In situ-laser measurement of skin friction drag of ship hull

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Agenda

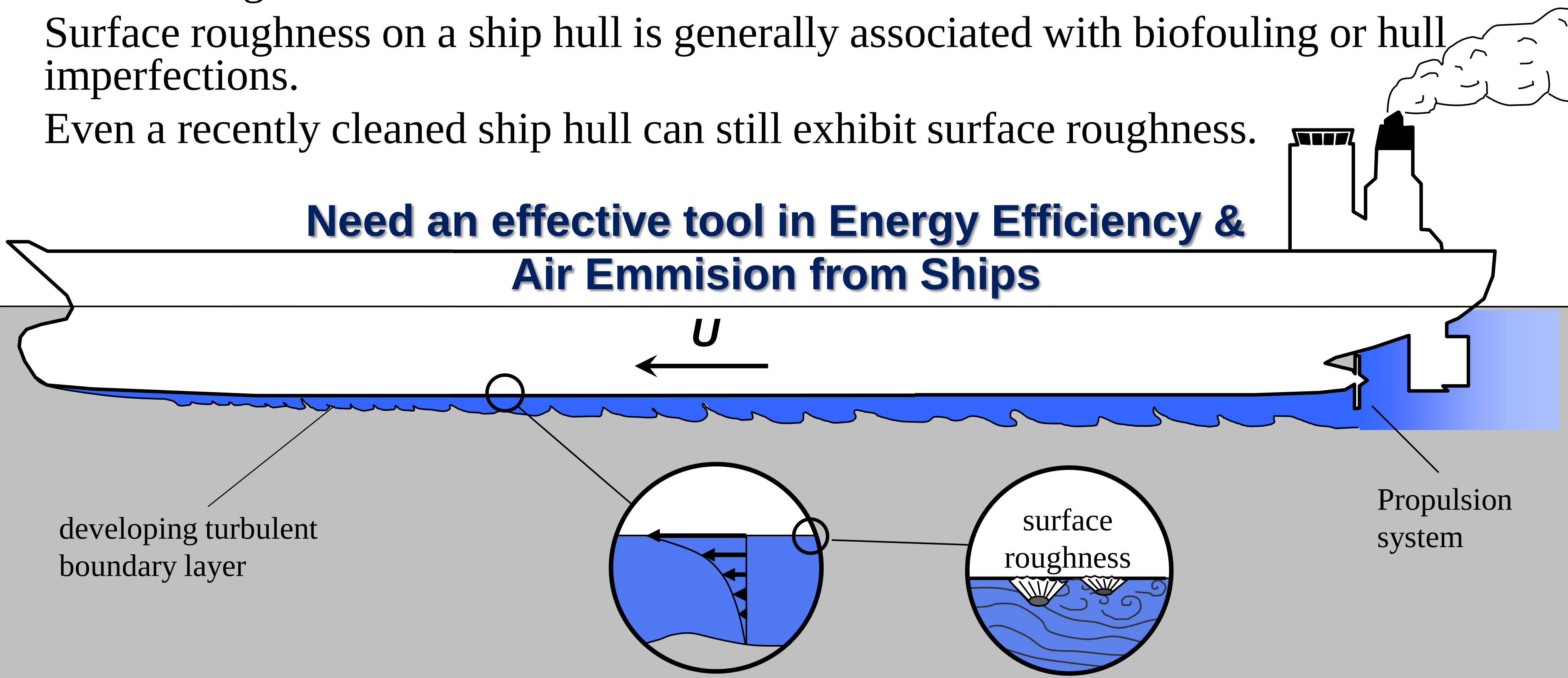
- Background
- Laboratory testing scale
- Shipboard in-situ measurement
- Regular monitoring of the hull state.

Background

Background

- Up to 80%–90% of the total drag experienced by a large bulk carrier could be due to turbulent skin-friction drag.
- The issue of skin-friction drag on a ship hull is exacerbated by the existence of surface roughness.
- Surface roughness on a ship hull is generally associated with biofouling or hull imperfections.
- Even a recently cleaned ship hull can still exhibit surface roughness.

Need an effective tool in Energy Efficiency & Air Emmision from Ships



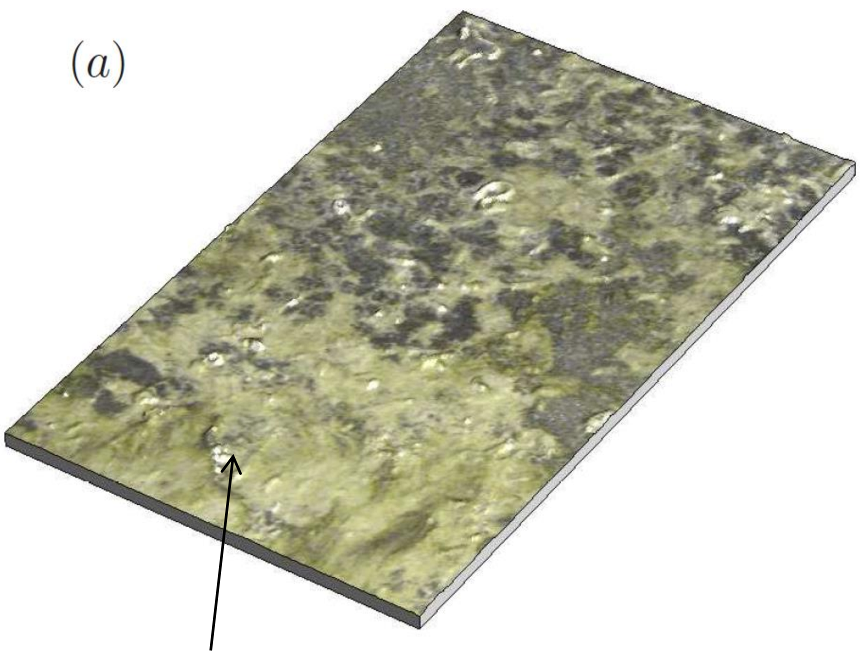
Townsin, Byrne, Svensen, Milne (1981) SNAME Trans. 89: 295-318
Kodama, Kakugawa, Takahashi, Kawashima, (2000) Int. J. Heat and Fluid Flow,.21:582–588
Jimenez (2004) Annu. Rev. Fluid Mech.. 36:173–196
Schultz (2007) Biofouling. 23(5-6):331–341, (2007)
IMO 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) (resolution MEPC.282(70))

Laboratory Testing scale

Determining drag penalty via lab experiment

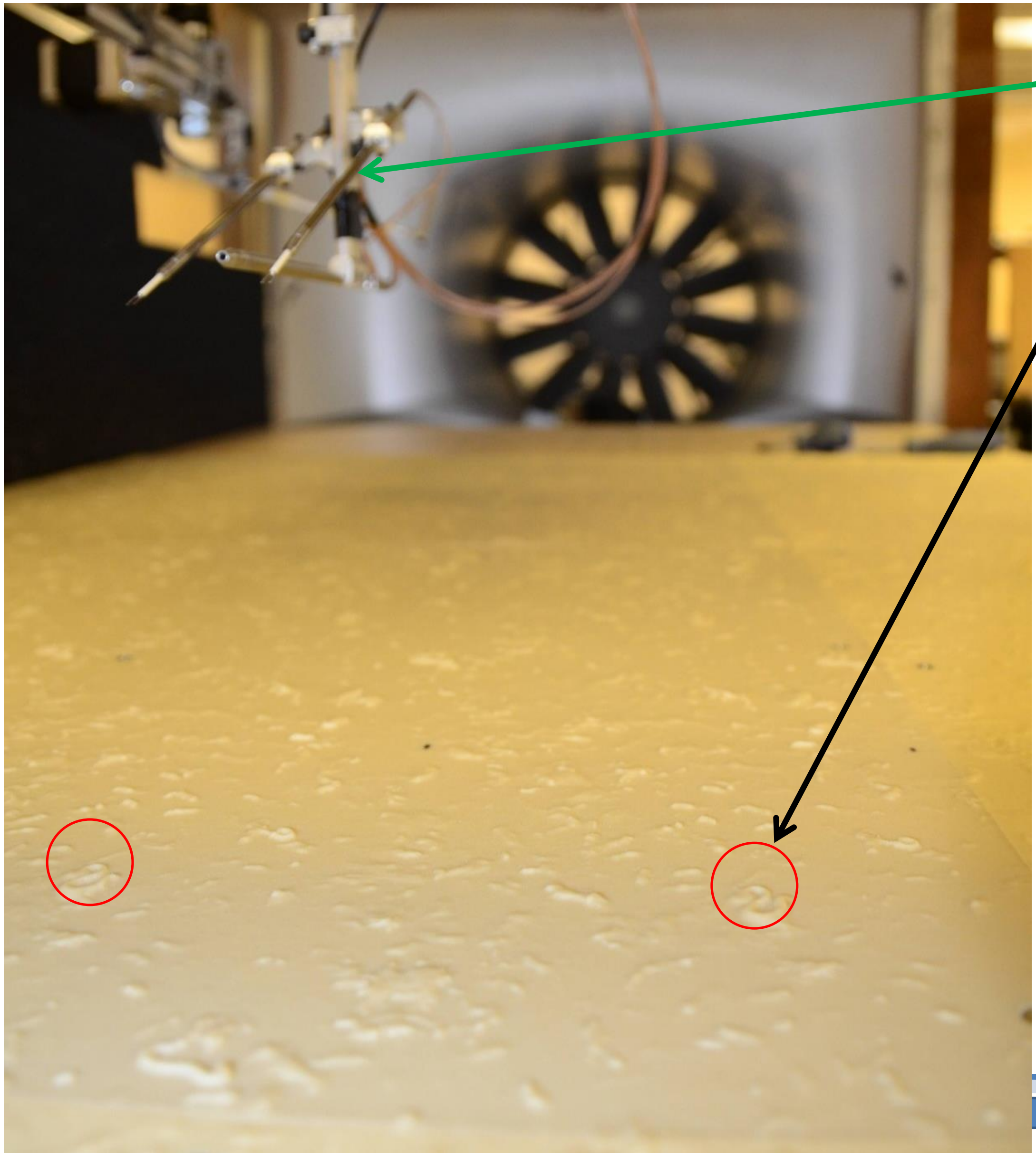
Photograph

Laser scan



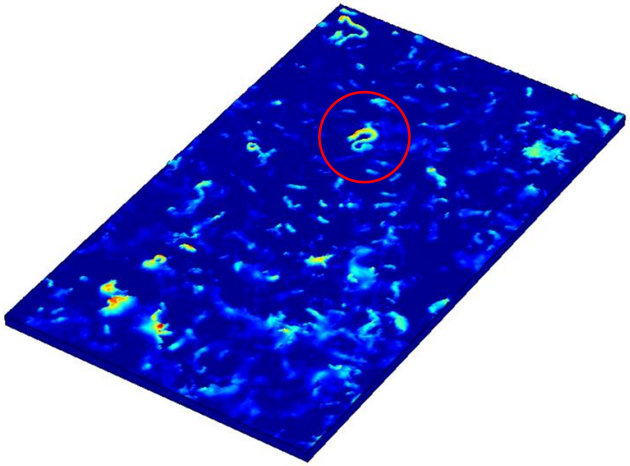
Biofouling on a steel coupon.

