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CFD Predictions for Ocean Gliders

6th NRC-IOT Workshop on Underwater Vehicle Technology

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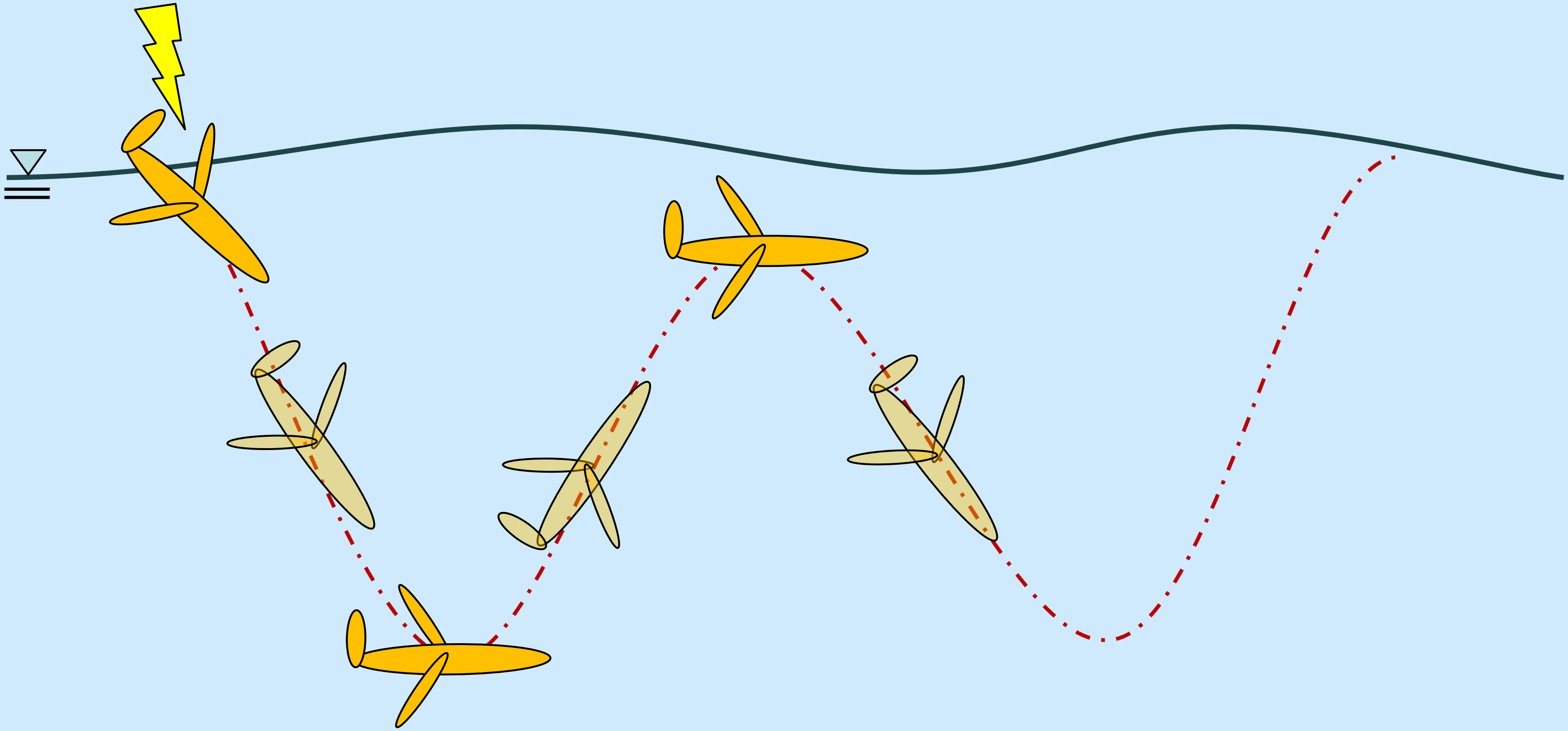
Outline

- Research background
  - Concept of acoustic survey using ocean glider
  - Roll of CFD analysis
- Numerical model for CFD analysis
  - Grid system
  - Turbulence mode
- Results
  - Velocity and pressure contour
  - Pressure & shear coefficient
  - Validation
- Summary & future work

