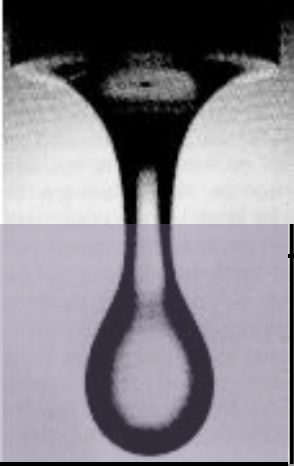


# Immersed Surfaces and Local Mesh Refinement using TransAT

Chidambaram Narayanan, Dr. sc. techn. ETH  
D. Caviezel, D. Lakehal

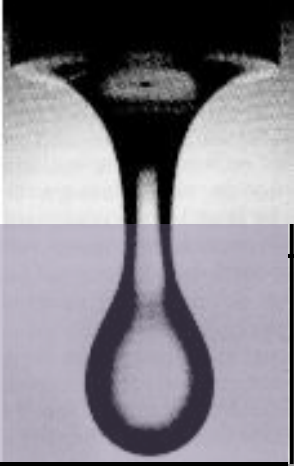
Head of R & D  
ASCOMP GmbH  
Technoparkstrasse 1  
8005 Zurich



# ASCOMP GmbH

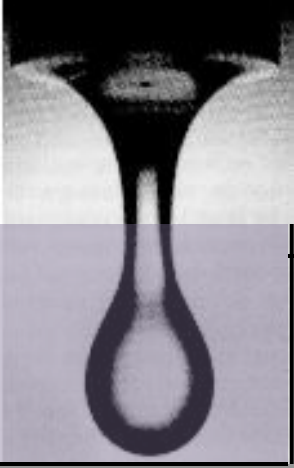
ASCOMP is a high-technology engineering consulting company

- 3D CFD simulation software: TransAT
- System modelling: Nuclear
- Multiphase flow simulation methods
- Fluid dynamics & turbulence modelling
- Engineering design & consulting



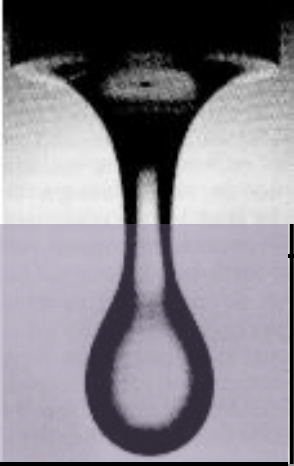
# TransAT – Single Phase Modelling

- Generalized body-fitted grids
- (In)compressible Navier-Stokes solver
- Heat transfer and scalar transport
- RANS turbulence models
- Large Eddy Simulation (LES)
- **Immersed Interfaces Technique (IST)**
- **Block Mesh Refinement (BMR)**
- Advanced solvers: GMRES-GMG, AMG



# TransAT: Two Phase Flow Modelling

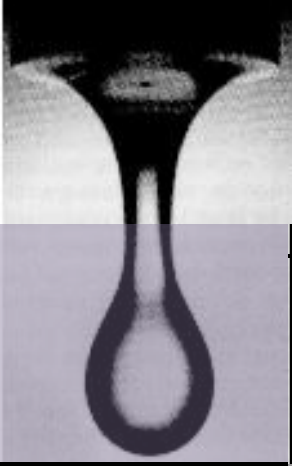
- Interface tracking - Level Sets & VoF methods
- Dispersed phase flow - Lagrangian particle tracking - one-way & two-way coupling
- Two-phase flow with heat transfer & phase change
- Dynamic contact angle treatment
- **Immersed interfaces**
- **BMR (under development)**



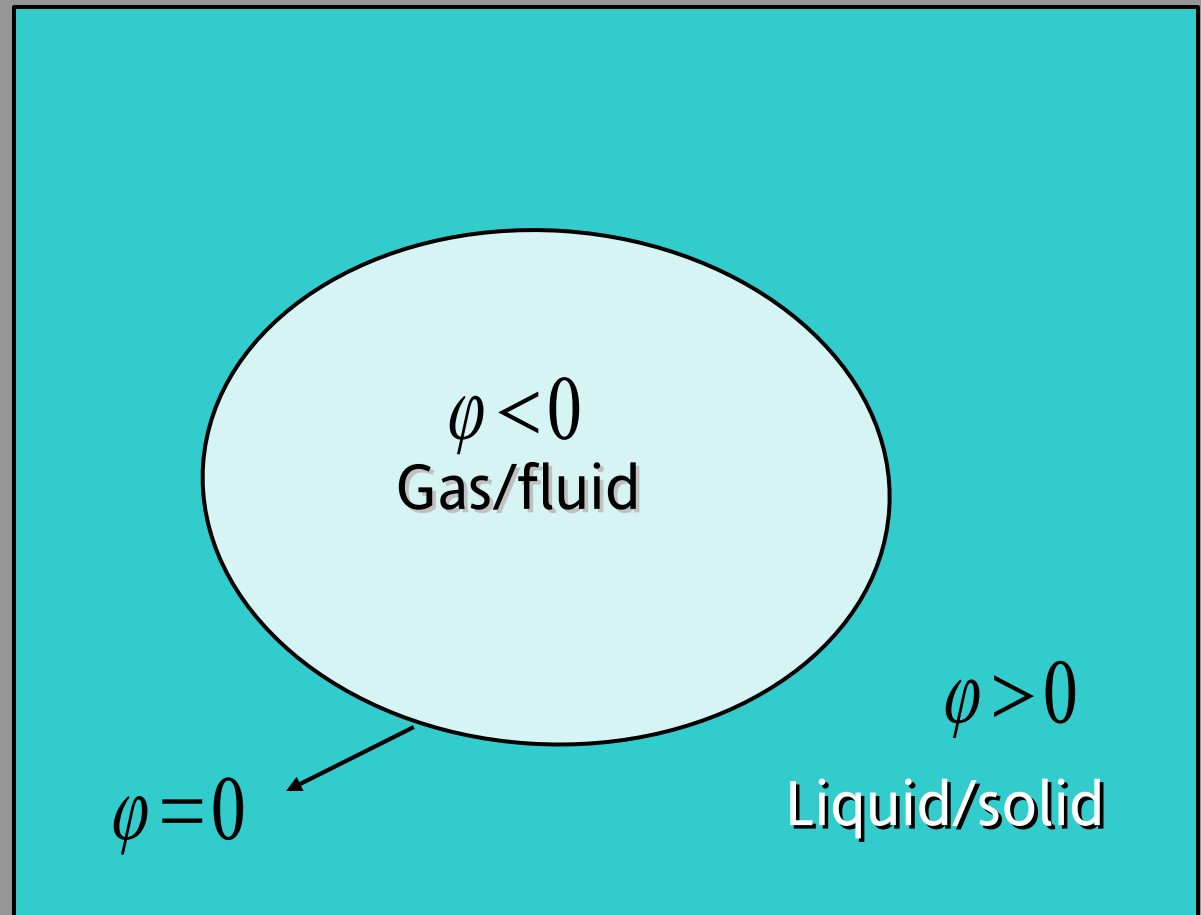
# TransAT: New developments

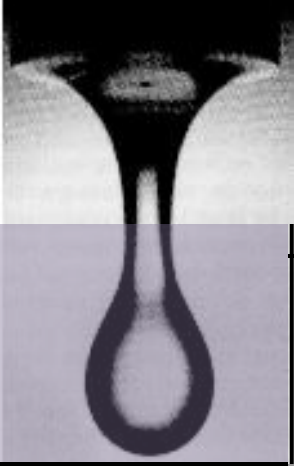
- **Immersed interfaces**
  - Direct CAD import using STL files
  - Rapid gridding of complex geometry
  - Moving bodies, fluid-structure interaction
  - Conjugate heat transfer
- **BMR**
  - Put resolution were needed
  - No need to change discretization
  - Local Defect Correction (LDC) – fully conservative