Determining drag via lab experiment



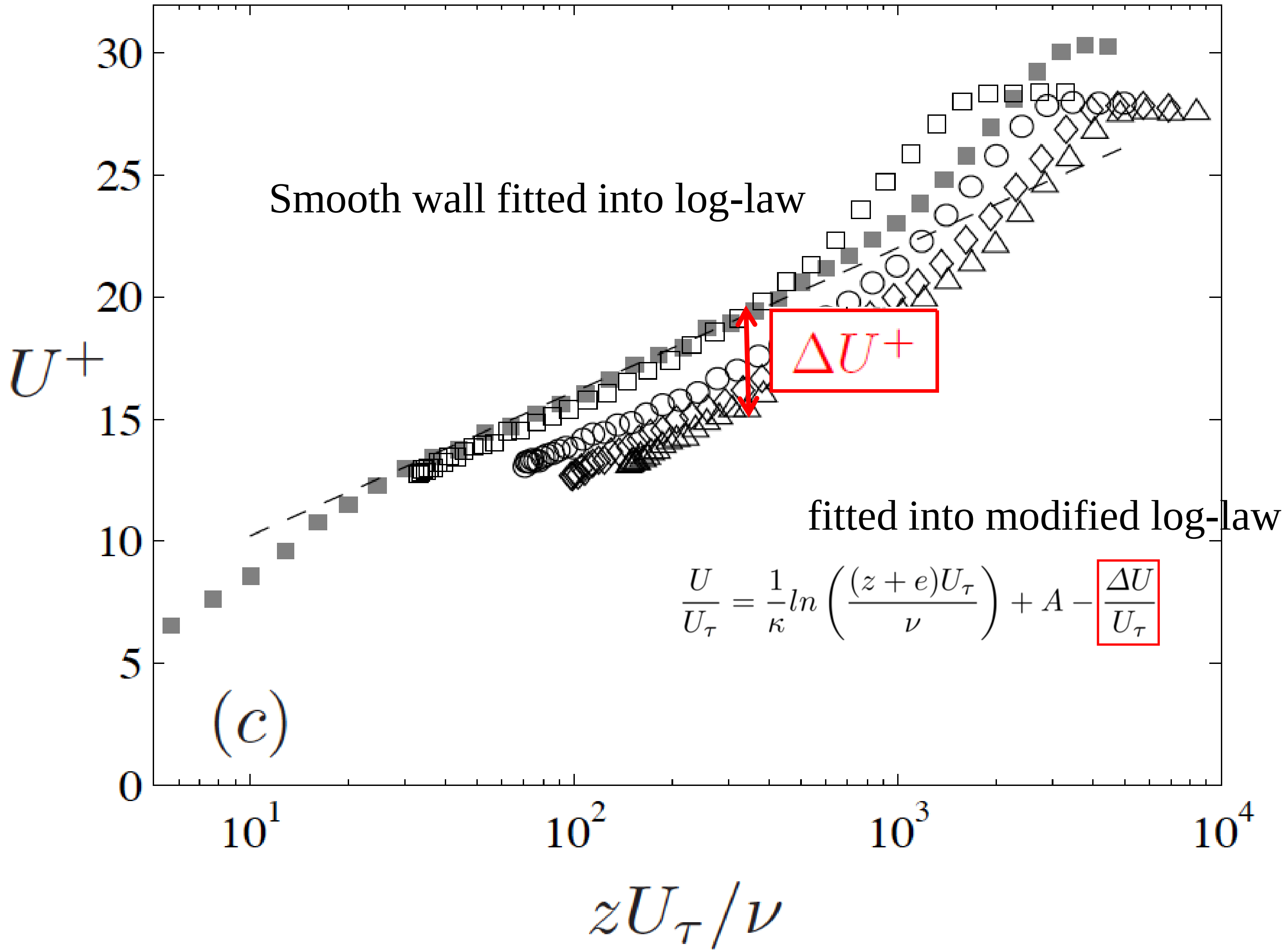
Mean velocity profile measurement via hot-wire Anemometer.

Replicated surface via CNC cutting and Moulding-Casting.



Determining drag via lab experiment

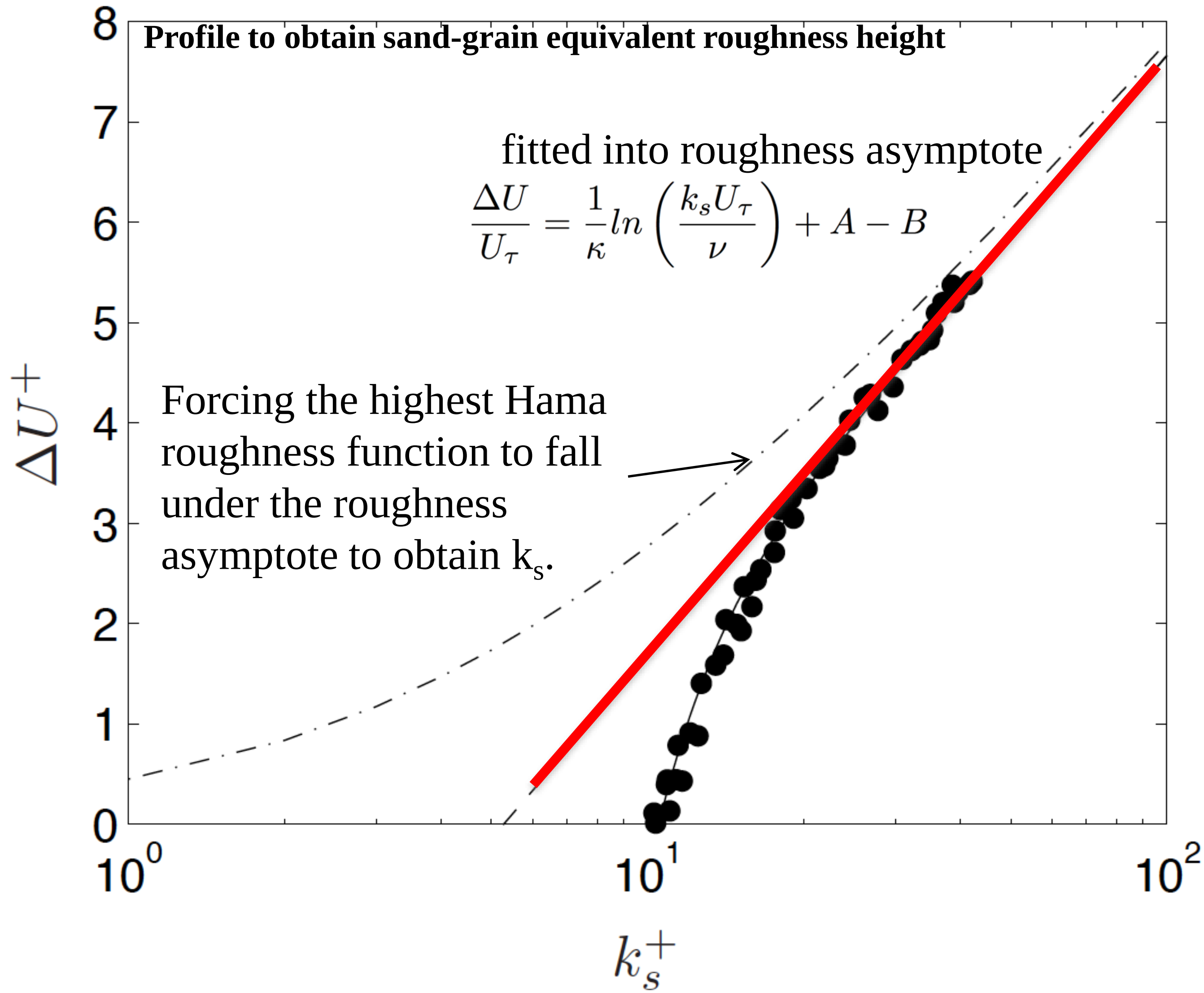
Mean Velocity profile to obtain skin friction velocity and Hama roughness function



Determining drag via lab experiment

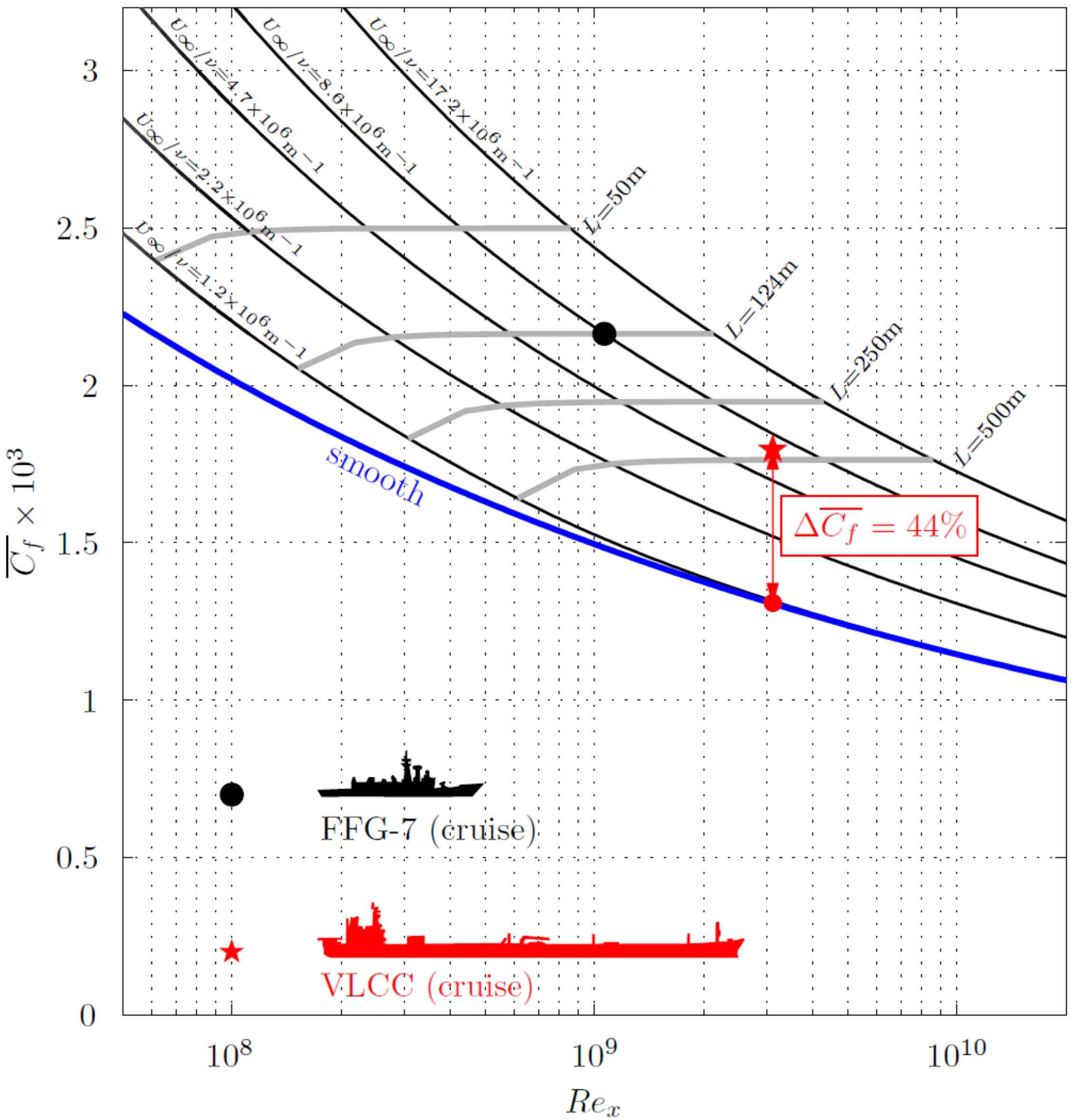
- Next step is to obtain sand-grain equivalent roughness height k_s
- k_s is a measure of the rough surface effect on turbulent boundary layer.
- k_s unit is in meter and cannot be measured directly, such as using profilo-meter.

Determining drag via lab experiment



Determining drag via lab experiment

Estimating full-scale ship drag via mean momentum integral



Determining drag penalty via lab experiment

Issue with lab experiment:

1. Very expensive in term of facility and time.

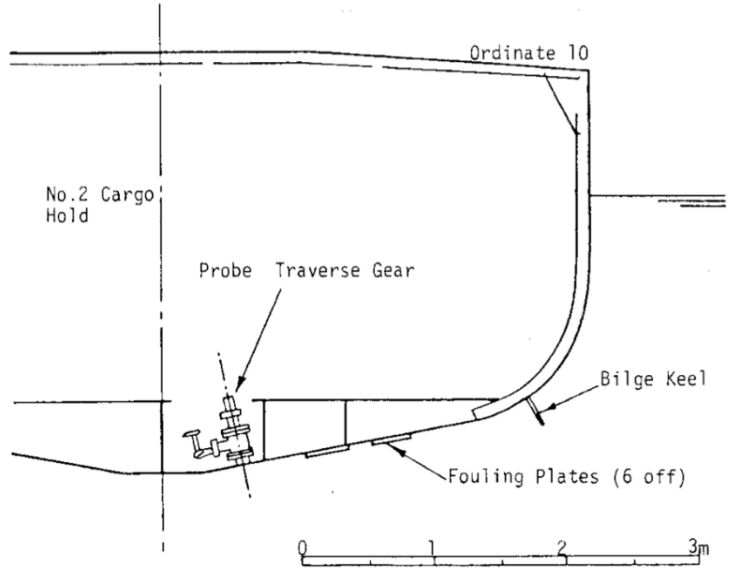
2. Difficult to obtain sand grain equivalent roughness.

