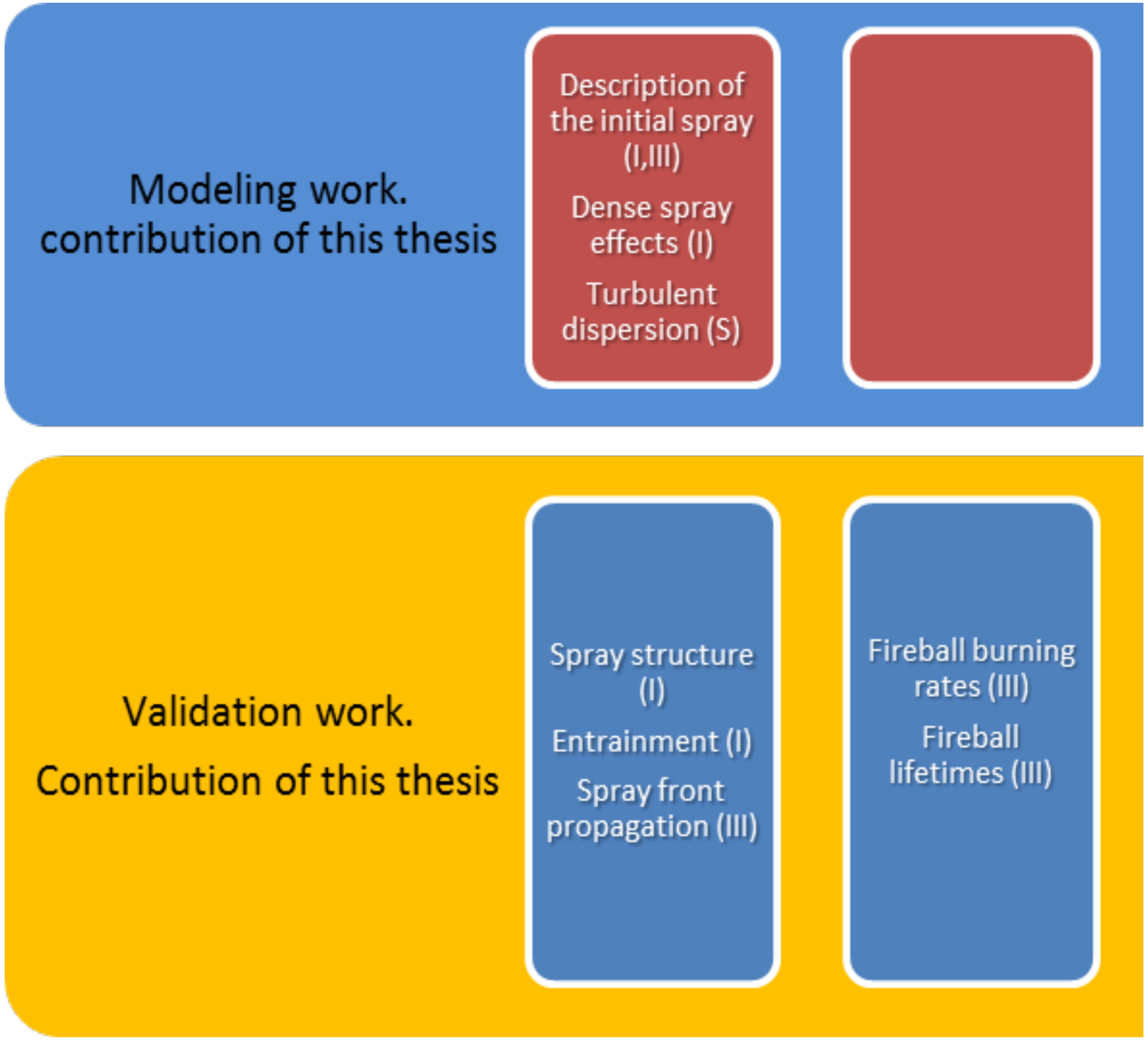
Background



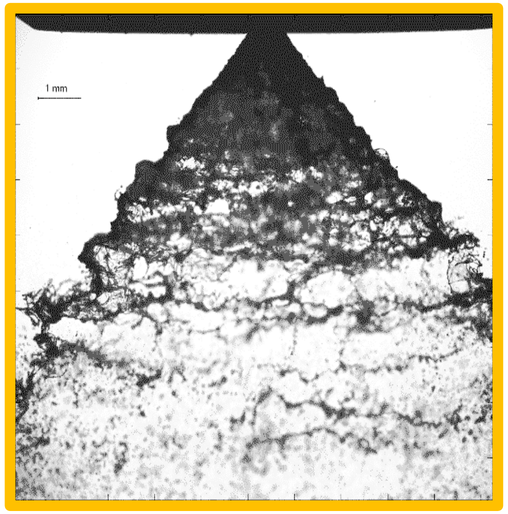
”Transport and evaporation of liquids”