# Immersed Interface Technique/ Level Set Method



Level Set: Signed  
distance to the  
interface





# IST: Smooth interface treatment

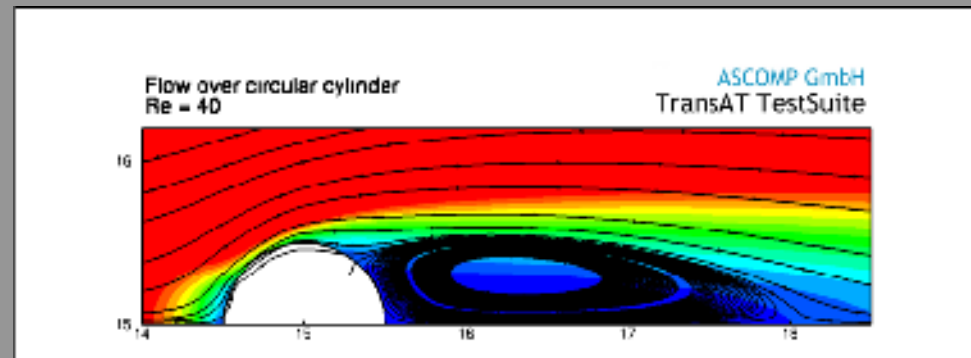
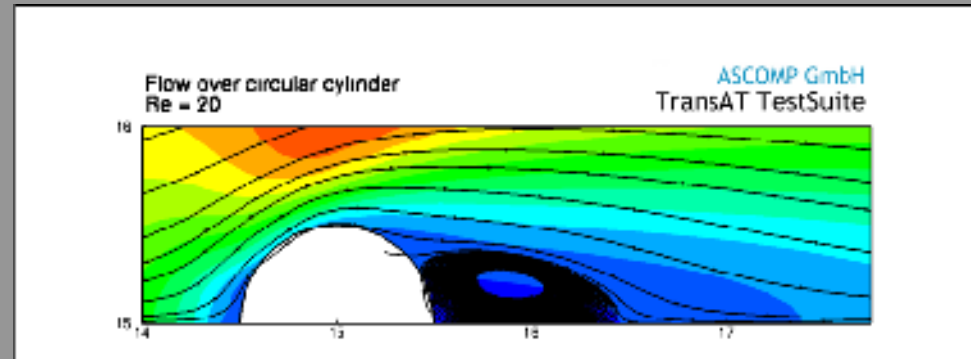
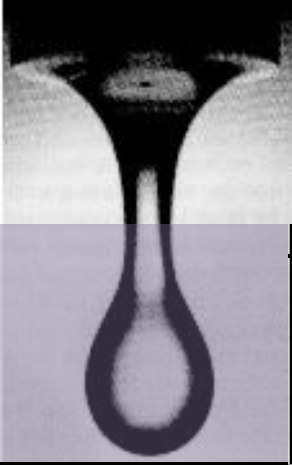
$$\frac{\partial \varphi}{\partial t} + u_j^I \frac{\partial \varphi}{\partial x_j} = 0;$$

$$H(\varphi) = \frac{1}{2} \left[ 1 + \tanh\left(\frac{2\varphi}{\delta}\right) \right]$$

$$\rho = \rho_L H(\varphi) + (1 - H(\varphi)) \rho_G$$

$$\mu = \mu_L H(\varphi) + (1 - H(\varphi)) \mu_G$$

# IST: Steady flow over cylinder

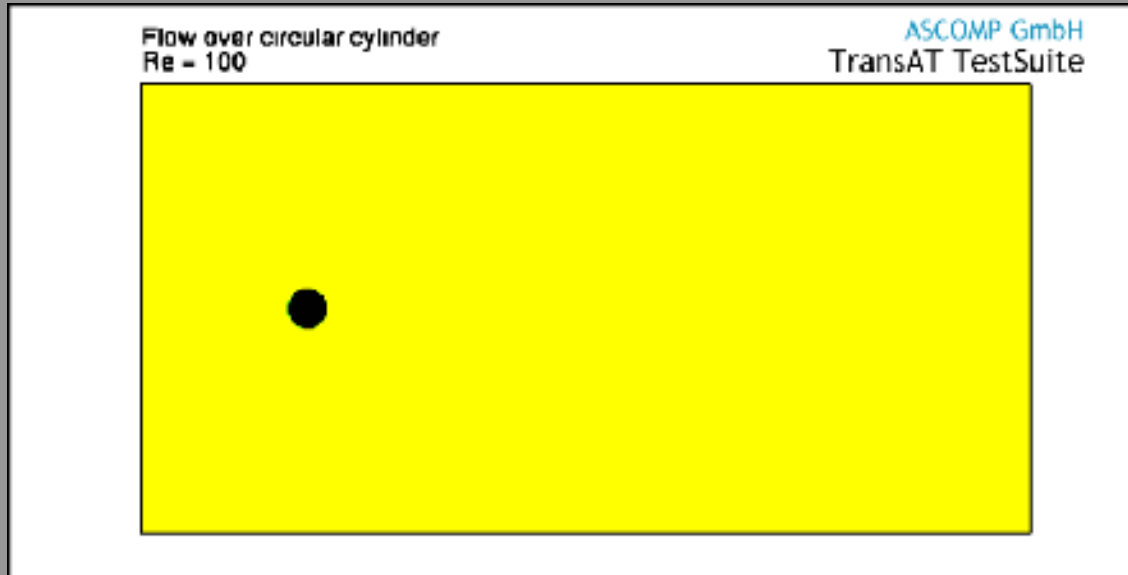
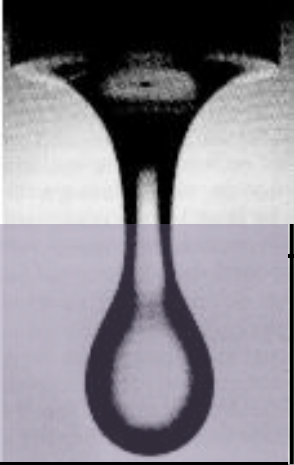


Re = 20, 40

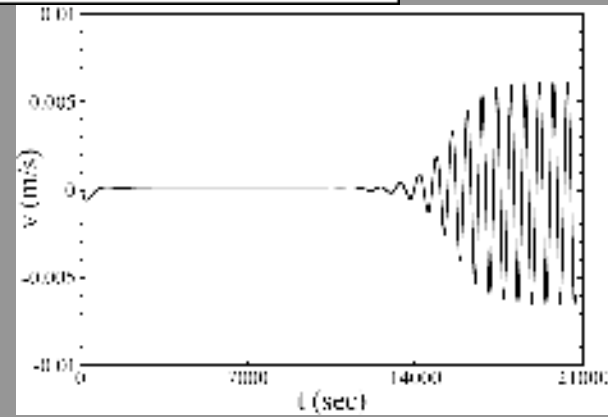
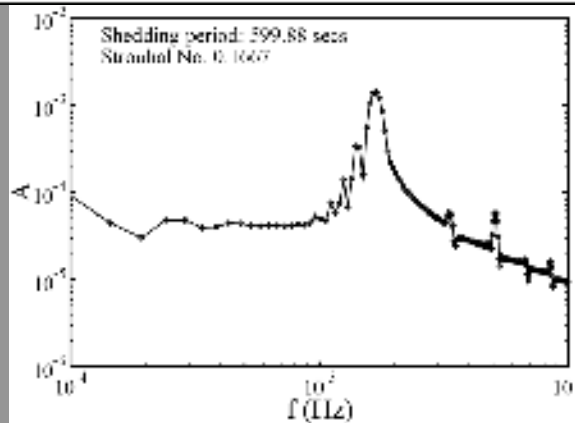
Xr = 0.945, 2.49



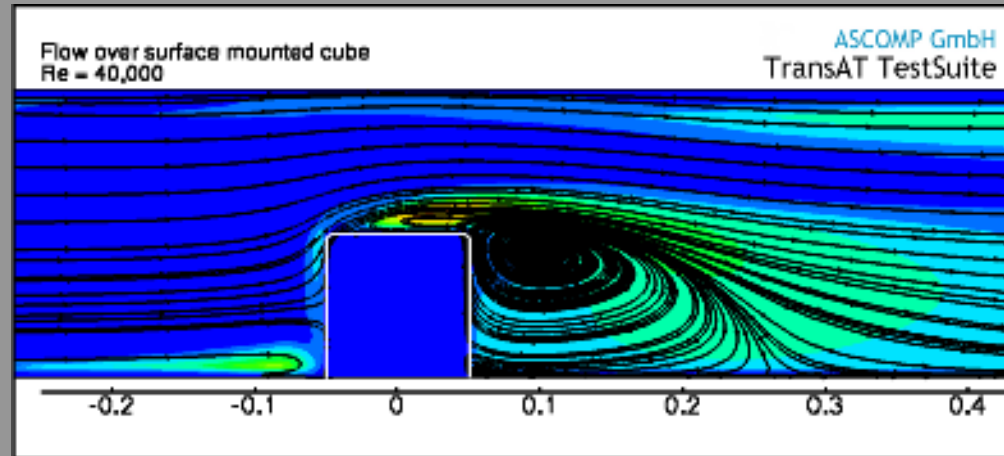
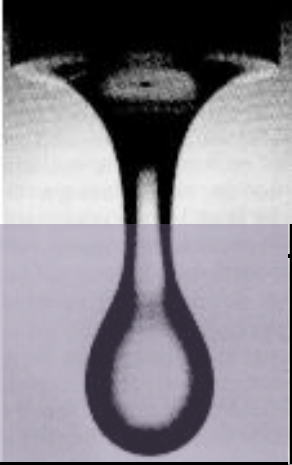
# Shedding flow over cylinder