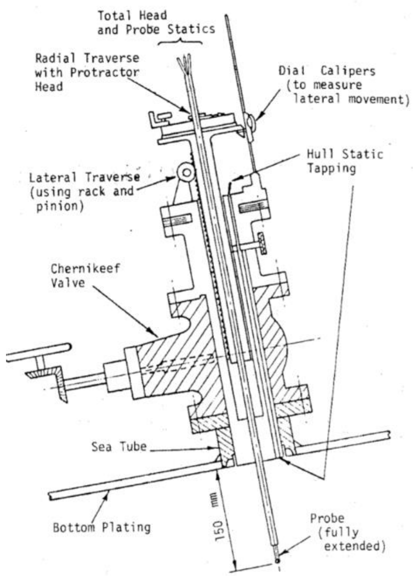
Shipboard in-situ measurements

Direct ship board experiment

Previous works:

Generally it involves pitot tube that goes through ship hull.





Denny, M.E., 1951. BSRA resistance experiments on the 'Lucy Ahton' : Part 1. Full scale measurements. *R. Inst. Naval. Architects. Trans. 93, 40–57.*

Smith, S.L., 1955. BSRA resistance experiments on the 'Lucy Ashton' : Part 4. Miscellaneous investigations and general appraisal. *R. Inst. Naval. Architects. Trans. 97, 525–548.*

Lewthwaite, J.C., Molland, A.F., Thomas, K.W., 1984. An investigation into the variation of ship skin frictional resistance with fouling. *R. Inst. Naval. Architects. Trans. 127, 269–284*

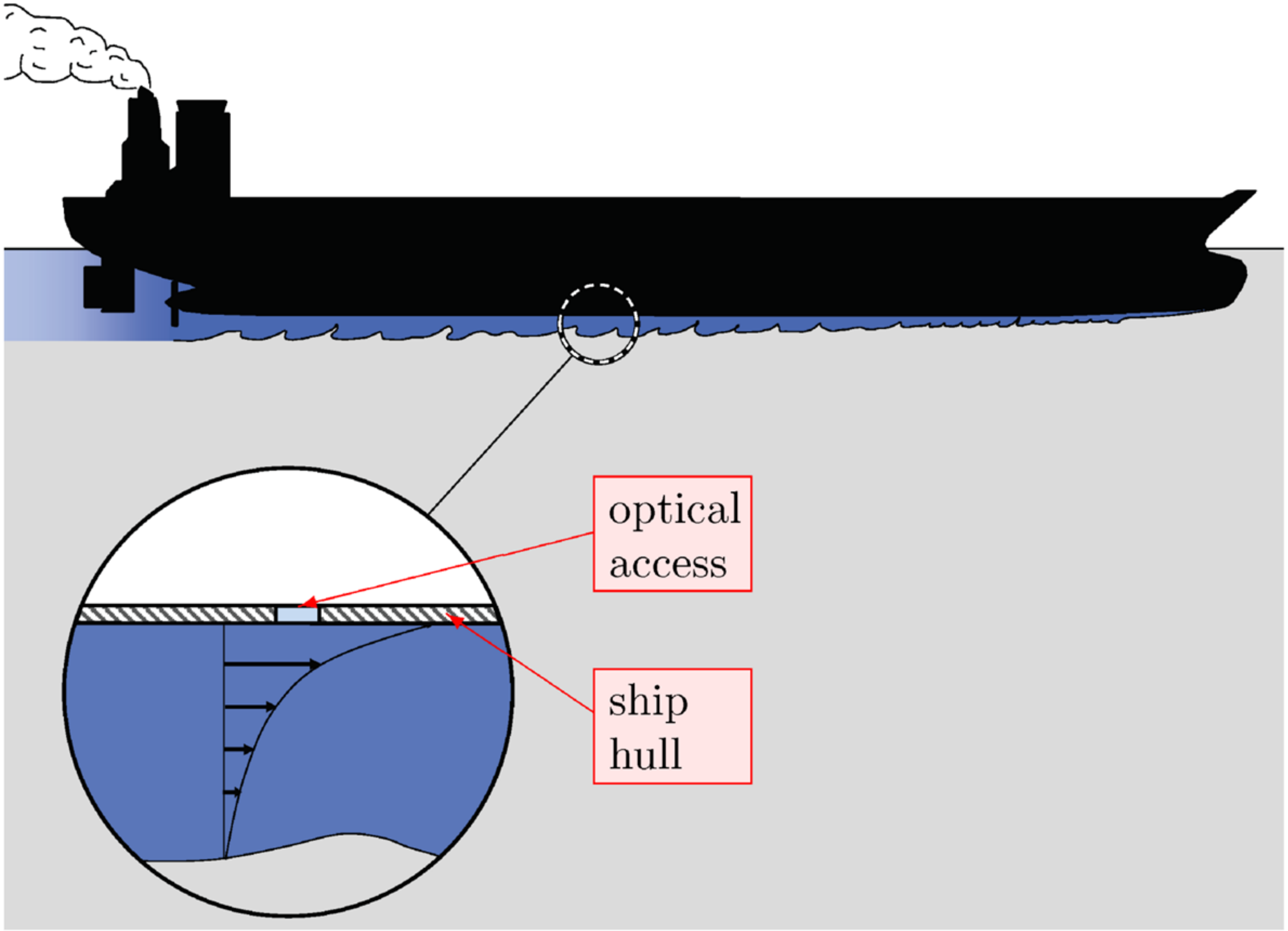
Direct ship board experiment

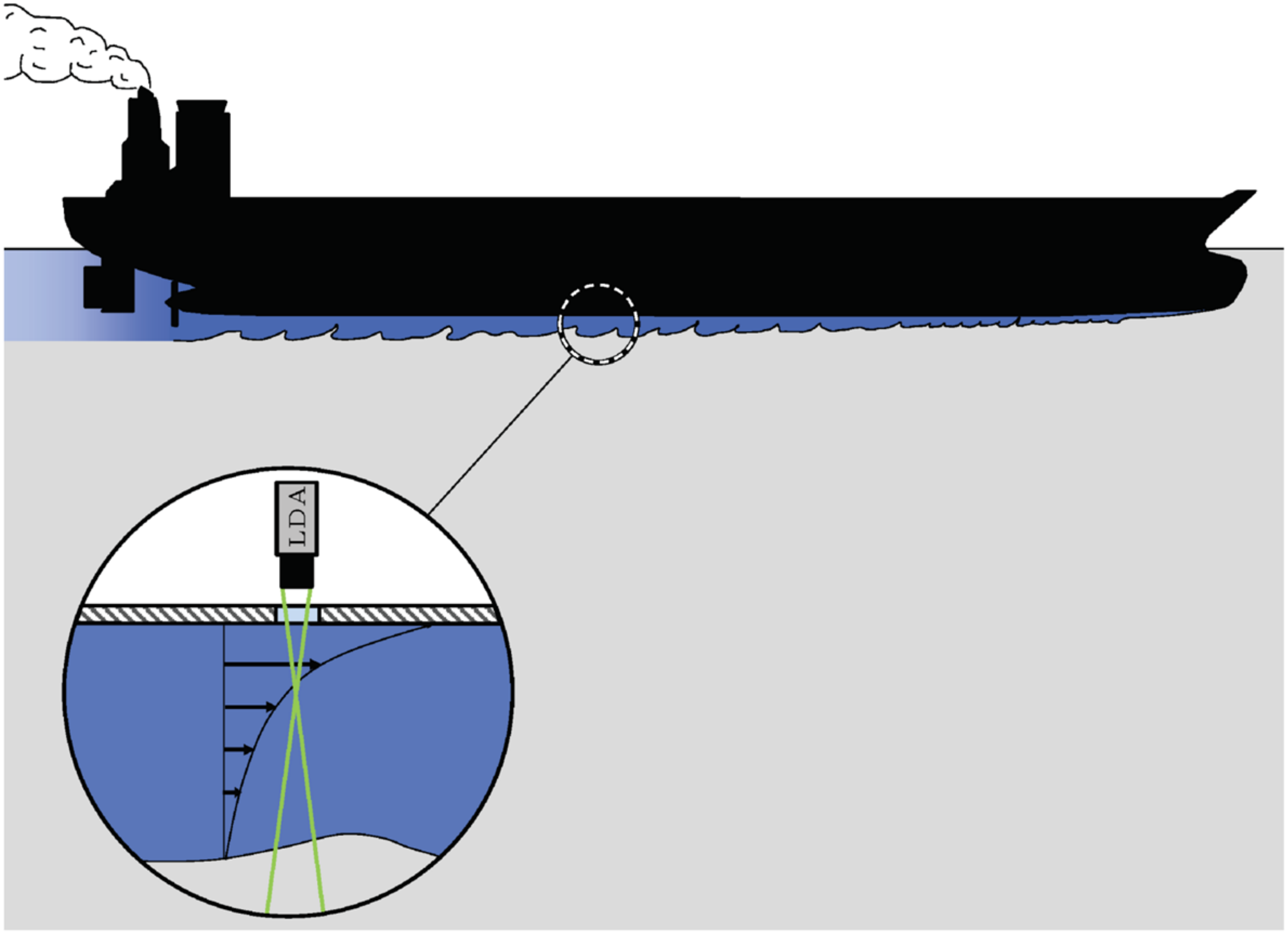
Issues with pitot tube measurement:

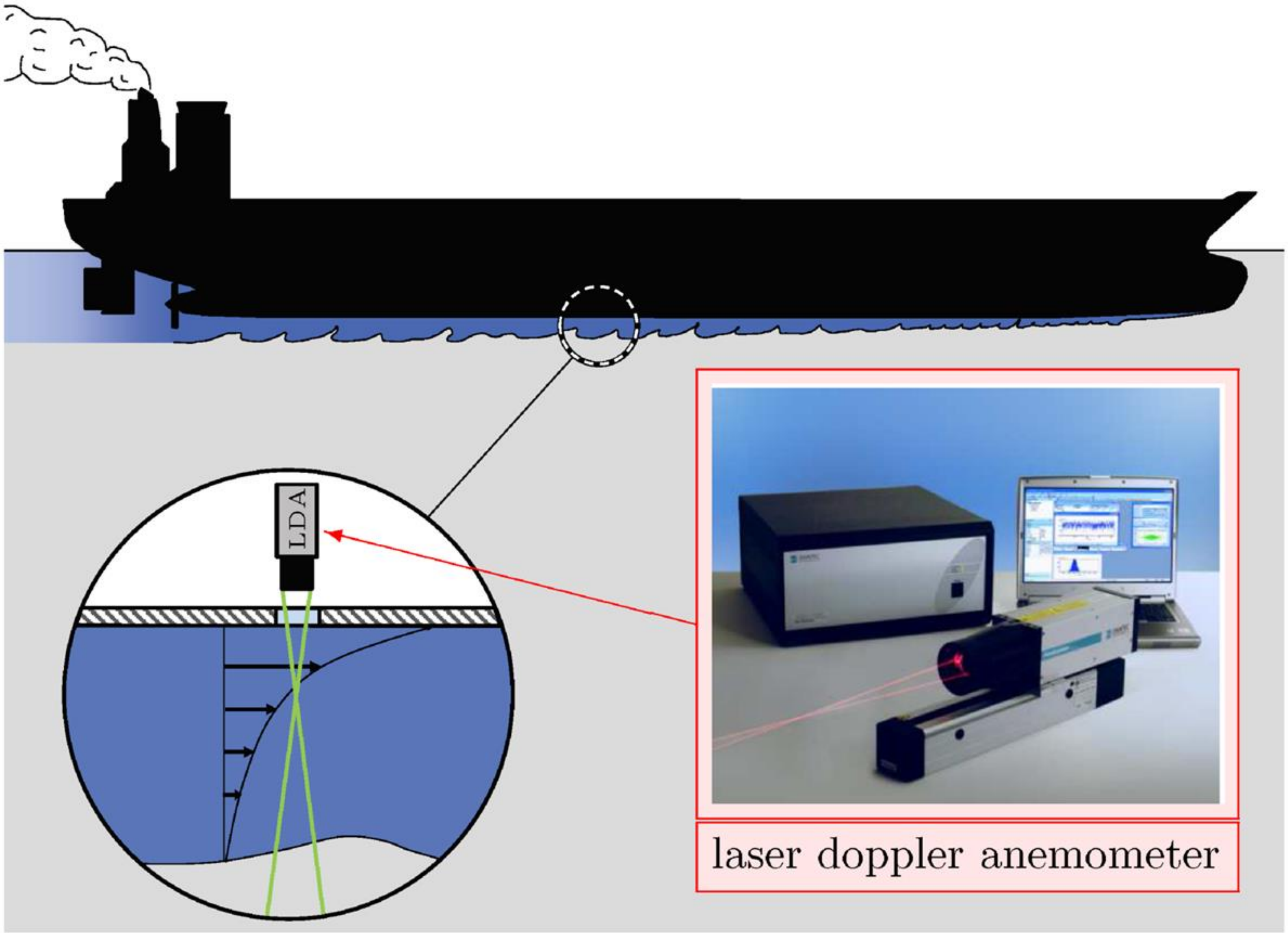
1. Intrusive towards the flow.
2. Readings depend on manometer (i.e human eye), prone to error.
3. Prone to blocking from marine objects.
4. Requires full hull penetration.

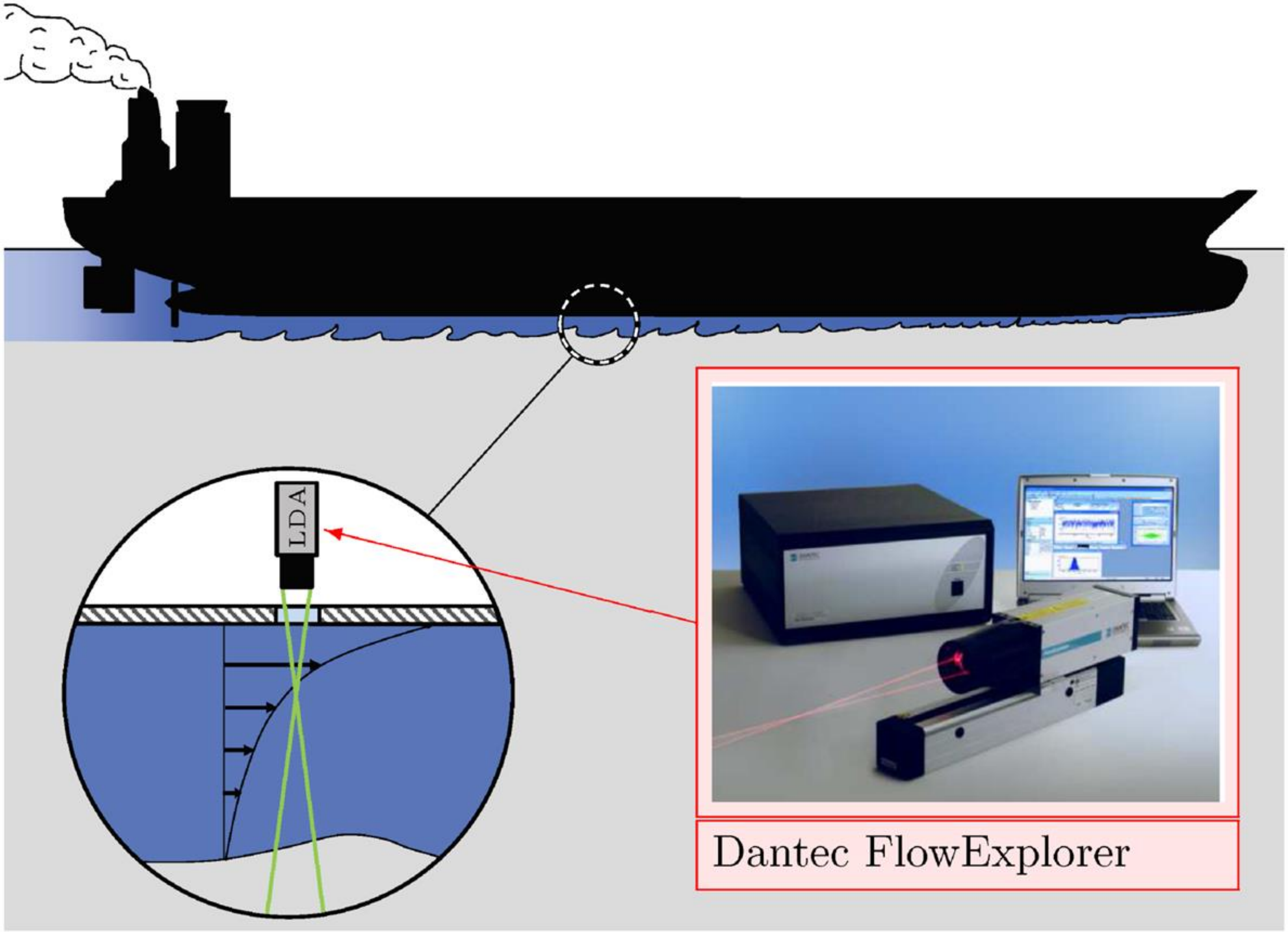
Advantages:

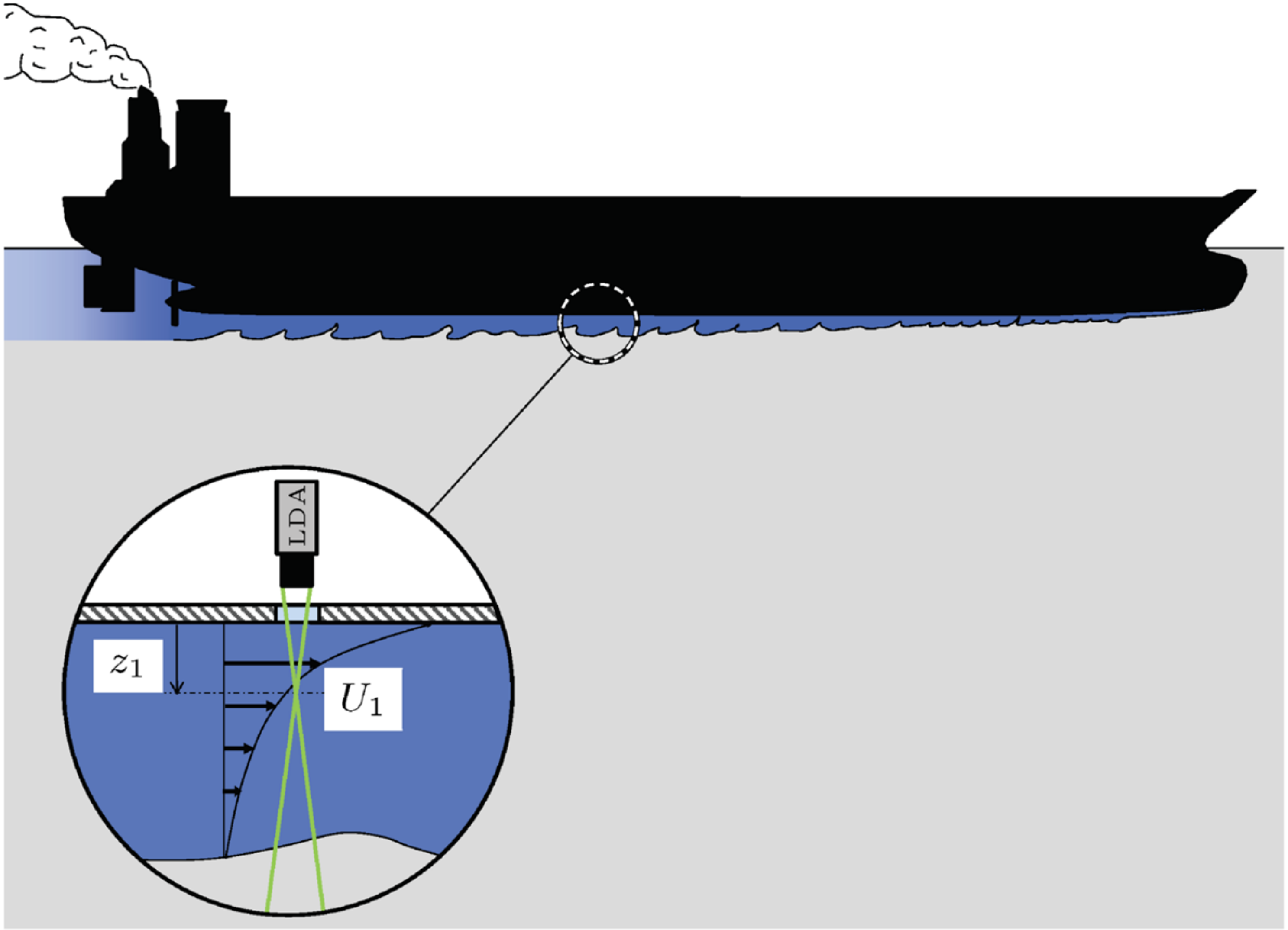
1. Bypass the costly laboratory experiment.
2. Measure the drag penalty directly.