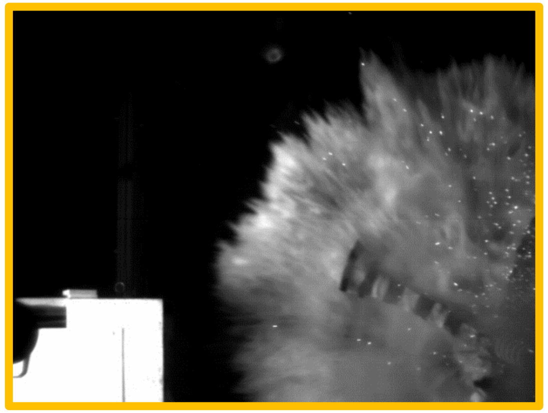
Spray related work



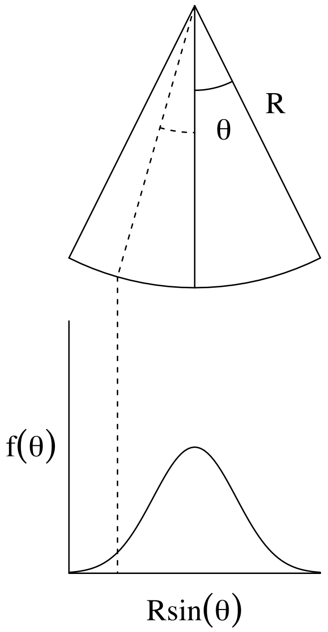
Spray modeling and validation

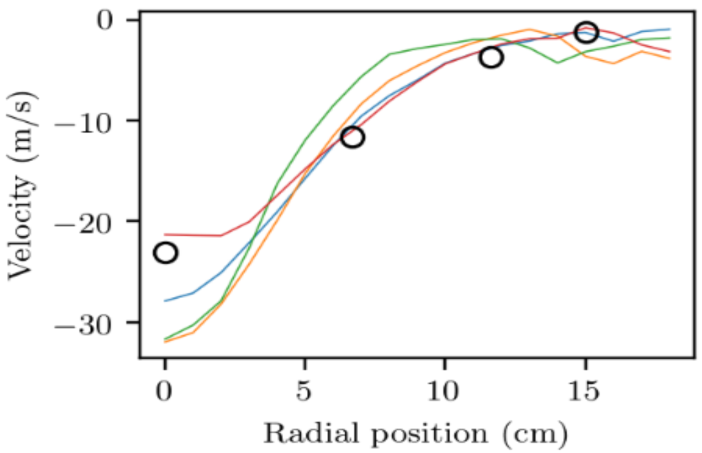


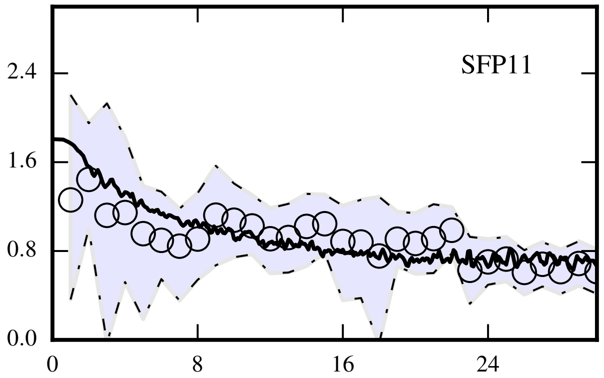
High pressure water mist sprays



Liquid filled missiles

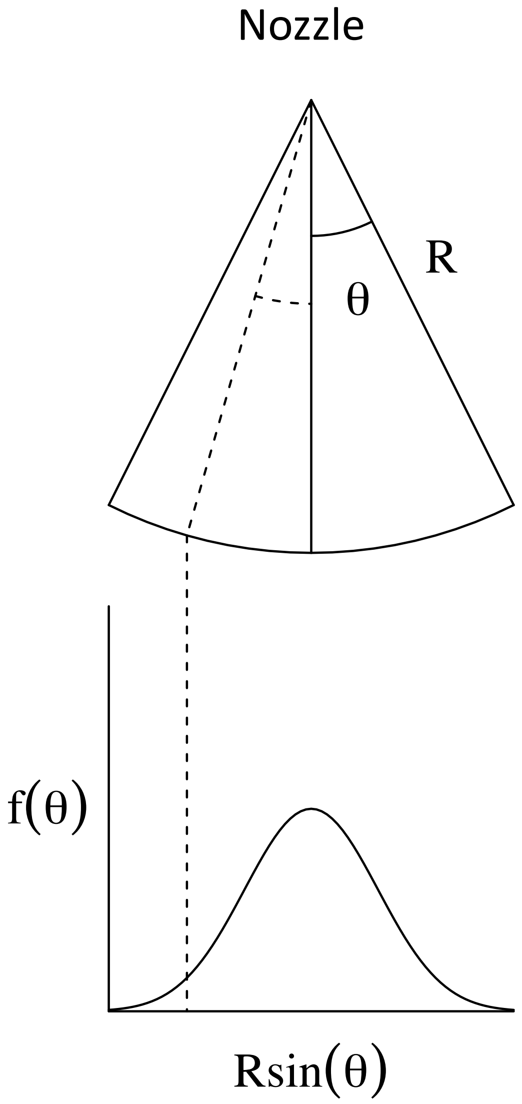






Spray modeling