Ocean glider

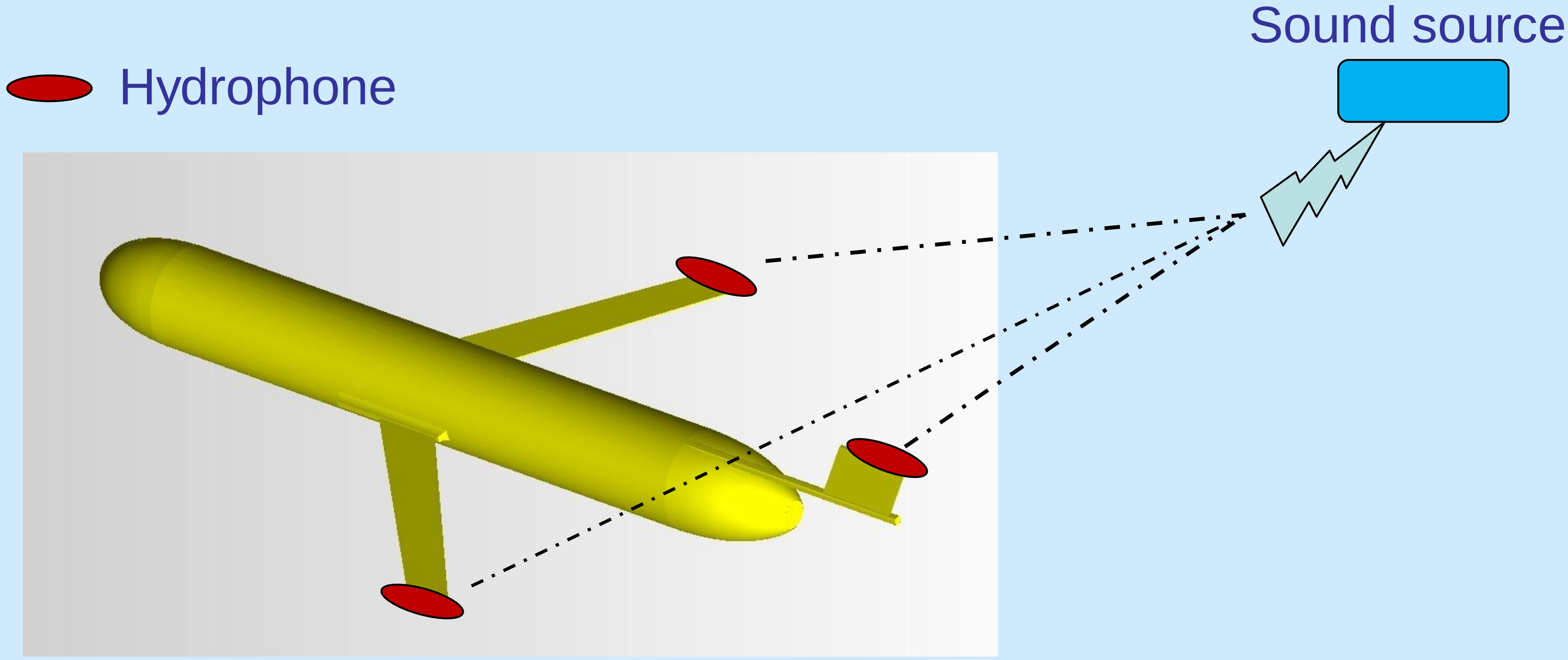
- Saw-tooth trajectory of ocean glider

  ➔ **Long operation time & wide coverage**



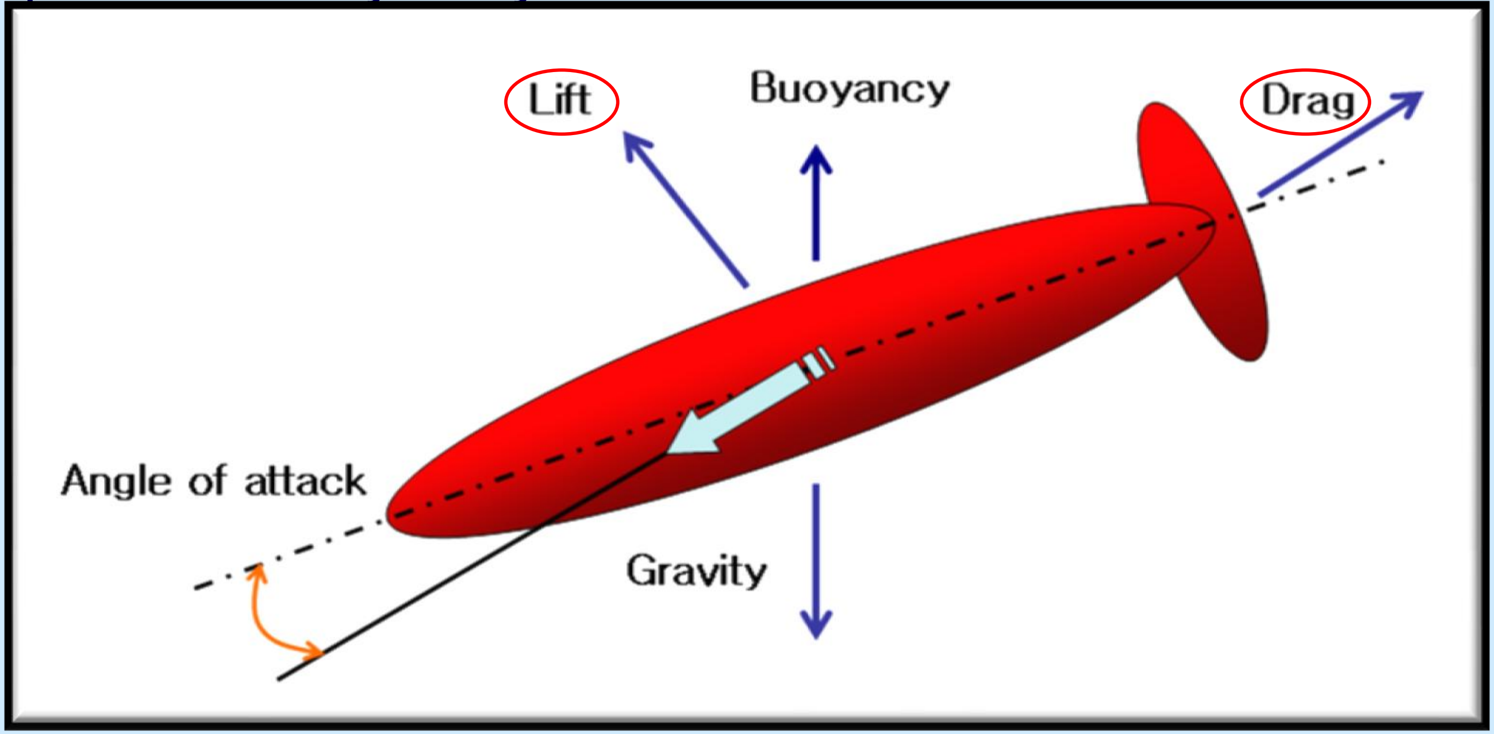
Acoustic survey using ocean glider

- Long operation time
- Low ambient noise due to no external propulsion device
- Long base line between hydro-phones



Balancing problem

- Importance of hydrodynamic force



To change the hull for installing the hydrophones

⇨ ***Needs for estimating hydrodynamic forces of the modified body***

Object of CFD analysis

At design stage,

to predict hydrodynamic forces such as drag and lift

- Optimum design of the buoyancy engine
- Accurate prediction of the operation time

to estimate the local flow around hydrophone

- Minimizing the ambient noise caused by violent flow

to predict maneuverabilty

- Radius of turning circle and the depth requirement for the mode change

In this study,

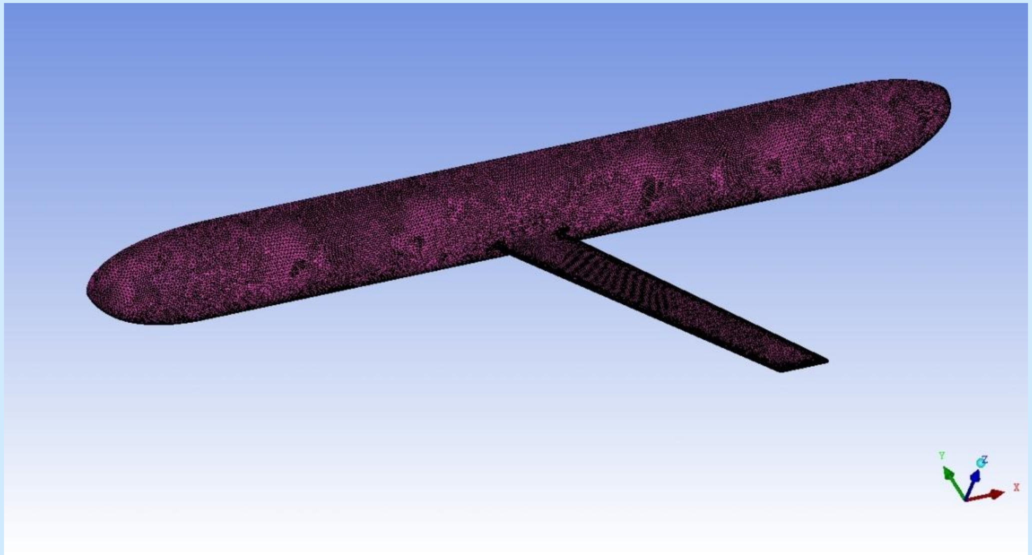
to examine CFD performance and prepare the hull modification

