



**LUT**

**Lappeenranta**

**University of Technology**



# INFRAL

Development of thermal-hydraulic  
infrastructure at LUT

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SAFIR Interim Seminar

Espoo, March 24, 2017

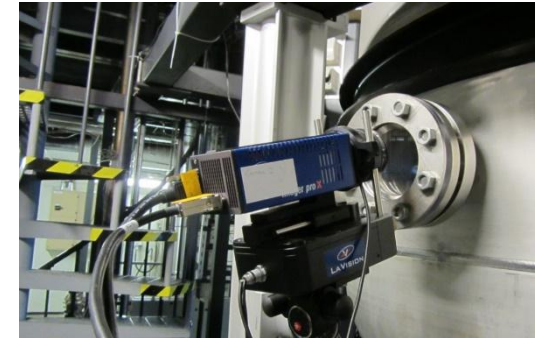
# Introduction to the INFRAL project

The aim of the project is to

- develop the Finnish thermal hydraulic measurement infrastructure at LUT
- secure the operability of the existing test facilities
- prepare for the new large-scale integral test facility
- co-operate with international top-level research institutes in the field

The significance of the project:

- Large test facilities require maintenance and development
- New measuring techniques can produce highly detailed data for
  - understanding of safety-relevant flow phenomena
  - development and validation of computational tools
- Deployment and utilization must be practiced



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# The INFRAL project in 2015–2016

## Advanced measurement techniques (WP1)

- Advanced and combined use of PIV/WMS/3D Cam systems (T1.1)
- Evolutionary WMS applications (T1.2)
- Improvement of 3D High-Speed Camera data analysis (T1.3)
- New applications of advanced measuring techniques (T1.4)

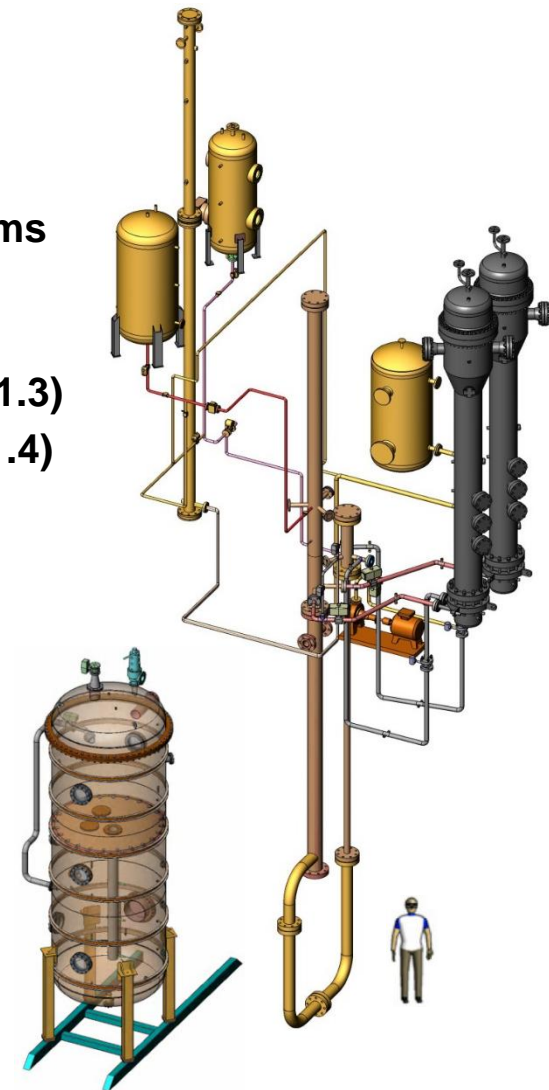
## Maintenance and equipment (WP2)

- PWR PACTEL / PACTEL maintenance (T2.1)
- Other equipment (T2.2)

## Modular Integral Test facility (MOTEL) (WP3)

## Project management, international co-operation and publications (WP4)

- Project management and publications (T4.1)
- International co-operation (T4.2)