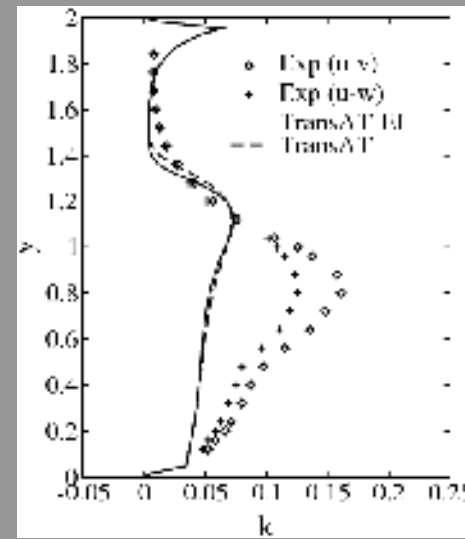
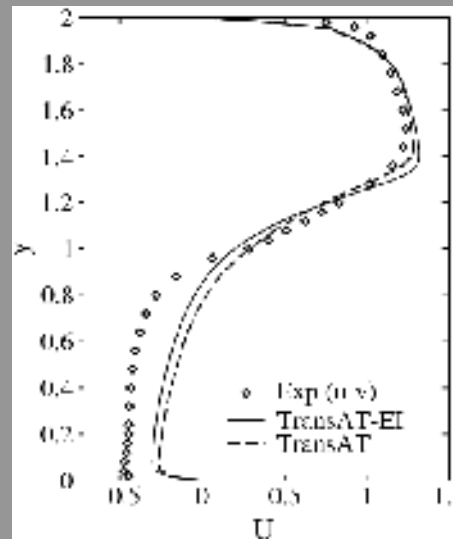
$Re = 100$   
 $St = 0.1667$



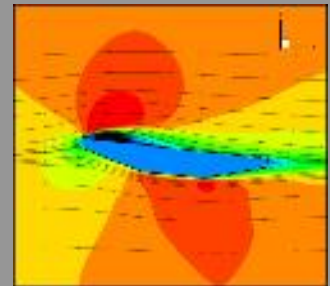
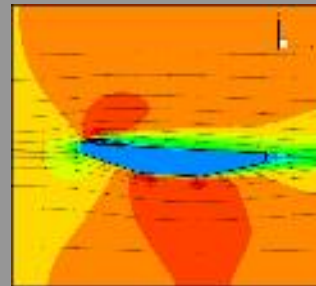
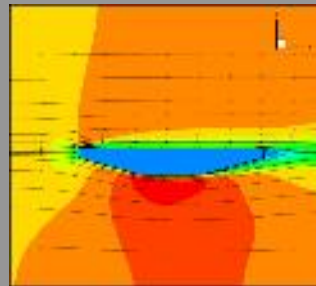
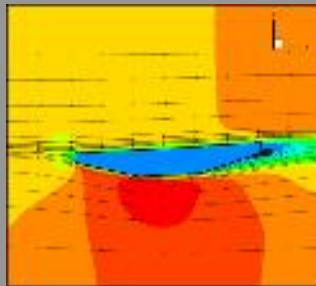
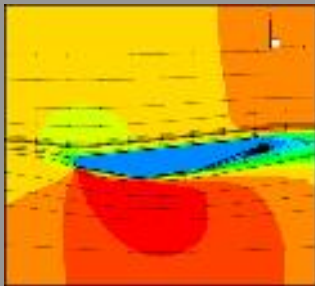
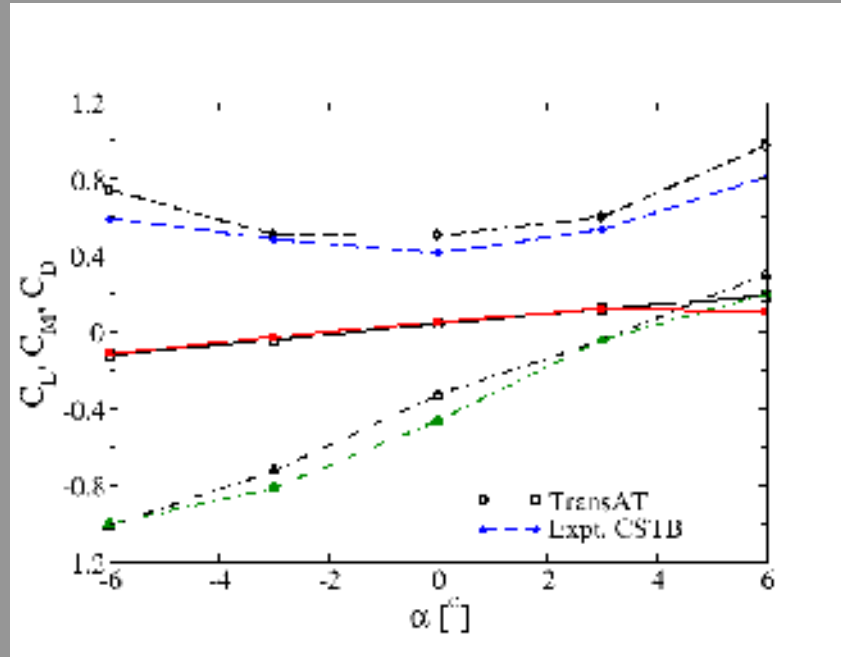
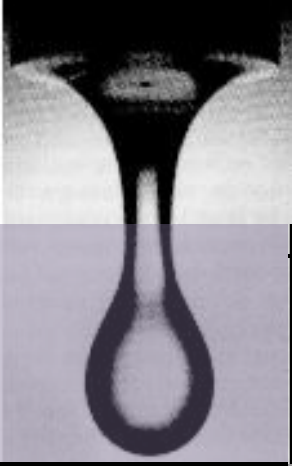
# IST: Turbulent flow over mounted cube



