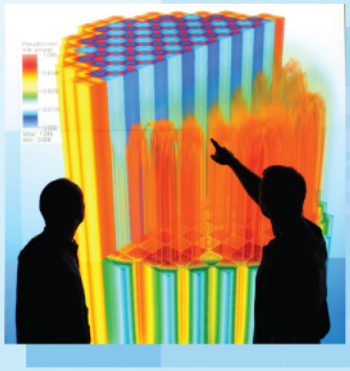
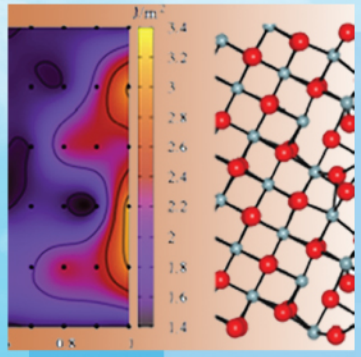
CASL-U-2011-0185-000-a

Power uprates
and plant life extension



Engineering design
and analysis

Science-enabling
high performance
computing



Fundamental science

Plant operational data

Consortium for Advanced Simulation of LWRs

ITM Benchmark #1: PHASTA Results - Presentation Slides

Igor Bolotnov

North Carolina State University

September 30, 2011

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

CASL-U-2011-0185-000-a

ITM Benchmark #1: PHASTA results

L3:THM.ITM.P3.02 milestone overview

Igor A. Bolotnov
North Carolina State University

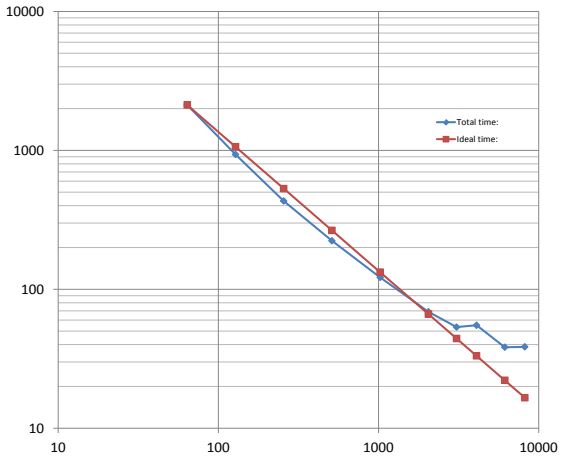
CASL-U-2011-0185-000-a

Milestone definition and motivation

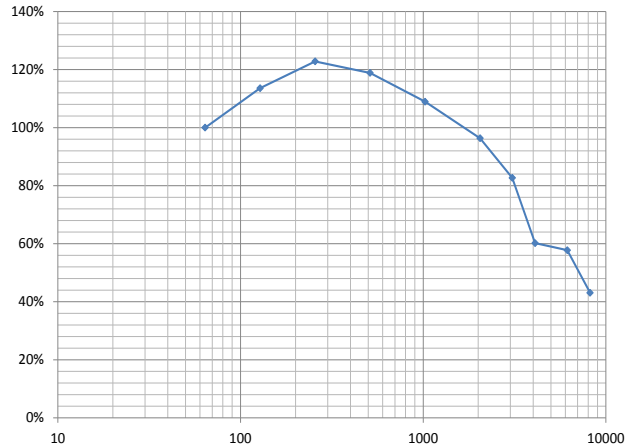
- Evaluate ITM code PHASTA on a leadership computing facility
- Perform weak and strong scaling tests
- Test PHASTA using ITM Benchmark #1: “Turbulent flow in closed channel with flat walls featuring a pattern of small hemispherical solid obstacles”
- **Motivation**: Demonstrate some of the current PHASTA capabilities and identify the required code enhancements to satisfy CASL goals for DNS/ITM codes

Results: PHASTA scaling

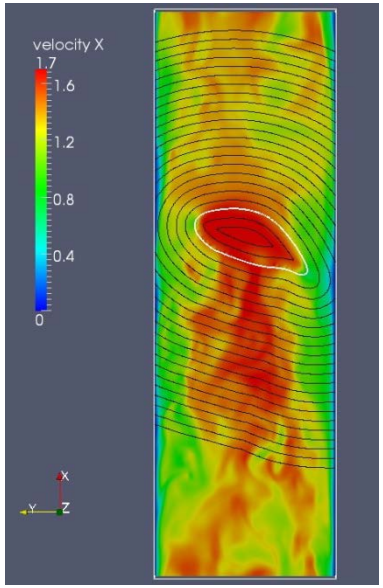
- Strong scaling for two-phase problem (same total grid size, 10.5M elements):



Wall clock time vs. Number of cores. 10 iteration times are shown in seconds.