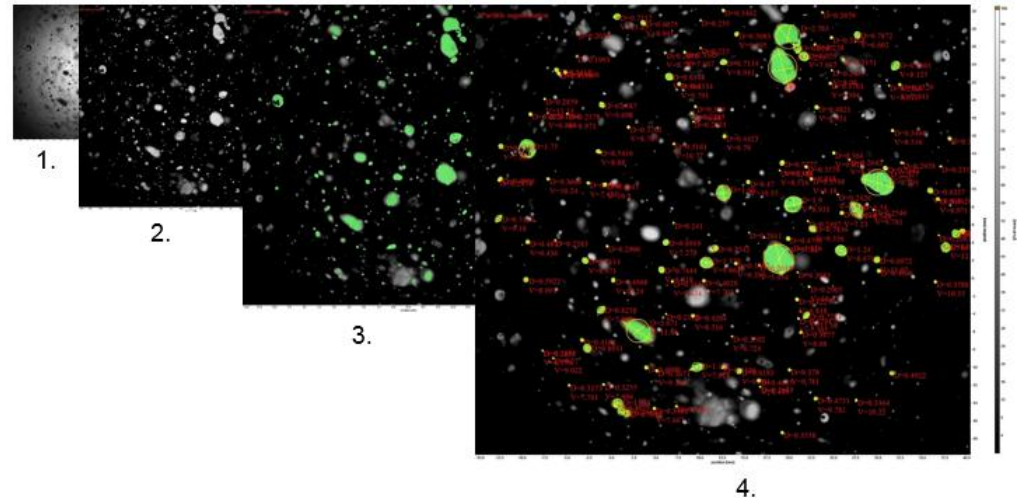
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# INFRAL WP1, Advanced measurement techniques: Particle Image Velocimetry

The Particle Image Velocimetry measurement system was upgraded with the shadowgraphy technique used for particle size measurements. Also new sCMOS cameras were purchased → doubles the measurement frequency.

Shadowgraphy procedure:

1. Raw image
2. Processed image
3. Droplet recognition
4. Droplet properties (size, velocity,...)



The PIV expertise has been broadened with measurements in a combustion chamber and in air with evaporating tracer particles  
→ Capabilities to produce CFD validation data with PIV have been extended

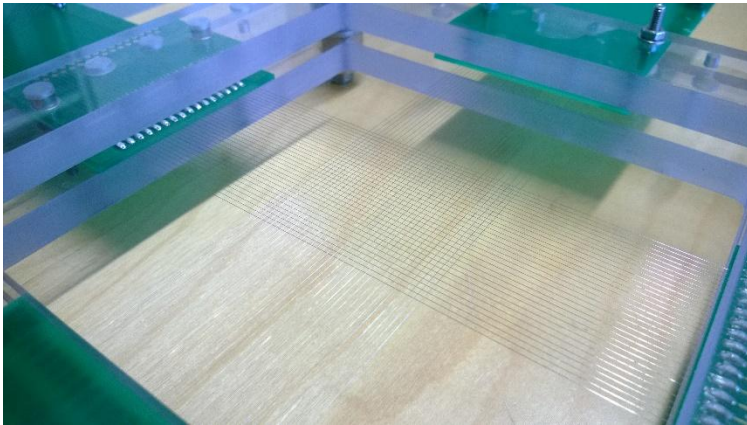
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# INFRAL WP1, Advanced measurement techniques: Wire-Mesh Sensors

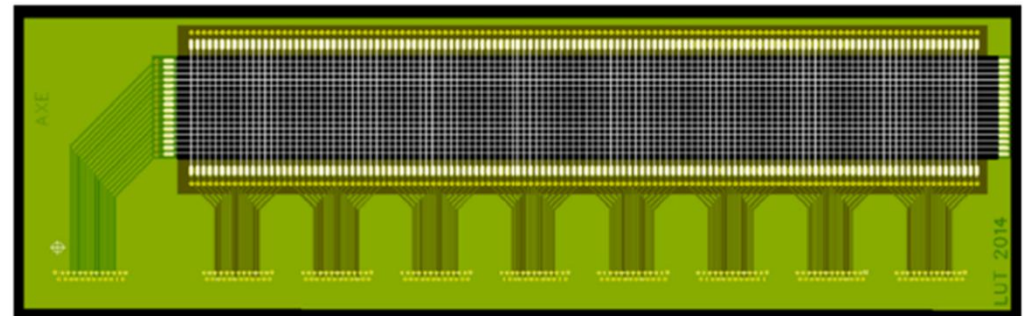
The advanced applications for the Wire-Mesh Sensors have been studied