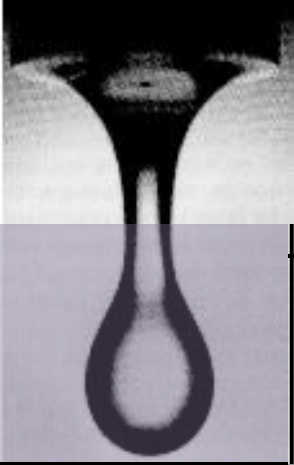
Re = 40000  
Xr ~ 2.0



# IST: Millaut Viaduct - France



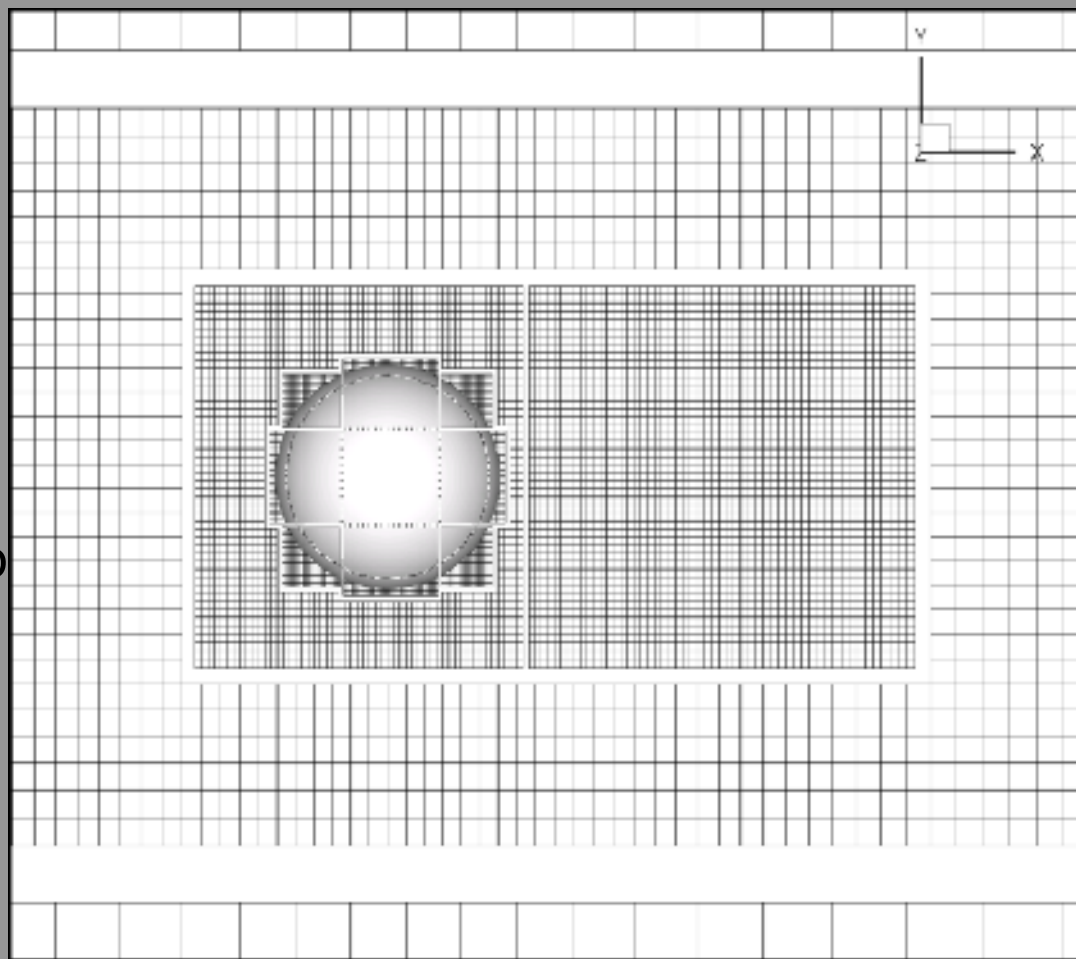
# Block Mesh Refinement (Multi-resolution)

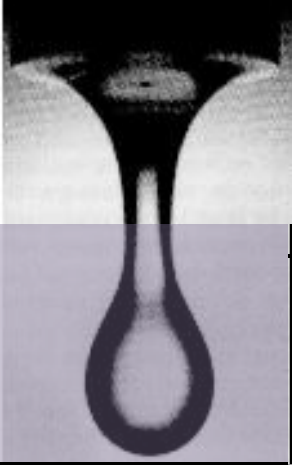


Import the CAD file

Automated grid refinement

Refinement factor can be multiples of 2

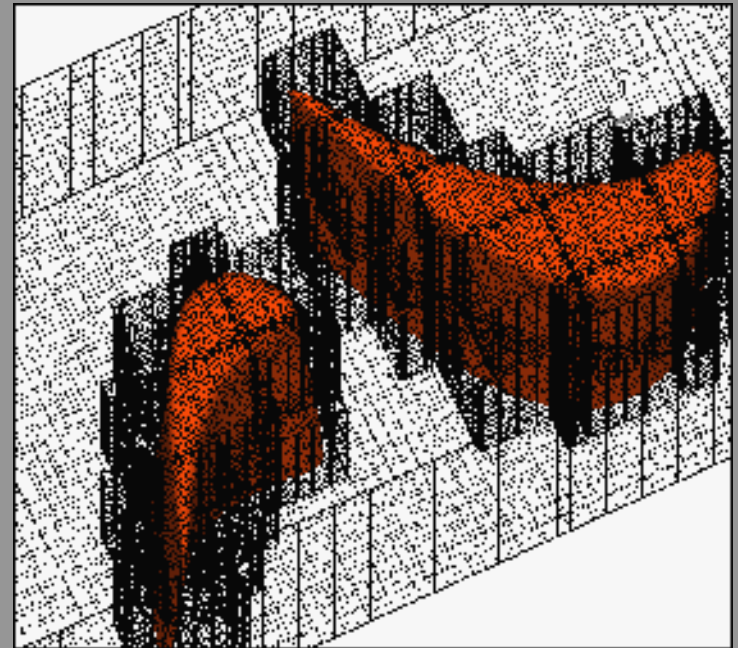
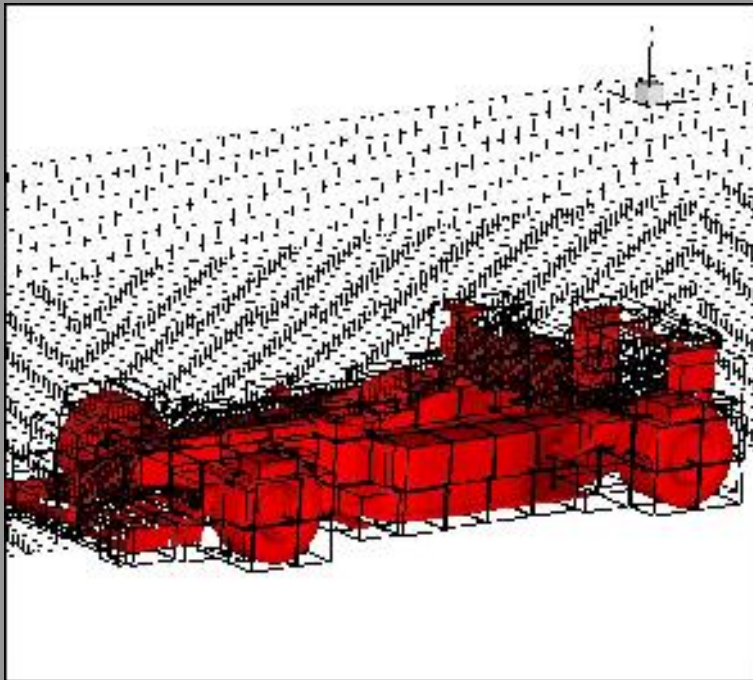




# BMR: Block Mesh Refinement

Scalable parallel multi-block method

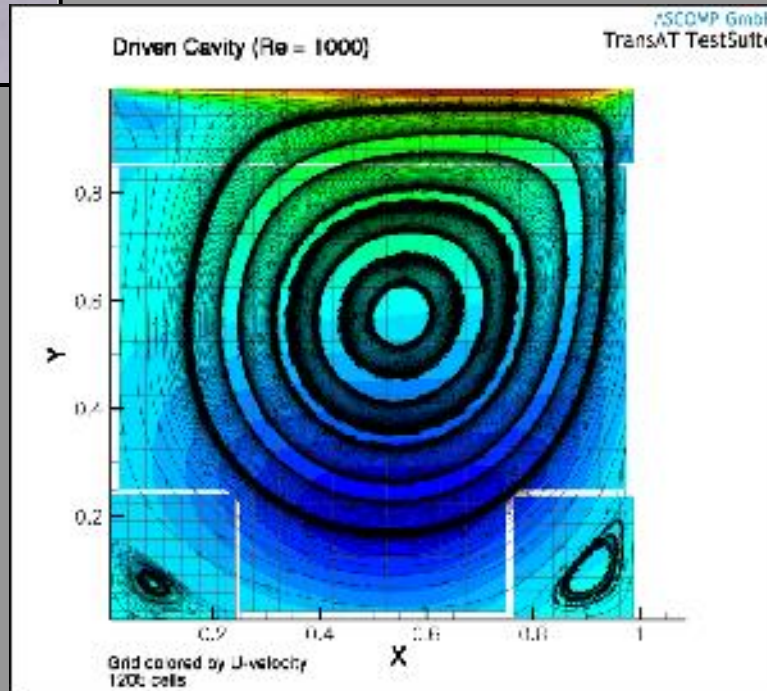
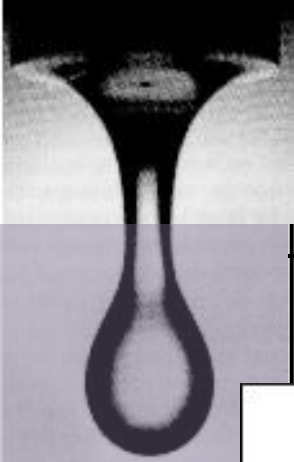
Saves up to 70% cells in 3D