Geometric model

Slocum glider

From www.webresearch.com

Simplified geometry without tail wing and small appendages



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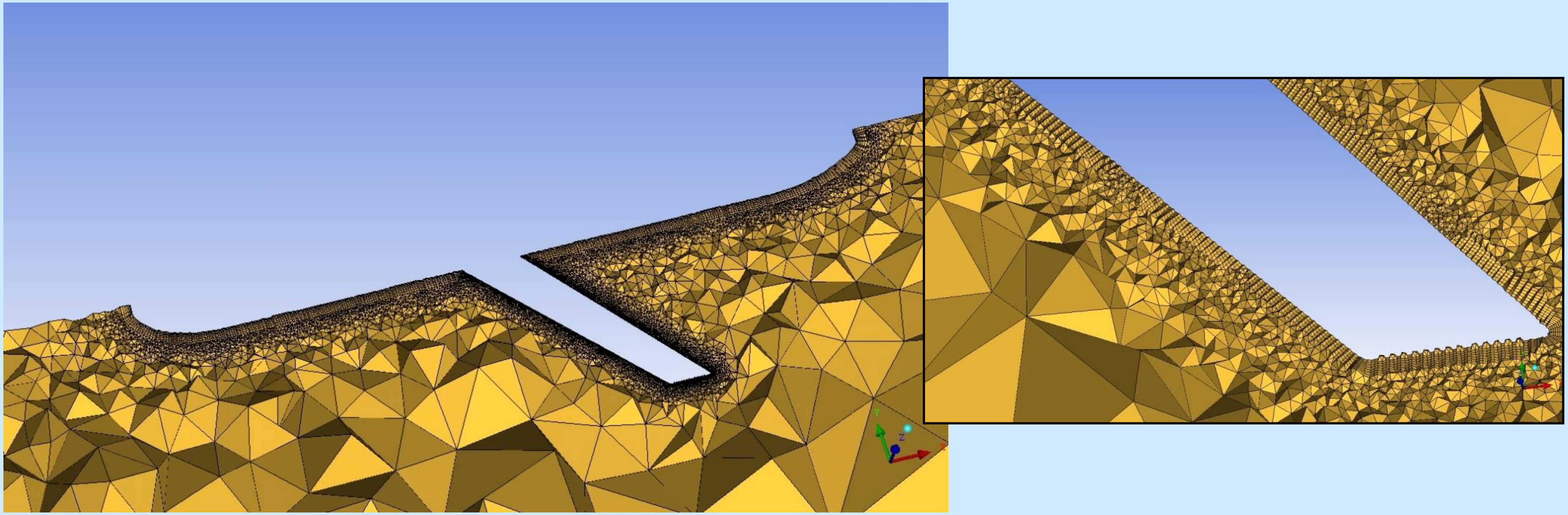
Grid system

- Hybrid grid system
  - Unstructured surface mesh
  - Prismatic layer
    - 7 layers with 2mm thickness of the first layer ~ $Y^+ < 10$
  - 1.8 million cells



Turbulence model

- Shear-stress transport (SST) k-ω model
  - Widely used model for streamlined aerodynamic and hydrodynamic bodies
- SST transition model
  - Developed for the laminar-turbulent transition
  - ***Reynolds number of ocean glider: 10^5 ~10^6***
  - Cost effective method compared with LES* or DNS** considering transition flow

** Large Eddy Simulation*
*** Direct Numerical Simulation*

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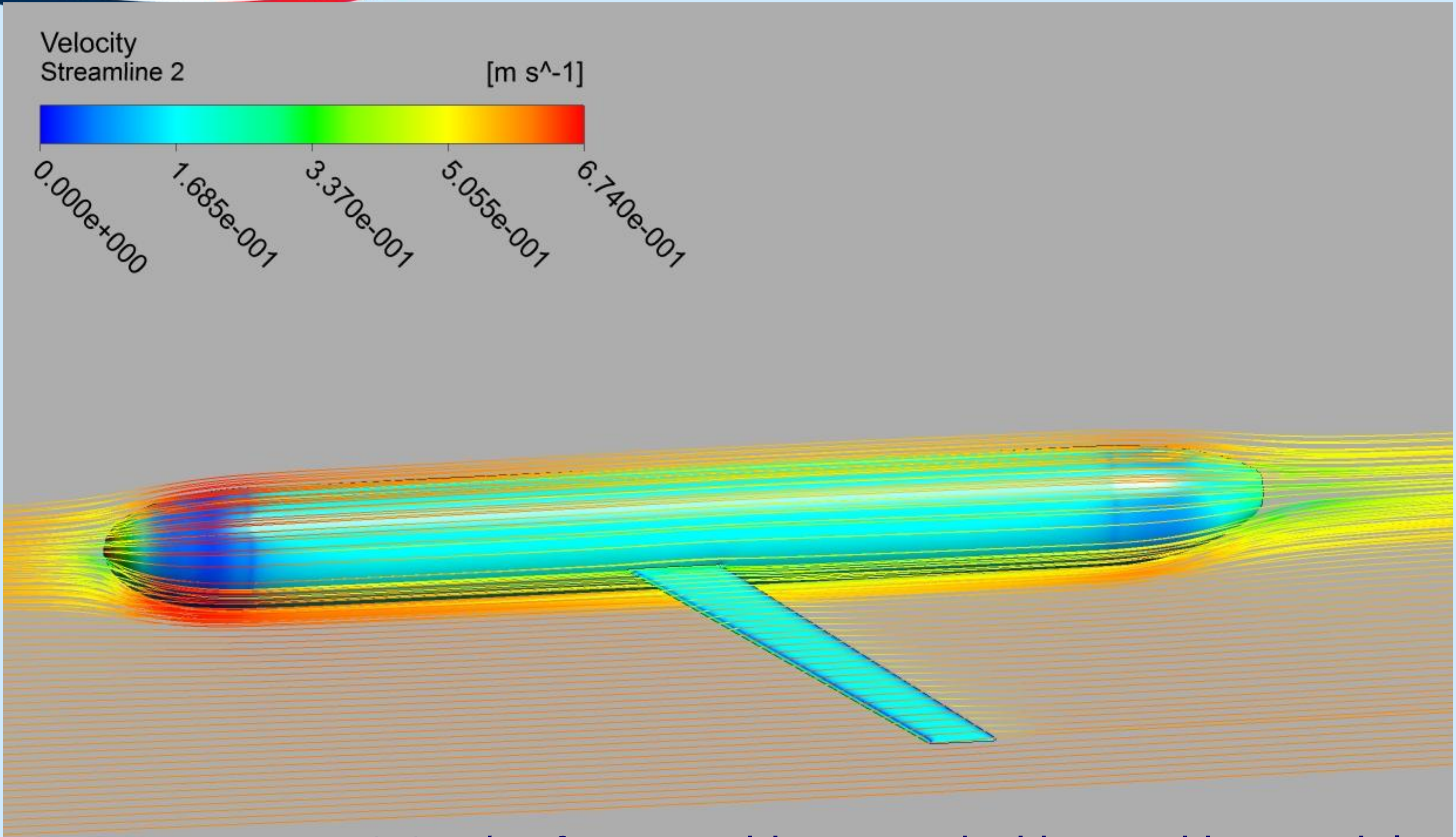
Simulation case