- The functionality and applicability of the axial sensor developed in LUT was studied under various flow conditions in the HIPE test facility
- Conference papers in the NURETH-16 conference (2015) and the SWINTH-2016 workshop (2016) on the axial WMS measurements
- Measurements conducted also in swirling two-phase flow

Traditional radial sensor



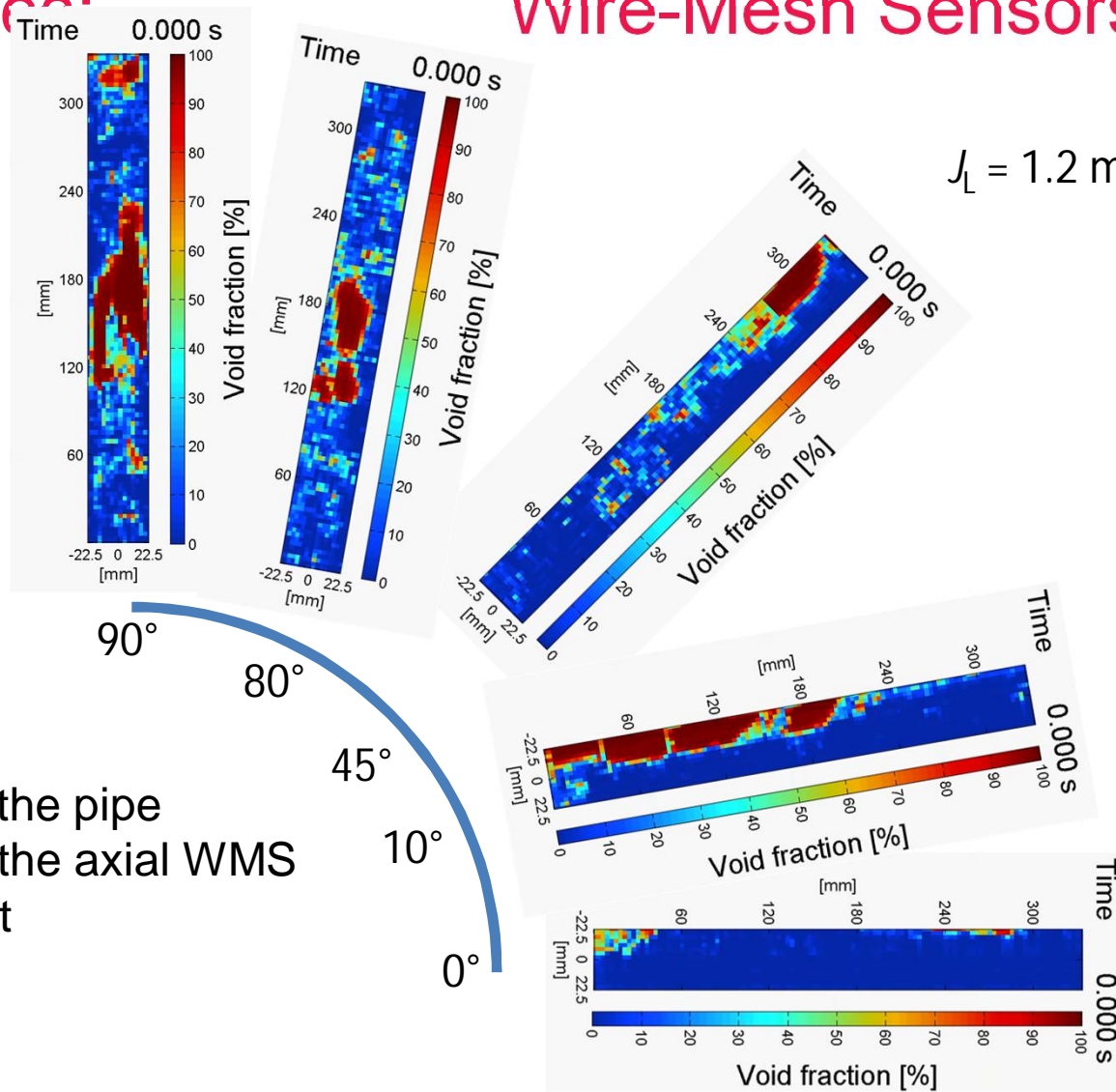
Axial sensor



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# INFRAL WP1, Advanced measurement techniques: Wire-Mesh Sensors

