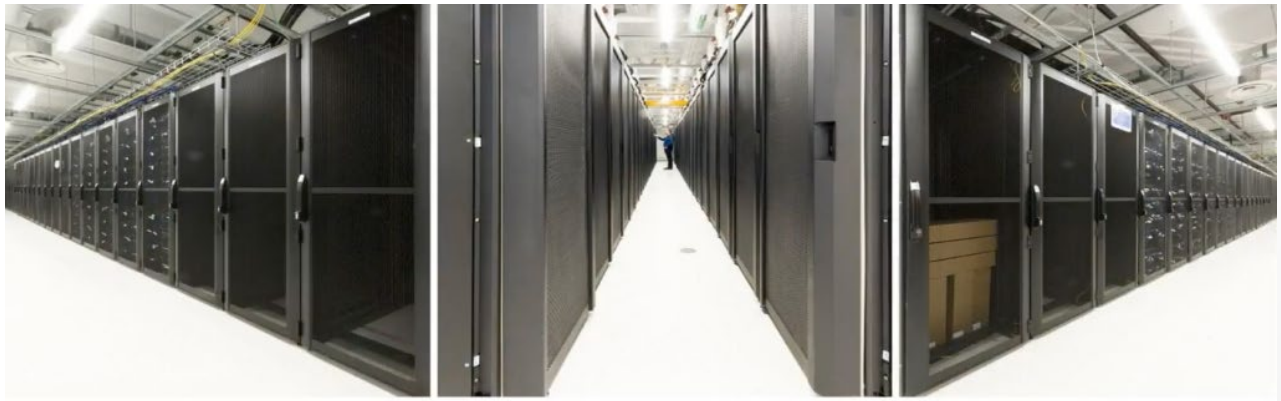
Introduction to CFD

کاربردها



What is CFD and its objective?

- Computational Fluid Dynamics
- Historically Analytical Fluid Dynamics (AFD) and EFD (Experimental Fluid Dynamics) was used. CFD has become feasible due to the advent of high speed digital computers.
- Computer simulation for prediction of fluid-flow phenomena.
- The objective of CFD is to model the continuous fluids with Partial Differential Equations (PDEs) and discretize PDEs into an algebra problem (Taylor series), solve it, validate it and achieve simulation based design.

Why use CFD?

- Analysis and Design
  - Simulation-based design instead of "build & test"
    - More cost effectively and more rapidly than with experiments
    - CFD solution provides high-fidelity database for interrogation of flow field
  - Simulation of physical fluid phenomena that are difficult to be measured by experiments
    - Scale simulations (e.g., full-scale ships, airplanes)
    - Hazards (e.g., explosions, radiation, pollution)
    - Physics (e.g., weather prediction, planetary boundary layer, stellar evolution)
- Knowledge and exploration of flow physics

CFD vs. Experiment

CFD gives an insight into flow patterns that are difficult, expensive or impossible to study using traditional (experimental) techniques

EXPERIMENTS	SIMULATIONS
Quantitative **description** of flow phenomena using measurements • for one quantity at a time • at a limited number of points and time instants • for a laboratory-scale model • for a limited range of problems and operating conditions Error sources: measurement errors, flow disturbances by the probes	Quantitative **prediction** of flow phenomena using CFD software • for all desired quantities • with high resolution in space and time • for the actual flow domain • for virtually any problem and realistic operating conditions Error sources: modeling, discretization, iteration, implementation

CFD vs. Experiment

As a rule, CFD does not replace the measurements completely but the amount of experimentation and the overall cost can be significantly reduced.

EXPERIMENTS	SIMULATIONS
• expensive • slow • sequential • single-purpose	• cheap(er) • fast(er) • parallel • multiple-purpose

Equipment and personnel are difficult to transport

CFD software is portable, easy to use and modify

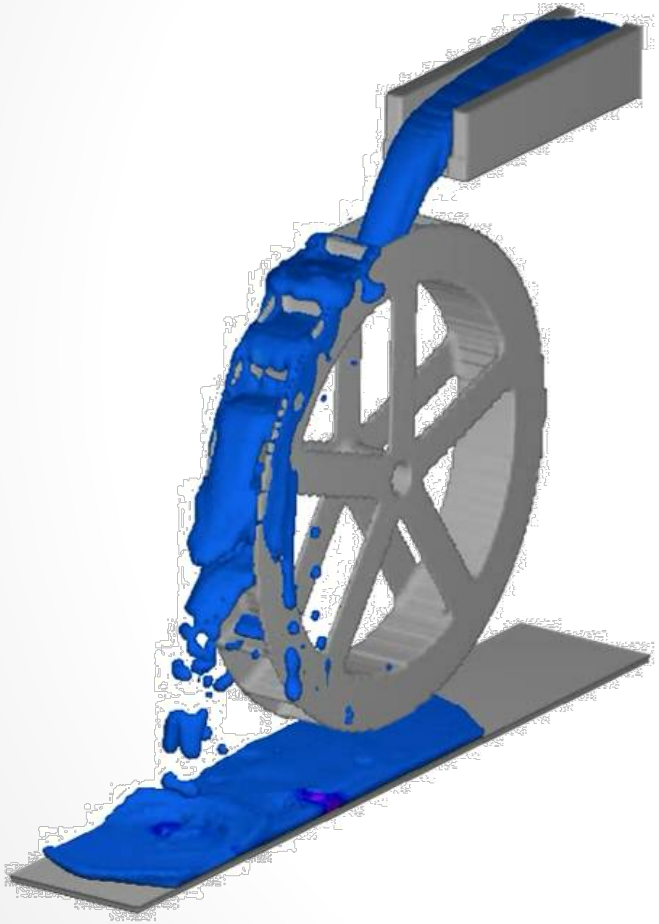
The results of a CFD simulation are never 100% reliable because

- the input data may involve too much guessing or imprecision
- the mathematical model of the problem at hand may be inadequate
- the accuracy of the results is limited by the available computing power

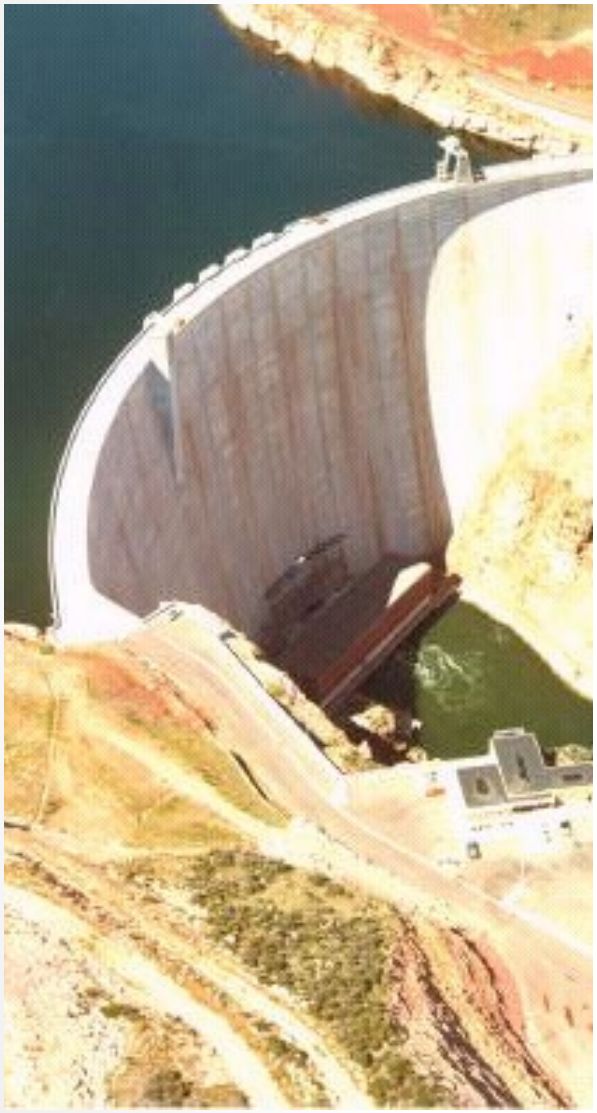
Applications of CFD

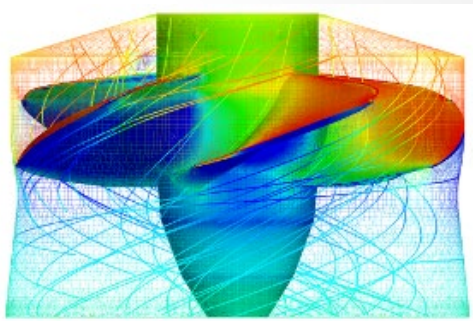
- Applications of CFD are numerous!
  - Flow and heat transfer in industrial processes (boilers, heat exchangers, combustion equipment, pumps, blowers, piping, etc.).
  - Aerodynamics of ground vehicles, aircraft, missiles. Film coating, thermoforming in material processing applications.
  - Flow and heat transfer in propulsion and power generation systems.
  - Ventilation, heating, and cooling flows in buildings.
  - Chemical vapor deposition (CVD) for integrated circuit manufacturing.
  - Heat transfer for electronics packaging applications.
  - And many, many more!