Spray boundary condition



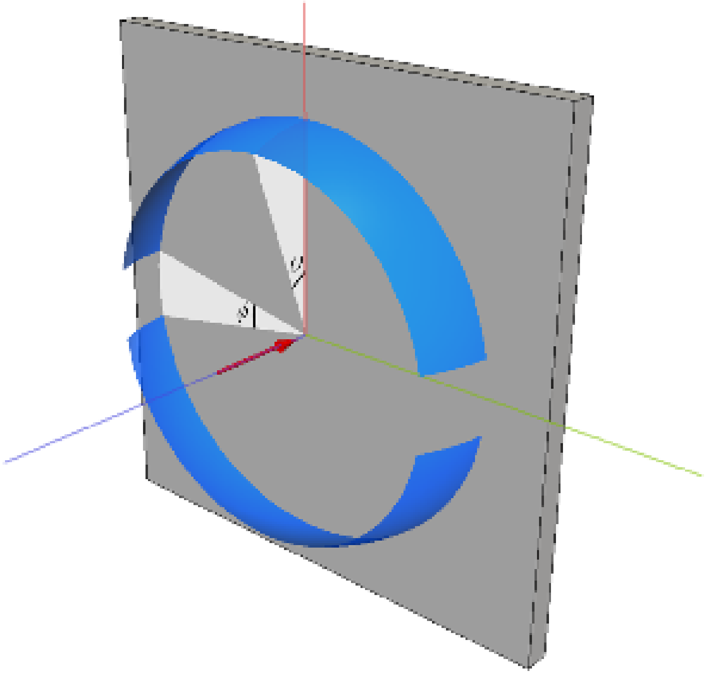
Droplets are launched at a spherical surface located at a distance R from the nozzle

Diameter and initial direction is random

All particles are given the same velocity

$$f(\theta) = exp\left[-\beta\left(\frac{\theta - \theta_\mu}{\theta_{max} - \theta_{min}}\right)^2\right]$$