Total time to ideal time ratio. Perfect scaling would mean a horizontal line at 100%.



- Weak scaling (same grid size for each core, single-phase):

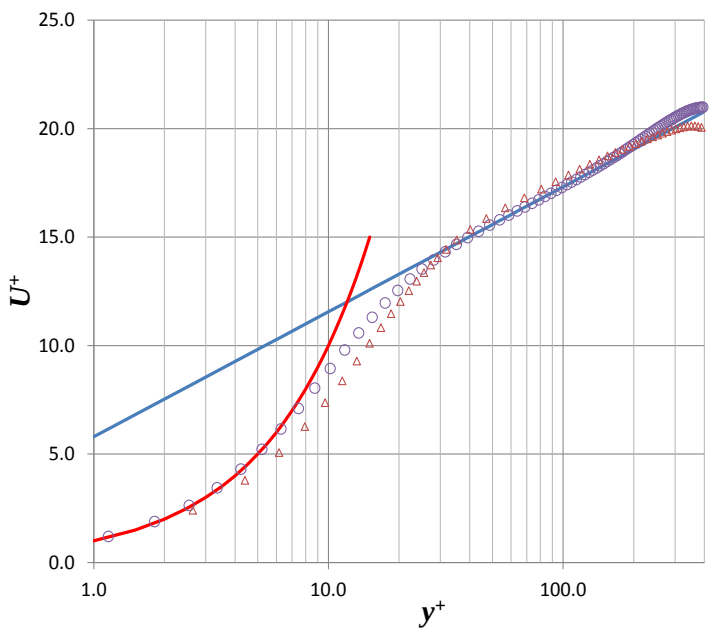
N cores:	L_x	L_y	L_z	N_x	N_y	N_z	Mesh size	Elem/core:	Δy^+, m
300	2.0	2.0	π	320	150	248	11,904K	39,680	0.0025
600	4.0	2.0	π	640	150	248	23,808K	39,680	0.0025
900	6.0	2.0	π	960	150	248	35,712K	39,680	0.0025

Wall clock times shown at different iterations:

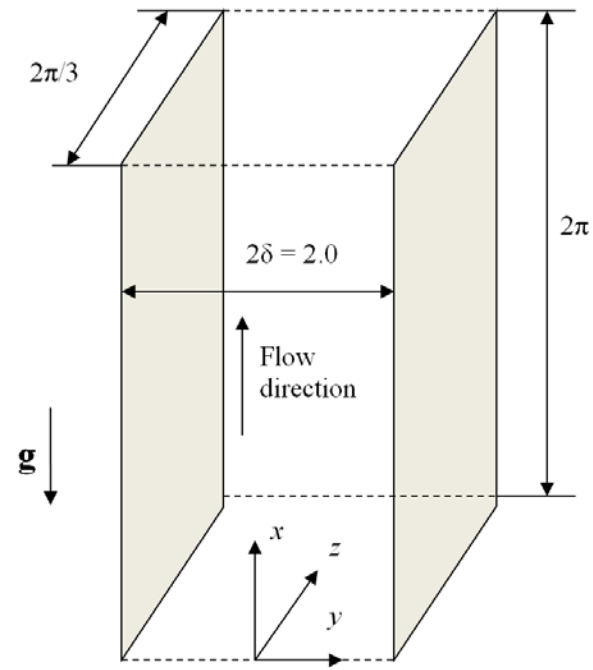
N cores:	T@10	T@29	T@49	T@60	T_1	T_2
300	963.8	3064	5271	6487	110.46	110.35
600	847.2	2550	4314	5288	88.816	88.2
900	961.5	2846	4802	5879	98.35	97.8

Results: smooth channel

Direction:	Boundaries:	Number of nodes:	Resolution:
x	0.0 … 2πh	256	$\Delta x^+ = 9.8$
y	-1.0h … 1.0h	189	$\Delta y^+ = 0.5 \ldots 5.0$
z	0.0 … πh	192	$\Delta z^+ = 6.5$