- Approaching velocity
  - 0.3 m/s and 0.5 m/s
- Turbulence model
  - SST-kω model and transition model
- Zero angle of attack

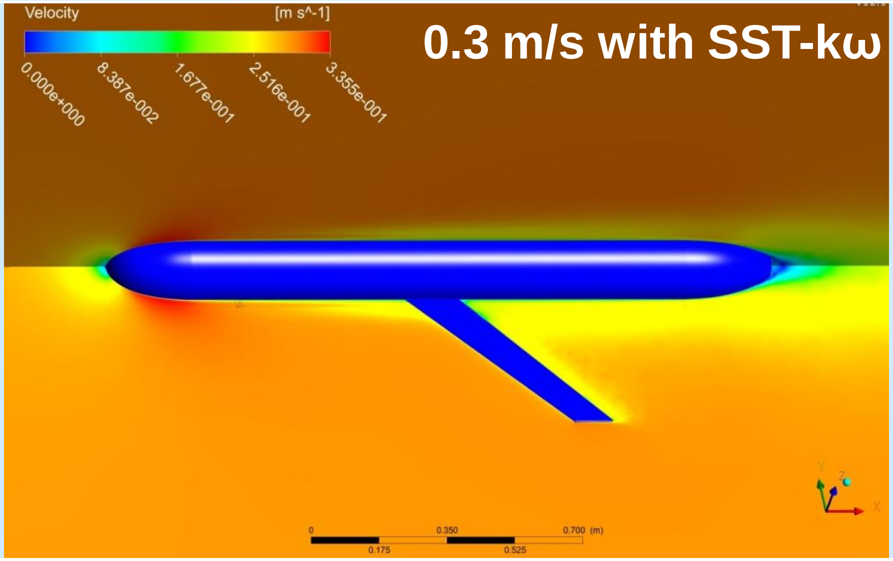
0.3 m/s with SST-kω	**0.3 m/s with transition**
0.6 m/s with SST-kω	**0.6 m/s with transition**