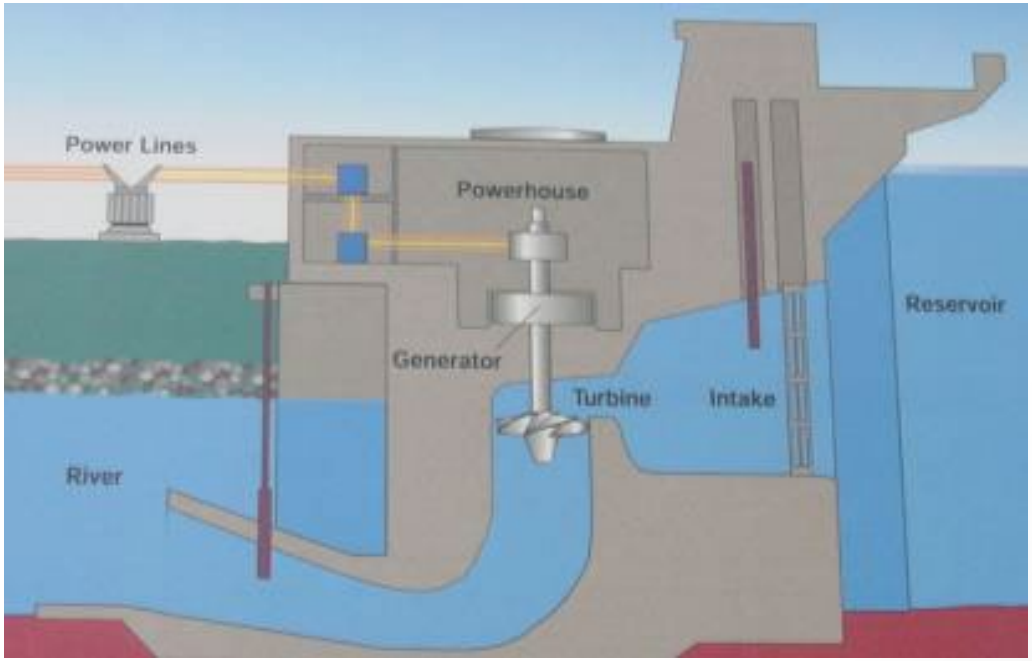
Water wheel



Water turbine

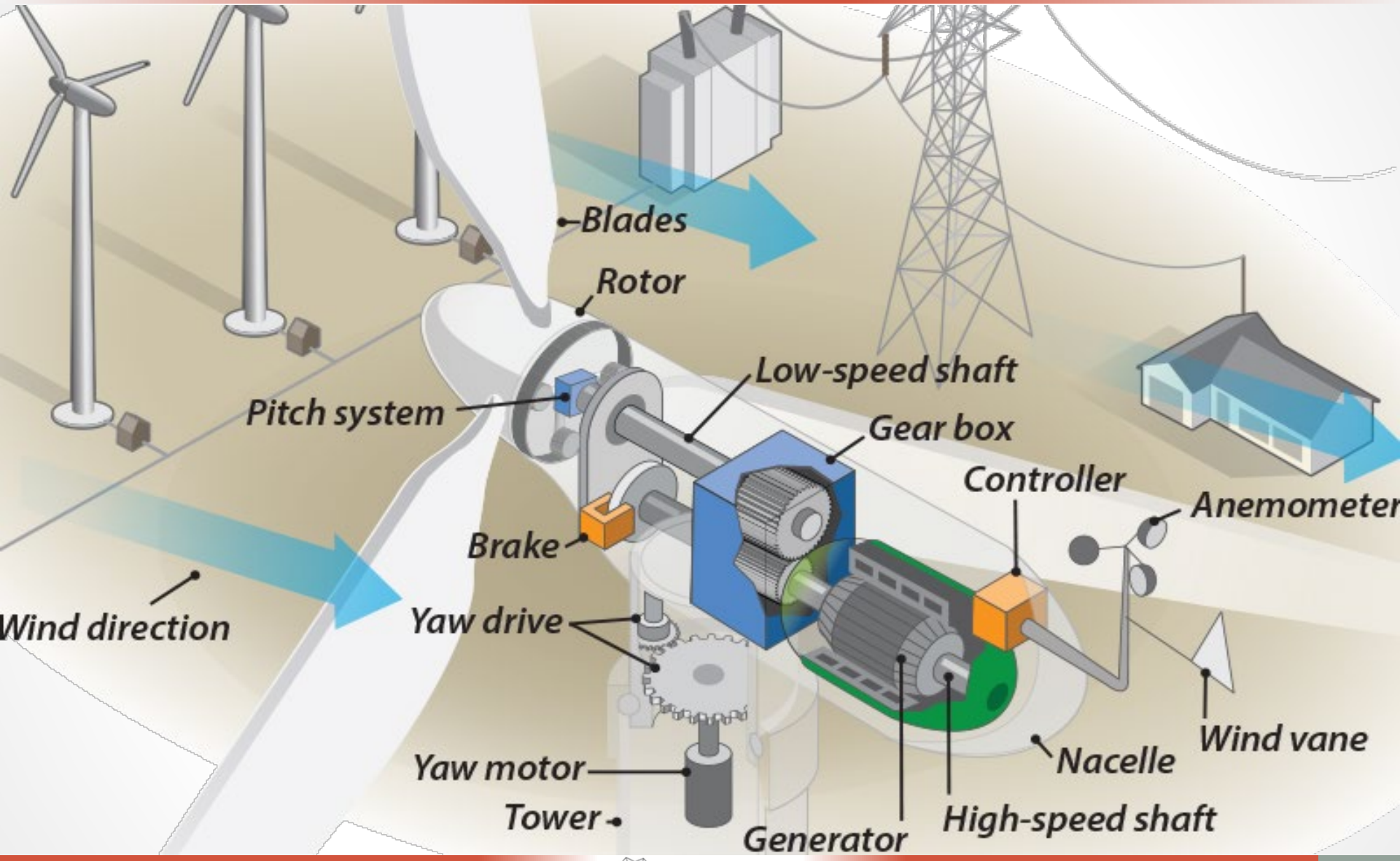




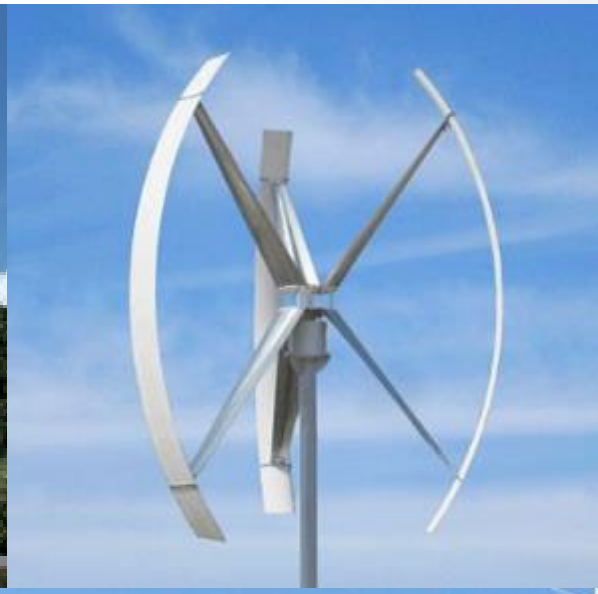


Windmill

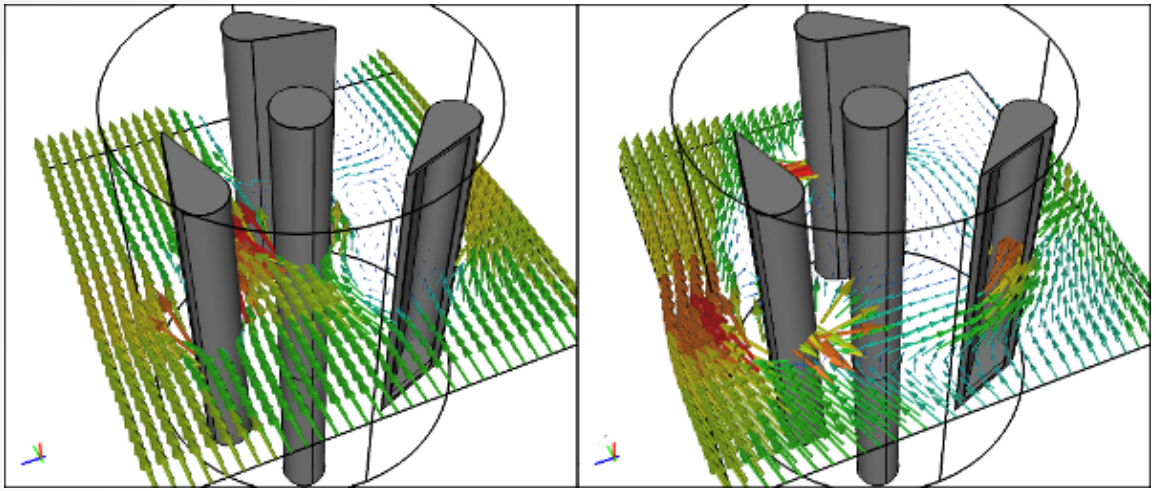
Wind turbine

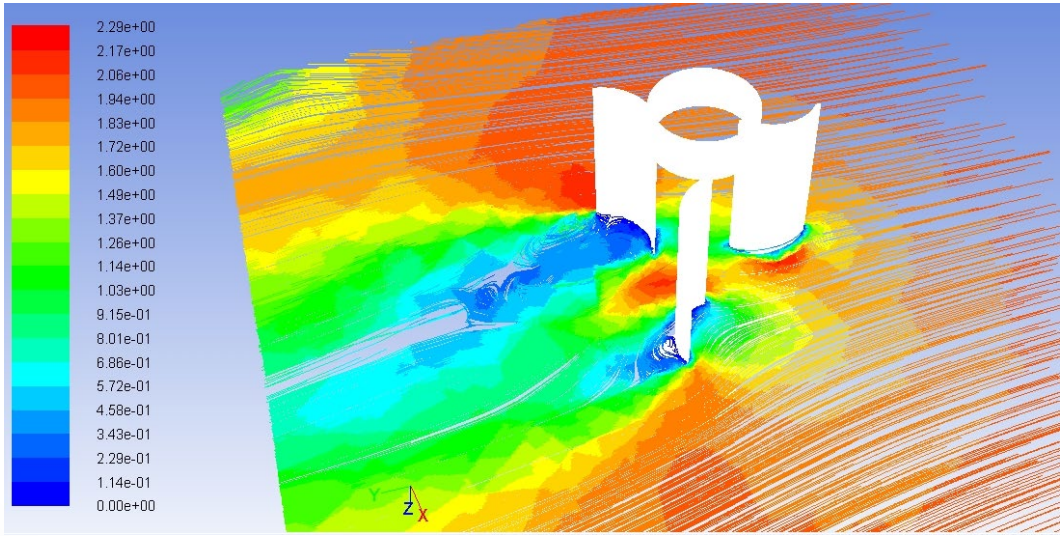


Wind turbine

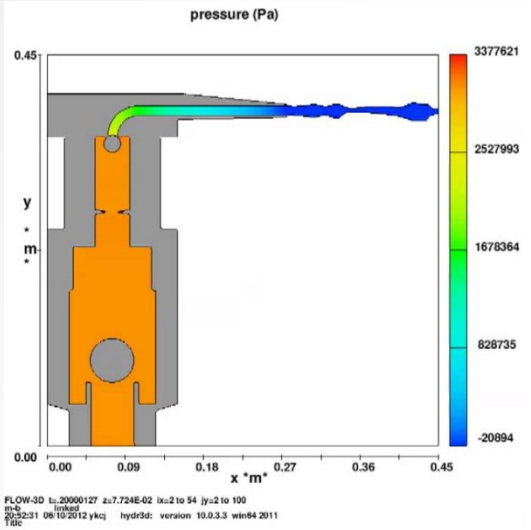


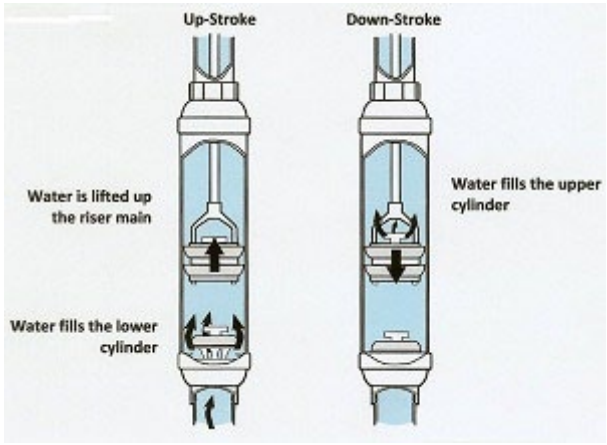
Wind turbine

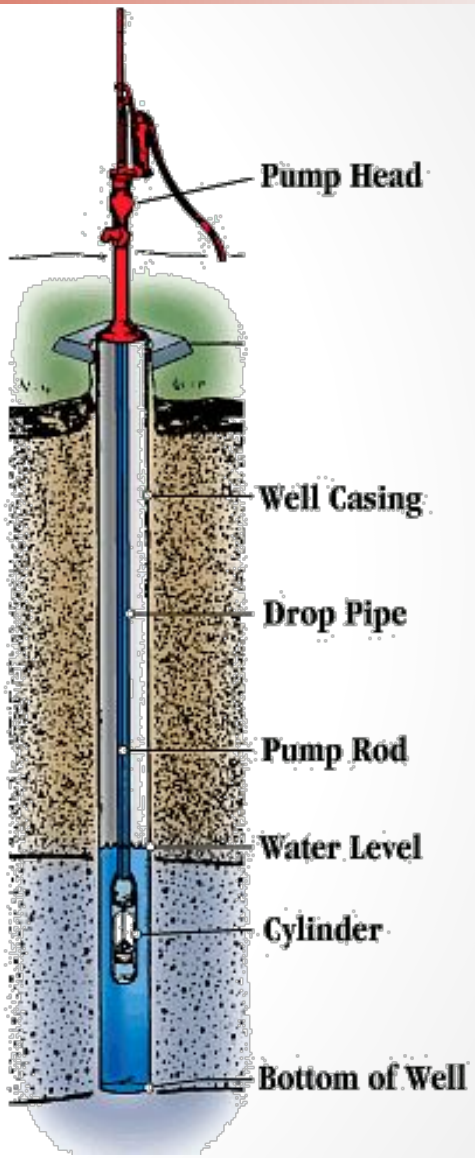




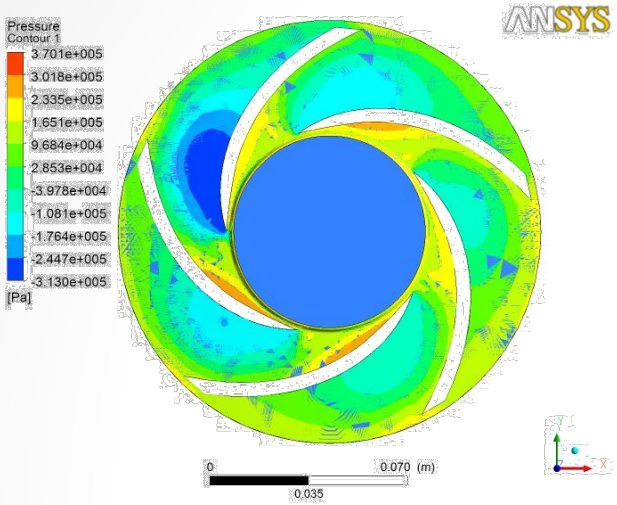
Hand pump

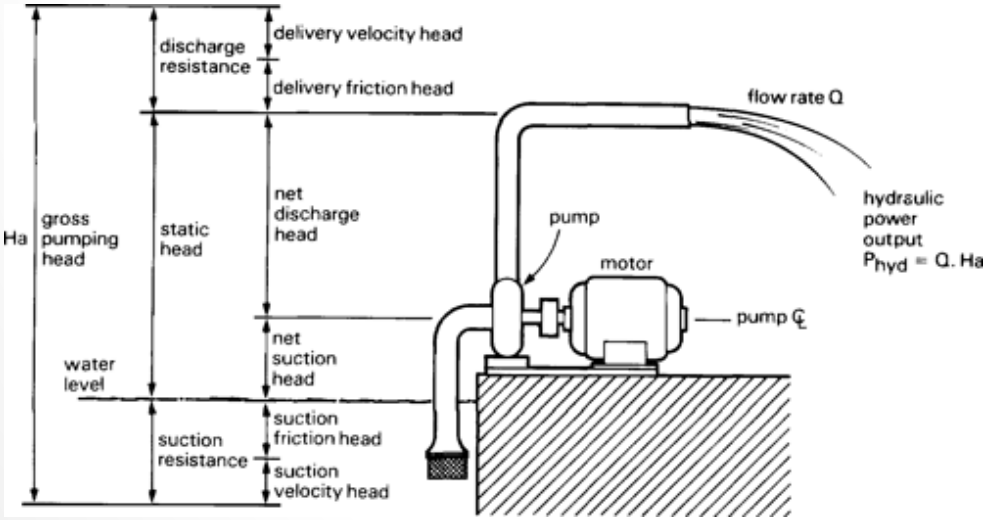

pressure (Pa)
3377621
2527993
1678364
828735
-20894
0.45
0.00
y
*
m
*
0.00
0.09
0.18
0.27
0.36
0.45
x *m*


Up-Stroke
Down-Stroke
Water is lifted up the riser main
Water fills the lower cylinder
Water fills the upper cylinder

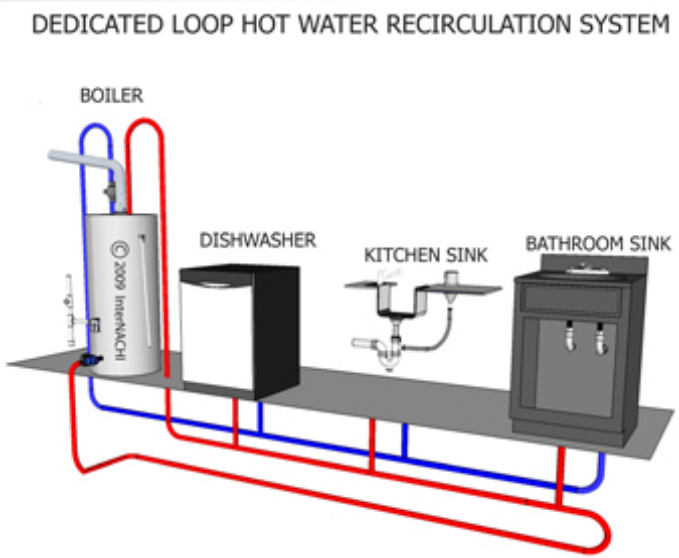

Pump Head
Well Casing
Drop Pipe
Pump Rod
Water Level
Cylinder
Bottom of Well

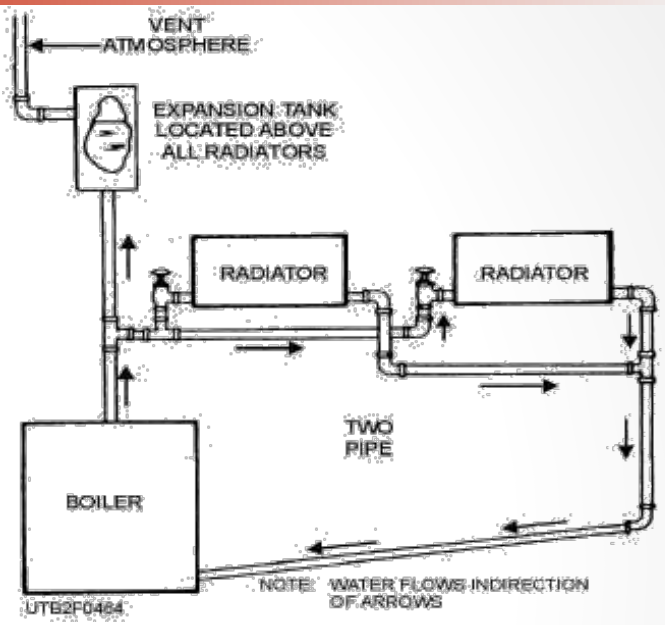
Motor pump

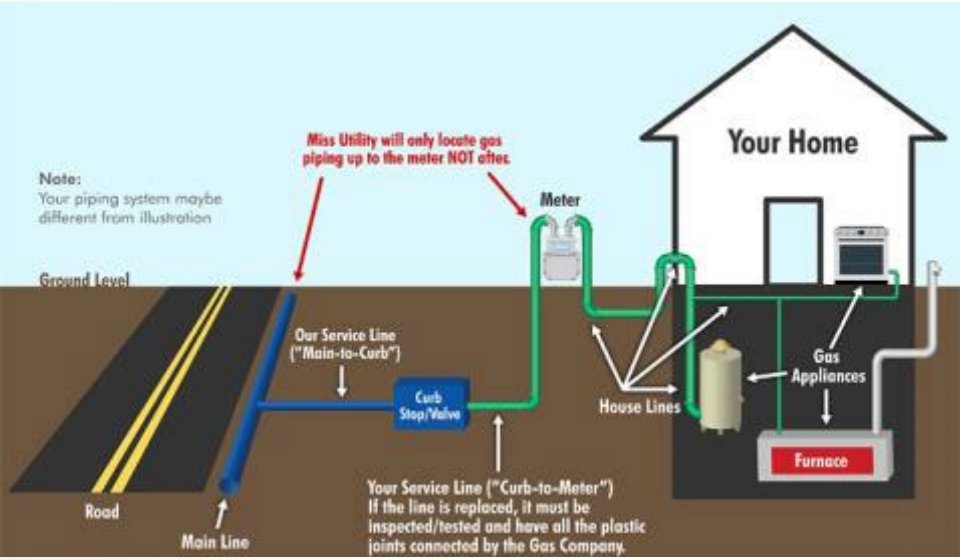

ANSYS
Pressure
Contour 1
3.701e+005
3.018e+005
2.335e+005
1.651e+005
9.684e+004
2.853e+004
-3.978e+004
-1.081e+005
-1.764e+005
-2.447e+005
-3.130e+005
[Pa]
0
0.070 (m)
0.035

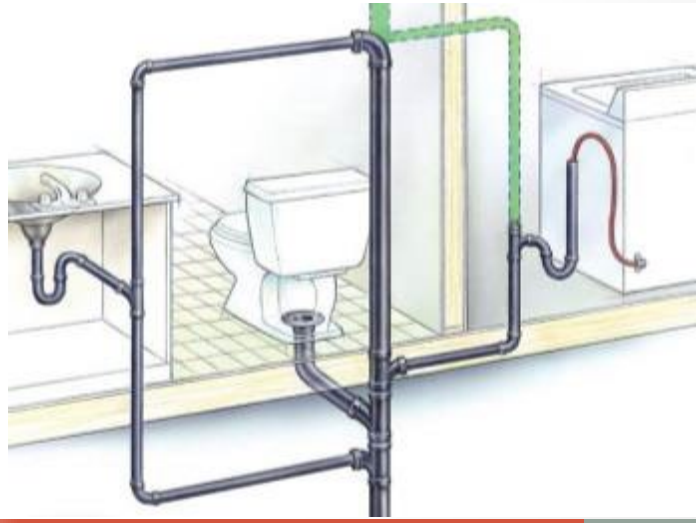

discharge resistance
delivery velocity head
delivery friction head
flow rate Q
hydraulic power output
$P_{hyd} = Q.Ha$
Ha
gross pumping head
static head
net discharge head
pump
motor
pump ℄
net suction head
water level
suction resistance
suction friction head
suction velocity head

Piping

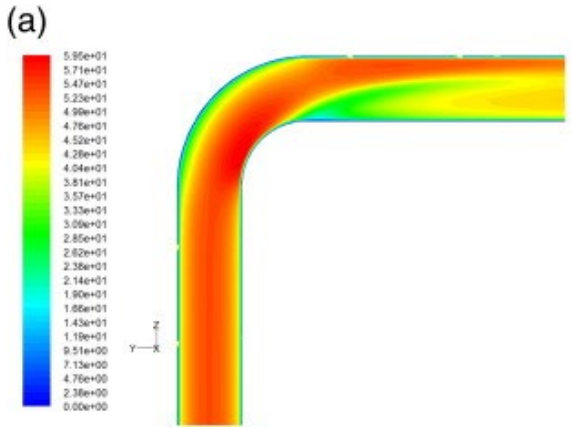

DEDICATED LOOP HOT WATER RECIRCULATION SYSTEM
BOILER
DISHWASHER
KITCHEN SINK
BATHROOM SINK
© 2009 InterNACHI

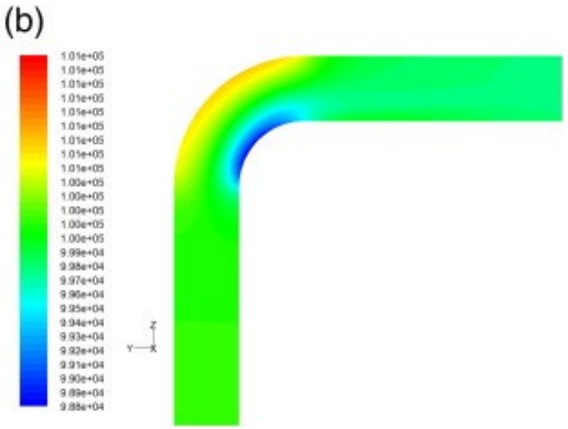

VENT
ATMOSPHERE
EXPANSION TANK
LOCATED ABOVE
ALL RADIATORS
RADIATOR
RADIATOR
TWO
PIPE
BOILER
NOTE WATER FLOWS INDIRECTION
OF ARROWS
UTB2P0464


Miss Utility will only locate gas
piping up to the meter NOT after.
Your Home
Note:
Your piping system maybe
different from illustration
Meter
Ground Level
Our Service Line
("Main-to-Curb")
Curb
Stop/Valve
House Lines
Gas
Appliances
Furnace
Road
Main Line
Your Service Line ("Curb-to-Meter")
If the line is replaced, it must be
inspected/tested and have all the plastic
joints connected by the Gas Company.



Piping


(a)
5.95e+01
5.71e+01
5.47e+01
5.23e+01
4.99e+01
4.76e+01
4.52e+01
4.28e+01
4.04e+01
3.81e+01
3.57e+01
3.33e+01
3.09e+01
2.85e+01
2.62e+01
2.38e+01
2.14e+01
1.90e+01
1.66e+01
1.43e+01
1.19e+01
9.51e+00
7.13e+00
4.76e+00
2.38e+00
0.00e+00