$$J_L = 1.2 \text{ m/s}, J_G = 0.6 \text{ m/s}$$



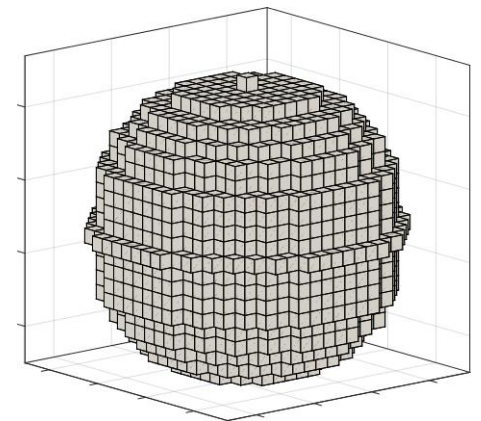
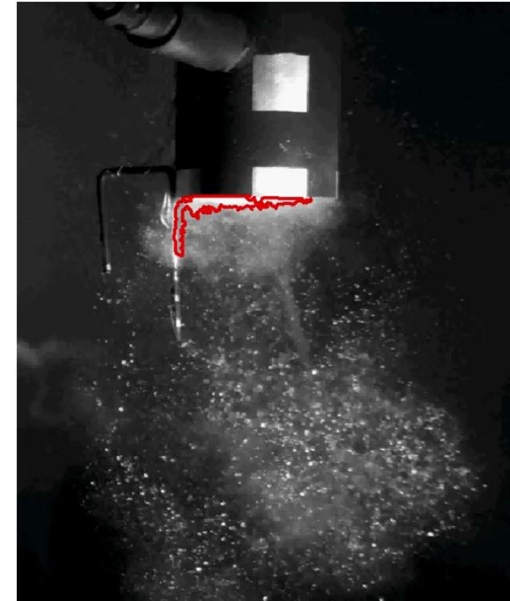
The effect of the pipe inclination to the axial WMS measurement

# INFRAL WP1, Advanced measurement techniques: High-Speed Cameras

High-Speed Cameras are used at LUT to support the data analysis of the PPOOLEX condensing experiments

The pattern recognition algorithm used for the analysis of the HSC raw data has been developed further

- It is now possible to calculate volume, surface area, diameter, condensation velocity/acceleration, and (chugging) frequency of condensing steam bubbles
- In 2015–2016, mainly analysis of older experiments
- Results were published in Nuclear Engineering and Design:
  - Patel, G., Tanskanen, V. Hujala E. & Hyvärinen, J. 2016. Direct contact condensation modeling in pressure suppression pool system. Nuclear Engineering and Design, Available online.



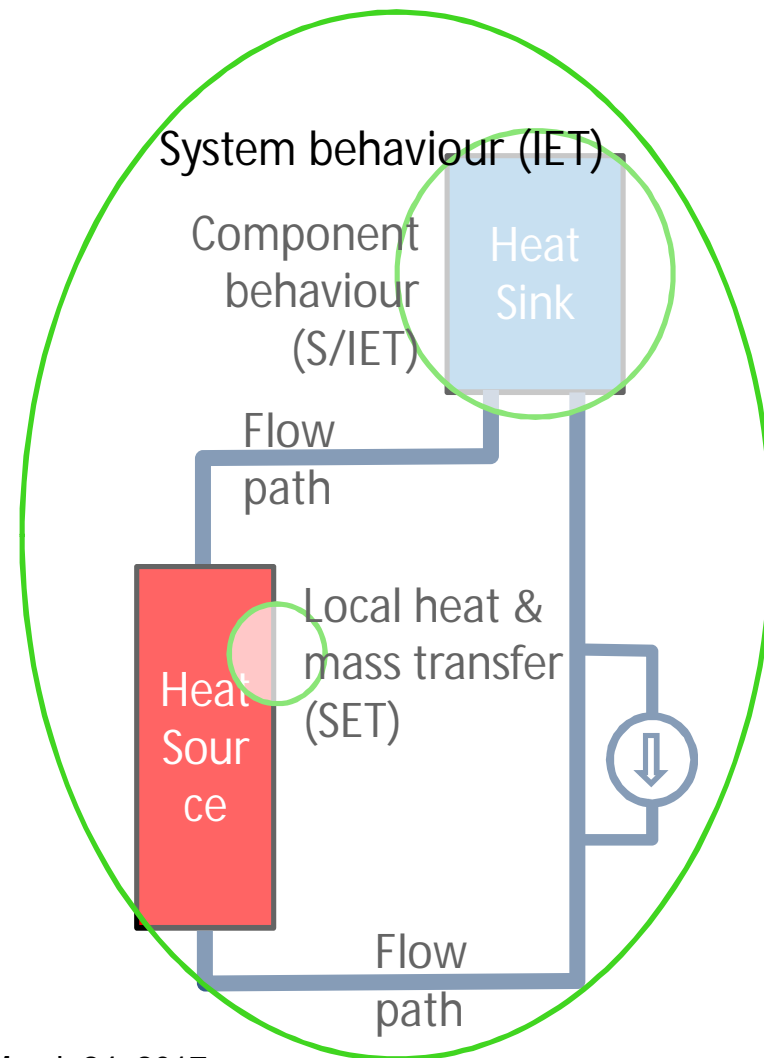
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# INFRAL WP3, Modular Integral Test facility (MOTEL)

