



IA HySafe Research Priorities Workshop on Hydrogen Safety  
26-27 September 2016, Petten, the Netherlands

# Computational safety engineering tools

D. Makarov, V. Molkov

Hydrogen Safety Engineering and Research Centre, Ulster University

[ulster.ac.uk](http://ulster.ac.uk)

# Acknowledgements

## HySAFER staff

- Dr Sile Brennan
- Dr Volodymyr Shentsov
- Dr James Keenan
- Dr Sergii Kashkarov

## Funders and colleagues in research projects

- EC HySafe
- EC HYPER
- EC H2FC Research Infrastructure
- FCH JU HyIndoor
- FCH JU HyResponse
- UK EPSRC H2FC SUPERGEN Hub
- UK EPSRC H2FC SUPERGEN Challenge

# Ulster engineering tools

## Developed and validated models

- Under-expanded CGH2 jet parameters (in real and notional nozzles)
- The similarity law for CGH2 concentration decay and hazard distances in axisymmetric expanded and under-expanded jets
- Tank blowdown dynamics as a function of volume, pressure, and leak diameter: adiabatic and isothermal releases
- Pressure peaking phenomenon for unignited release for: (1) constant mass flow rate release and (2) tank blowdown
- Flame length and three hazard distances (no-harm, injury, fatality) for jet fires
- Passive ventilation in an enclosure with one vent
- Blast wave decay from high-pressure GH2 tank storage
- Vent sizing correlation for deflagration mitigations
- Nomogram for effect of buoyancy on hazard distances

# Ulster engineering tools

## Tools to be developed

### Models available

- Forced ventilation system parameters
- Upper limit of hydrogen inventory in closed space
- Mitigation of localised non-uniform deflagration by venting
- Blowdown time as a function of storage pressure, volume and TPRD diameter

### Models not yet available

- Pressure peaking phenomenon for ignited releases
- Radiation from hydrogen fireball after high-pressure CGH<sub>2</sub> tank rupture in a fire
- Effect of buoyancy on jet fire hazard distances

# CFD tools for safety engineering

## Vision for open source CFD code

- ❖ License-free CFD code “HyFOAM” for academic research and industrial safety engineering design (financial support is required) based on OpenFOAM
- ❖ Legacy of EC FP7 H2FC project
- ❖ Collection of case studies, demos and tutorials:
  - Releases
  - Fires
  - Deflagrations
  - Detonations
  - etc.
- ❖ Current progress
  - CGH2 axisymmetric jet
  - Deflagration in open atmosphere

# Concluding remarks

**Wide range of published and validated models for consequence analysis available**

- ❖ Releases and ventilation (8)
- ❖ Fires (1)
- ❖ Blasts (1)
- ❖ Deflagration in closed and vented enclosures (3)

**Thank you for your  
attention!**