Spray boundary condition: application to liquid filled missiles

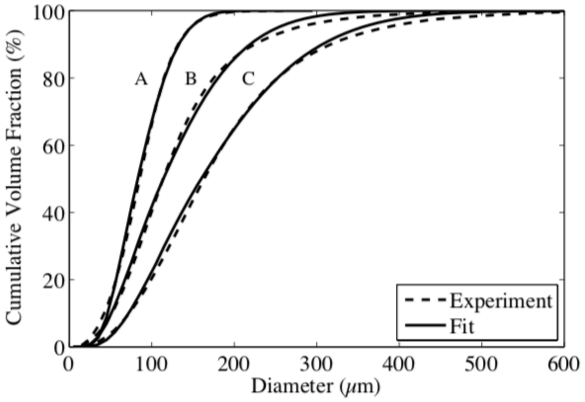


Same basic priniciple as in modeling regular sprays

Also an option to leave gap for wings

Droplet size distributions

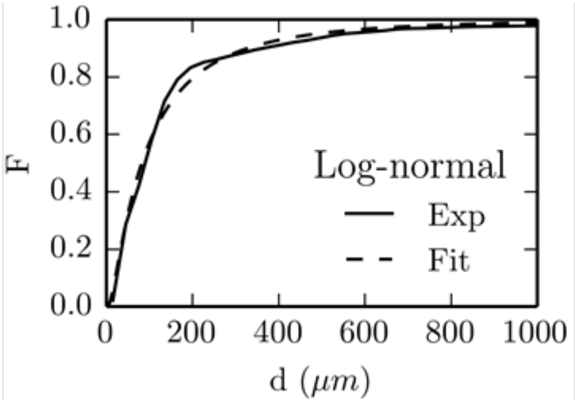
Water mist sprays



$d_{v,50} \approx 50\ \mu m$

Rosin-Rammler-Lognormal Distribution.

Liquid filled missiles



$d_{v,50} \approx 50\ \mu m$

Lognormal distribution.

In both cases droplet size distributions were determined by direct imaging (DI)

Forwater mist sprays, a modified NFPA spray characterizaton experiment

For missiles a single measurement point.

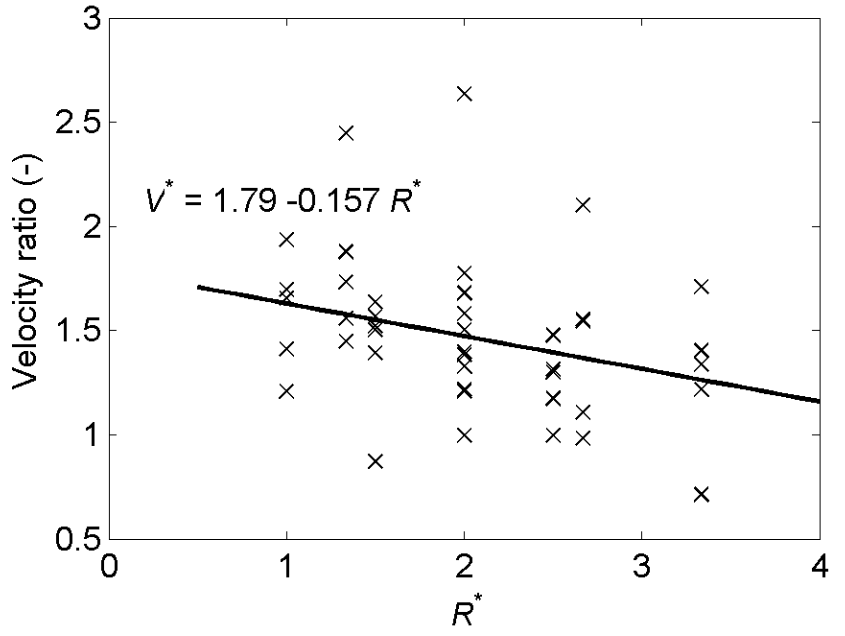
Initial velocities

Water mist sprays

Bernoulli velocity with correction: $v_0 = C\sqrt{\frac{2p}{\rho}}$ $v_0 \approx 100\ m/s$