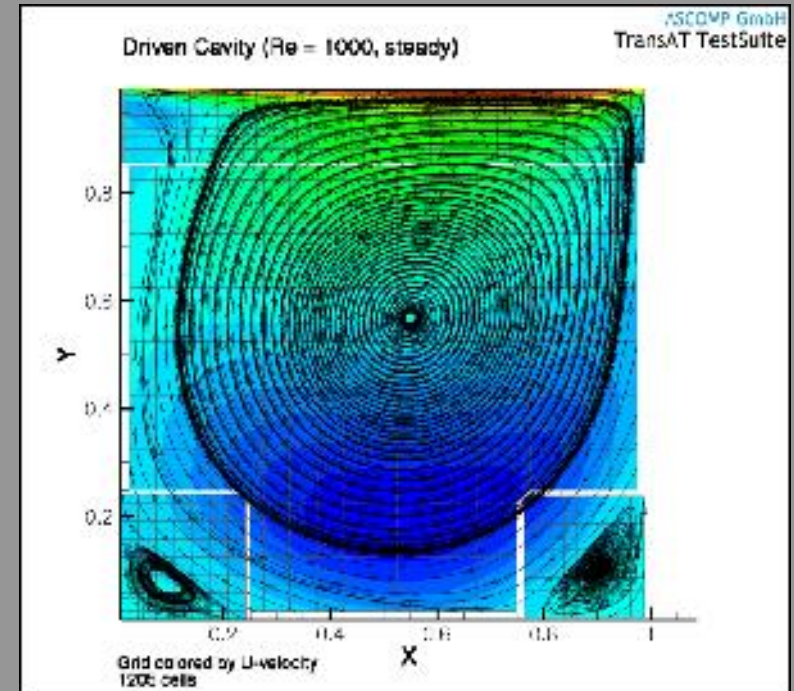
Detailed complex geometries  
Automatized refinement per blocks



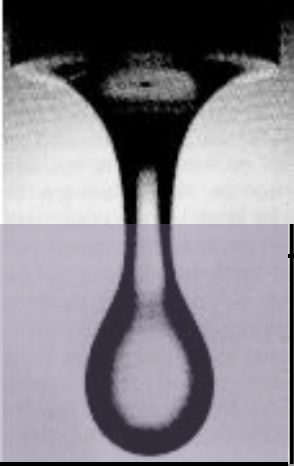
# BMR: Block Mesh Refinement



Unsteady simulation



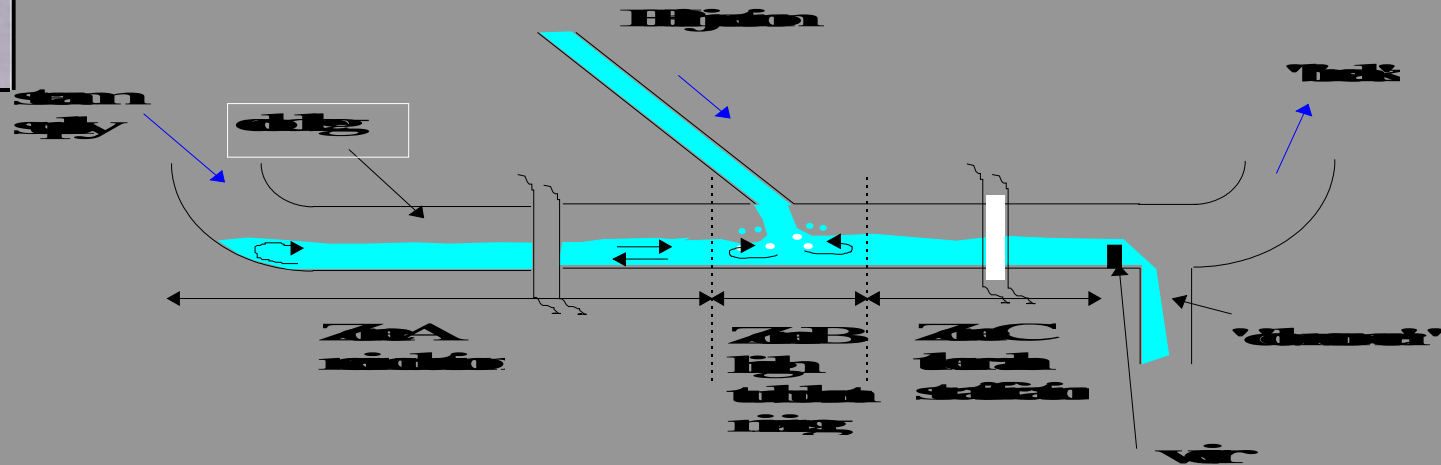
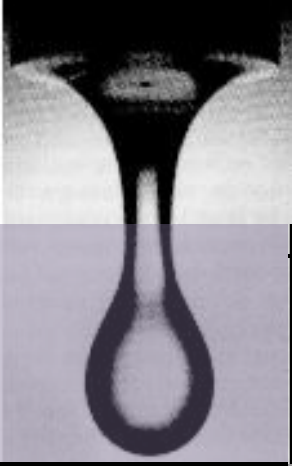
Steady simulation: all eqns use LDC



## Examples of IST and two-phase flows.

- Loss of Coolant Accident (LOCA)
- Boiling heat transfer in nuclear fuel assembly

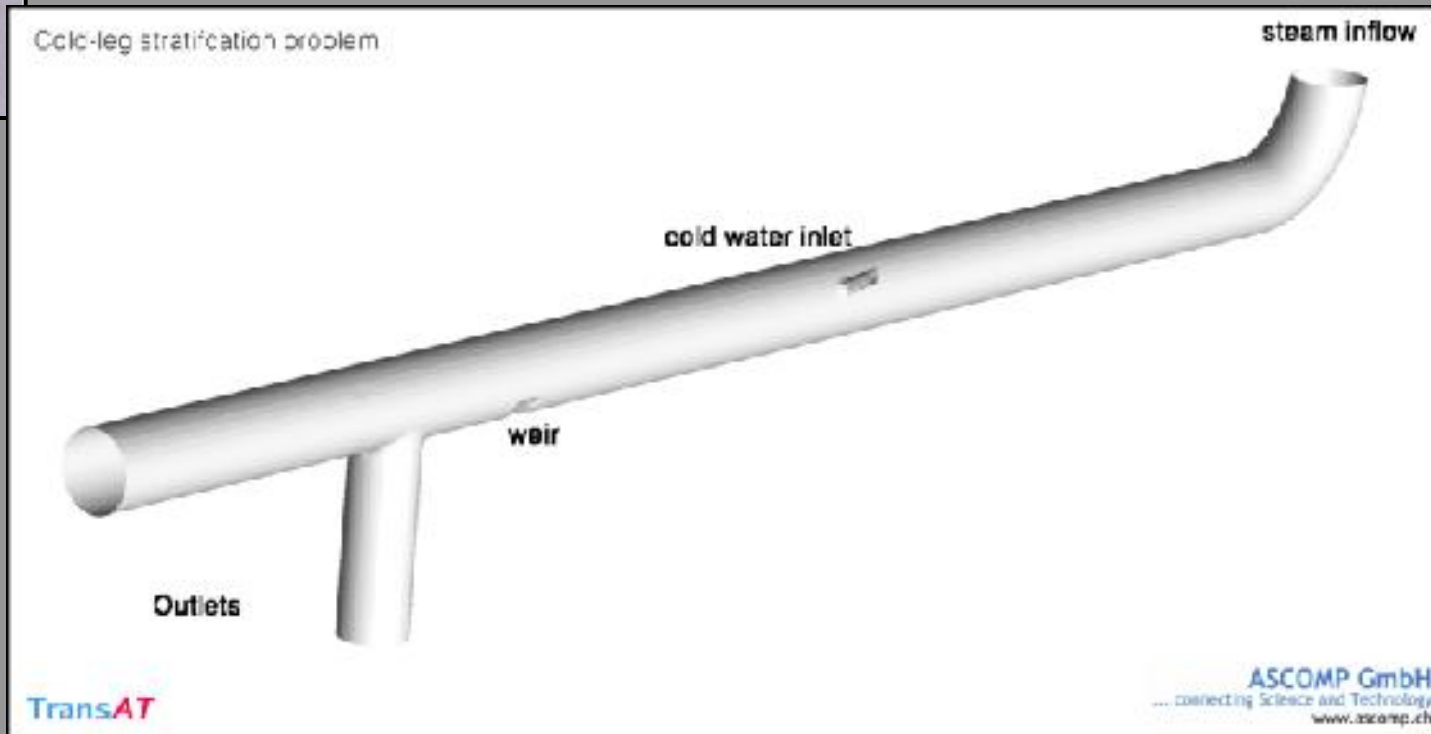
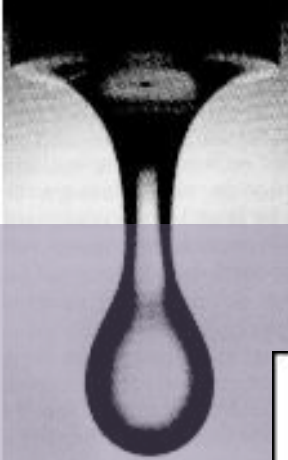
# Nuclear safety systems: LOCA (ECC Injection)



During a hypothetical SB-LOCA, cold water is injected into the cold leg to limit the Reactor Pressure Vessel lifetime (Emergency Core Cooling, ECC). The injected water mixes with the hot fluid in the cold leg and the mixture flows towards the downcomer, leading to extreme thermal gradients in the structural components and thus to very high stresses.