The work package started in 2016

- Preliminary studies for the new large-scale modular integral test facility
  - Interchangeable “modules”
- In 2016, the research based requirements were surveyed
  - International trends and future needs in (experimental) thermal hydraulic research
  - The research based requirements and guidelines for the design of MOTEL
- Design of the facility started in 2016 with a survey of the options for the first heater element
  - The design and the construction are funded by the Academy of Finland

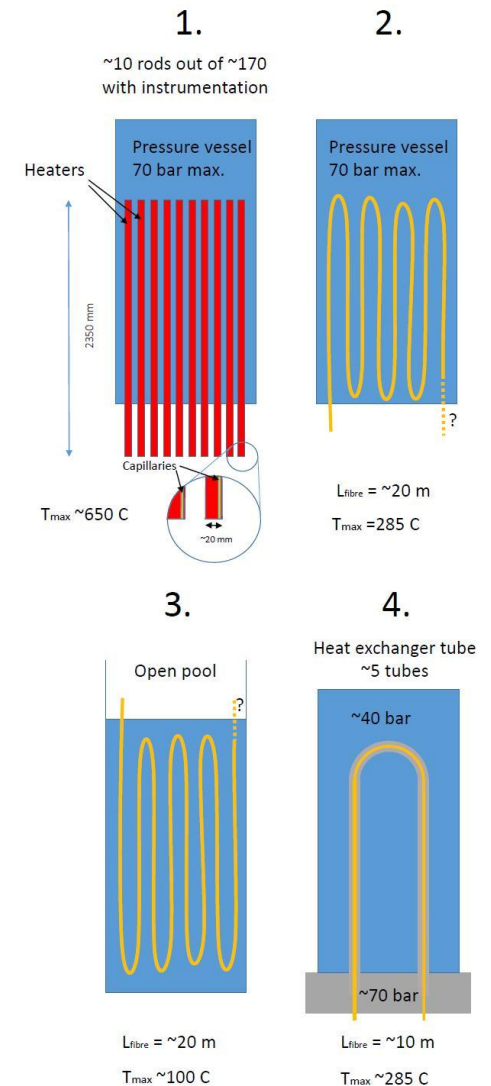


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# Conclusions

INFRAL benefits the whole Finnish nuclear safety community:

- Existing thermal hydraulic facilities have been well maintained
- New measurement techniques and their use have been further developed:
  - WMS, PIV, HSCs
  - More in the pipeline: optic fibre based temperature and strain distributions
- Future advanced facilities are in the works, Academy funding also obtained



Example configurations for optical fibre measurement

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Thank you for the attention!



# INFRAL WP4, Project management, international co-operation and publications

Research visit to University of Michigan in September/October 2016

- Two researchers from LUT attended the visit
- WMS, PIV and laser doppler velocimetry measurements were conducted, and related data processing procedures were practiced
- Gamma tomography and X-ray imaging systems of UMICH were introduced, and the details and characteristics of those were discussed
- The visit served as a good opportunity for networking, and the good connections to UMICH were enhanced

Communication with other top-level research institutes using similar research infrastructure as LUT has continued

- ETH Zurich, Helmholtz-Zentrum Dresden Rossendorf, Paul Scherrer Institute,...

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