Liquid filled missiles

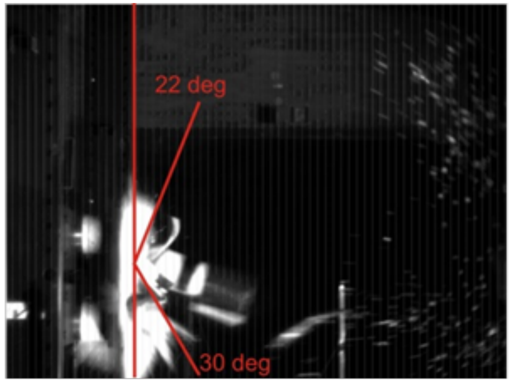
Empirical correlation based on experiments:

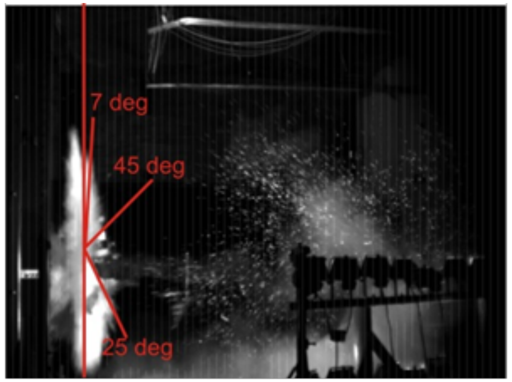


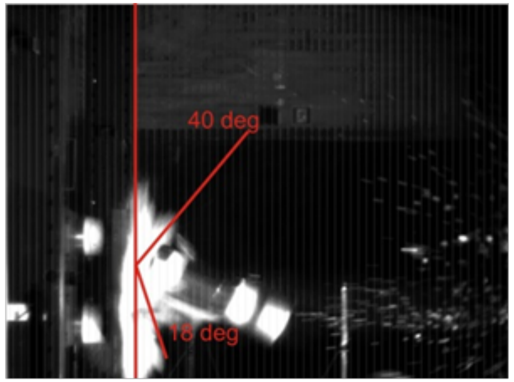
$v_0 \approx 200\ m/s$

Shape parameters for the spray boundary

Spray angle parameters determined from video evidence



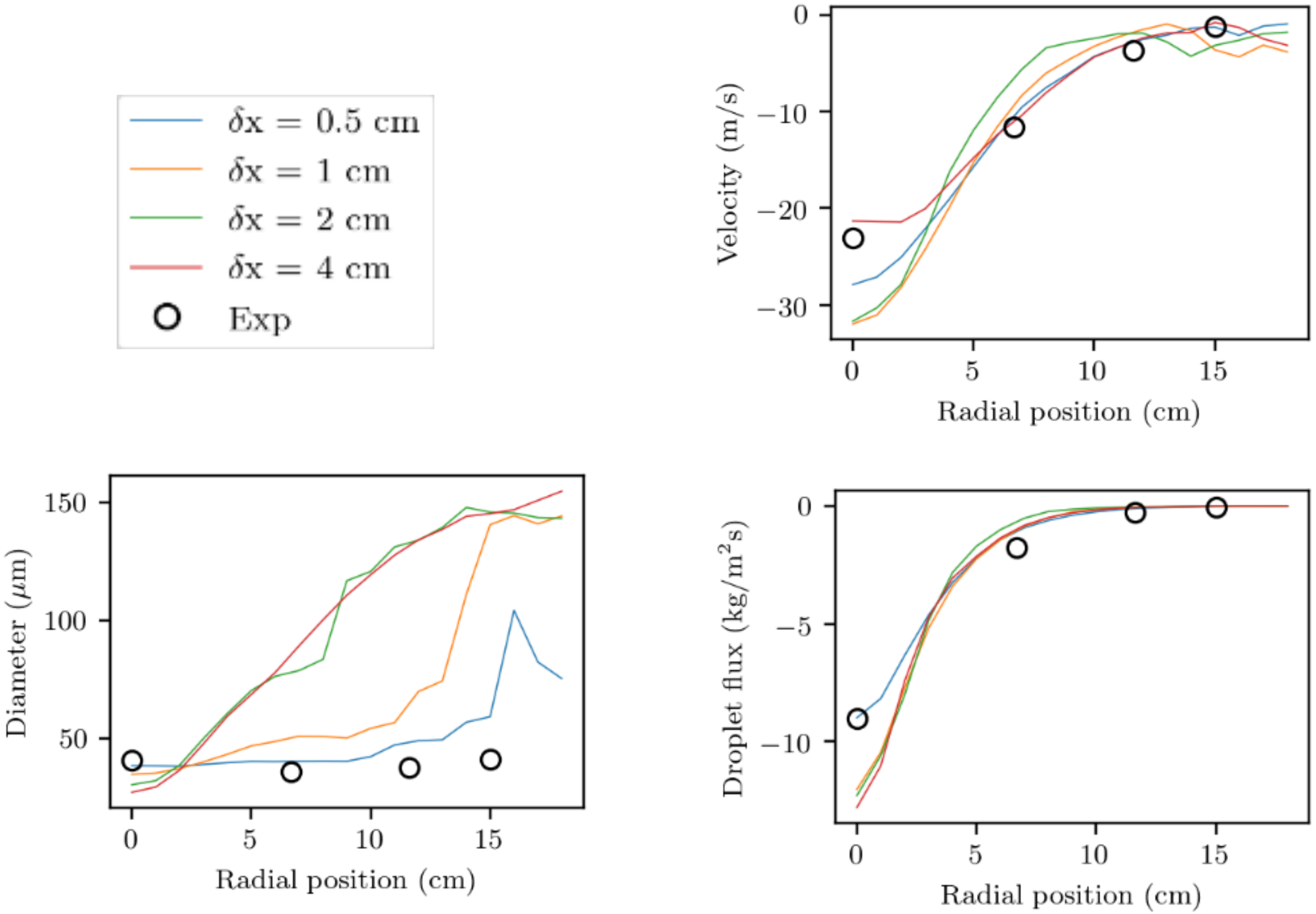