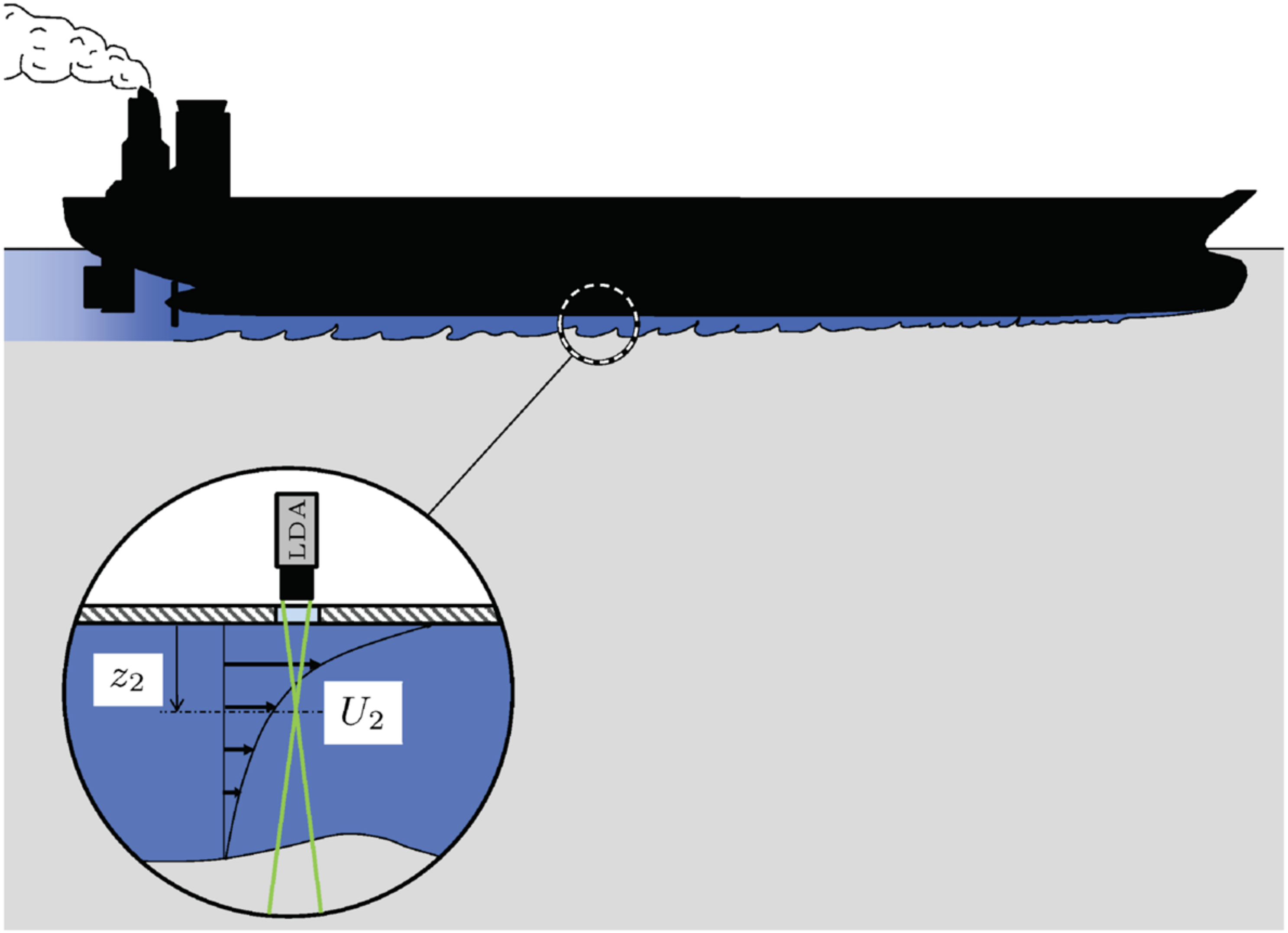

optical
access
ship
hull

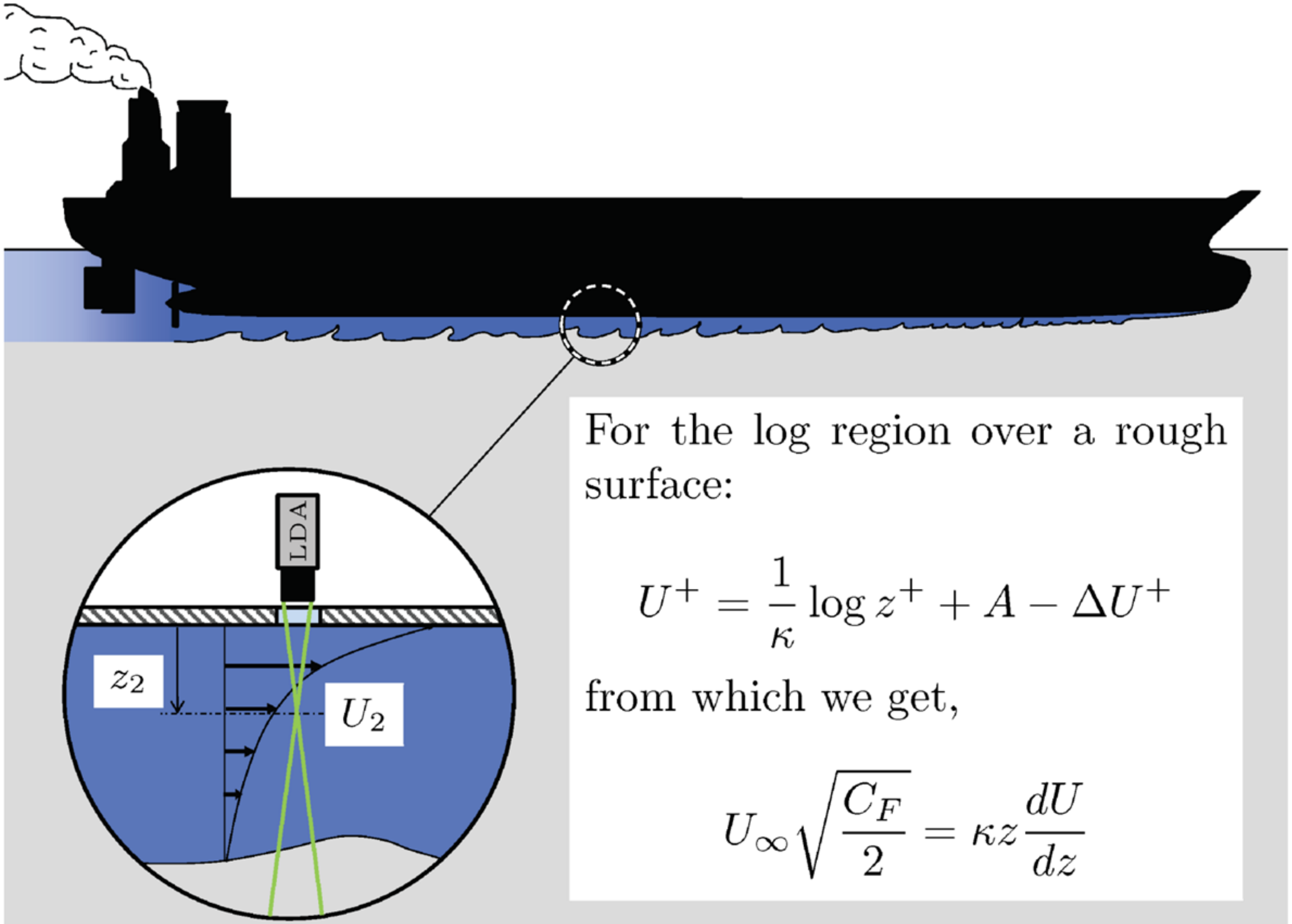

LDA


LDA
laser doppler anemometer


LDA
Dantec FlowExplorer


LDA
z_1
U_1


LDA
z_2
U_2

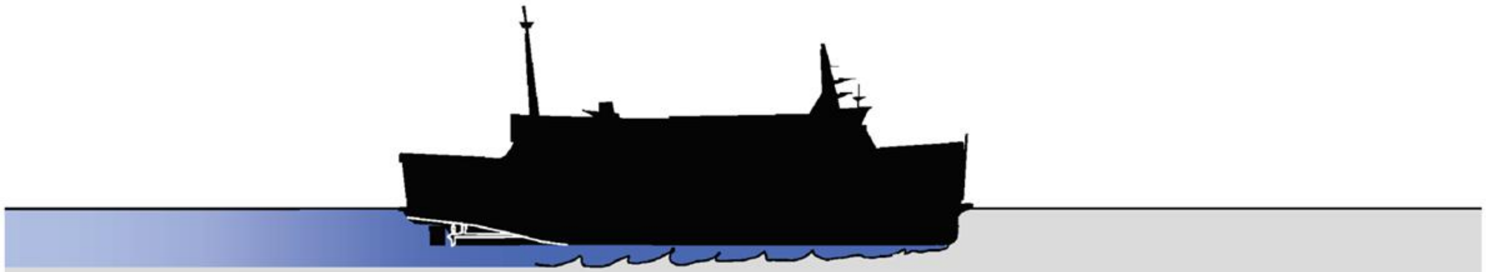


For the log region over a rough surface:

$$U^+ = \frac{1}{\kappa}\log z^+ + A - \Delta U^+$$

from which we get,

$$U_\infty \sqrt{\frac{C_F}{2}} = \kappa z \frac{dU}{dz}$$



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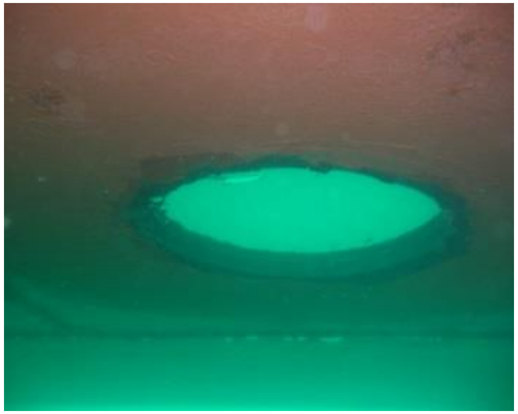
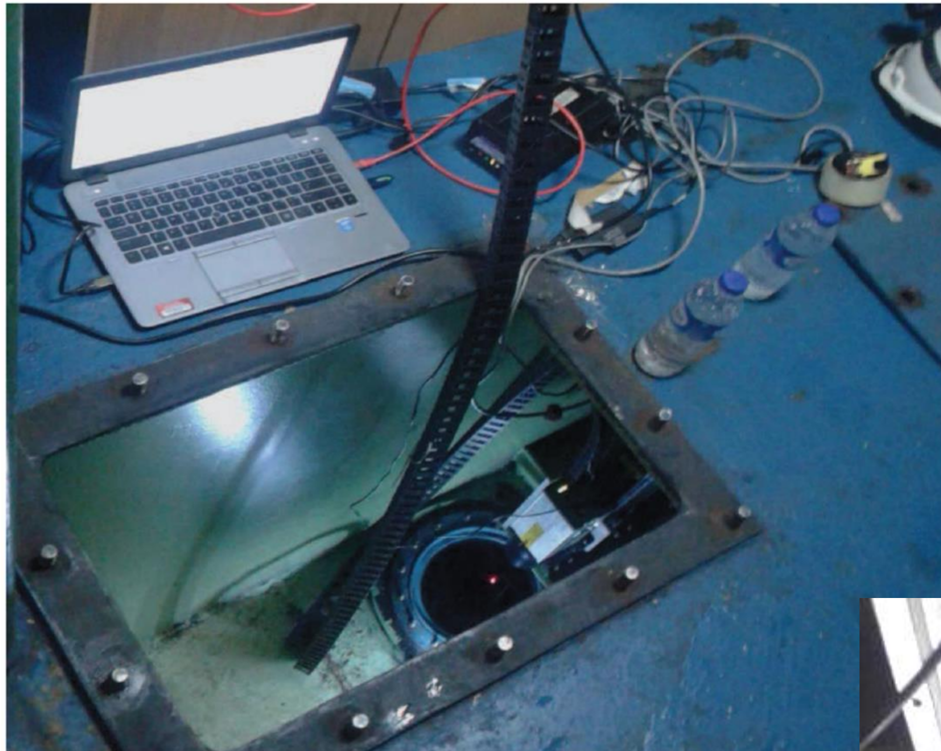
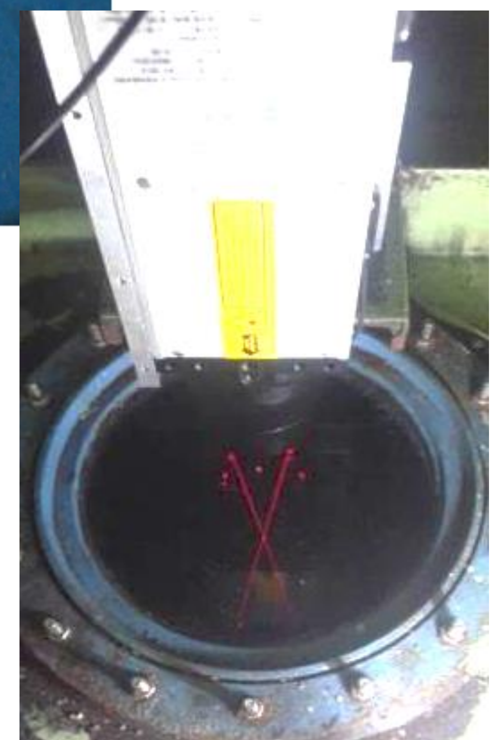
PT. DHARMA LAUTAN UTAMA
armada pelayaran nasional