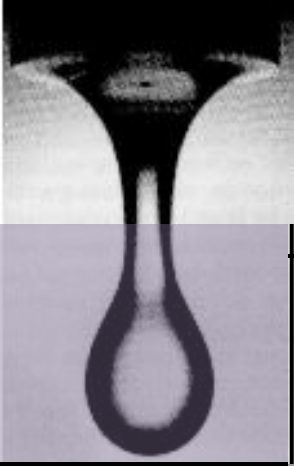


# LOCA (ECC Injection)

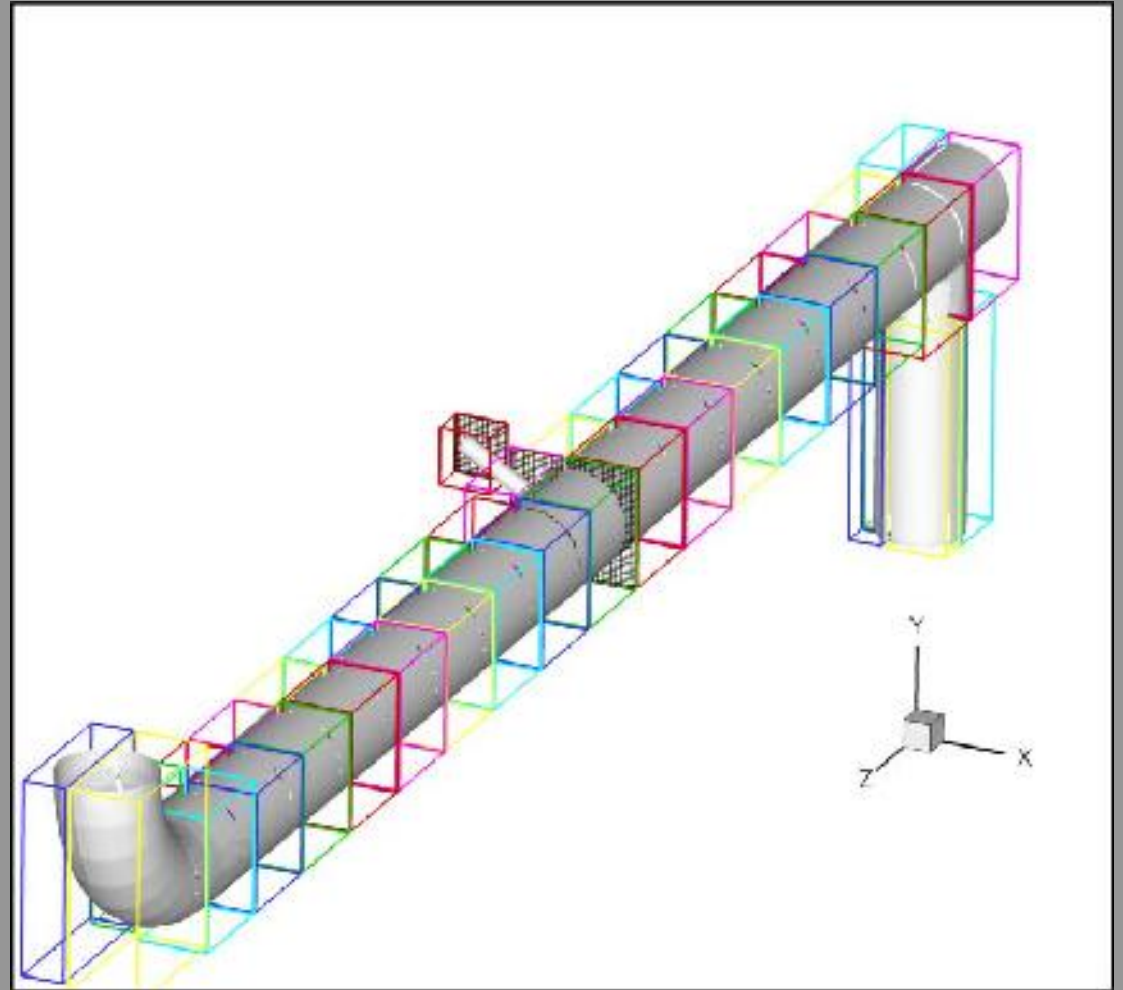


Import the CAD file (STL format)

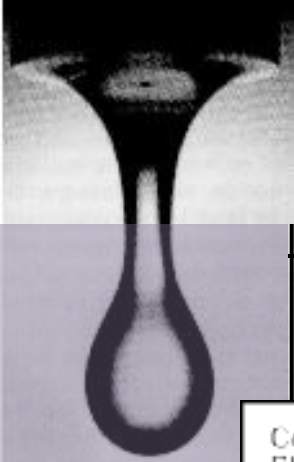
# LOCA (ECC Injection)



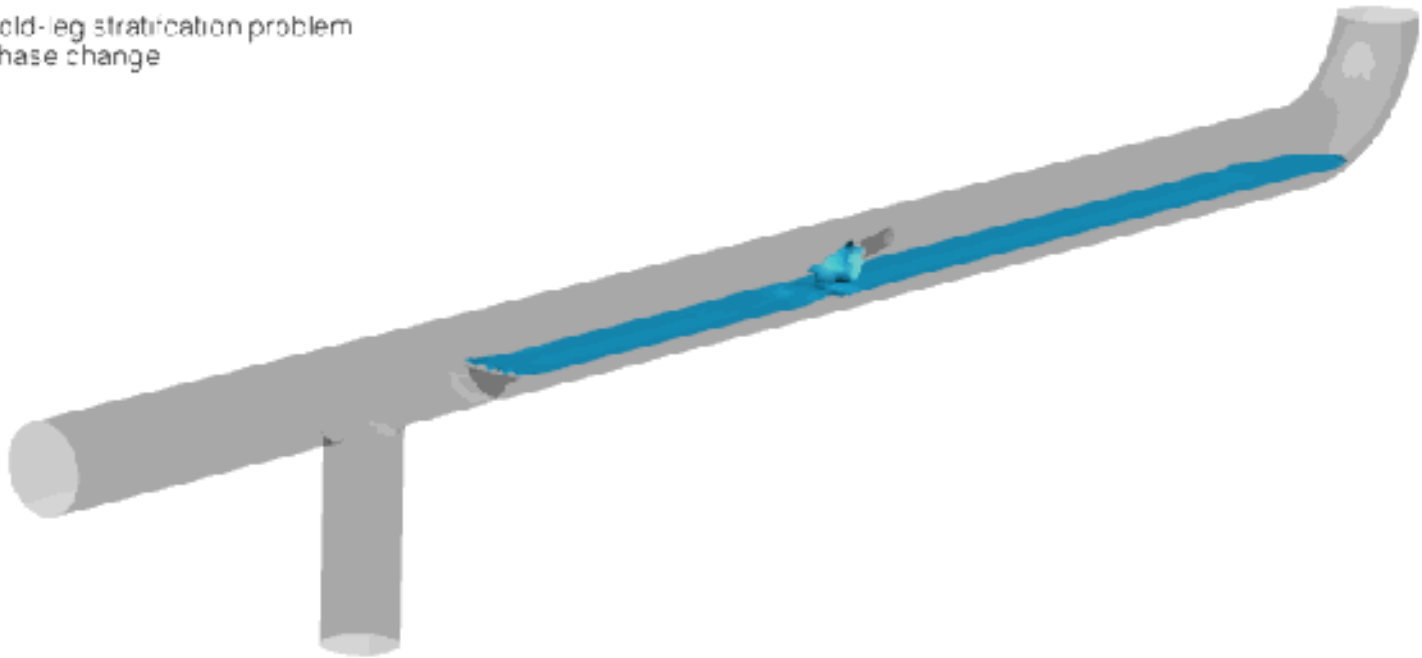
Apply IST/BMR



# LOCA (ECC Injection)



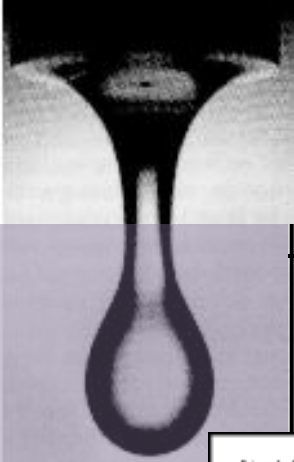
Cold-leg stratification problem  
Phase change