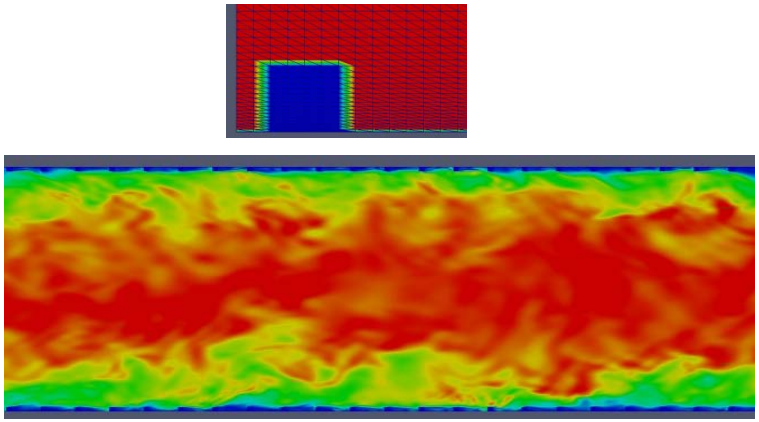


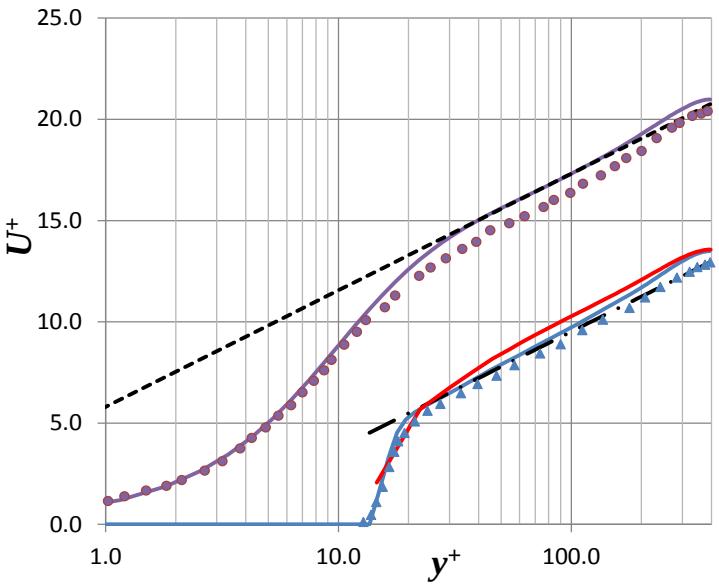
Smooth wall channel flow compared with the law of the wall. PHASTA (circles) and TransAT/MIT LES (triangles) results are shown.



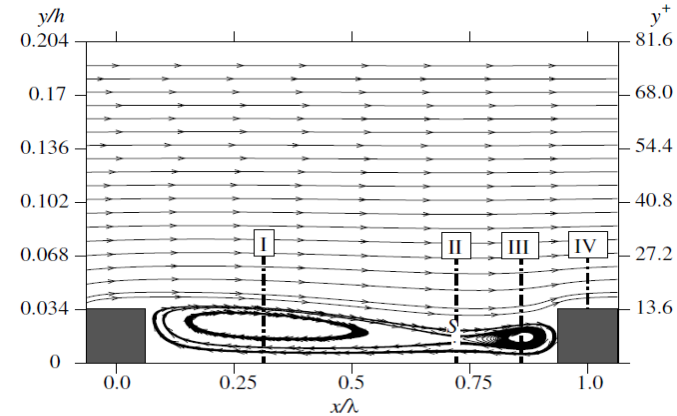
Moody's diagram friction factor estimate is 0.024. The obtained DNS based result is f = 0.02419