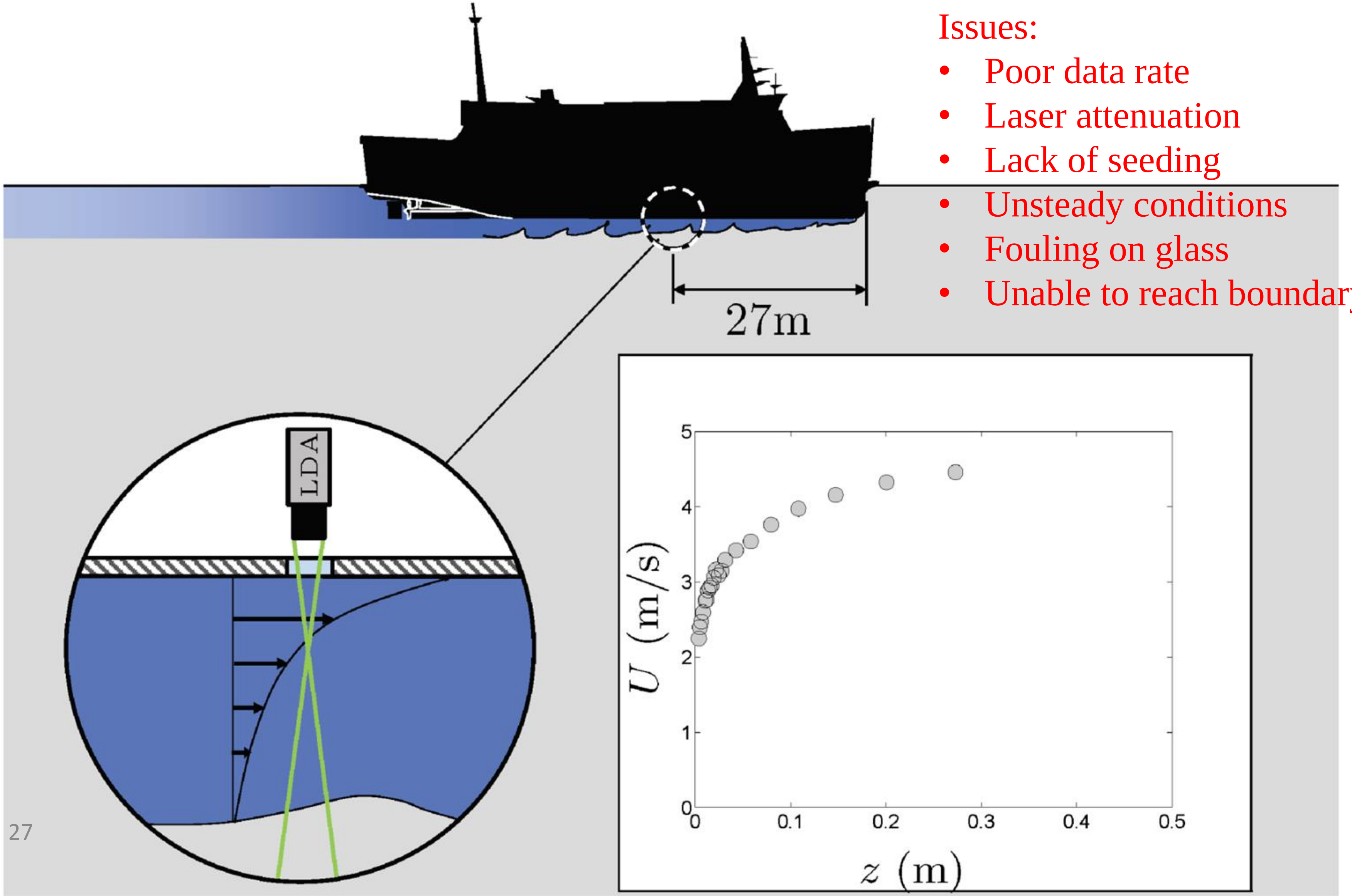
Dharma Kencana IX - RORO ferry






EAGLES

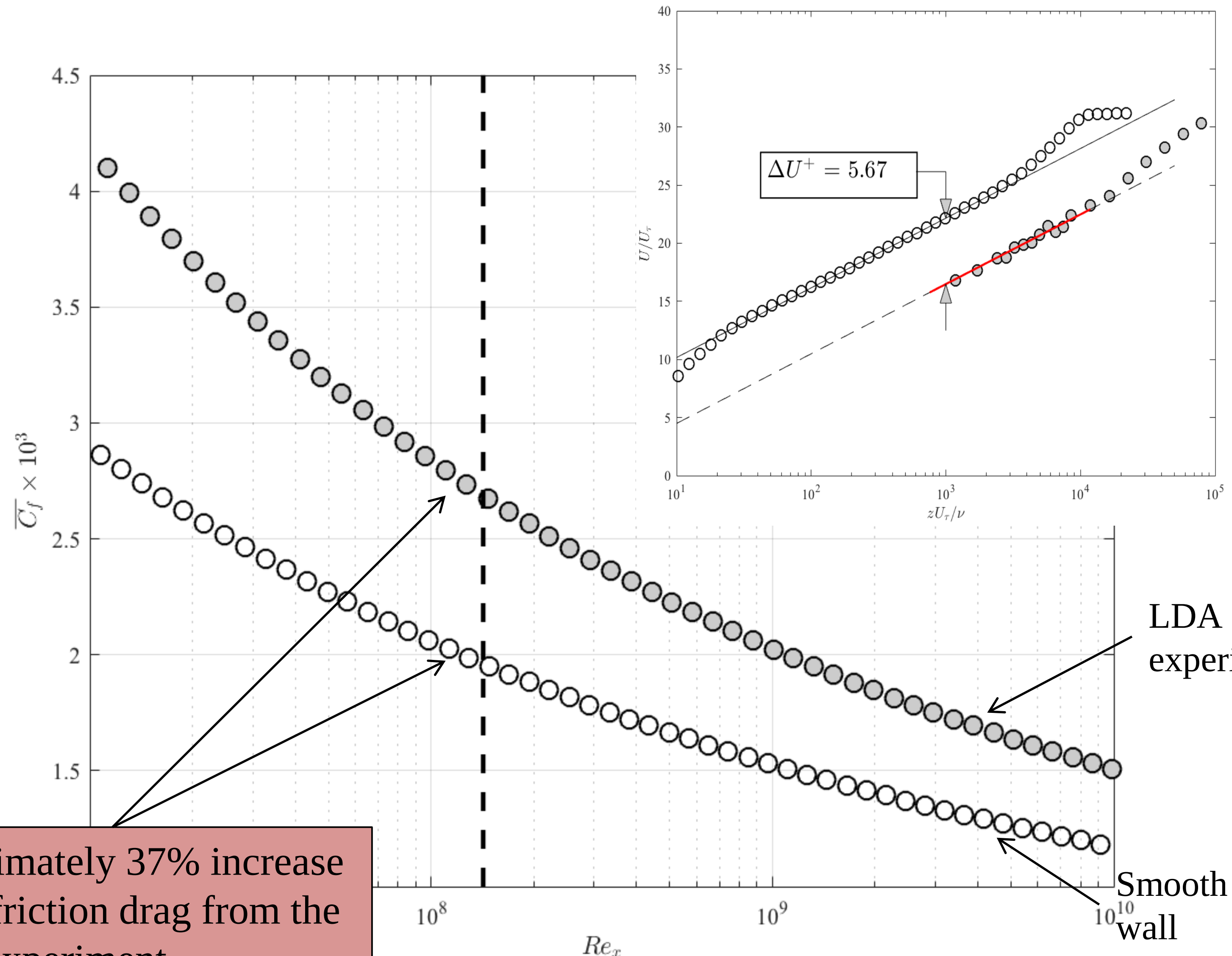




Issues:

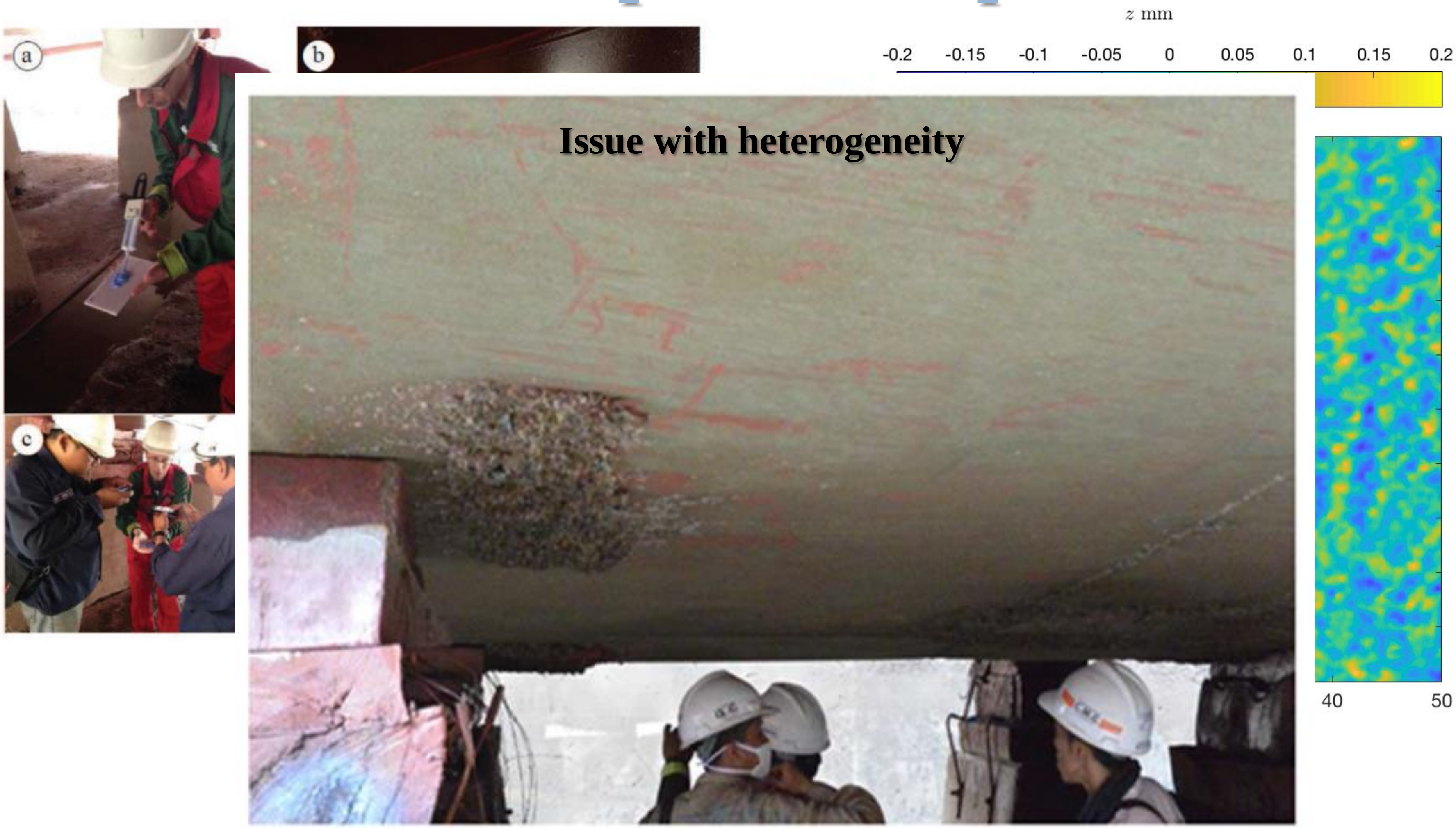
- Poor data rate
- Laser attenuation
- Lack of seeding
- Unsteady conditions
- Fouling on glass
- Unable to reach boundary layer.