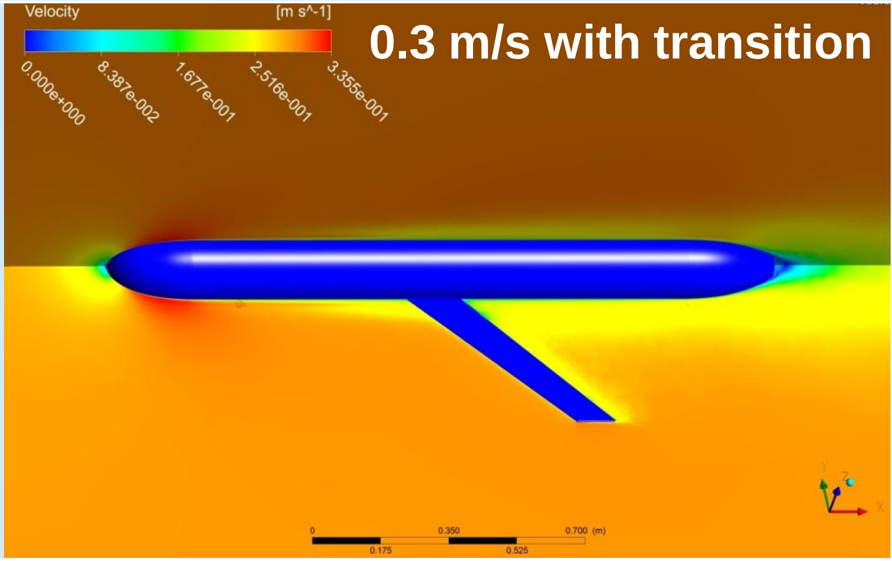
Stream line

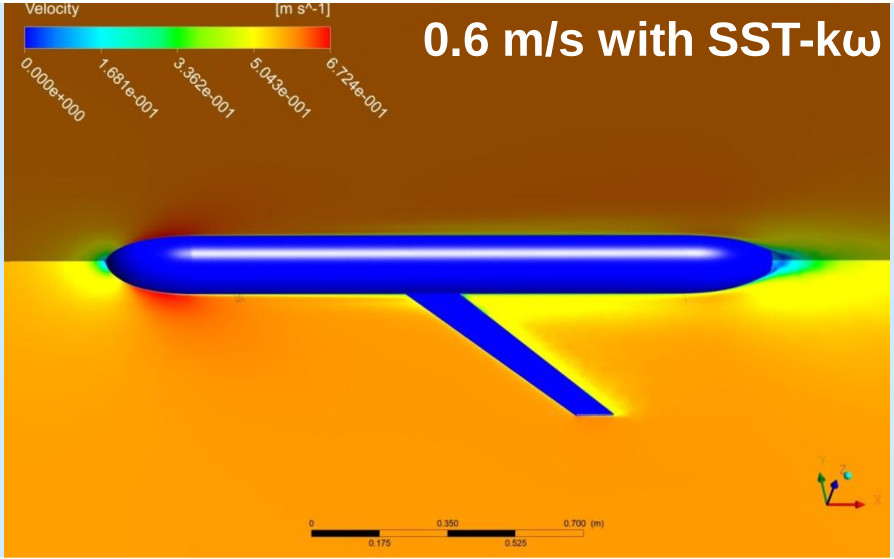


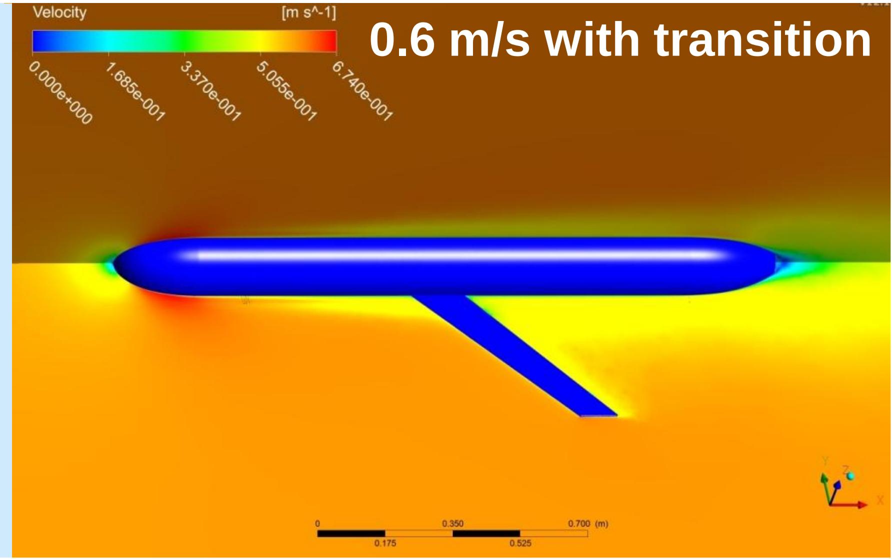
At 0.6 m/s of approaching speed with transition model