Spray parameter $\beta = 5$ selected to best fit the watr mist spray experiments

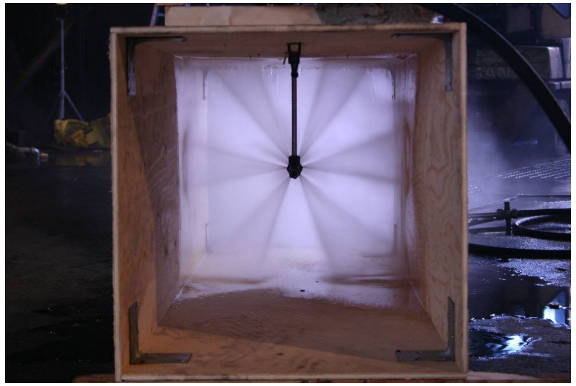
Spray model validation

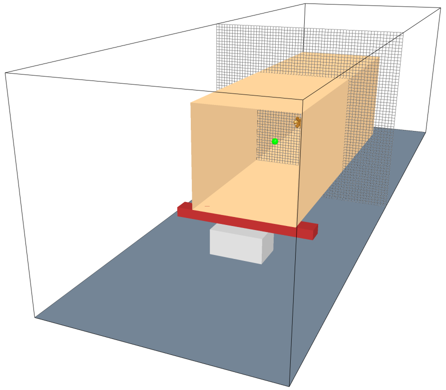
Water mist spray structure

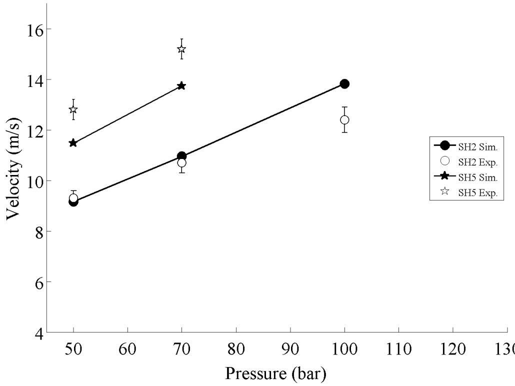


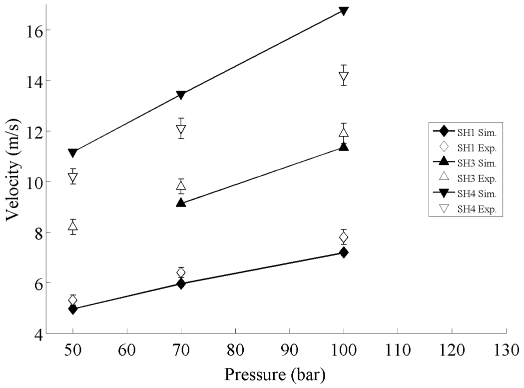
Results 1 m below the nozzle, with varying grid size