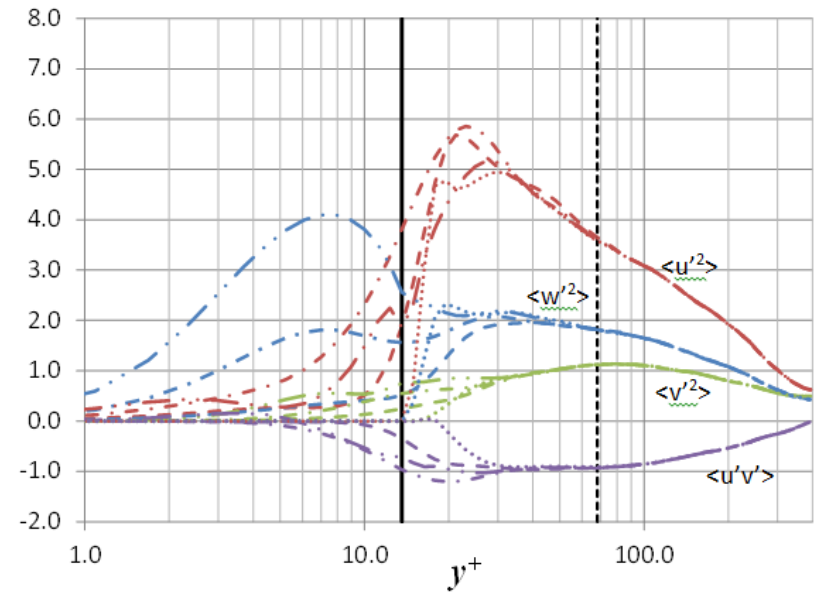
Results: Rectangular roughness





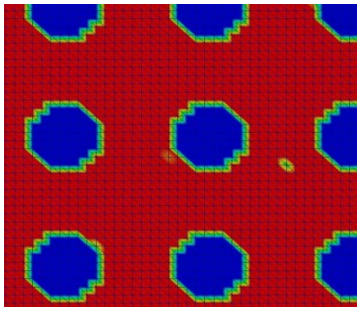
Mean velocity profiles in inner coordinates for smooth and rough (rectangular roughness elements) channel flow simulations by PHASTA (violet and blue solid lines) and DNS results by (Krogstad, et al., 2005) (symbols). TransAT/MIT result is shown in red.

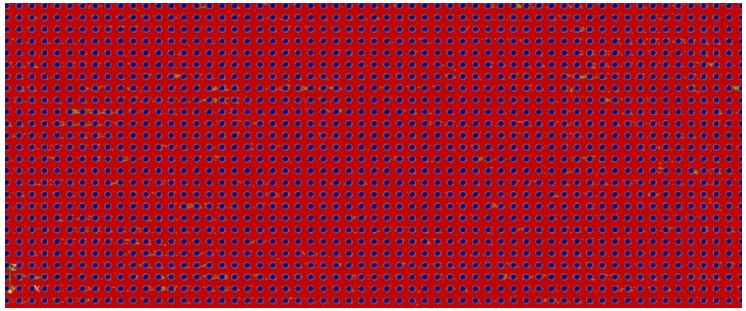


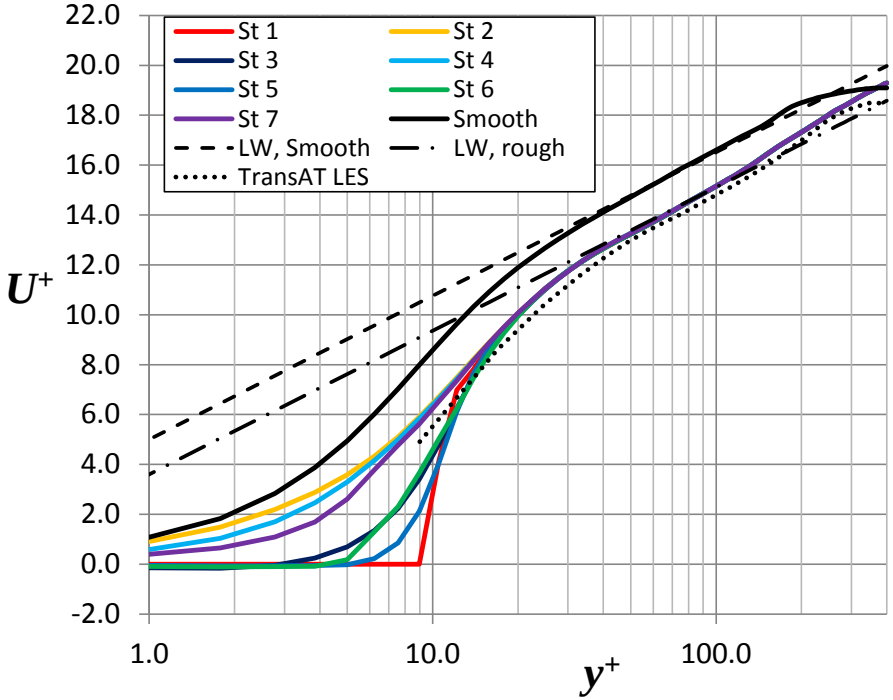


Reynolds stresses in inner coordinates, normalized by u_τ^2. Solid black line shows the height of roughness elements, black dashed line designates roughness sublayer. Colors designate Reynolds stress component: $\langle u'^2 \rangle$ is red; $\langle v'^2 \rangle$ is green; $\langle w'^2 \rangle$ is blue; $\langle u'v' \rangle$ is violet. Line style shows the measuring station location: Station 1: dashed lines; Station 2: dash-dot lines; Station 3: dash-dot-dot lines; Station 4: dotted lines.