Velocity contour

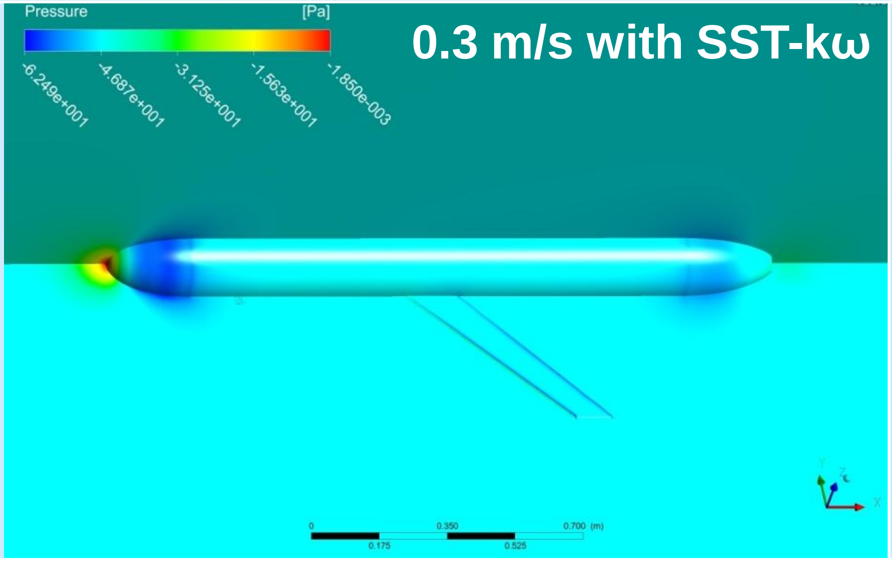


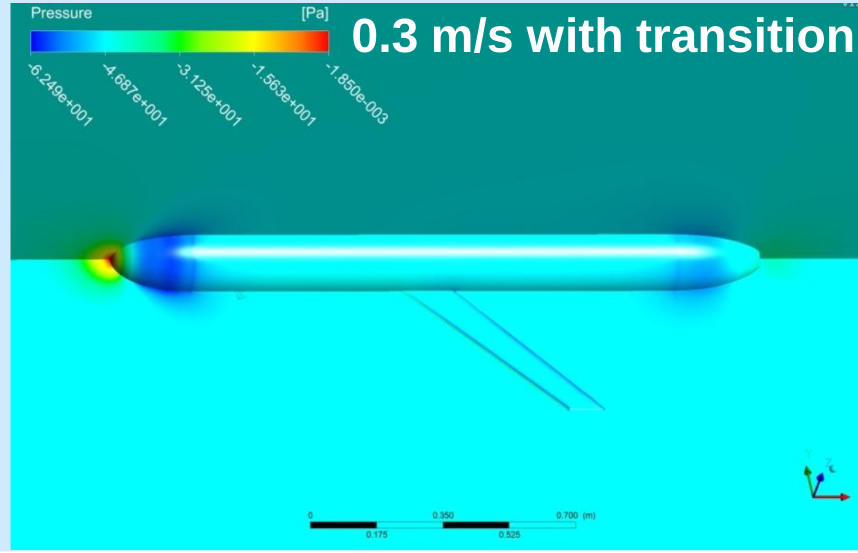


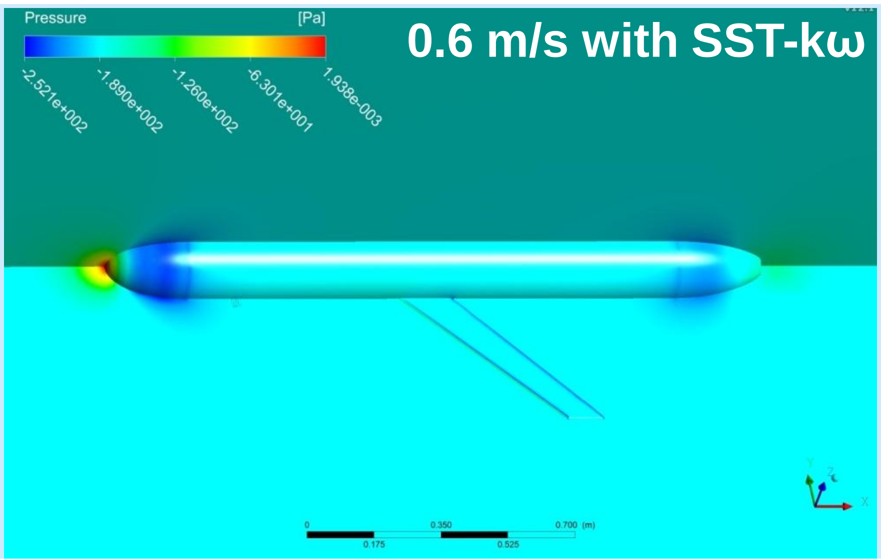


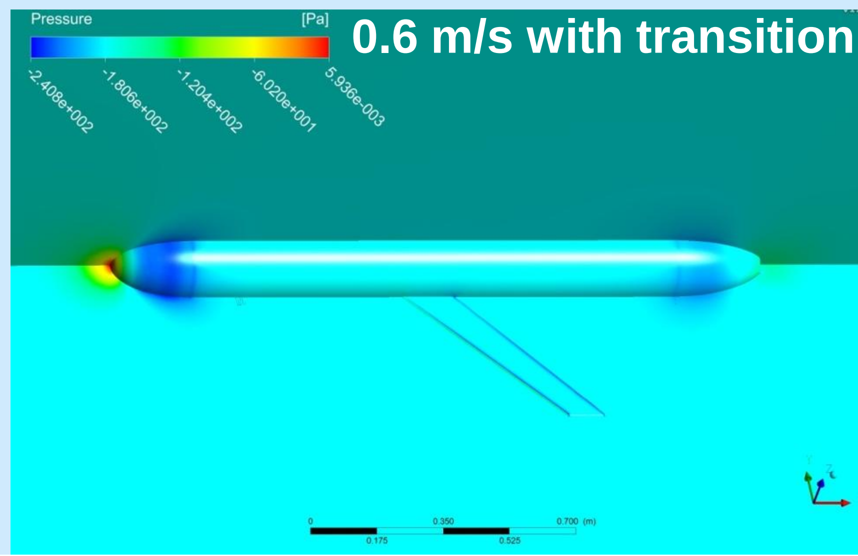


Pressure contour





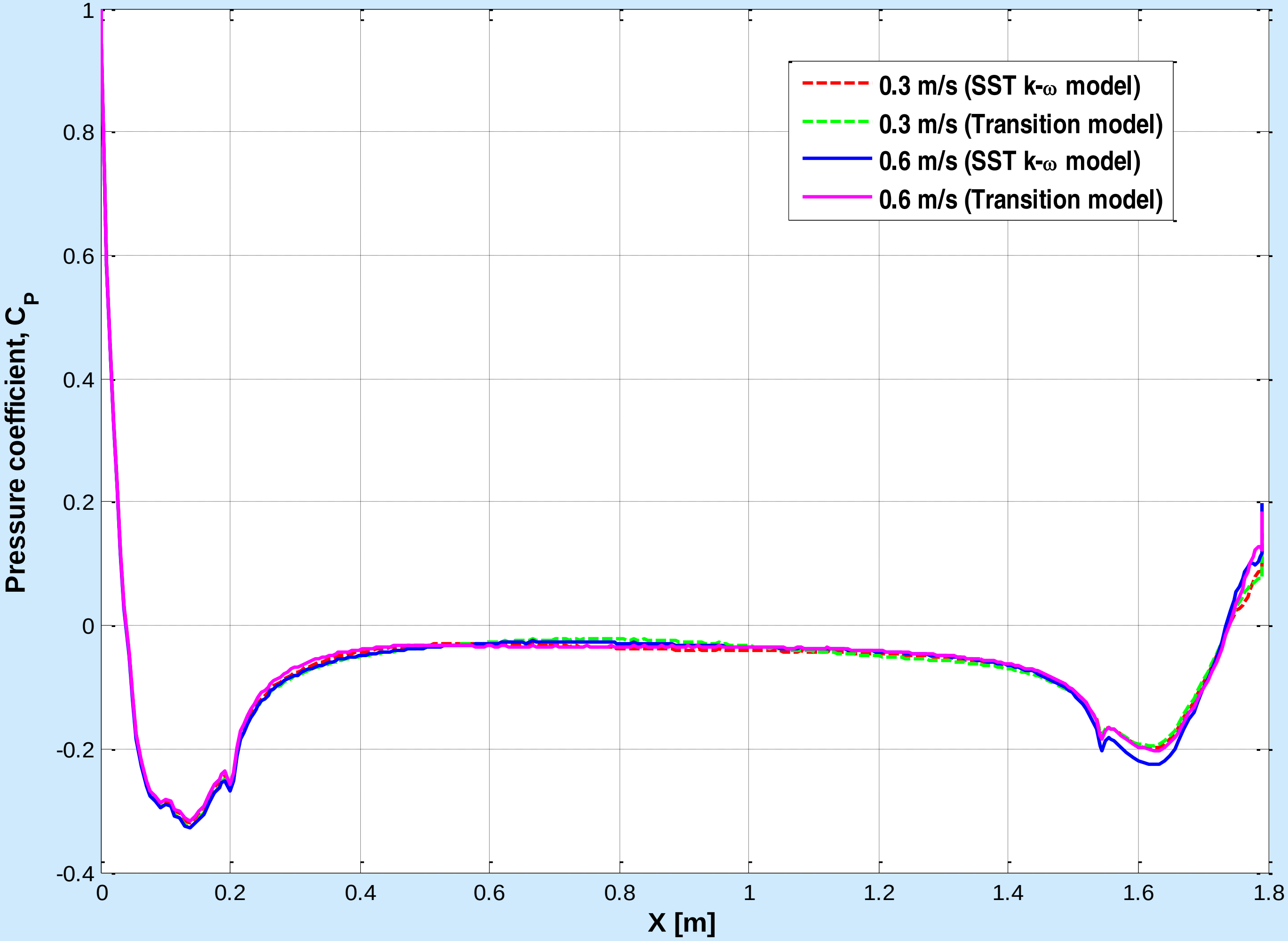




Drag component

Velocity [m/s]	Drag component	SST k-ω model		Transition model	
		Force [N]	Portion [%]	Force [N]	Portion [%]
0.3	Pressure drag	0.18	37	0.18	*33*
	Viscous drag	0.32	63	0.35	*67*
	Total Drag	0.50	100	0.53	100
0.6	Pressure drag	0.68	38	0.70	*39*
	Viscous drag	1.12	62	1.11	*61*
	Total Drag	1.80	100	1.81	100