Mean velocity profile, normalised



Approximately 37% increase in skin friction drag from the in-situ experiment

Direct ship board experiment



Regular monitoring of the hull state

Regular monitoring of the hull state

- Main issue with previous in-situ experiments in 50's and 80's :
- Lack of information regarding the rough surface statistics.
- We do not know what kind of roughness characteristics that caused the increase in skin friction drag

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- Smith, S.L., 1955. BSRA resistance experiments on the 'Lucy Ashton' : Part 4. miscellaneous investigations and general appraisal. *R. Inst. Naval. Architects. Trans. 97, 525–548.*
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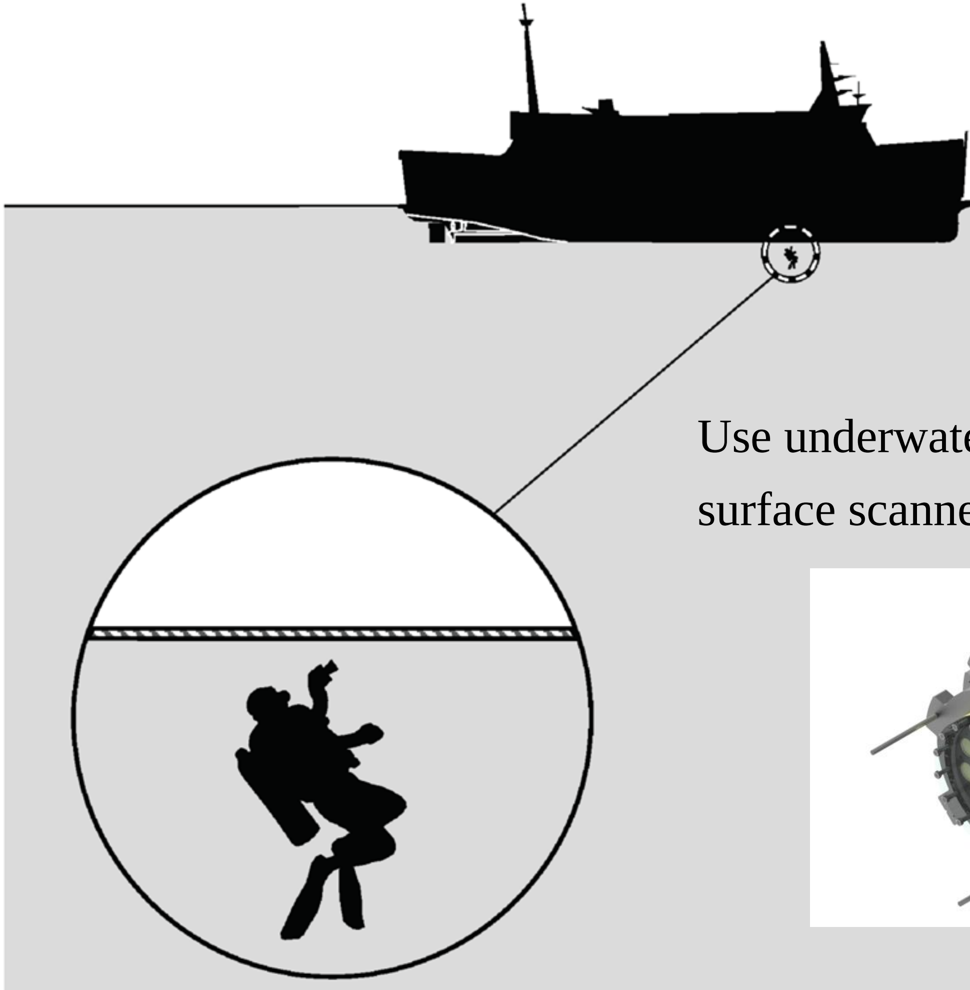
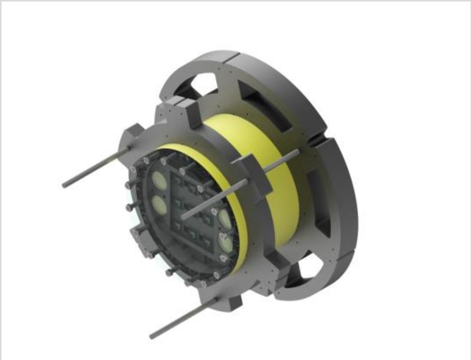
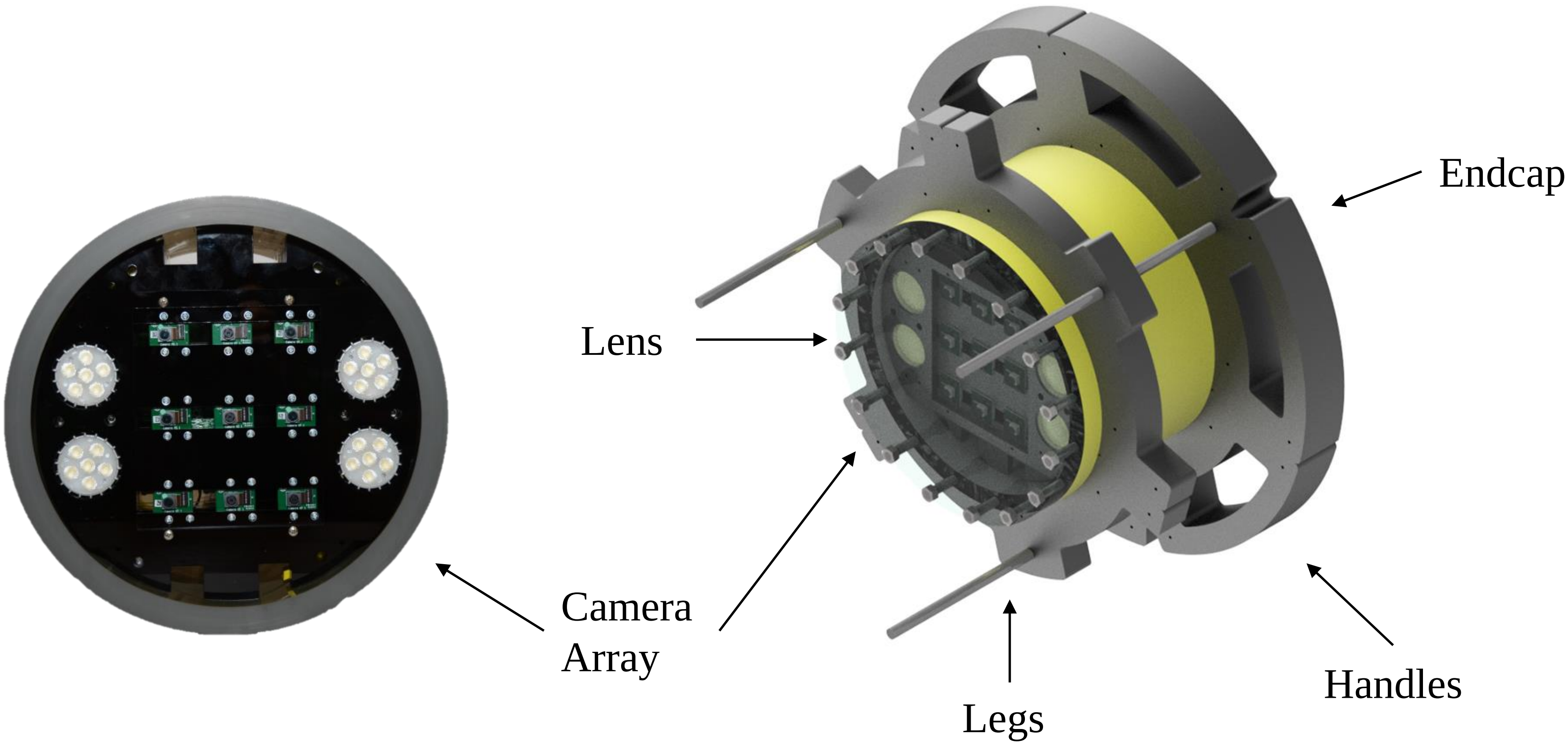
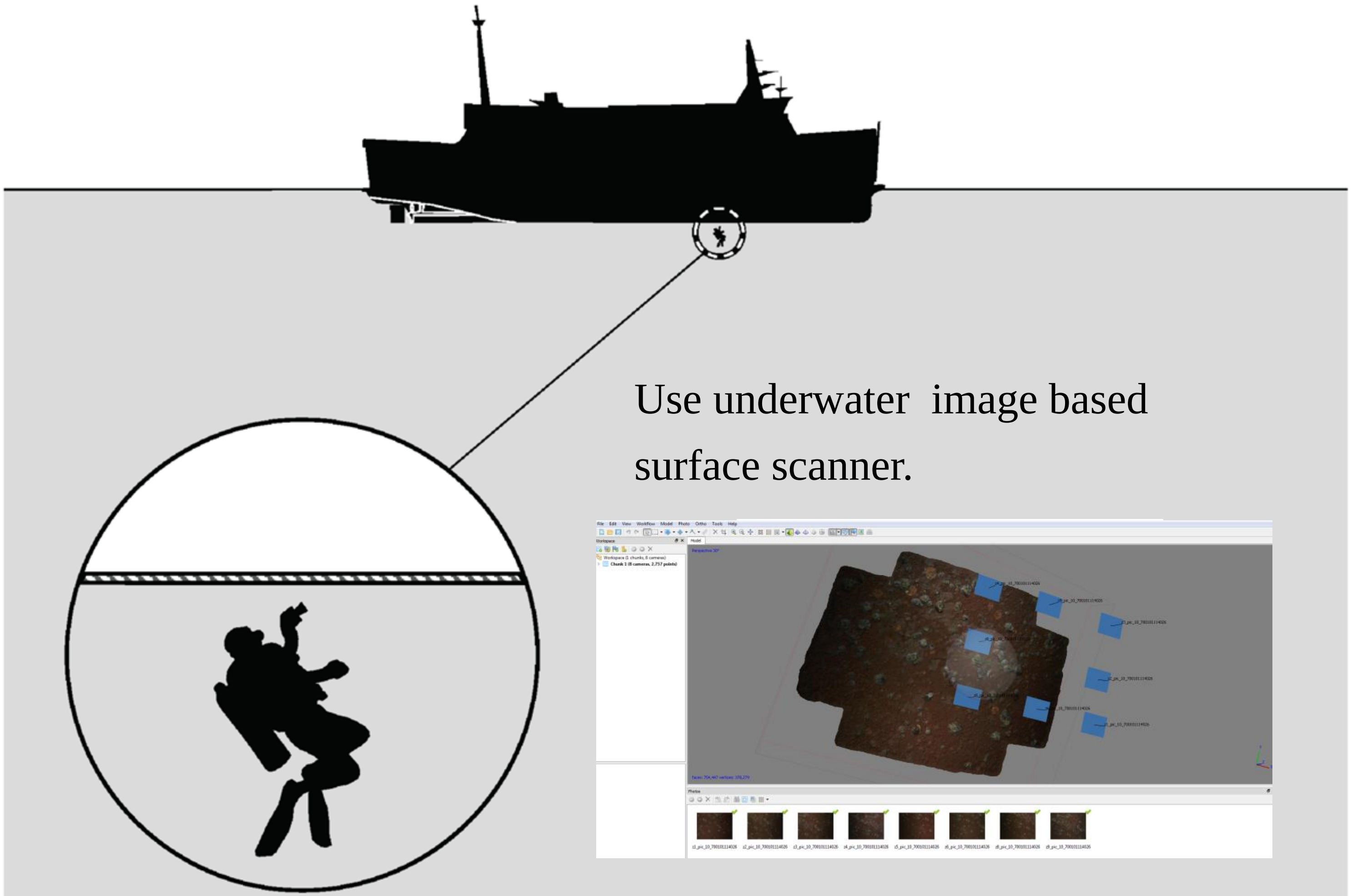