(b)
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.01e+05
1.00e+05
1.00e+05
1.00e+05
1.00e+05
1.00e+05
9.99e+04
9.98e+04
9.97e+04
9.96e+04
9.95e+04
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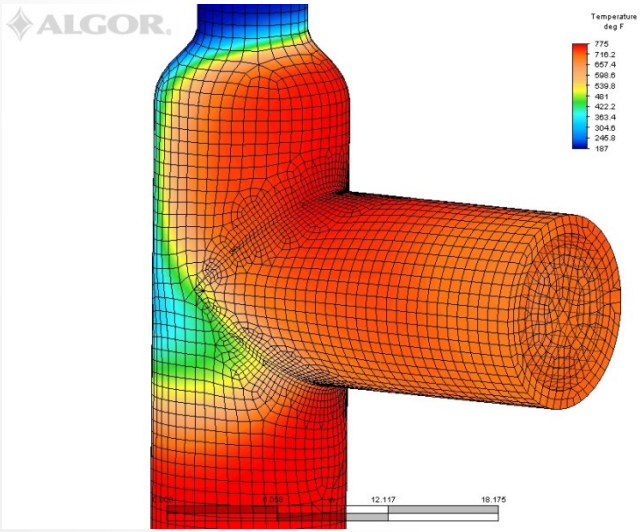
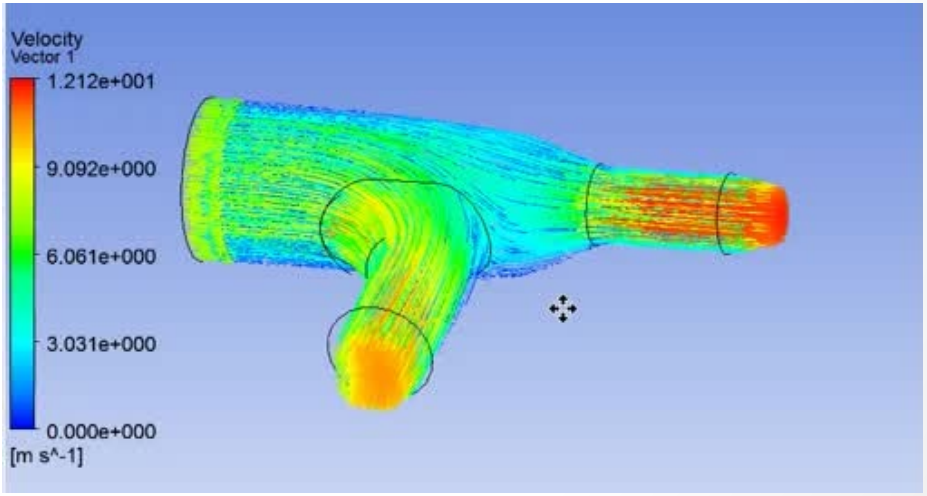
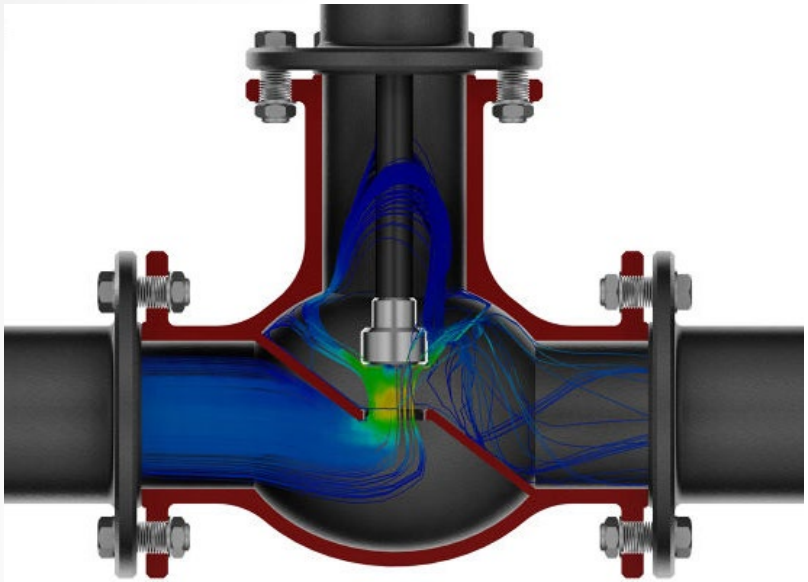
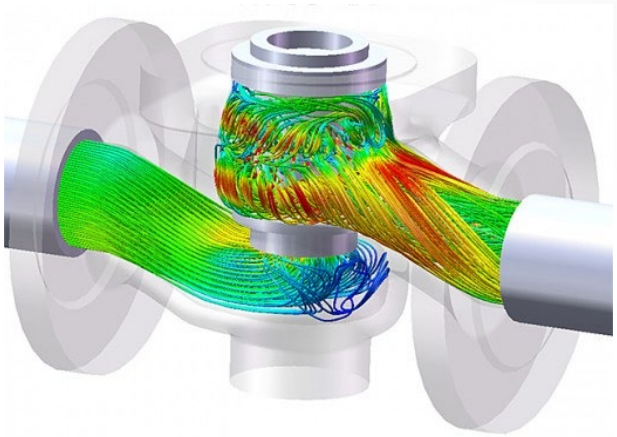
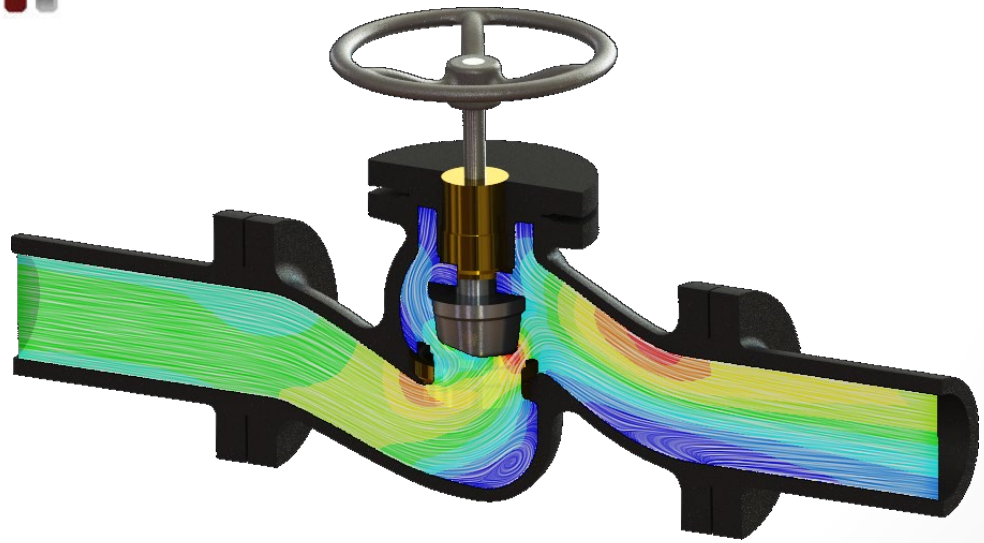
9.89e+04
9.88e+04


ALGOR
Temperature
deg F
775
716.2
657.4
598.6
539.8
481
422.2
363.4
304.6
245.8
187
12.117
18.175

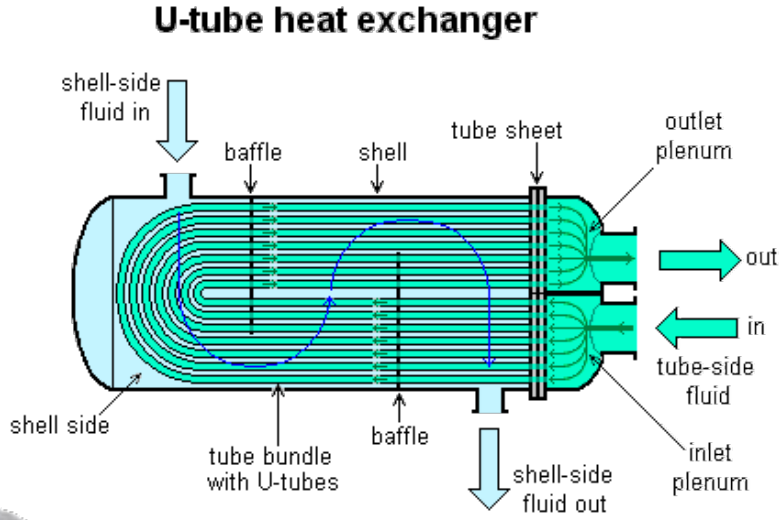

Velocity
Vector 1
1.212e+001
9.092e+000
6.061e+000
3.031e+000
0.000e+000
[m s^-1]

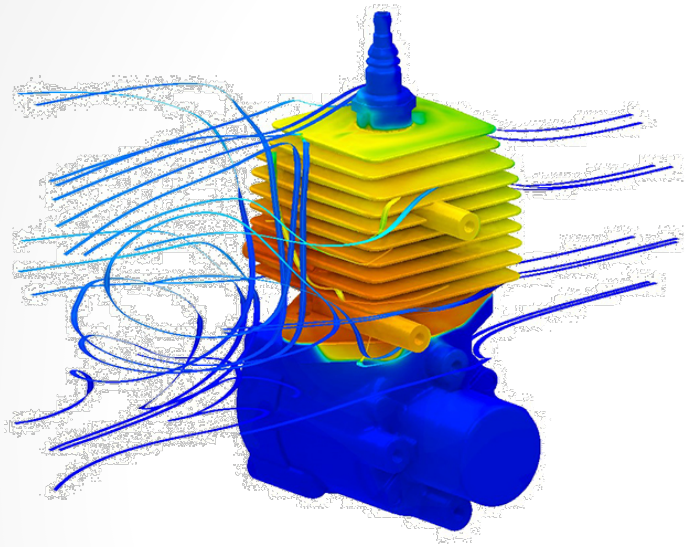


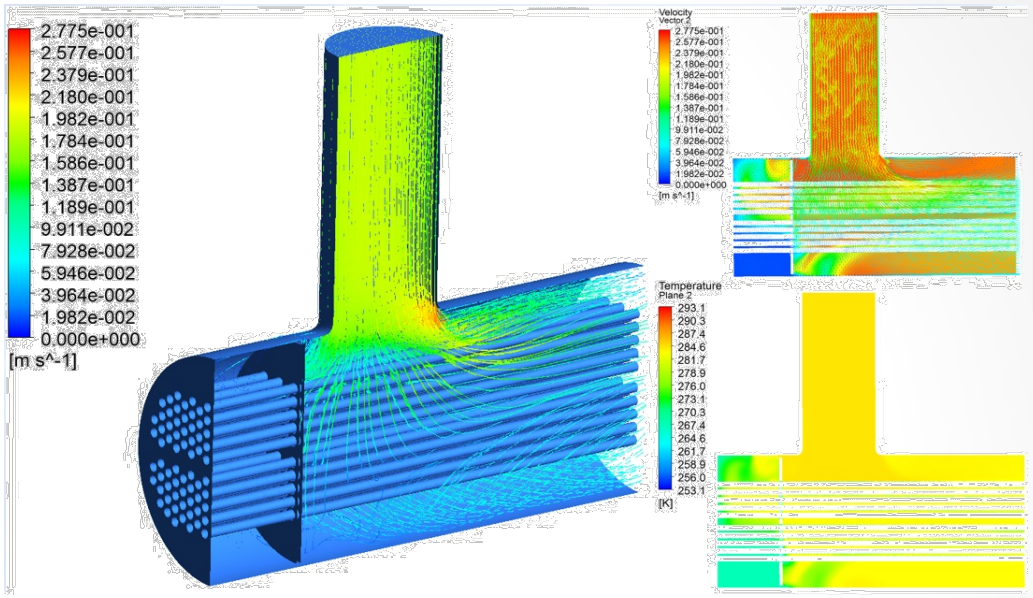


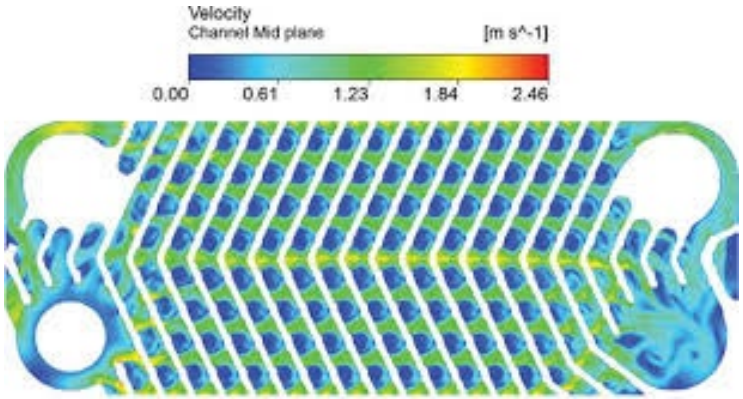


Heat exchanging



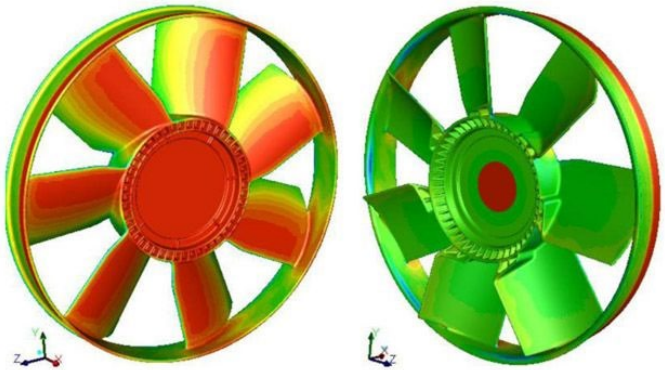



2.775e-001
2.577e-001
2.379e-001
2.180e-001
1.982e-001
1.784e-001
1.586e-001
1.387e-001
1.189e-001
9.911e-002
7.928e-002
5.946e-002
3.964e-002
1.982e-002
0.000e+000
[m s^-1]
Velocity
Vector 2
Temperature
Plane 2
[K]


Velocity
Channel Mid plane
[m s^-1]
0.00
0.61
1.23
1.84
2.46

Heat, Ventilation and Air Conditioning (HVAC)

CFD Analysis of Ring Fan

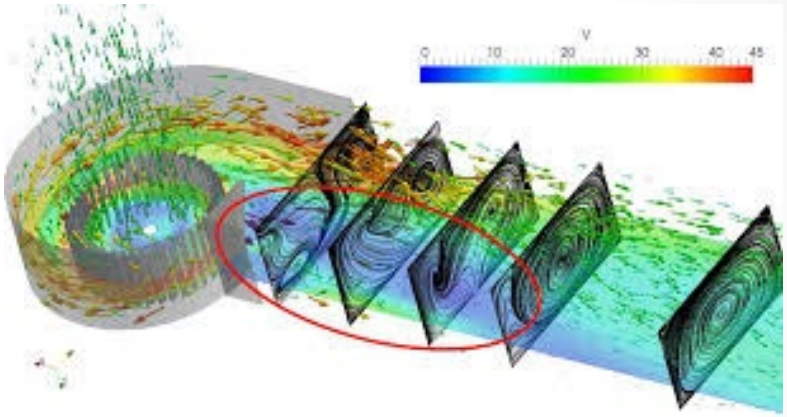


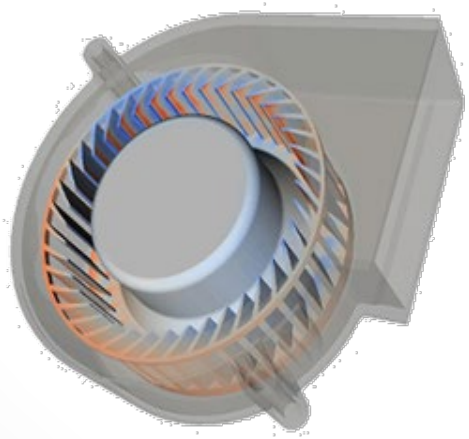
Front side view

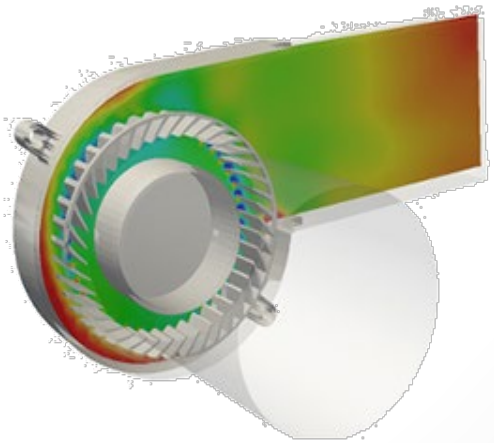
Rear side view

Static Pressure Distribution over the surface of Ring Fan

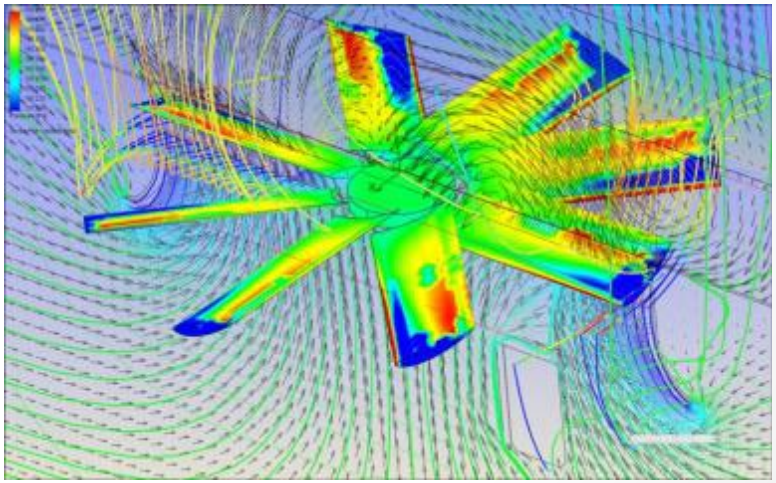
Heat, Ventilation and Air Conditioning (HVAC)