TransAT

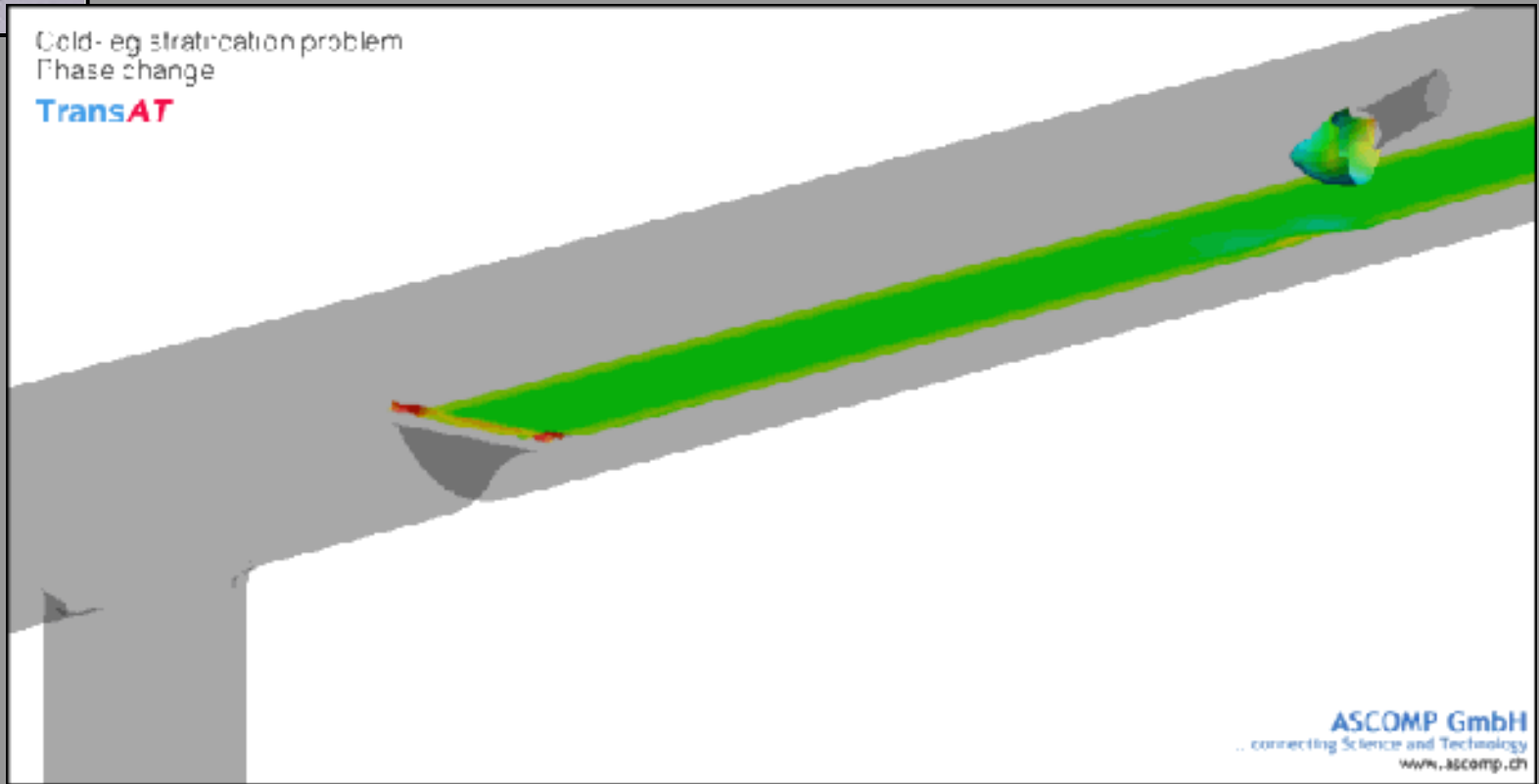
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www.ascomp.ch

# LOCA (ECC Injection)



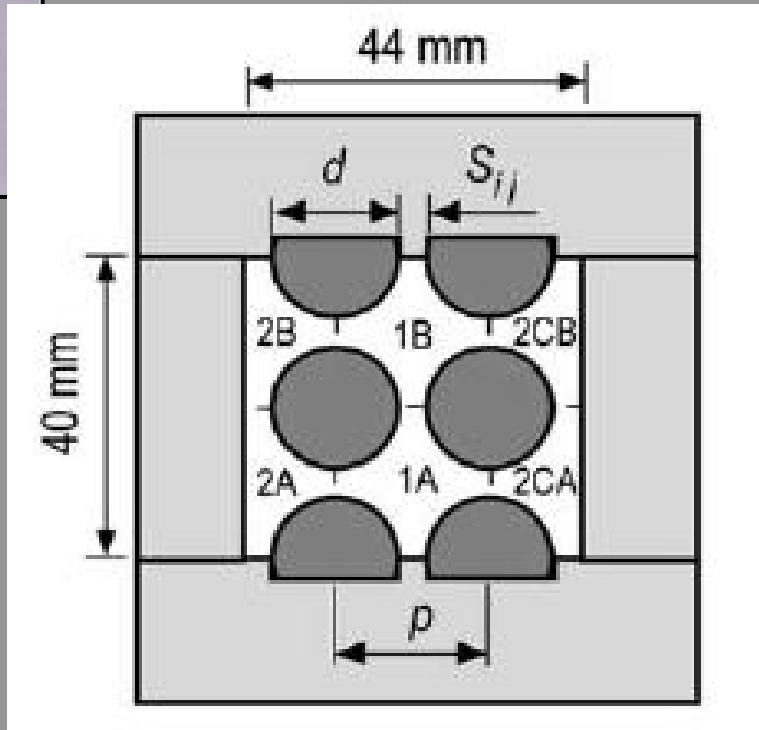
Cold-eg stratification problem  
Phase change

**TransAT**

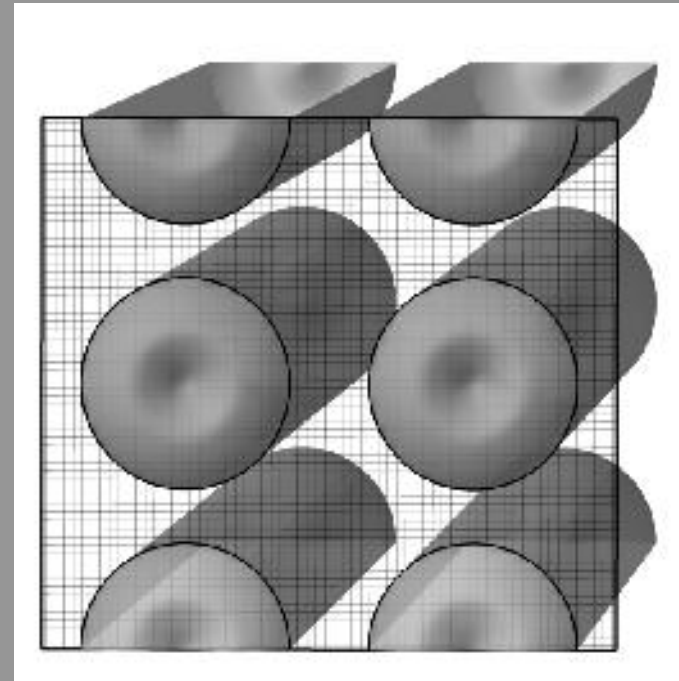


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# Optimisation of nuclear fueling systems: sub-channel Analysis