Pressure coefficient



$$C_P = \frac{P - P_\infty}{1/2\rho V_\infty^2}$$

where,

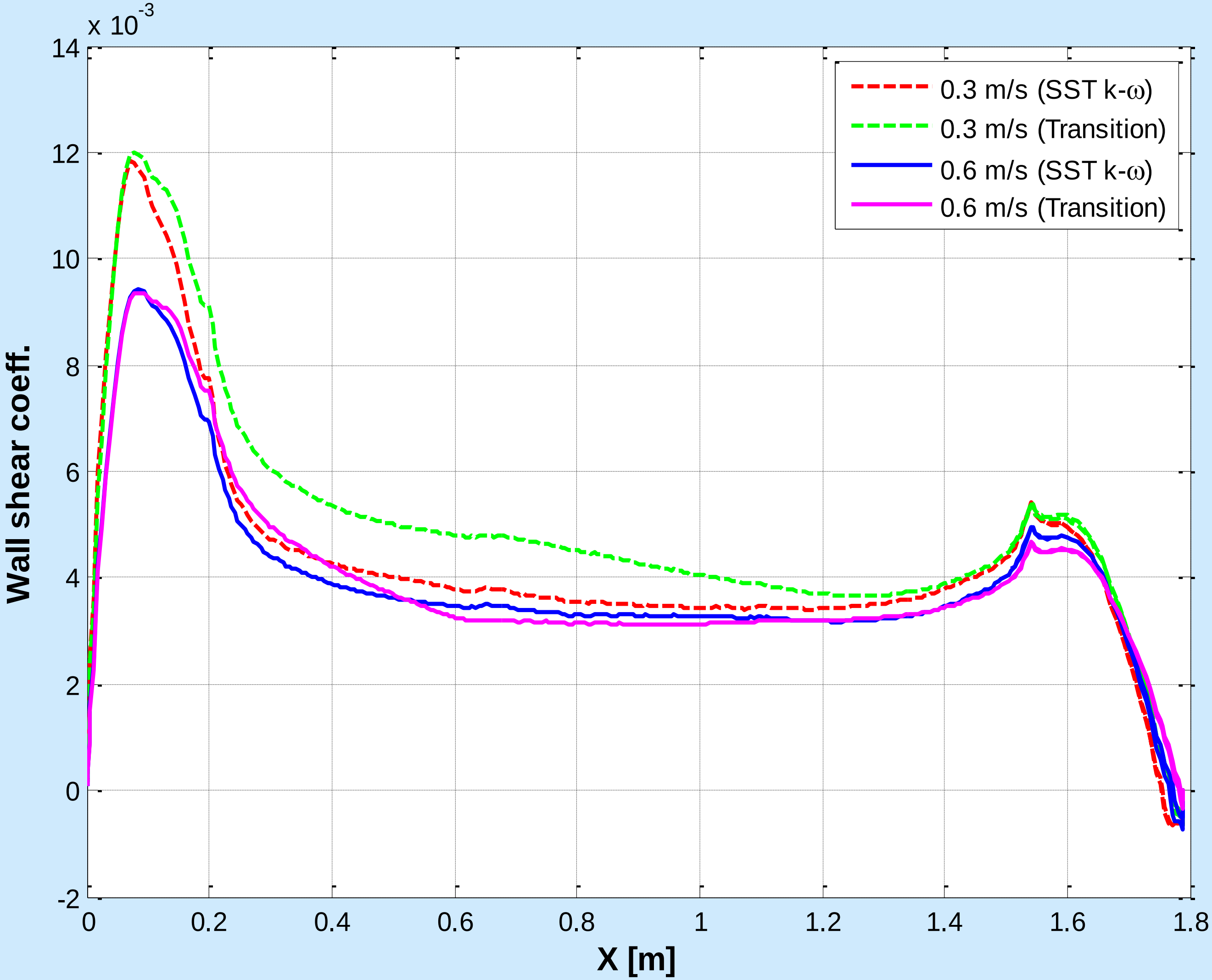
P : Pressure

P_∞ : Ambient pressure

ρ : Density

V_∞ : Ambient velocity

Shear coefficient



$$C_S = \frac{\tau_{shear}}{1/2\rho V_\infty^2}$$

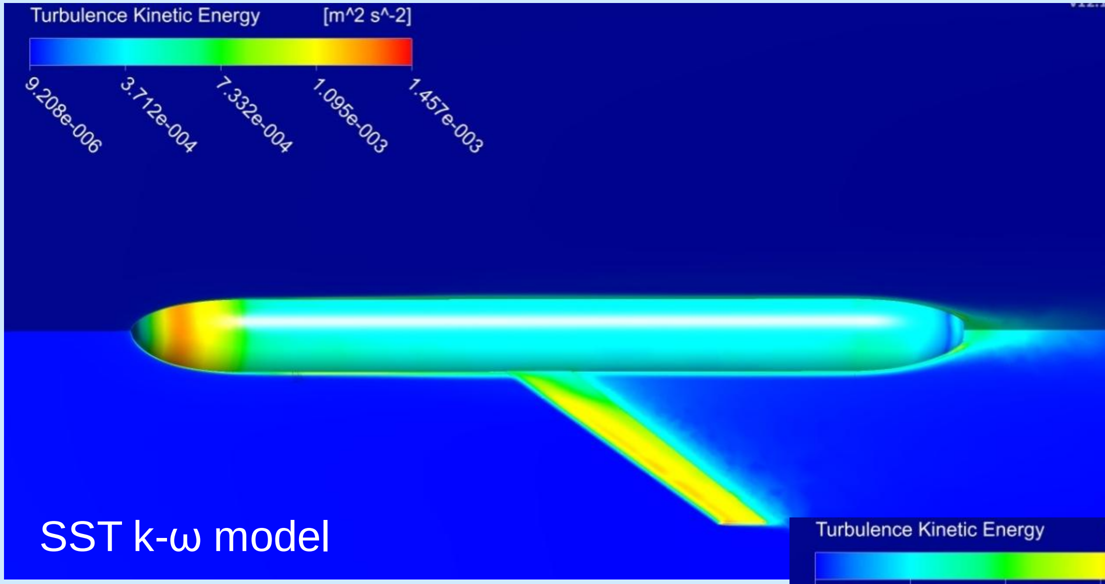
where,

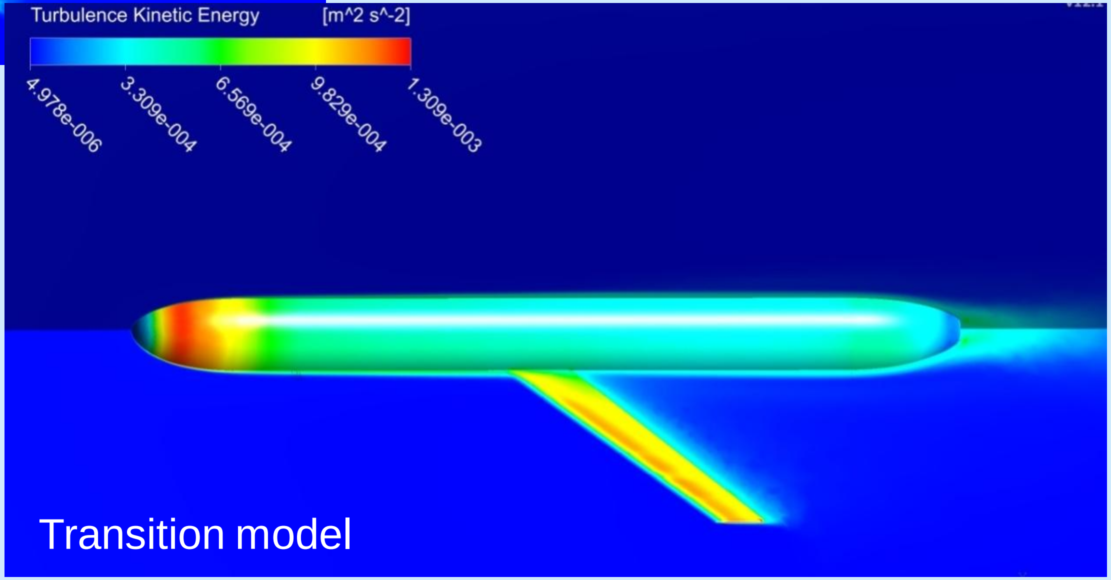
τ_{shear} : Shear stress

ρ : Density

V_∞ : Ambient velocity

Turbulence kinetic energy contour (0.3 m/s)