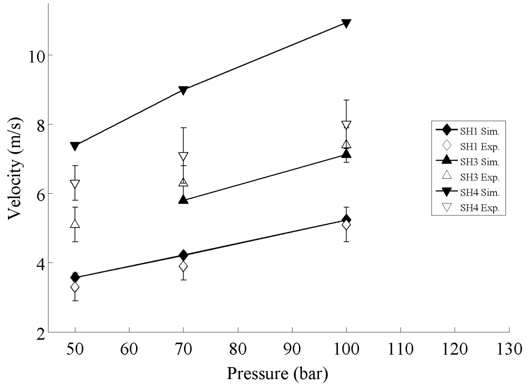
Entrainment



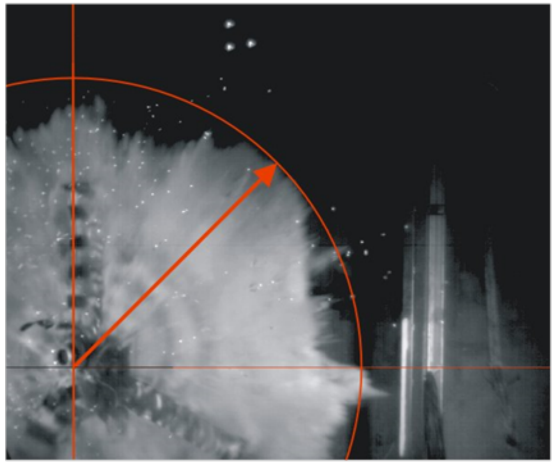


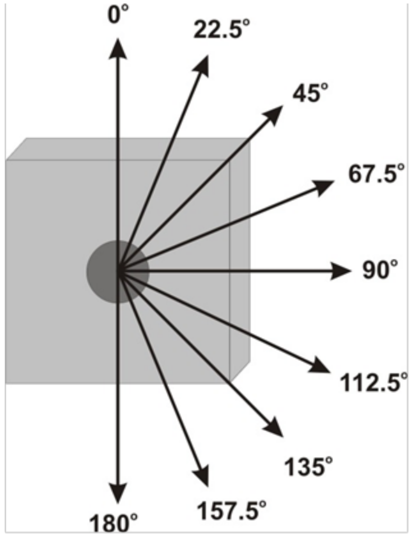


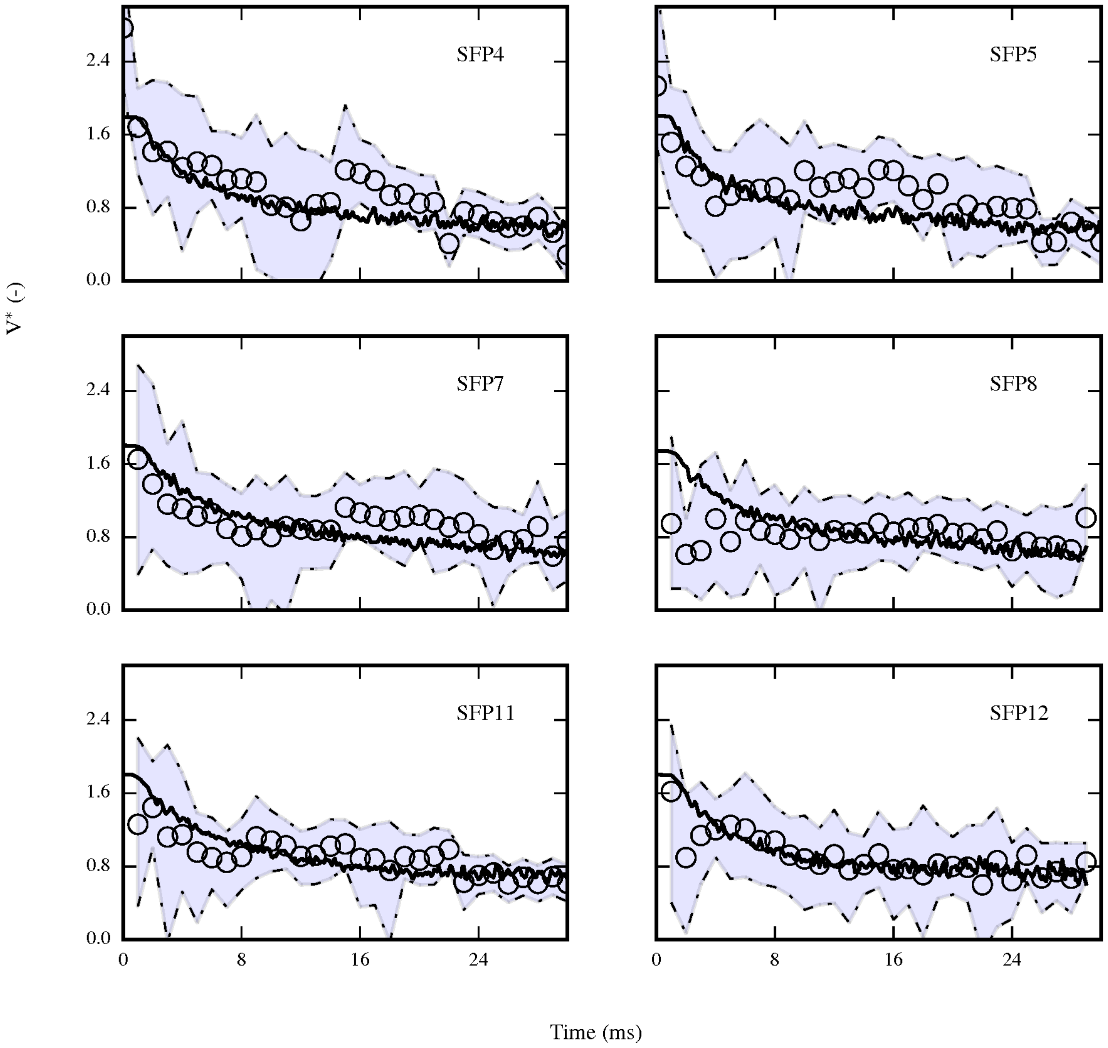




Spray Front propagation







Sikanen, T., & Hostikka, S. (2017). Numerical simulations of liquid spreading and fires following an aircraft impact. *Nuclear Engineering and Design*, *318*, 147-162.

Concluions

Conclusions

High speed water sprays were modelled with Fire Dynamics Simulator.

1. ”Big” thigs like entrainment are adequtely captured even on fairly coarse grids
2. Capturing detailed spray structure requires very fine grids.
3. For fine water mists, far away from the droplet turbulent dispersion has a significant effect

General observations

1. Typical listing experiments such ase the NFPA spray charcterization experiment are not good for model development
2. Sprays from liquid filled missiles and high pressure water mist had similar characterisrics

Future research needs

Better numerical modeling of water mist sprays would require:

1. Better description of the spray boundary condition and Better modeling of the spray boundary condition
   - Need high quality measurements of the initial spray
   - These can then be used to develop more detailed spray boundary condition models
   - Typical listing experiments are not well suited for modeling
2. Methods to alleviate the grid resolution reguirements
   - Adaptive mesh refinement ?
   - Sub grid scale models ?
   - Something else ?