Import the CAD file

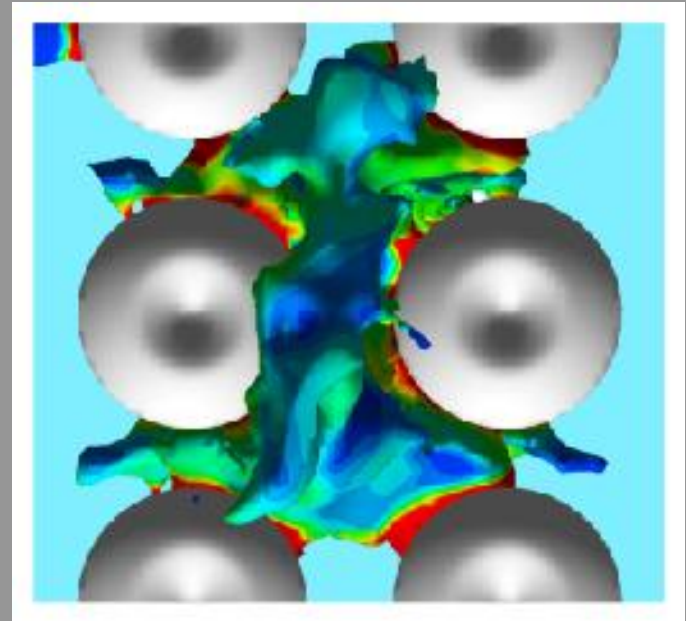
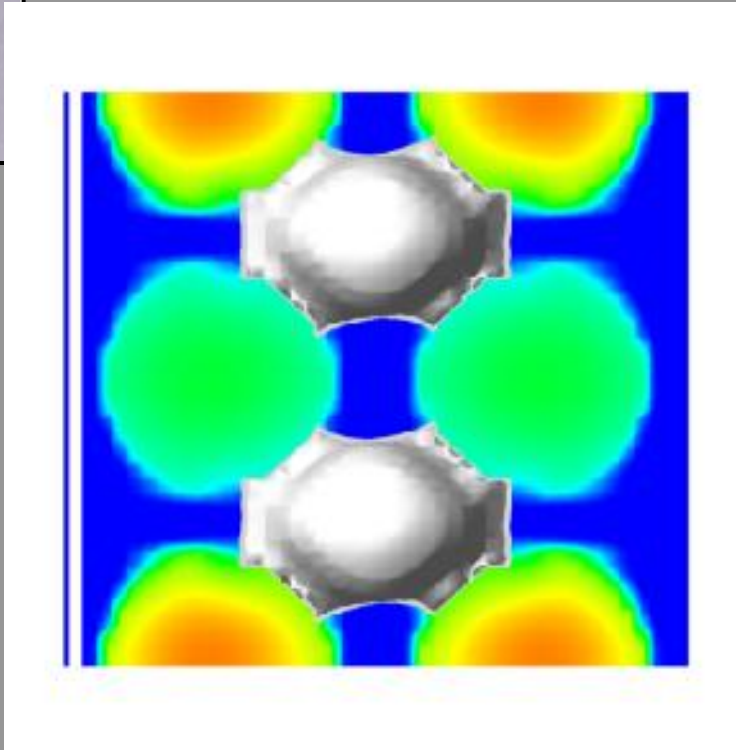


Apply IST

Exp. Data of Sadatomi et al., IJMF, 2004

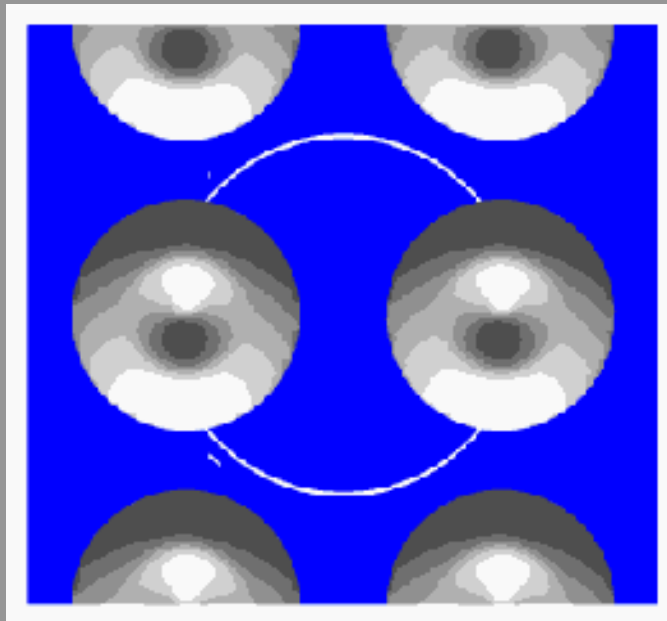
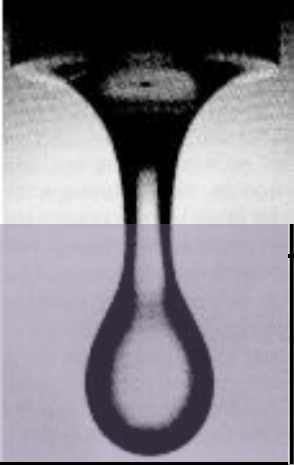
IST grid and cross-sectional geometry and dimensions of the test channel.

# Sub-channel Analysis

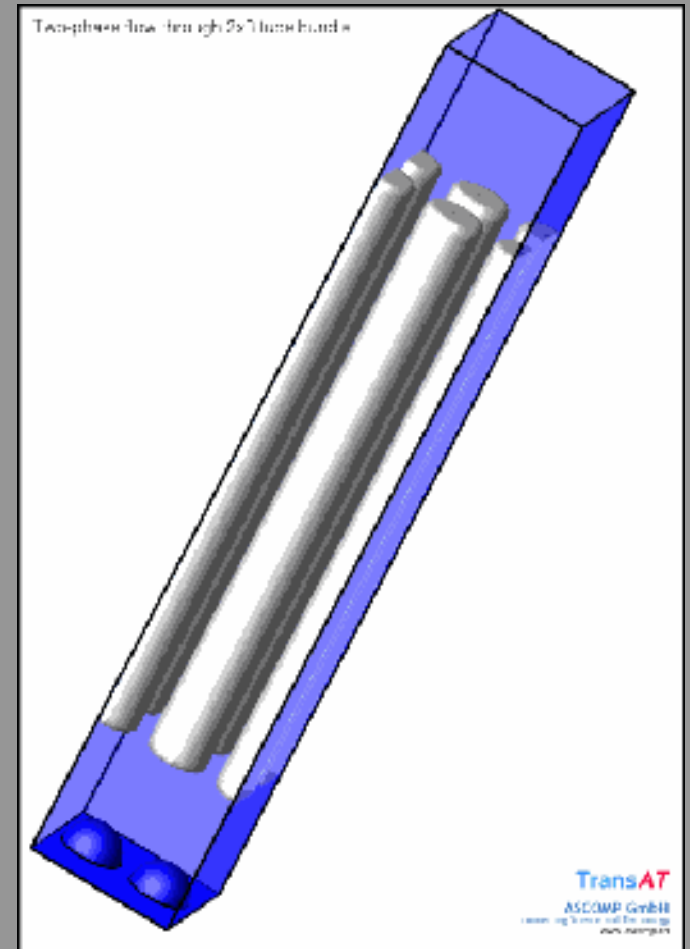


Level Set method

Temperature and gas phase in laminar and turbulent cases.



Interface and heat contours

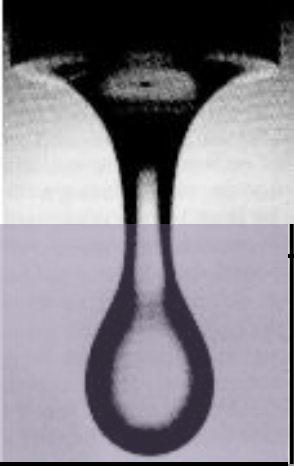




# Summary

- Immersed interface method along with two-phase flow – same formulation.
- Conjugate heat transfer is treated in a natural way
- BMR method along with LDC method gives automated grid generation.





Thank you for your attention!