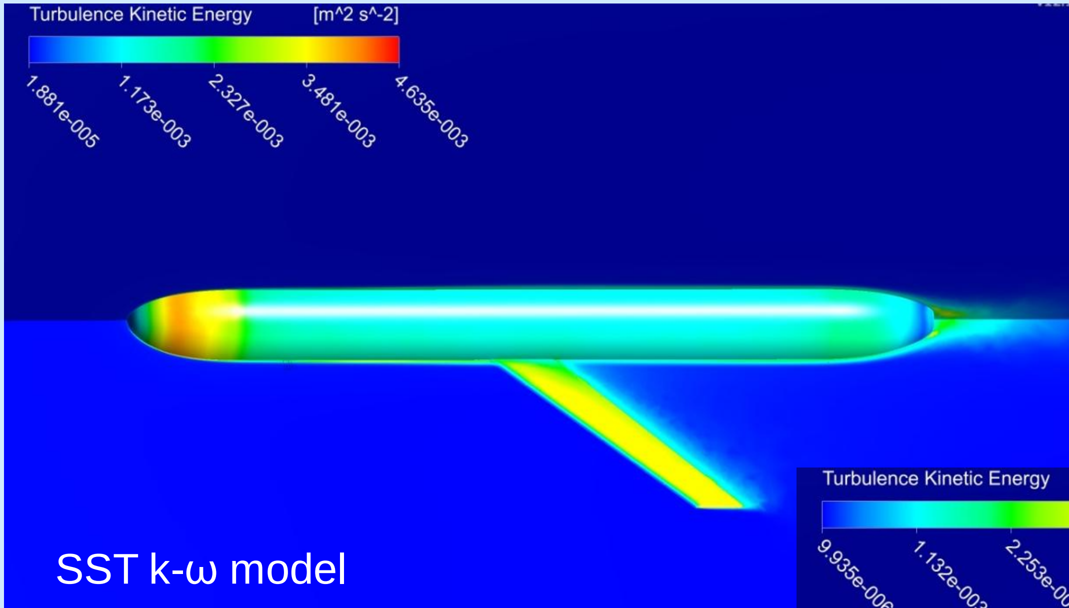
$$TKE = \frac{1}{2}\left(\overline{(u_1')^2} + \overline{(u_2')^2} + \overline{(u_3')^2}\right)$$

where,

u_i' : Turbulent velocity (fluctuation term)

i.e. $u_i = \overline{u_i}$(mean value) $+ u_i'$(fluctuation)

Turbulence kinetic energy contour (0.6 m/s)



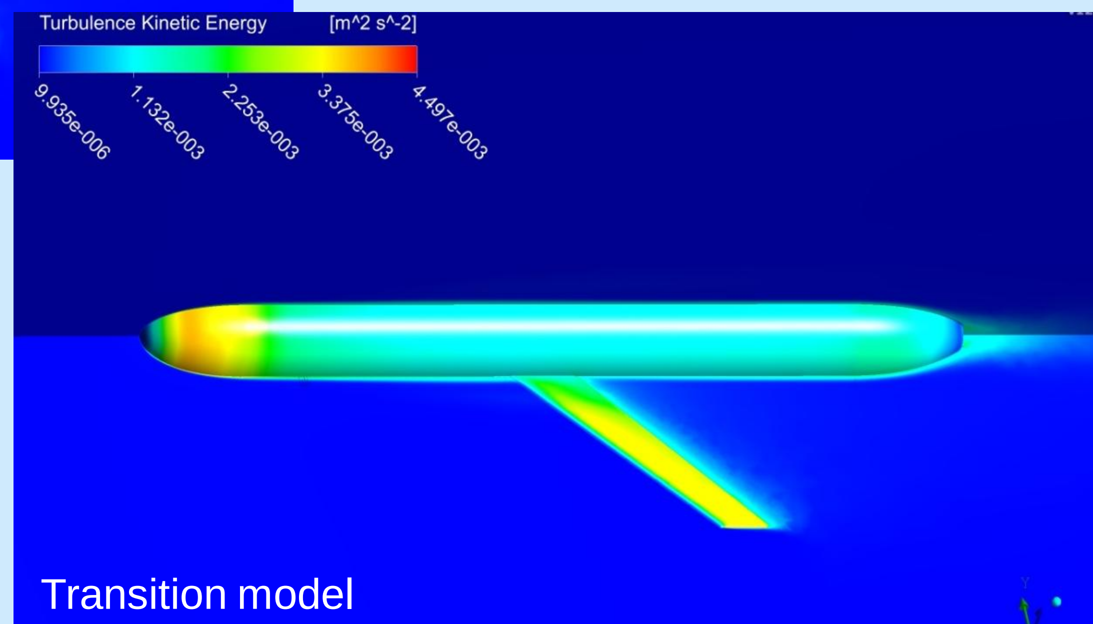
SST k-ω model

$$TKE = \frac{1}{2}\left(\overline{(u_1')^2} + \overline{(u_2')^2} + \overline{(u_3')^2}\right)$$

where,

u_i' : Turbulent velocity (fluctuation term)

i.e. $u_i = \overline{u_i}$ (mean value) $+ u_i'$ (fluctuation)



Transition model

Computation time

On a 2.1 GHz Pentium® Dual core CPU with 2Gb memory

Velocity (m/s)	SST k-ω model Time (sec)	Transition model Time (sec)
0.3	13,144	16,744
0.6	15,240	18,239

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Validation

- Comparison with the experiment

Velocity (m/s)	CFD		Experiment* [N]
	SST k-ω model [N]	Transition model [N]	
0.3	0.50	0.53	0.50
0.6	1.80	1.81	1.75

* *From B. Claus et al., JEME, 2010*

Summary & future work

- Drag force is predicted by CFD method. The result is well agreed with the experimental result.
- Two turbulence model, SST-kω and SST Transition model are examined. Both of two models give the similar result. However, at some region, the flow shows little different pattern.

- *Hydrodynamic forces will be estimated using the candidate hull shape for the hydrophone installation.*
- *More study and more validation is needed for the transition model.*

Thanks for your attention!