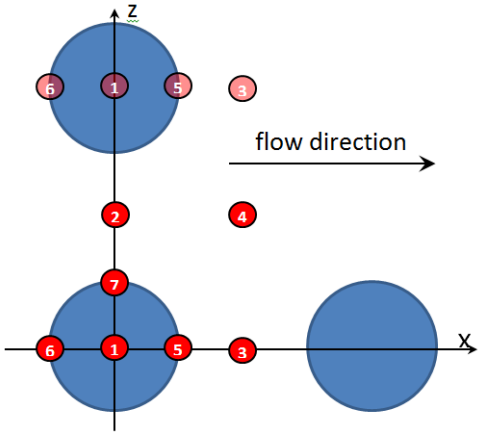
Results: Hemispherical roughness



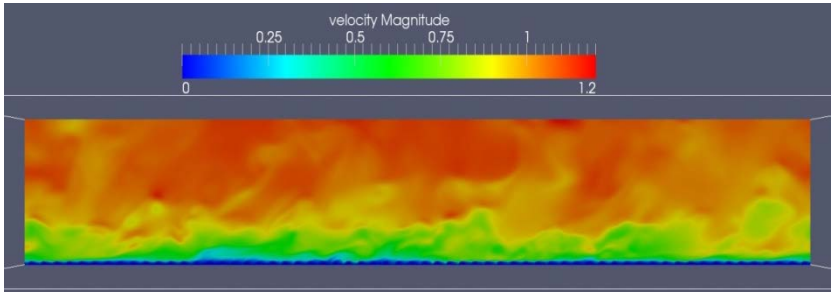




Mean velocity profiles at different measuring stations compared with the smooth wall result and the law of the wall plots. Dotted line shows TransAT/MIT LES

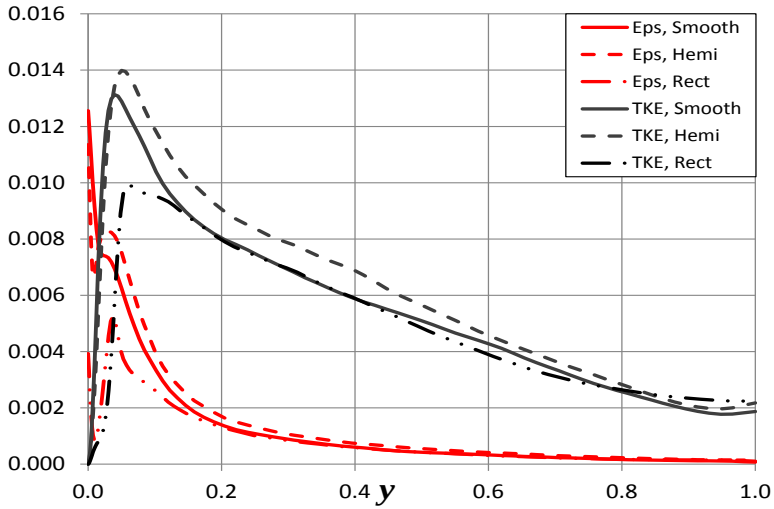


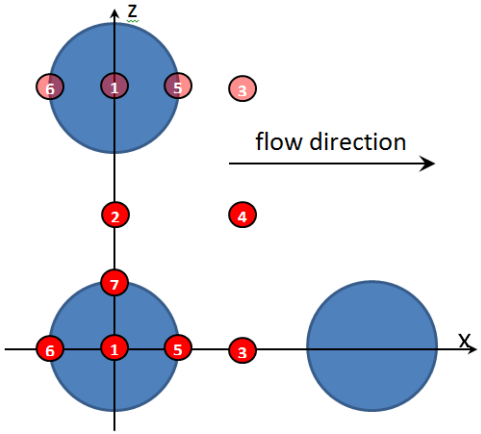
Location of 7 virtual probe sets in the hemispherical roughness case