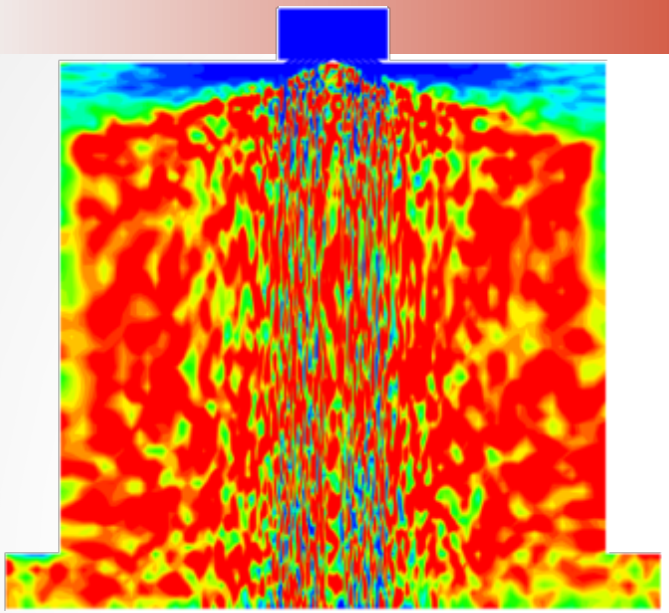


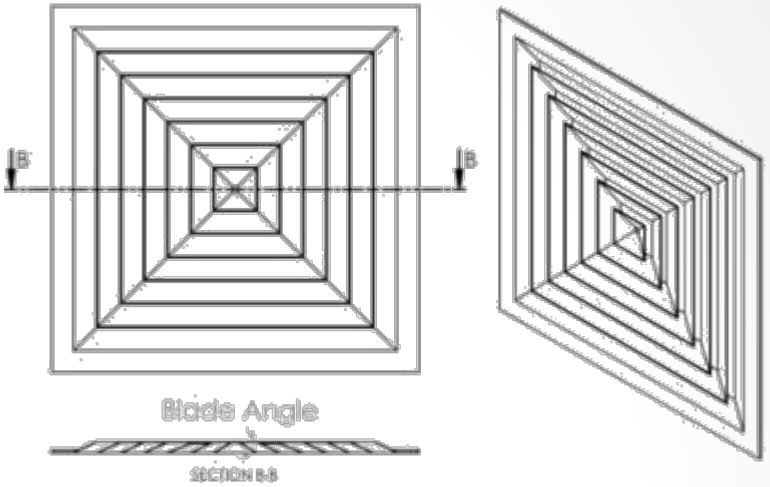


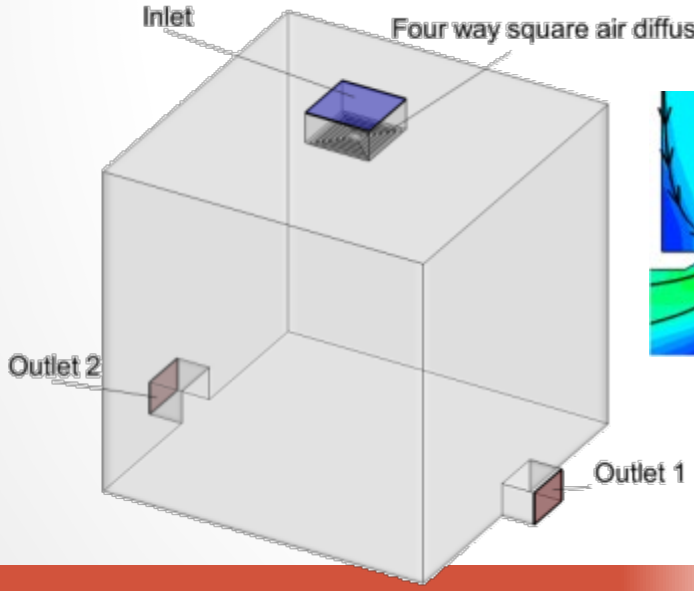
Cleanroom

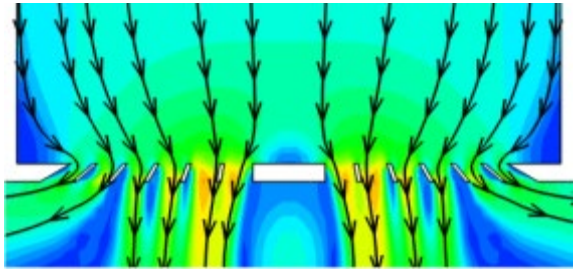


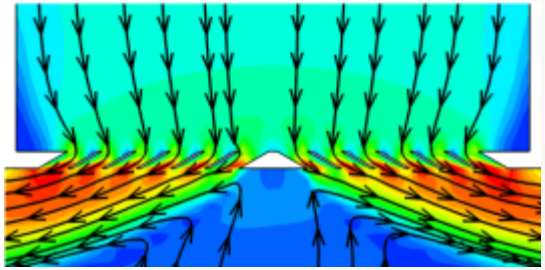
HVAC



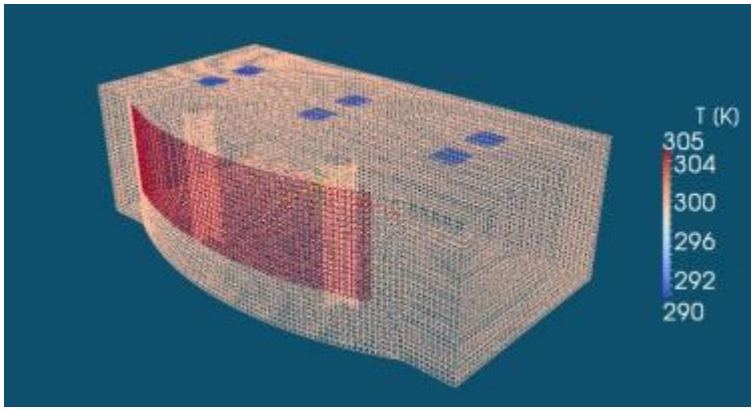

B
B
Blade Angle
SECTION B-B

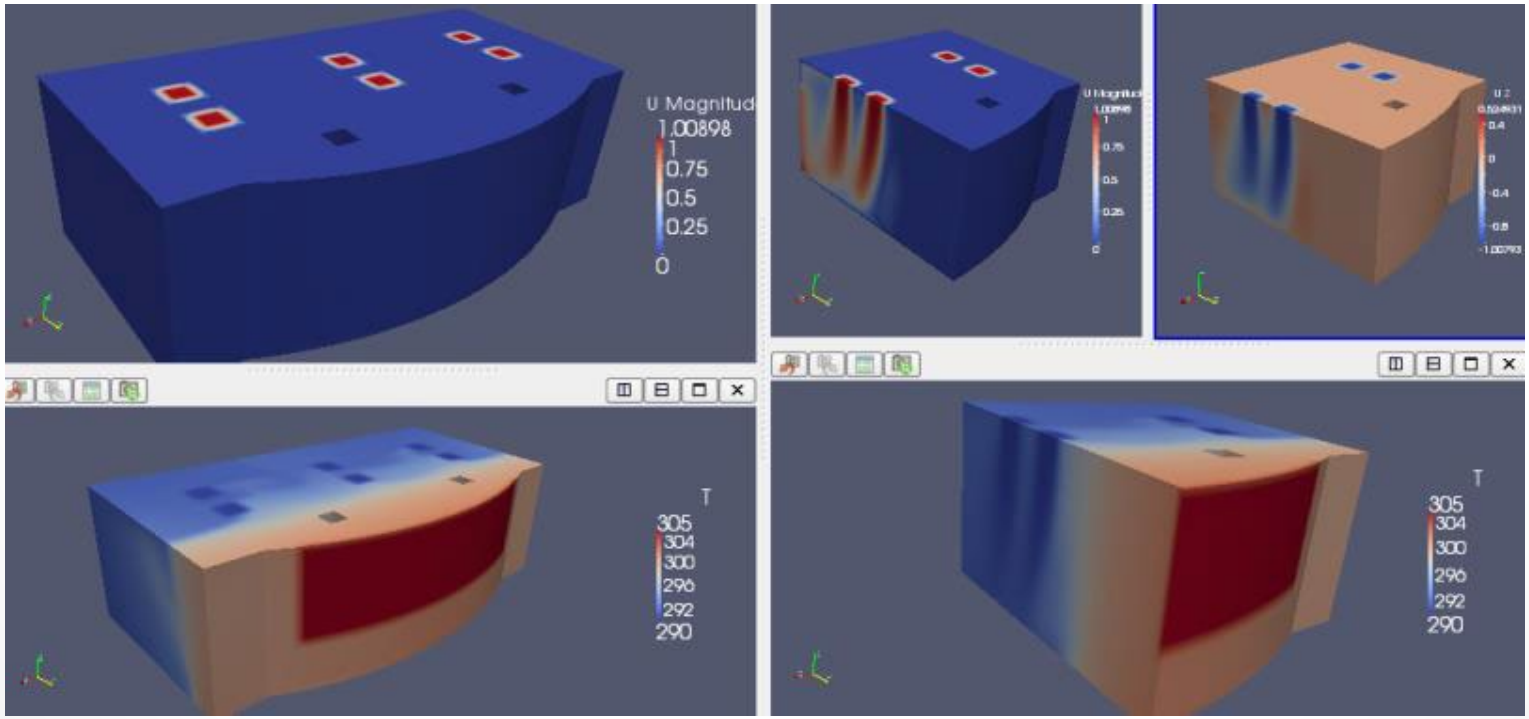

Inlet
Four way square air diffuser
Outlet 2
Outlet 1



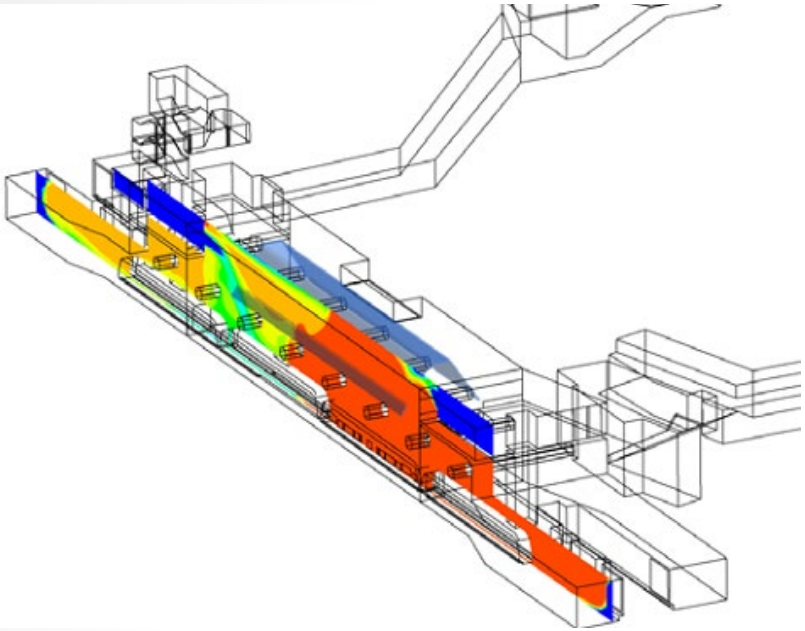


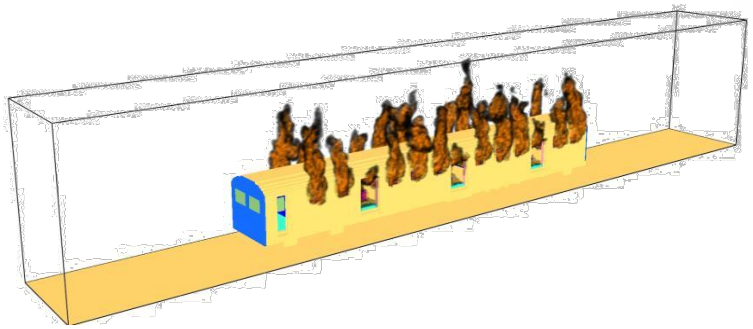
HVAC

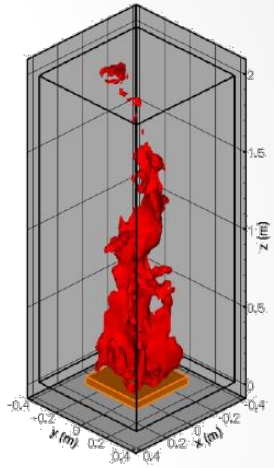

T (K)
305
304
300
296
292
290

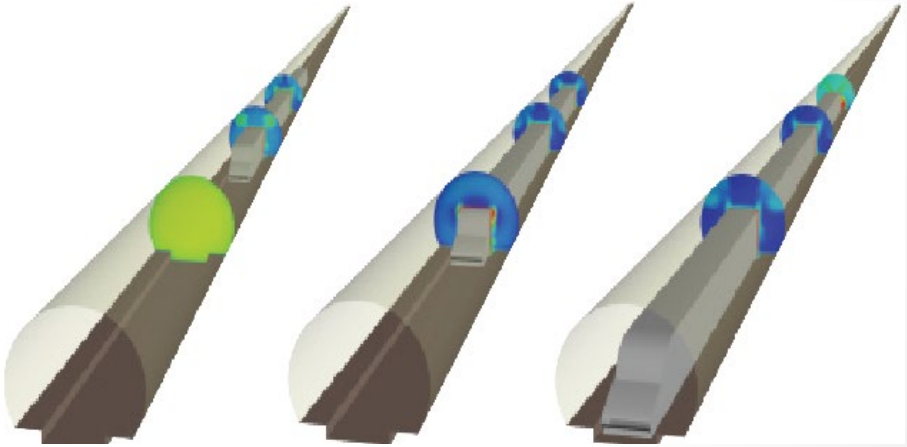

U Magnitud
1.00898
1
0.75
0.5
0.25
0
T
305
304
300
296
292
290
T
305
304
300
296
292
290

Fire modeling









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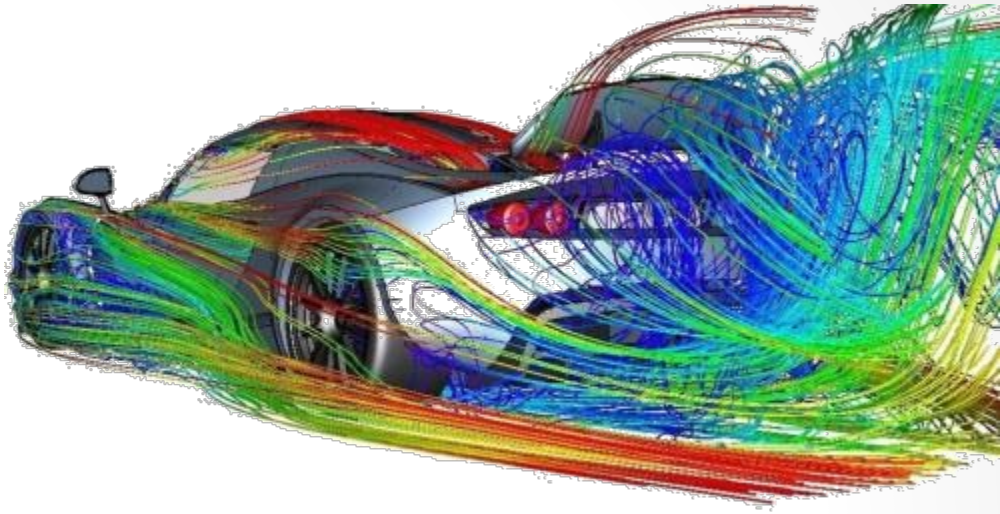

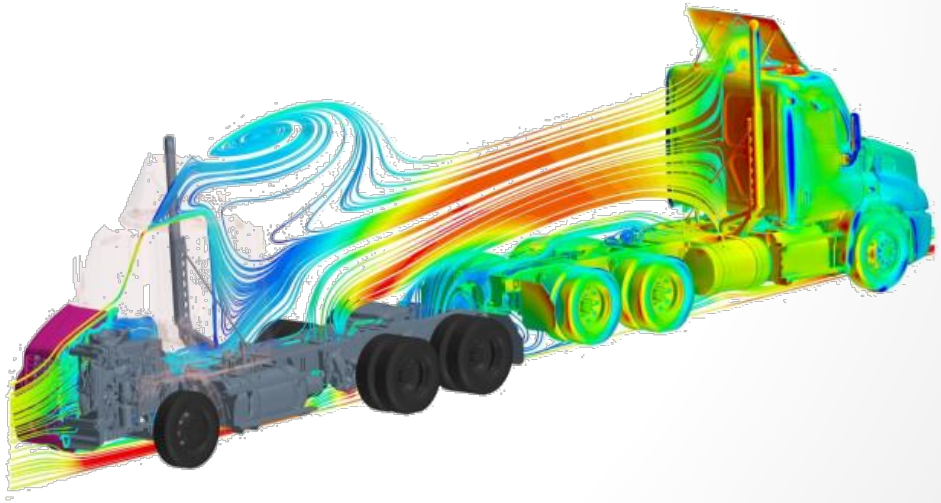

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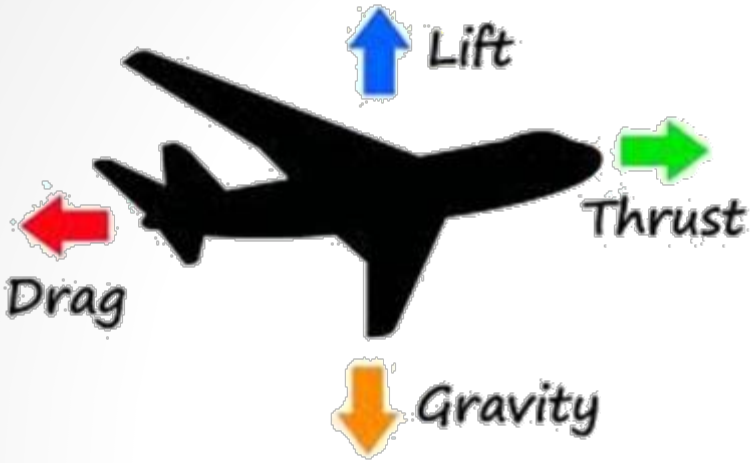

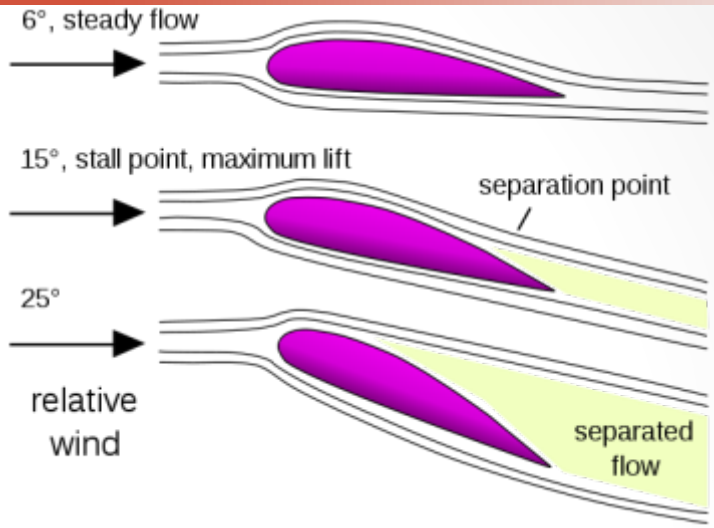

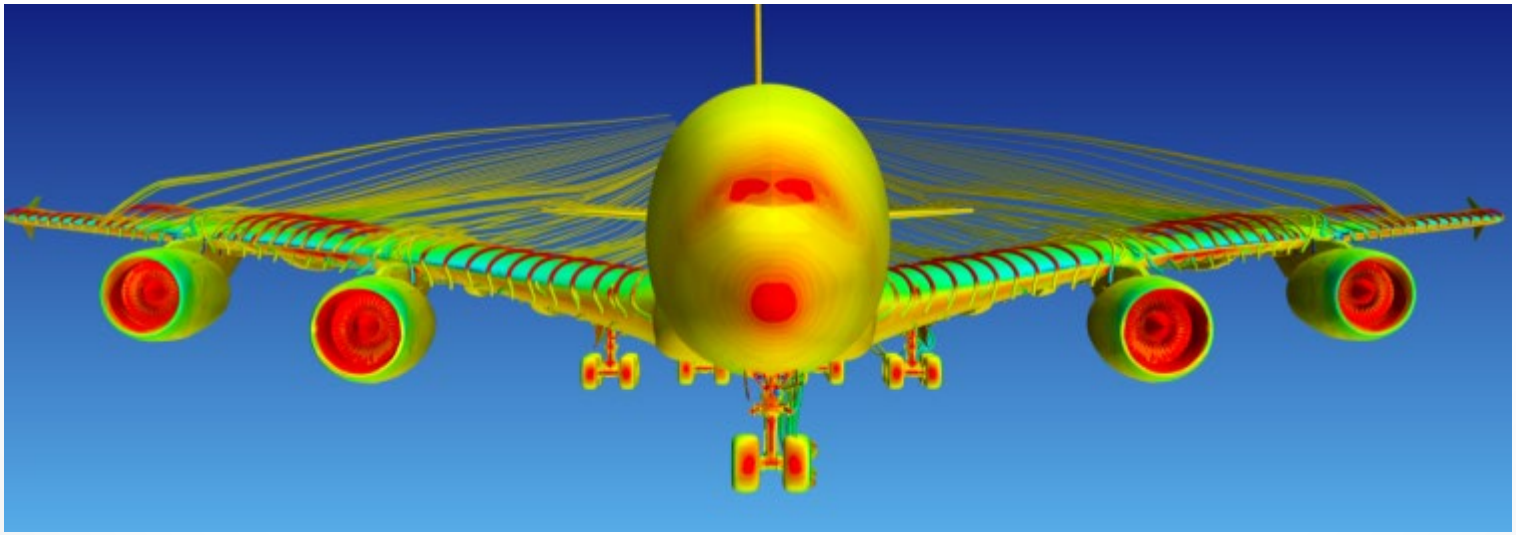

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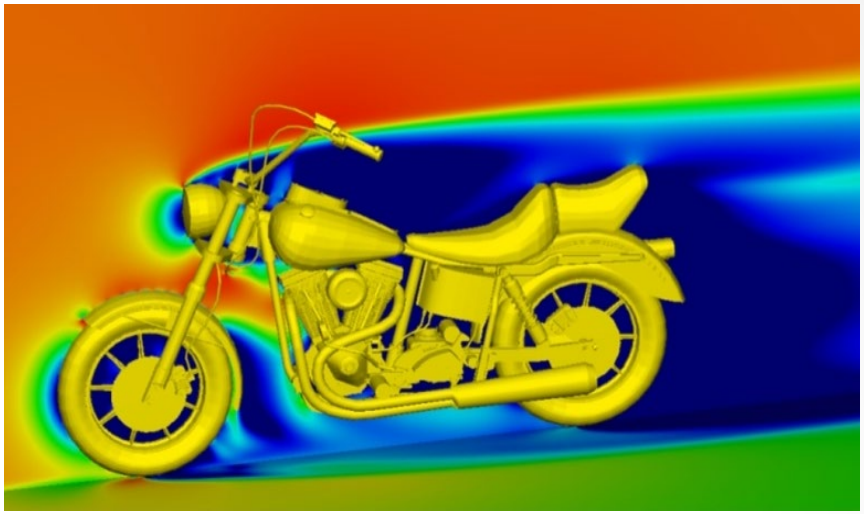