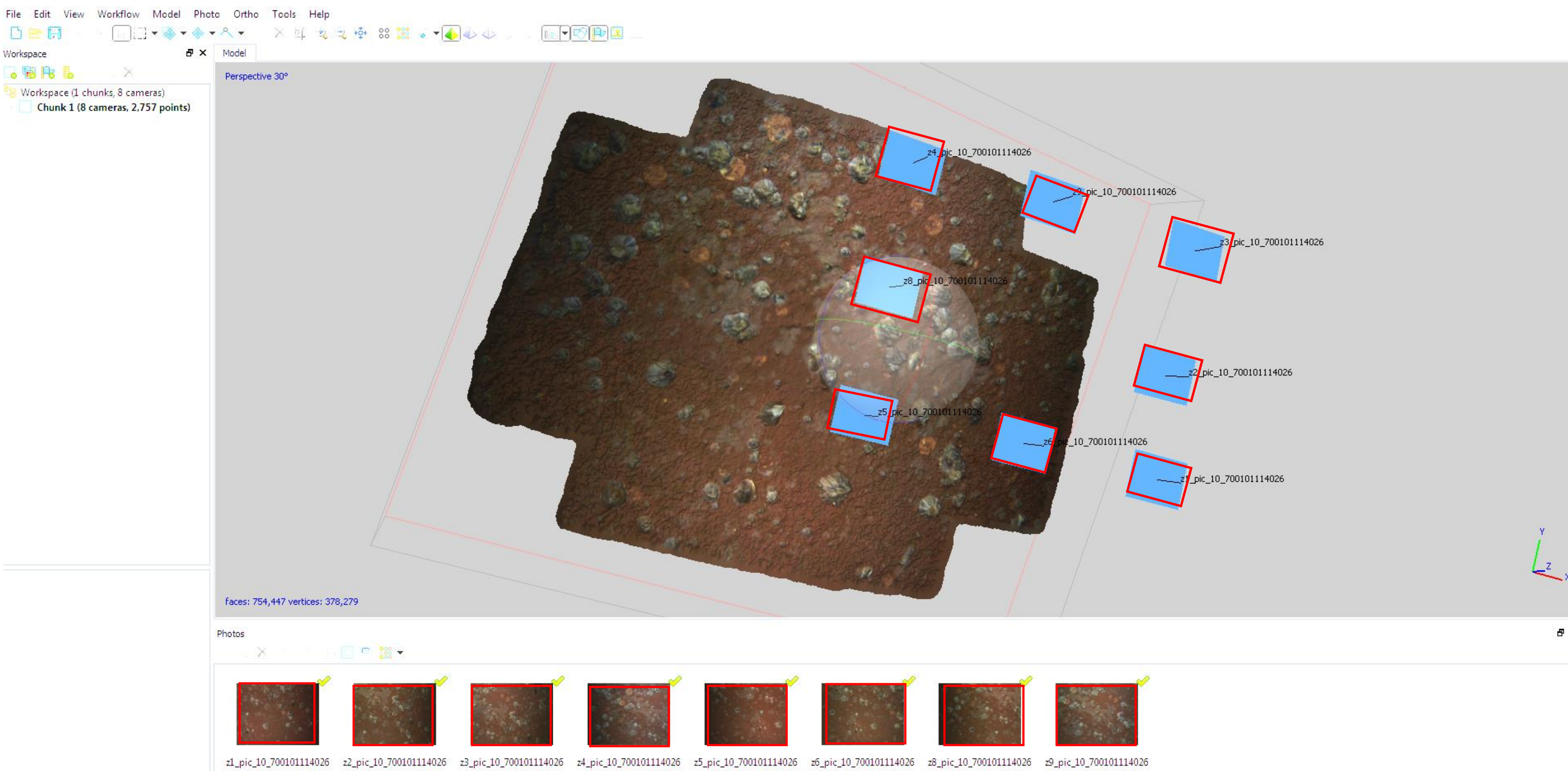
Use underwater image based surface scanner.

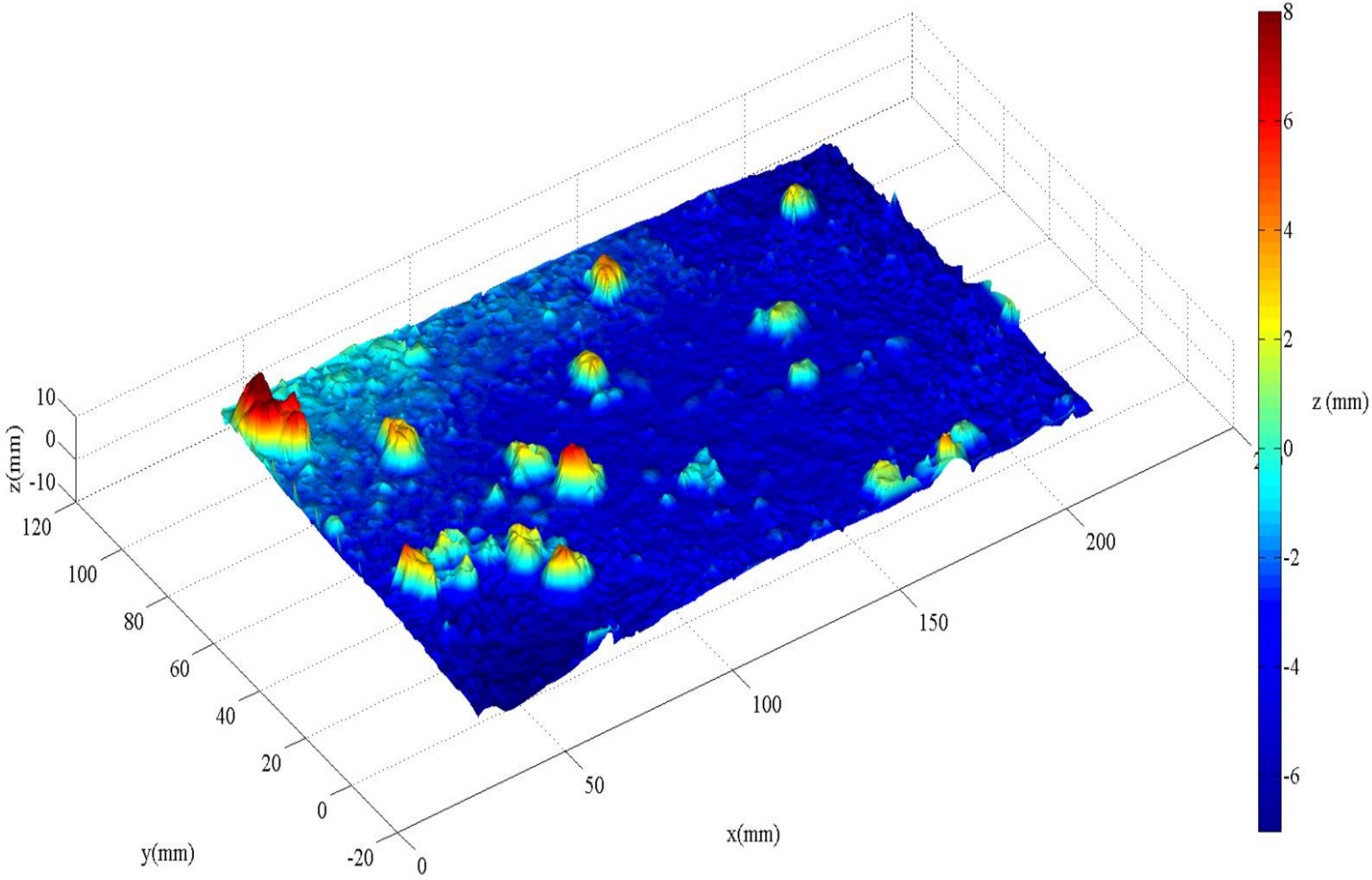



Endcap
Lens
Camera Array
Legs
Handles


Use underwater image based surface scanner.

Using tomography techniques, multiple images are reconstructed to produce 3D surface scan data.



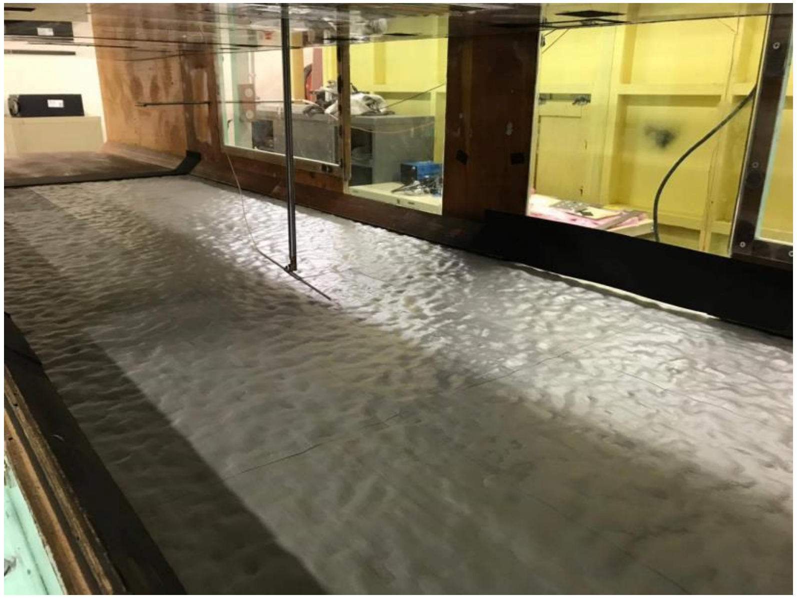

10
0
-10
z(mm)
120
100
80
60
40
20
0
-20
y(mm)
0
50
100
150
200
x(mm)
8
6
4
2
0
-2
-4
-6
z (mm)

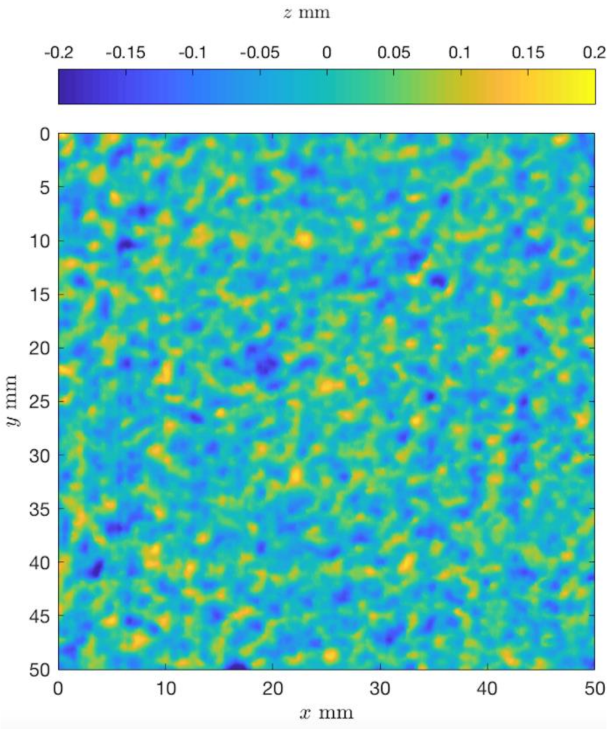
Future work

Future work

1. More LDA measurement with different laser wavelength. i.e green and blue instead of red and infra red.

2. Lab experiment for the newly cleaned ship hull to complement field experiment.





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3. Experiment on a larger ship

Future work

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2. Lab experiment for the newly cleaned ship hull to complement field experiment.

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4. Further improvement of the image surface scanner.

5. Other issue:
    - Baseline study to identify the biodiversity of ship fouling based on ship route.
    - The statistical data of biofouling growth and model
    - Development model of biofouling management plan

Conclusion

Conclusion

1. Results are very preliminary.
2. Challenges using LDA, attenuation, low data rate, etc.
3. Initial results look promising.
4. Even a recently cleaned ship will experience severe drag-penalty.
5. Provide the tools for ship biofouling and its managements, include with the possibility to gather information of statistical fouling growth & model, biodiversity database of ship fouling.

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B. Nugroho, R. Baidya, M. N. Nurrohman, A. K. Yusim, F. A. Prasetyo, M. Yusuf, I. K. Suastika, I. K. A. P. Utama, J. P. Monty, N. Hutchins, B. Ganapathisubramani (2017) *In-situ turbulent boundary layer measurements over freshly cleaned ship-hull under steady cruising*. Royal Institution of Naval Architects (RINA) Conference, International Conference on Ship and Offshore Technology (ICSOT). Jakarta, Indonesia.

I. K. A. P. Utama, B. Nugroho, C. Chin, M. L. Hakim, F. A. Prasetyo, M. Yusuf, I. K. Suastika, J. P. Monty, N. Hutchins, B. Ganapathisubramani (2017) *A study of skin friction drag from realistic roughness of a freshly cleaned and painted ship hull*. International Symposium on Marine Engineering (ISME). Tokyo, Japan.

N. Hutchins, J. P. Monty, B. Ganapathisubramani, B. Nugroho, I. K. A. P. Utama (2016) *Turbulent boundary layers developing over rough surfaces: from the laboratory to full-scale systems*. Plenery speaker paper. 20th Australasian Fluid Mechanics Conference (AFMC). Perth, Australia.