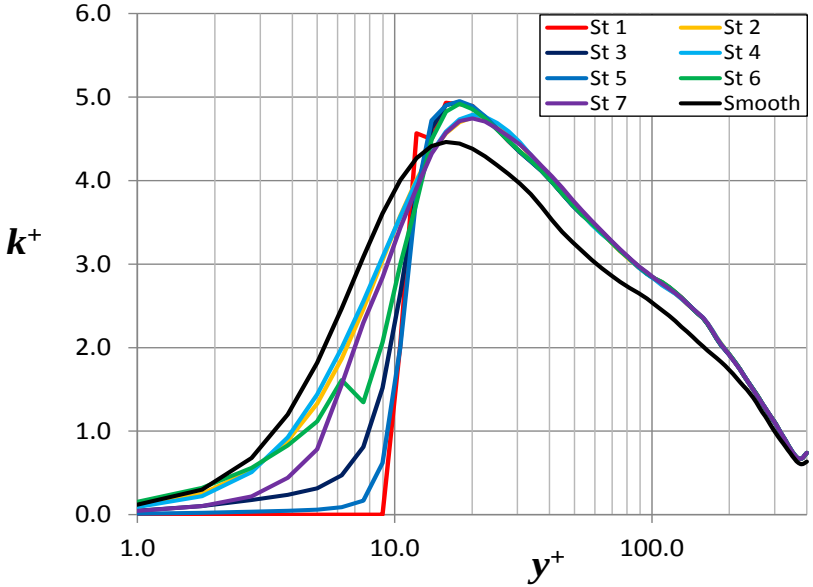
Considering the rough wall conditions with roughness $\frac{\varepsilon}{d} = 0.00625$; Re_D = 26,000 (based on hydraulic diameter, and computed velocity) the Moody's diagram friction factor estimate is 0.035. The obtained DNS based result is f = 0.0303.

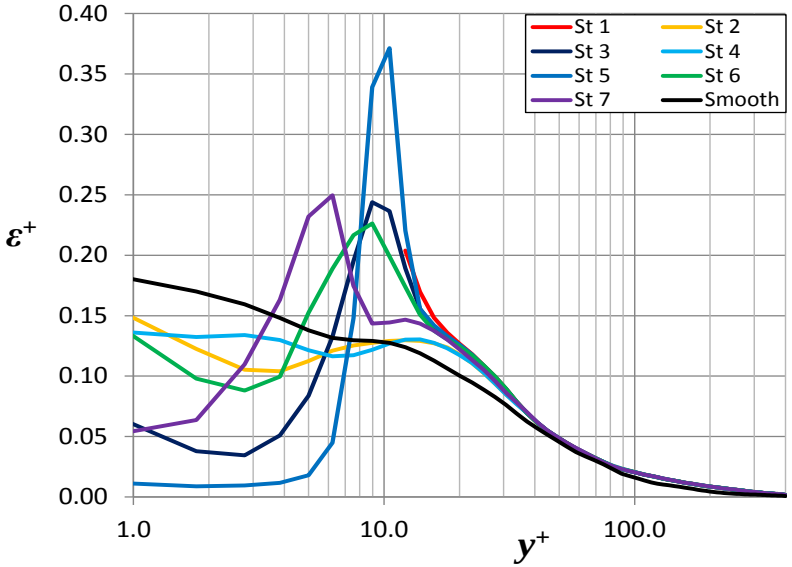
Results: k and ε





Location of 7 virtual probe sets in the hemispherical roughness case





Turbulent kinetic energy and turbulent dissipation rate profiles at different measuring stations compared with the smooth wall result.

Proposed Future Work

- Develop upscaling methodology from ITM to CMFD and demonstrate this approach on a adiabatic two-phase bubbly channel flow example
- Collaborate with TAMU (Y. Hassan) on ITM challenge problem definition and subsequent PHASTA validation based on experimental data
- Perform mesh convergence study for the rough channel flow simulation
- Collaborate with MIT (J. Buongiorno) to contribute to single database of DNS/LES of rough wall flows
- Implement contact angle treatment in PHASTA level set formulation
- Develop two-phase heat transfer in PHASTA, capable of simulating evaporation/condensation phenomena and boiling flows in complex geometries on a large scale