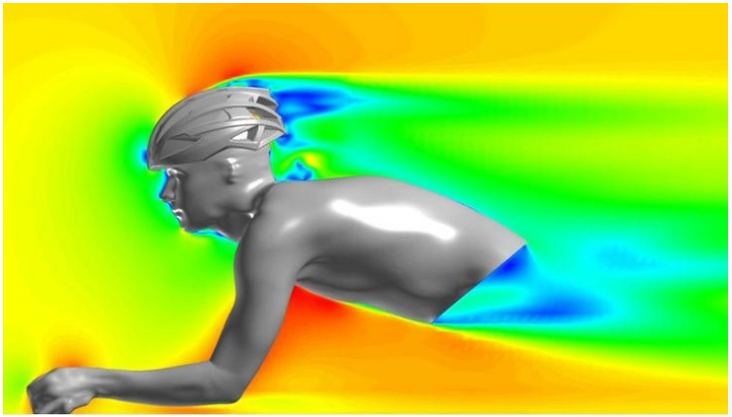

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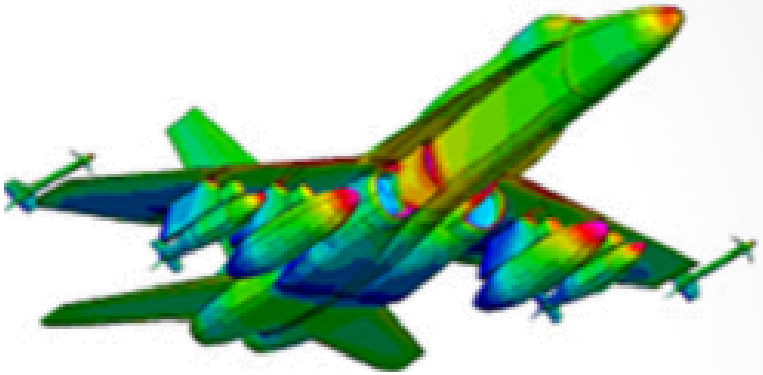
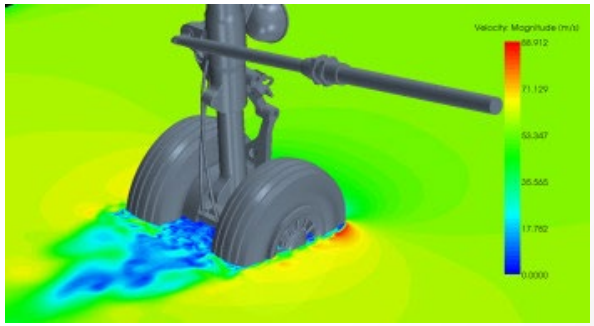
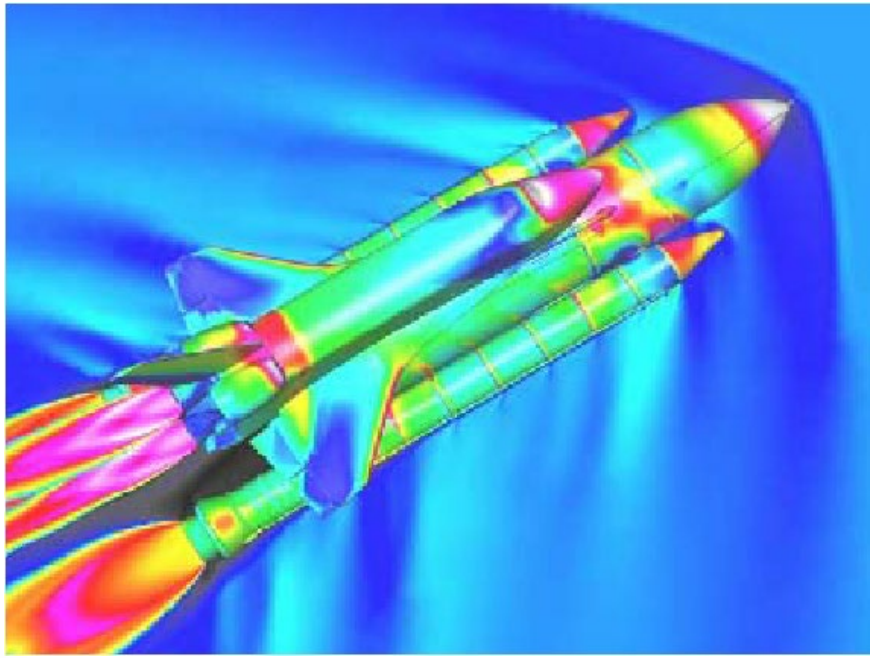
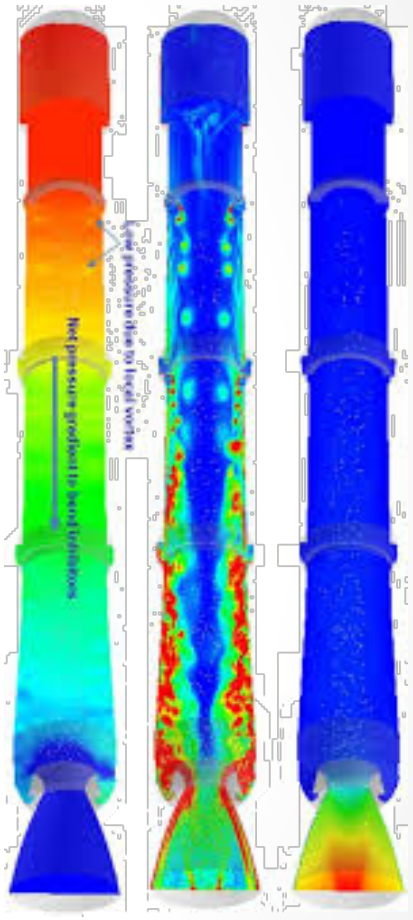




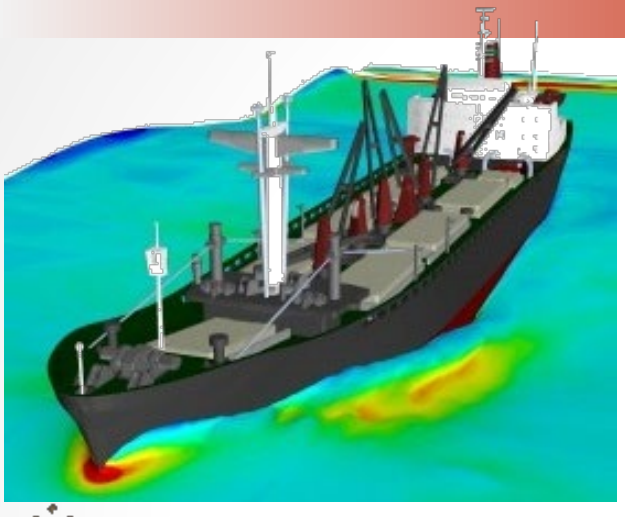
Thrust

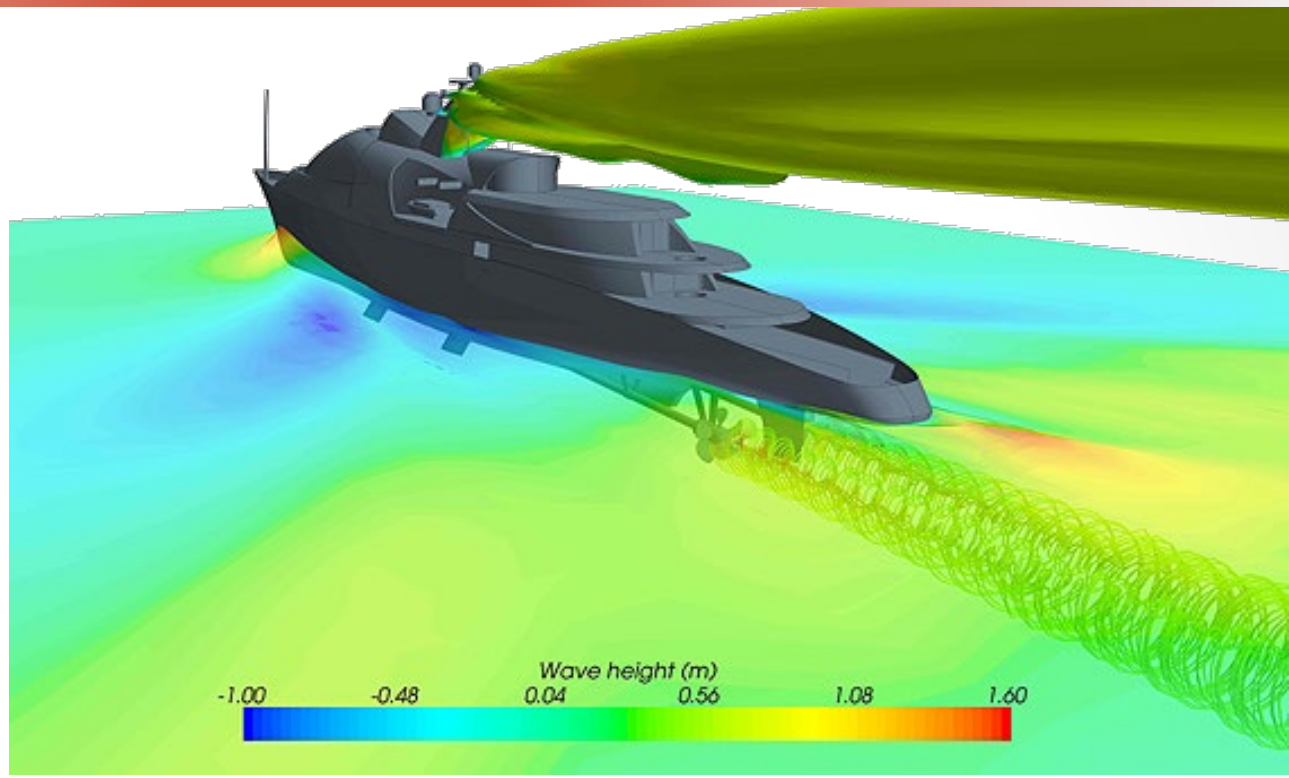
Thrust

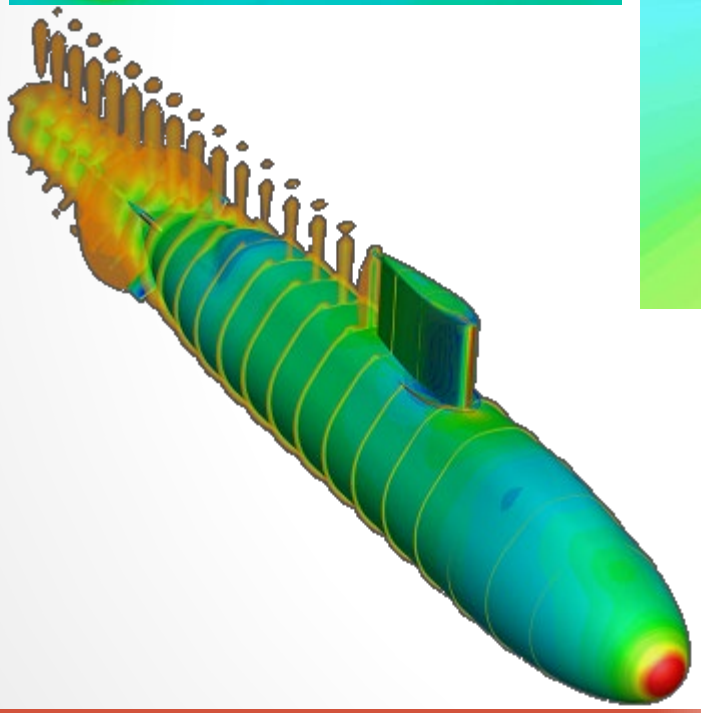




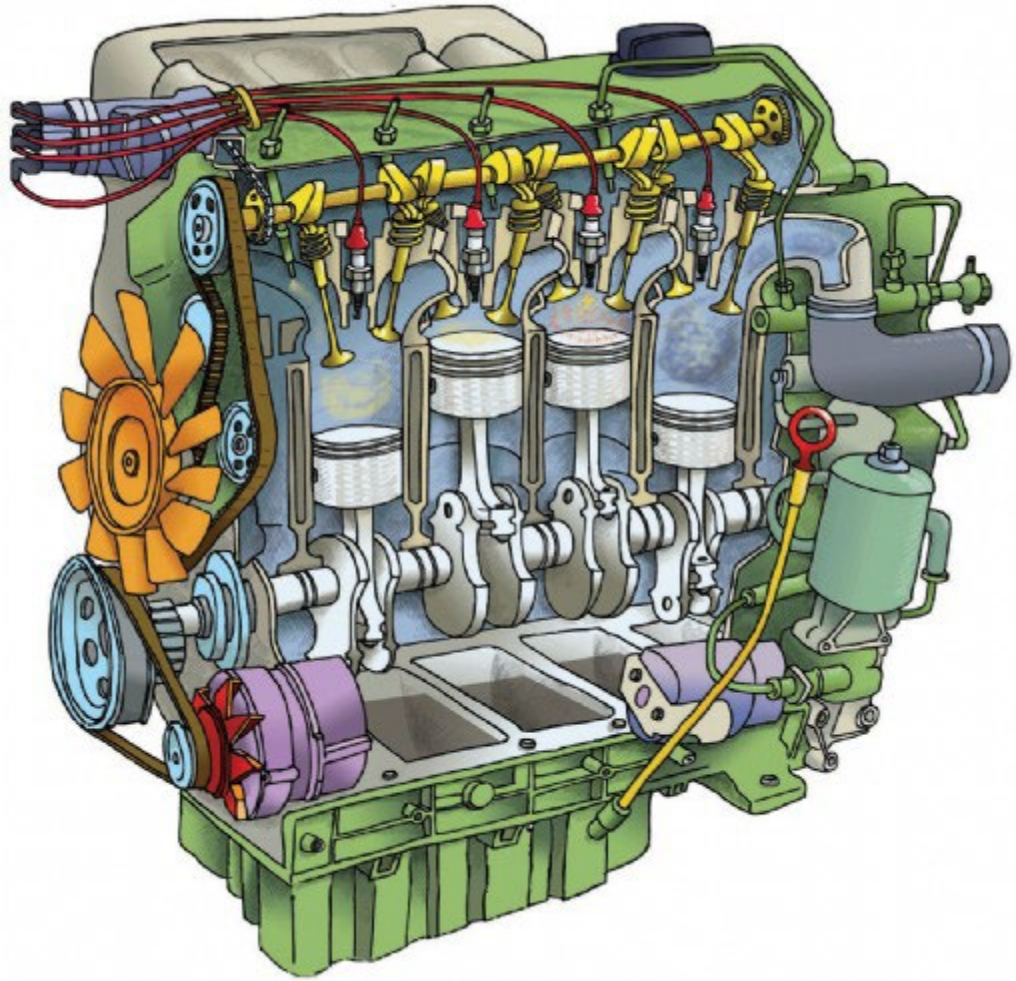
Marine



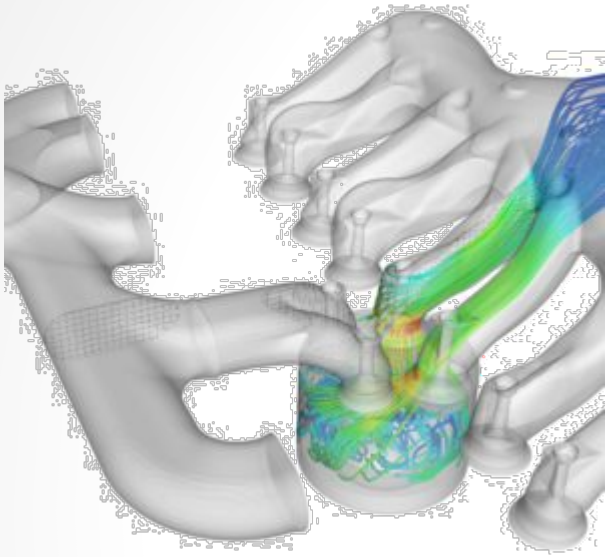


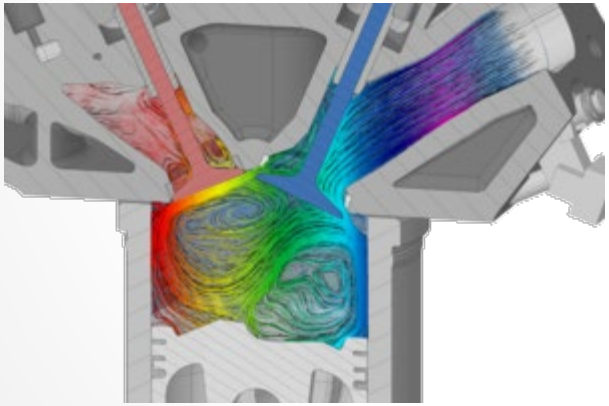


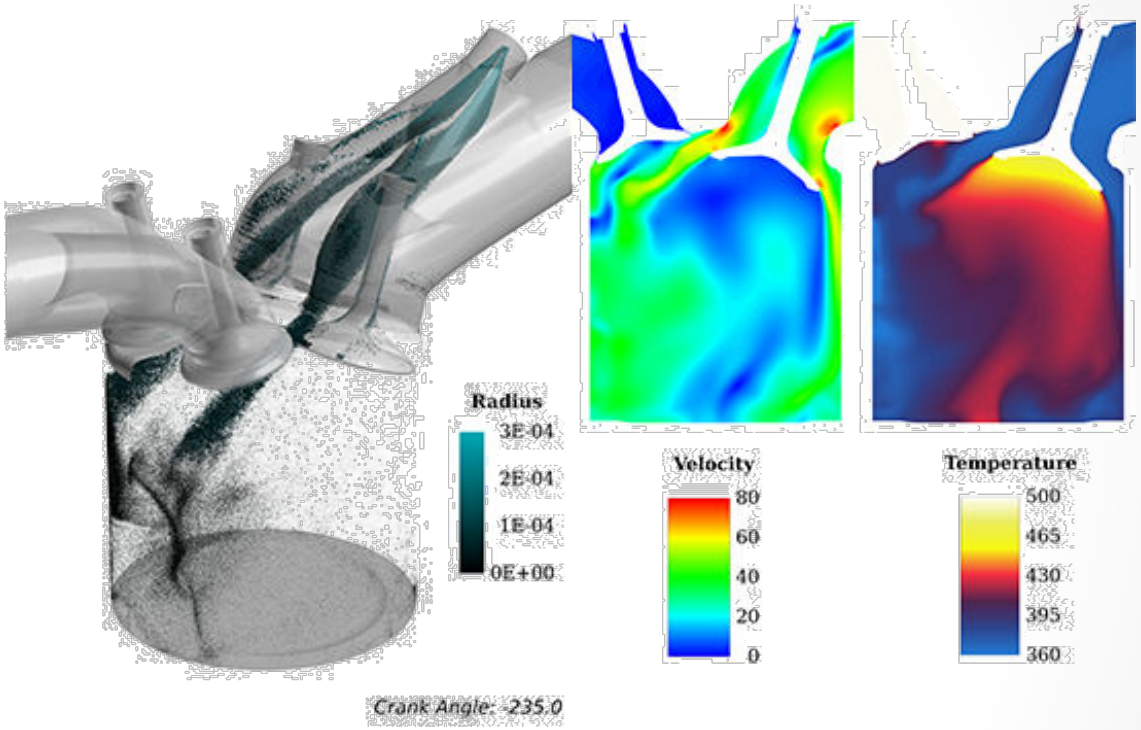
Internal combustion engines



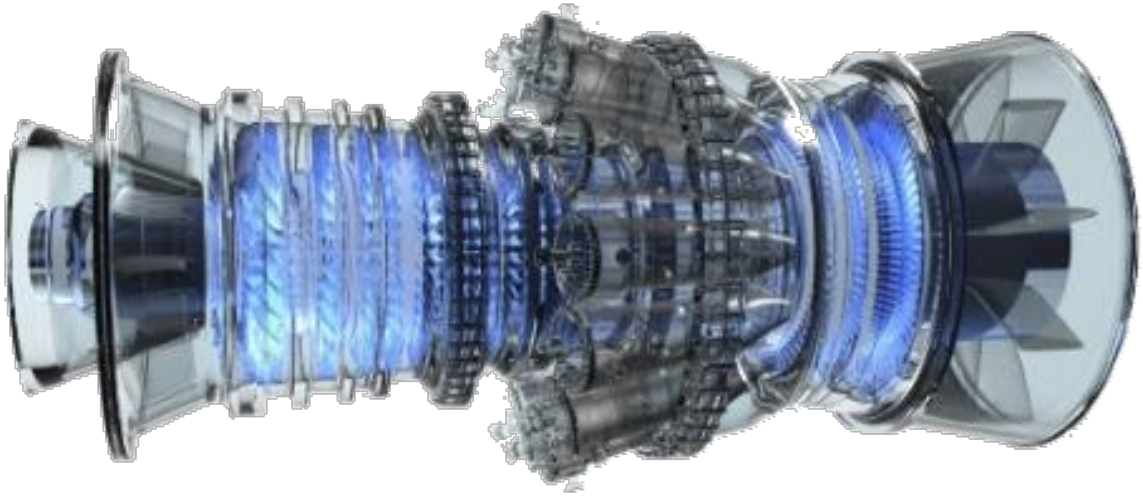
Internal combustion engines

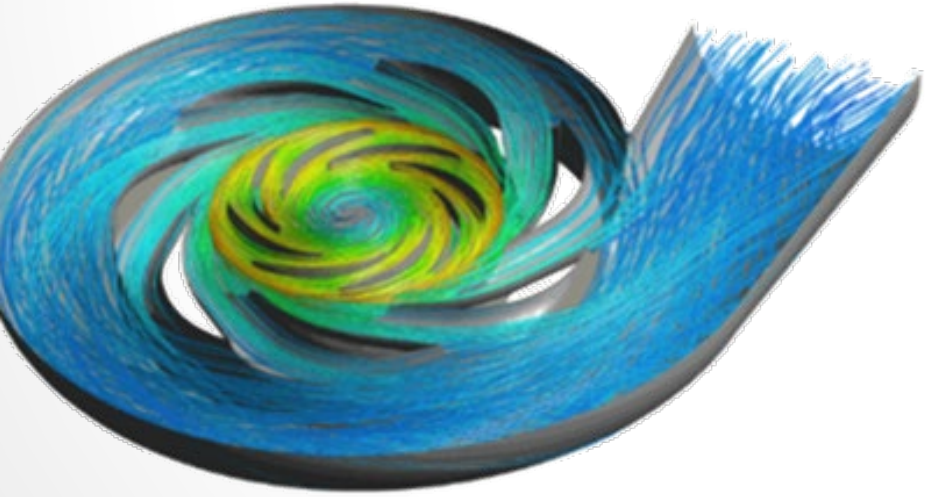


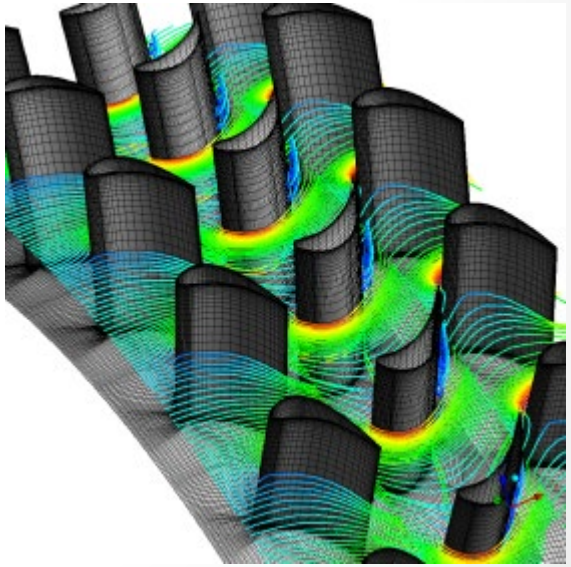




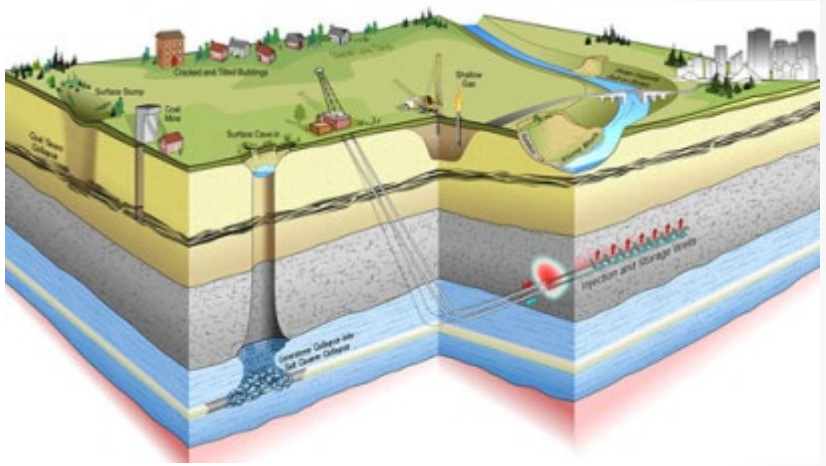
Turbo machinery



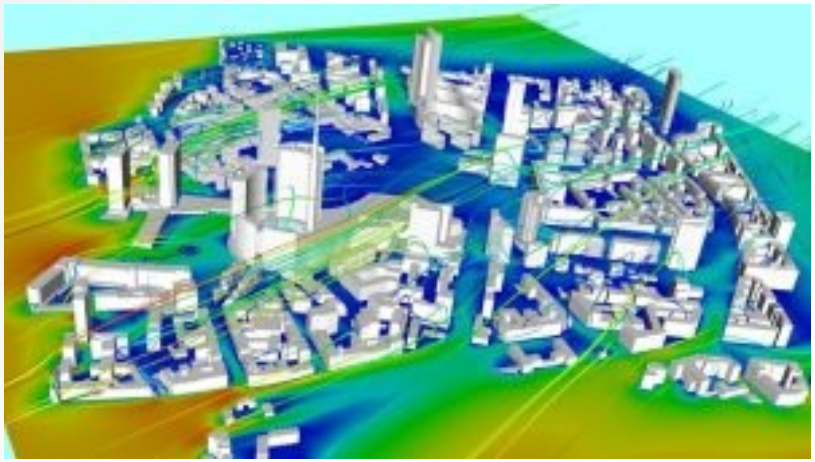


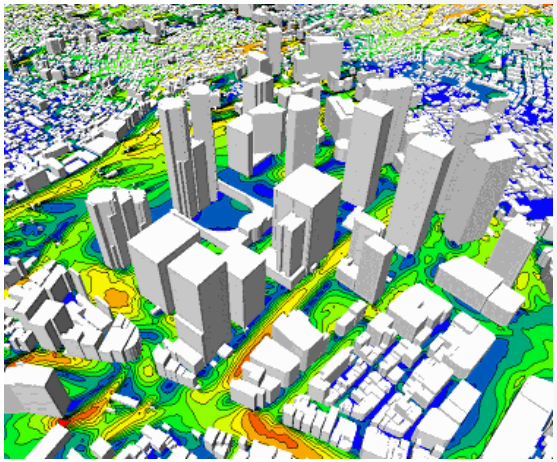


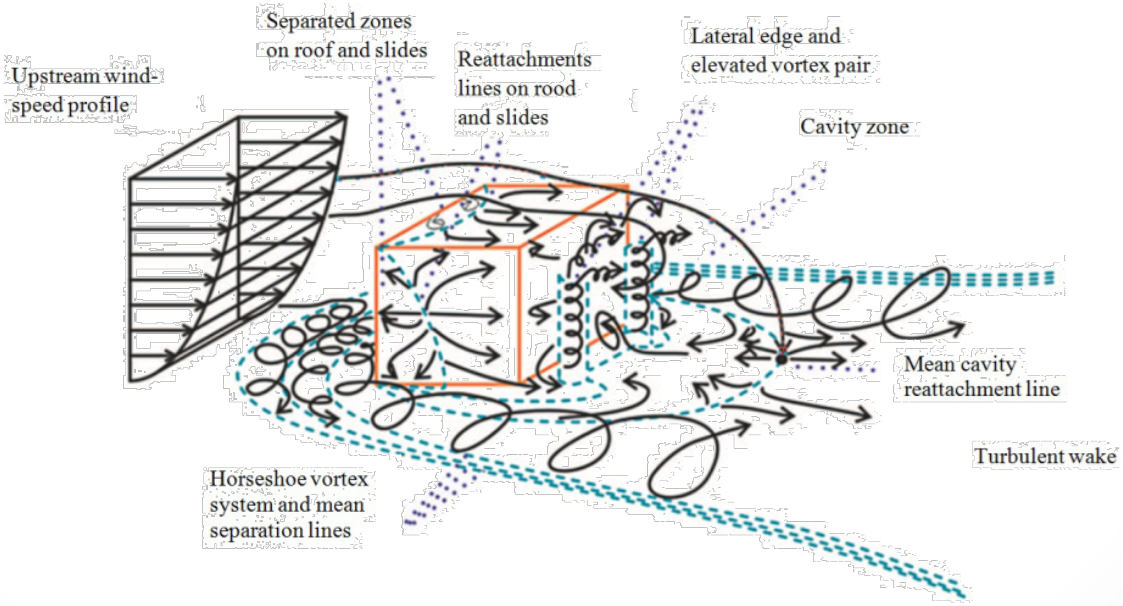
Geological fluid mechanics



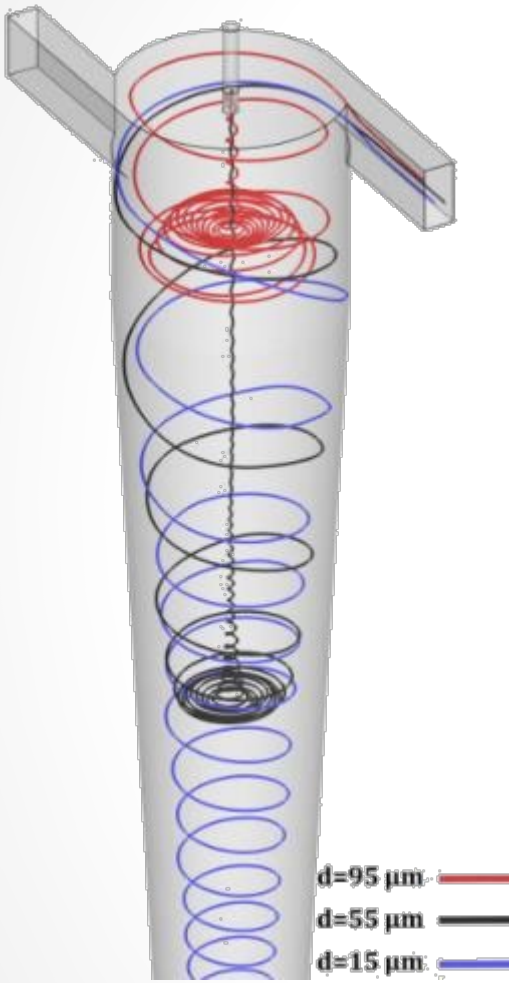
Airflow over buildings

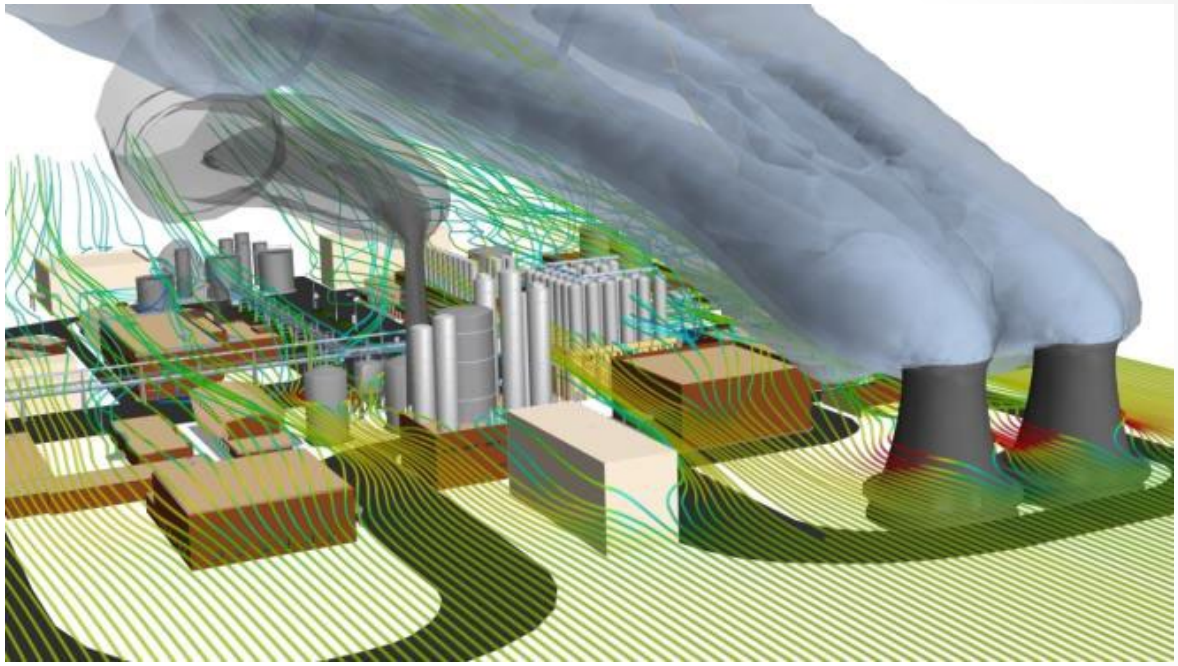






Pollution control

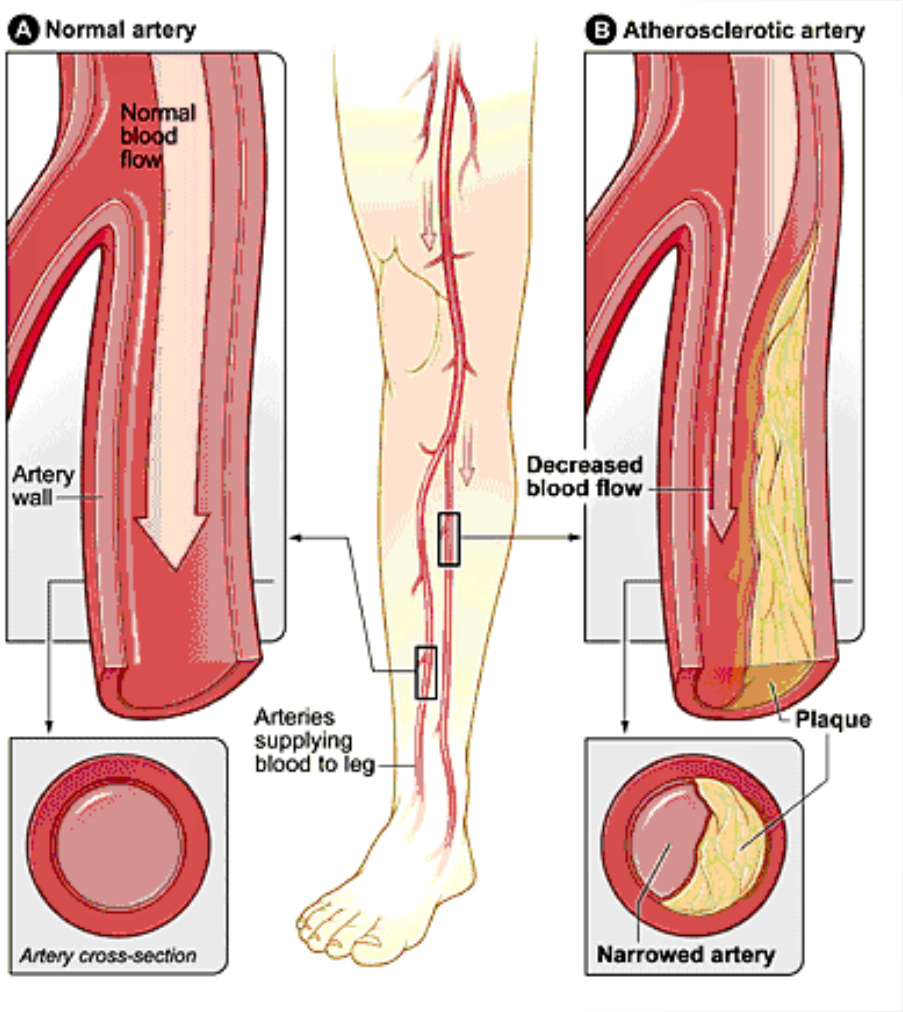




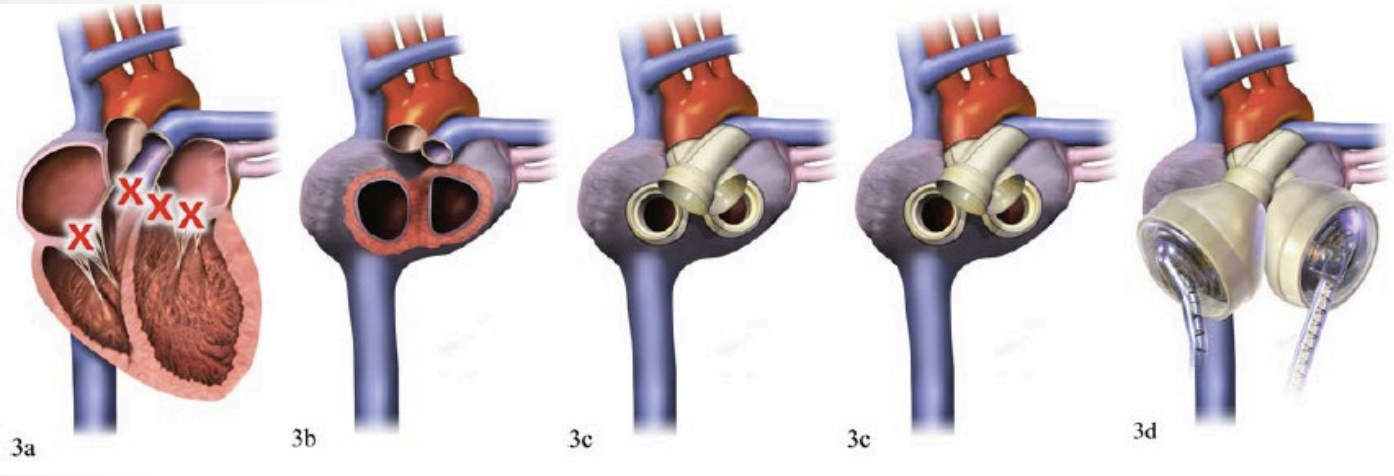
Blood flow

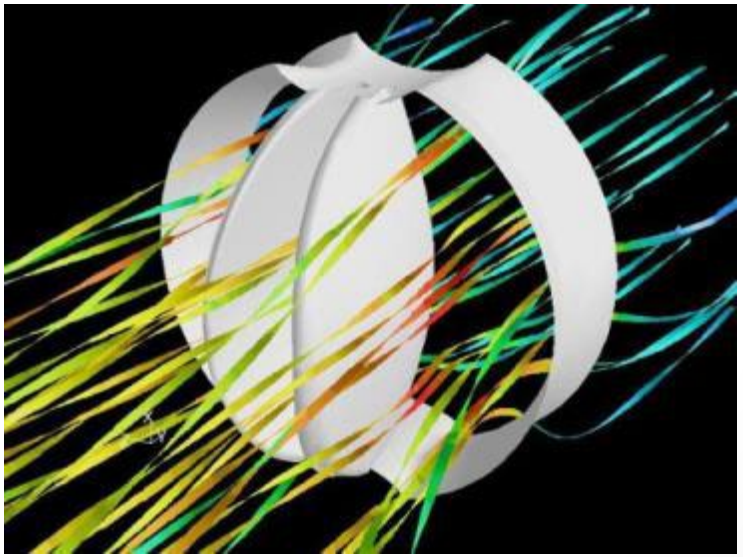
Challenges:

- Very Complex
- Rheology of blood
- Walls are flexible
- Pressure-wave travels along the arteries.
- Frequently encounter bifurcation
- There are vary small veins

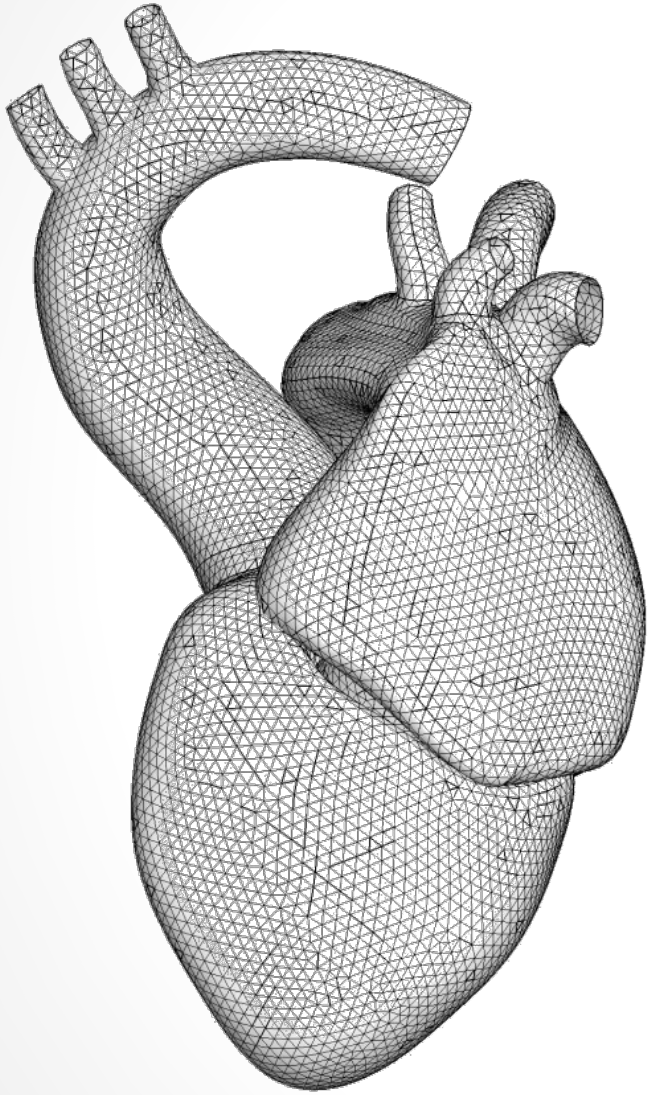


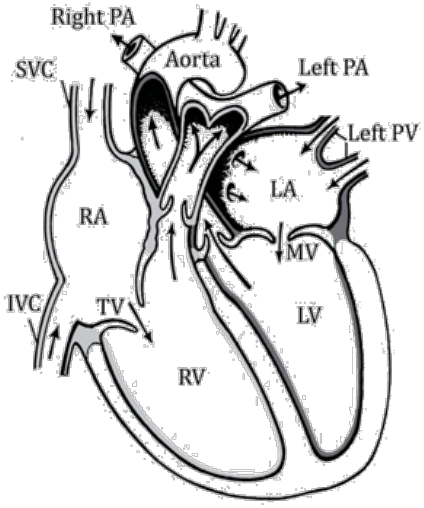
Artificial heart

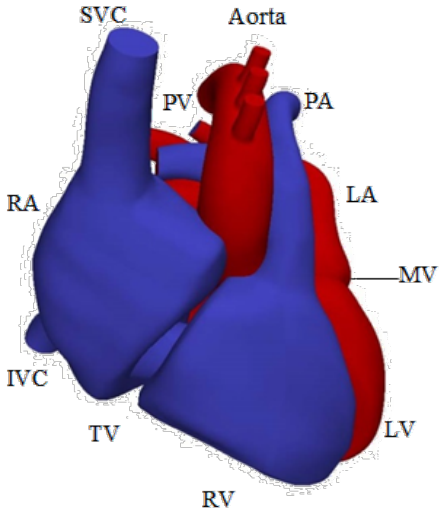




Cardiology

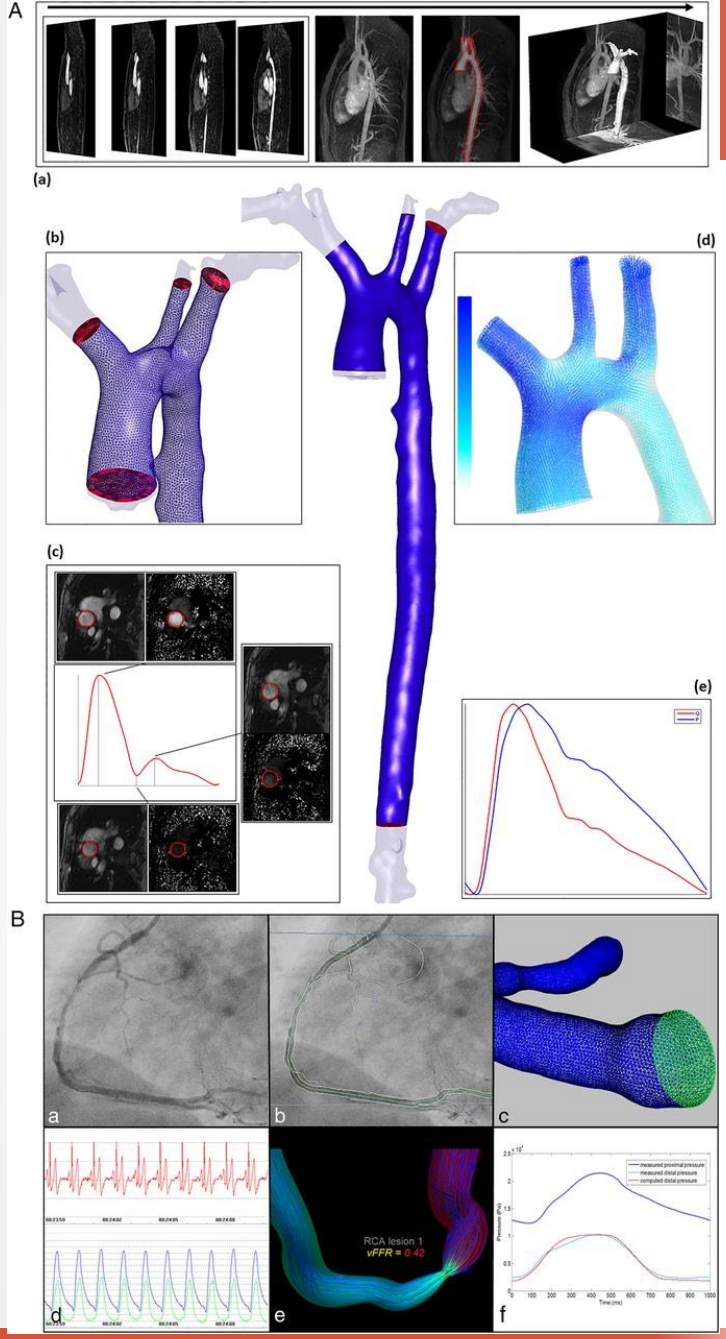


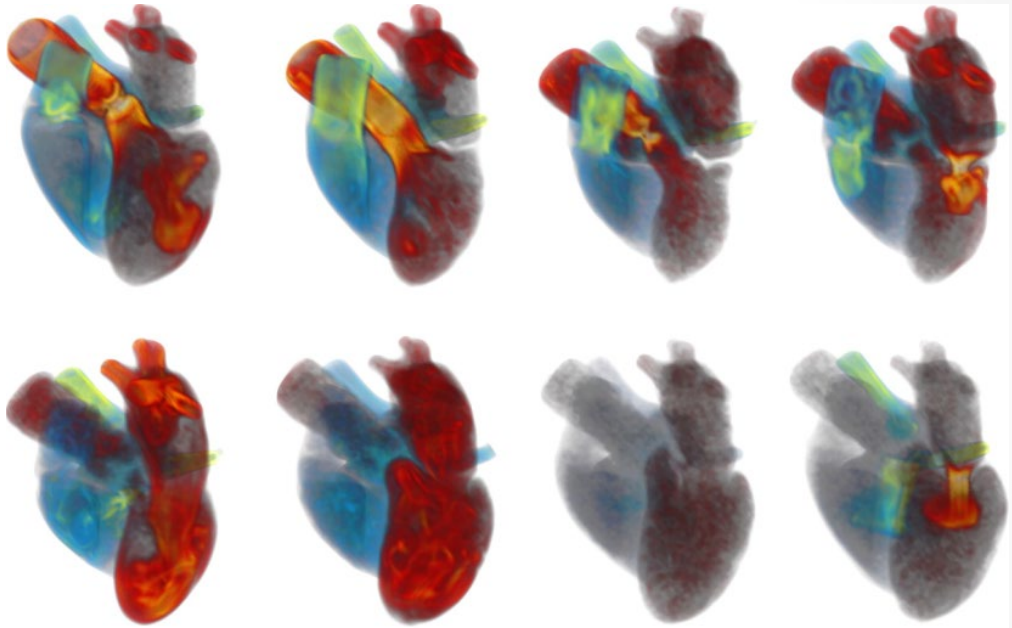




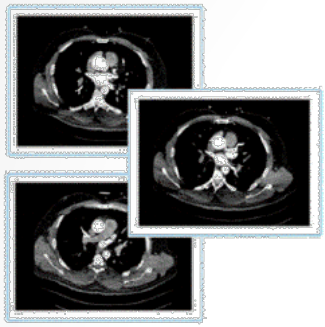
PV	Pulmonary vein
LA	Left Atrium
MV	Mitral valve
LV	Left ventricle
RA	Right Atrium
PA	Pulmonary artery
RV	Right ventricle
SVC	Superior vena cava
IVC	Inferior vena cava
TV	Tricuspid valve

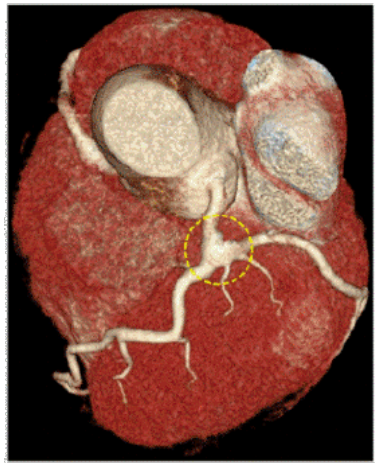
Cardiology

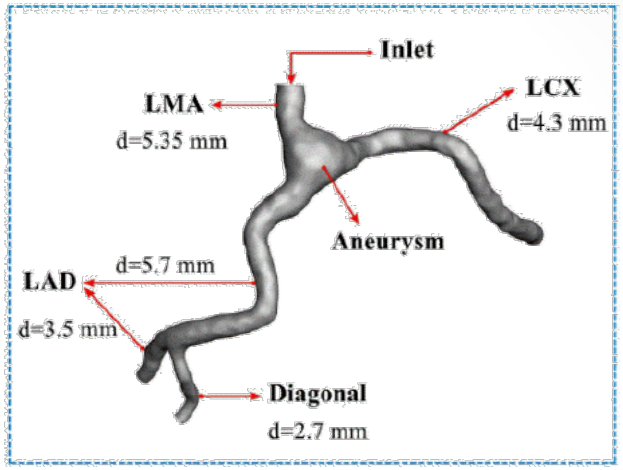


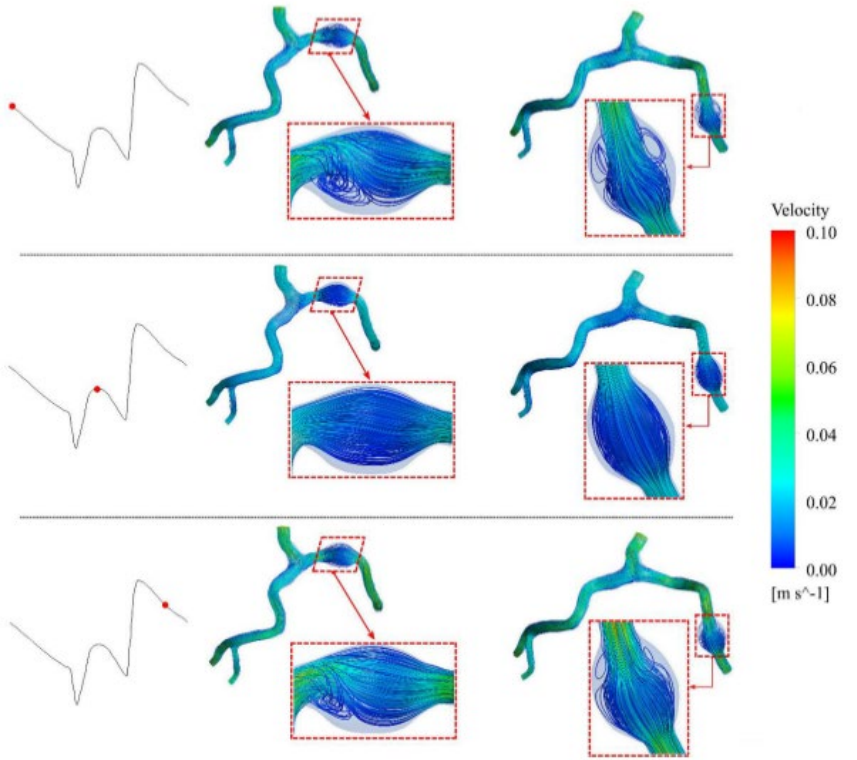


Blood Flow in Coronary Artery

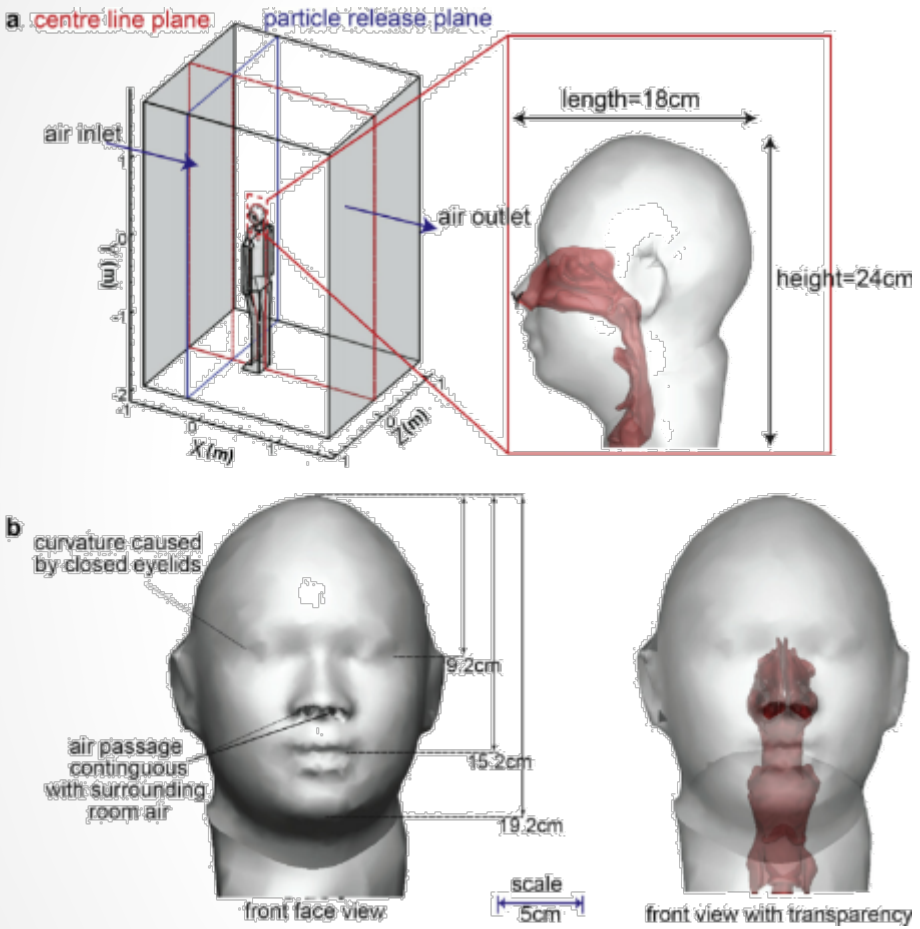


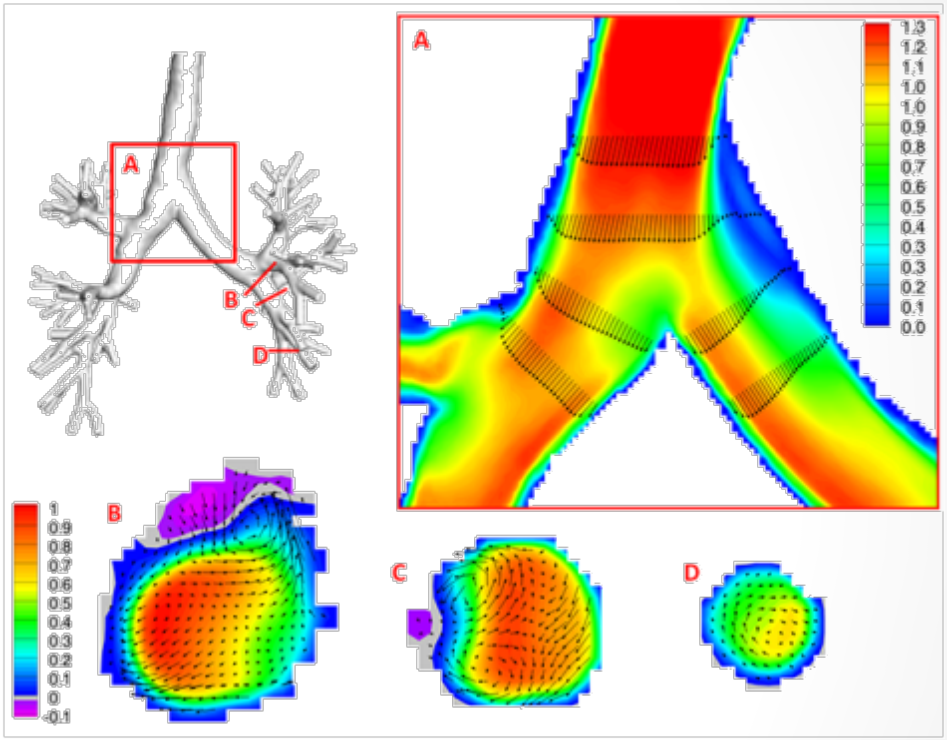




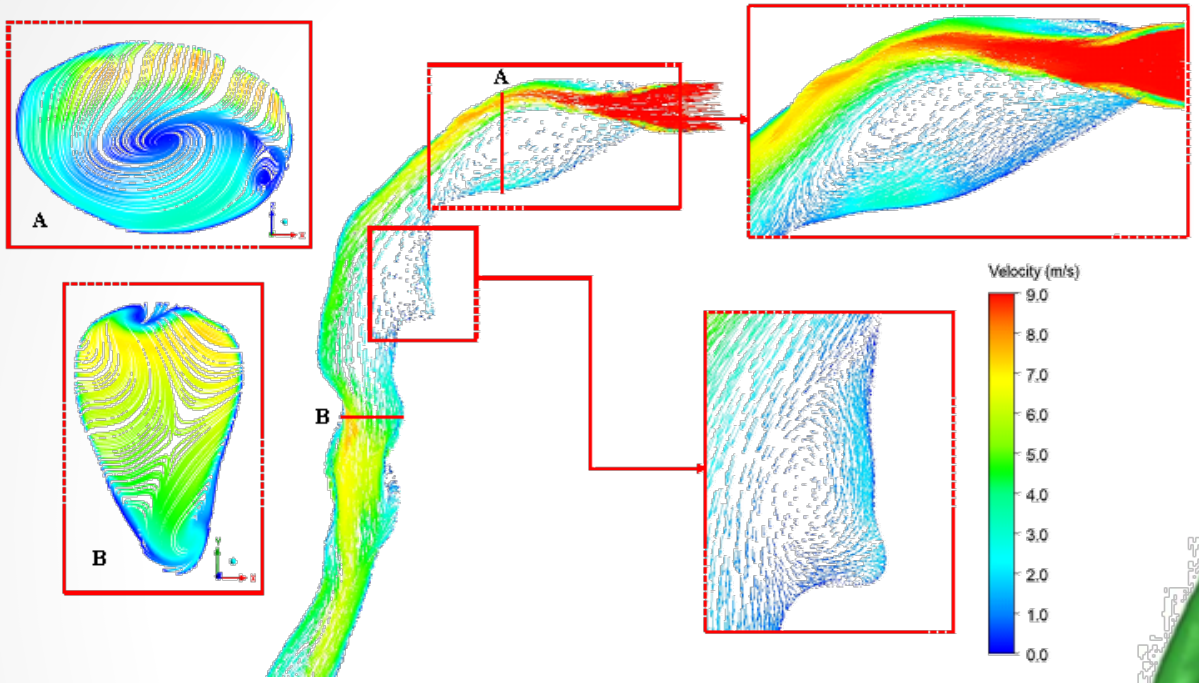


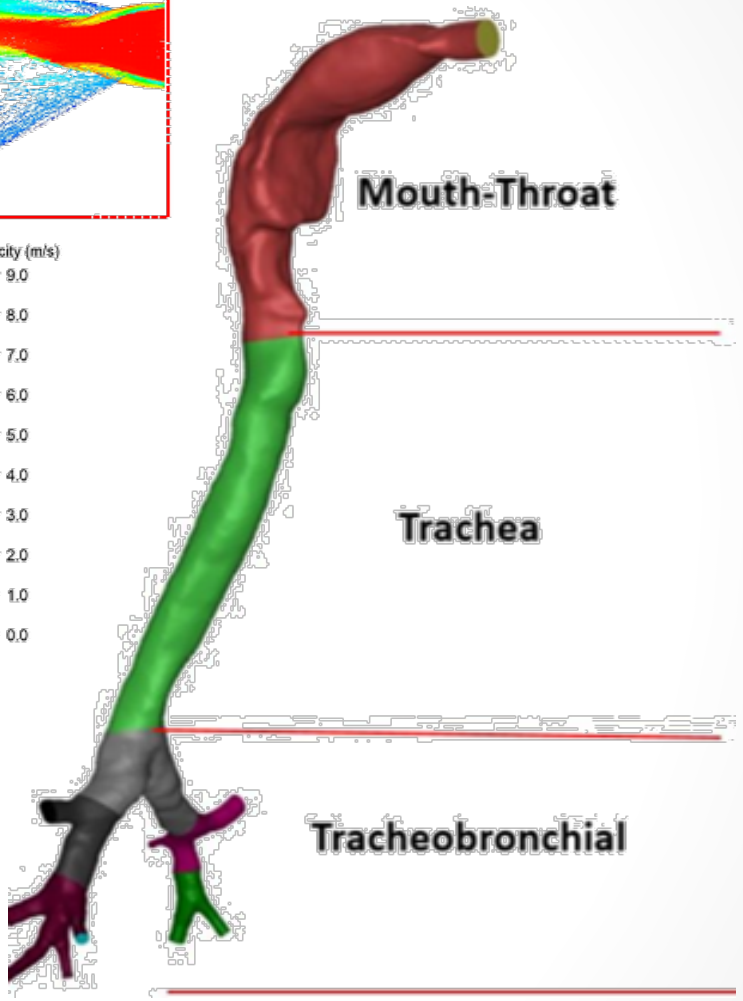
Human airway





Respiratory Airway





Gas-solid flow

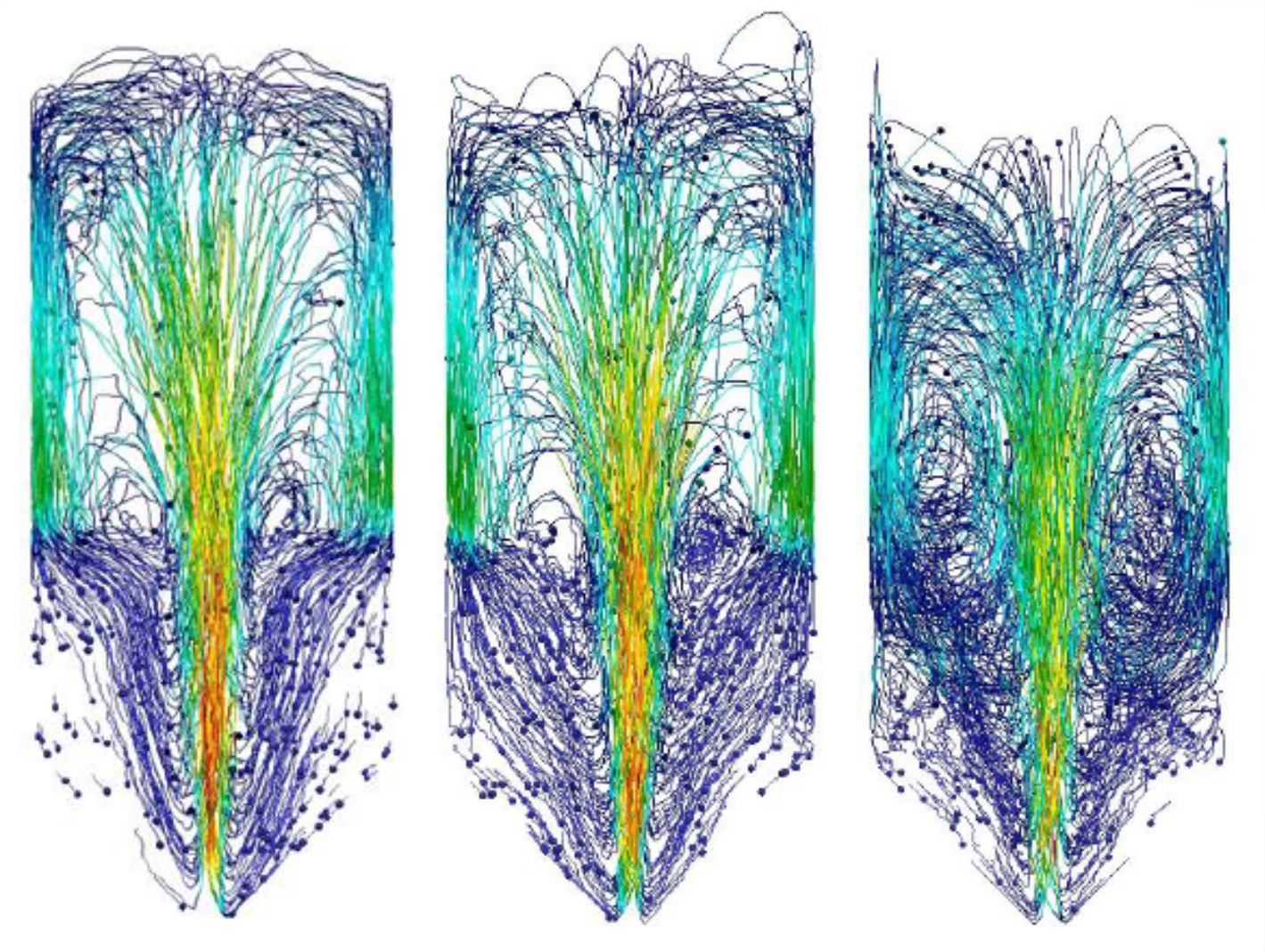
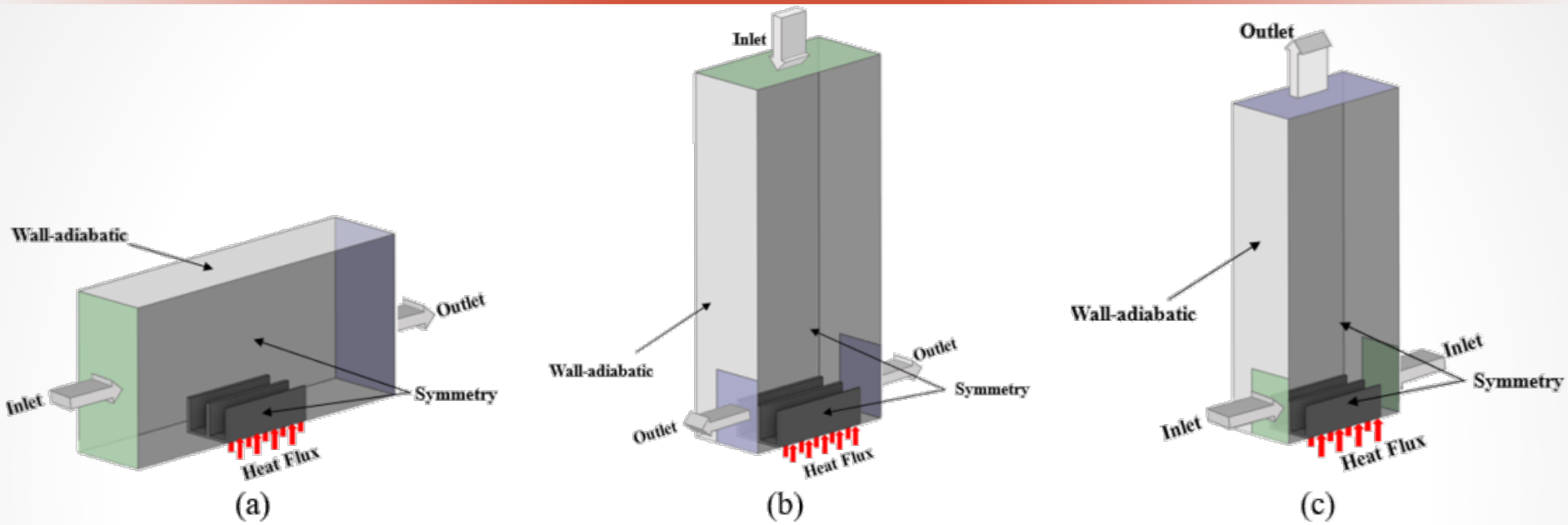
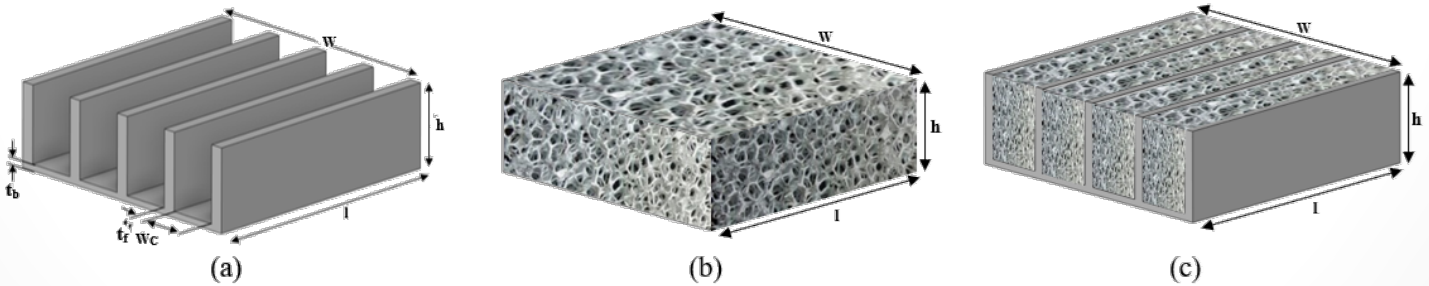


Plate-fin, metal foam, and hybrid heat sinks

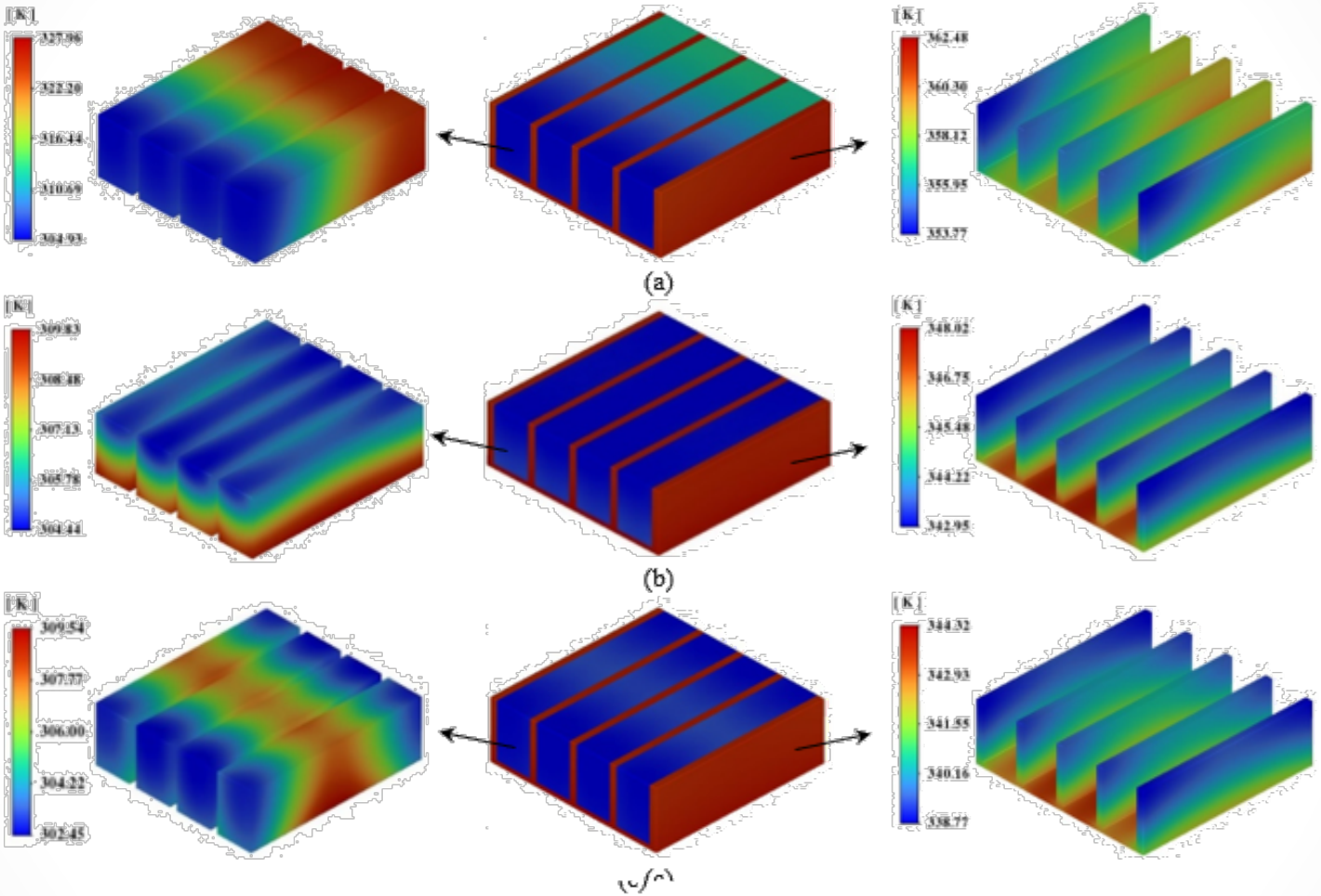


Boundary conditions and computational domain for (a) parallel, (b) impinging, and (c) induced flow.



Geometry of (a) plate-fin, (b) metal foam, and (c) hybrid heat sinks.

Plate-fin, metal foam, and hybrid heat sinks



Temperature contour of the hybrid heat sink under (a) parallel, (b) impinging, and (c) induced flows

از حسن توجه شما سپاسگزارم