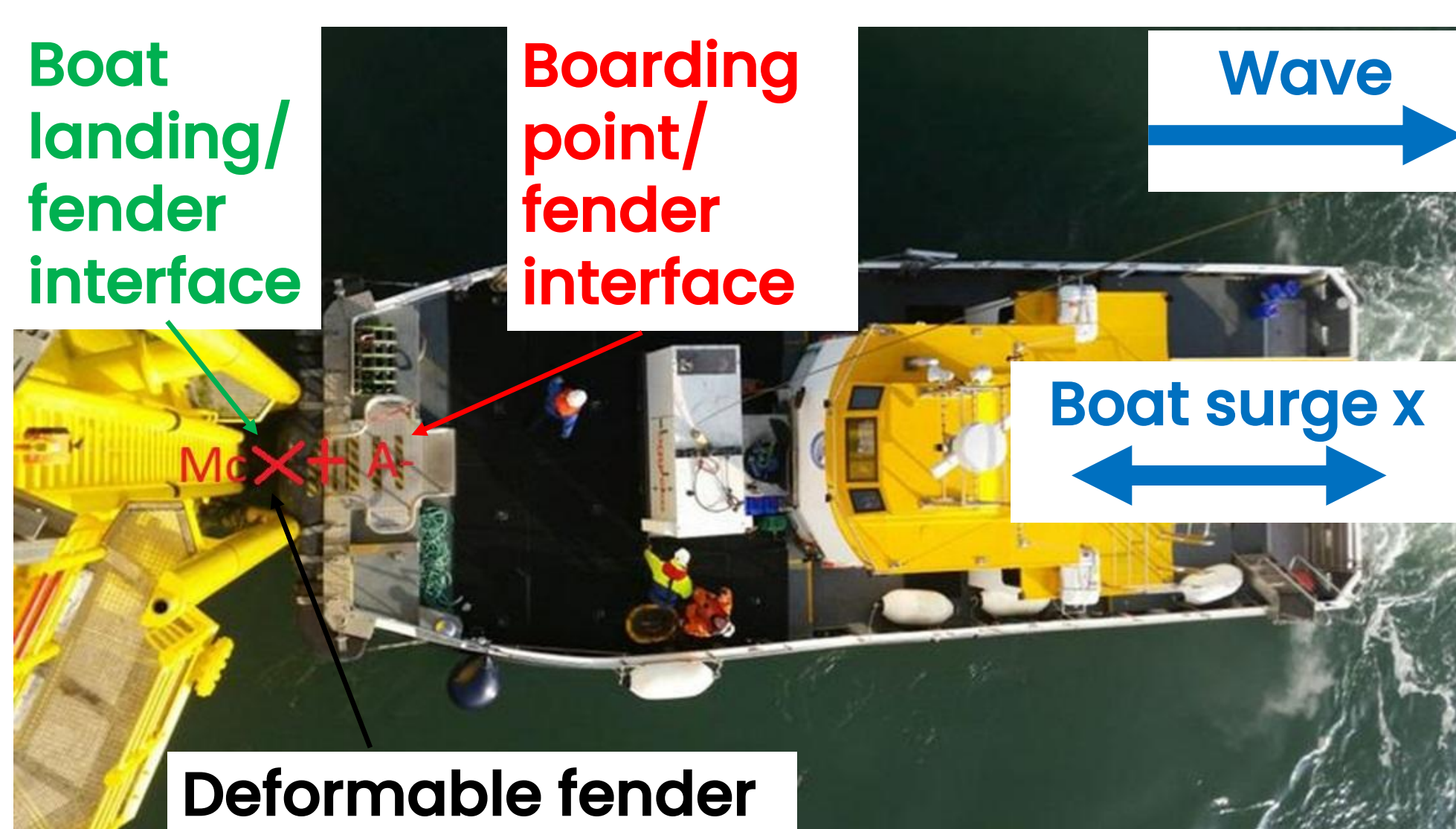
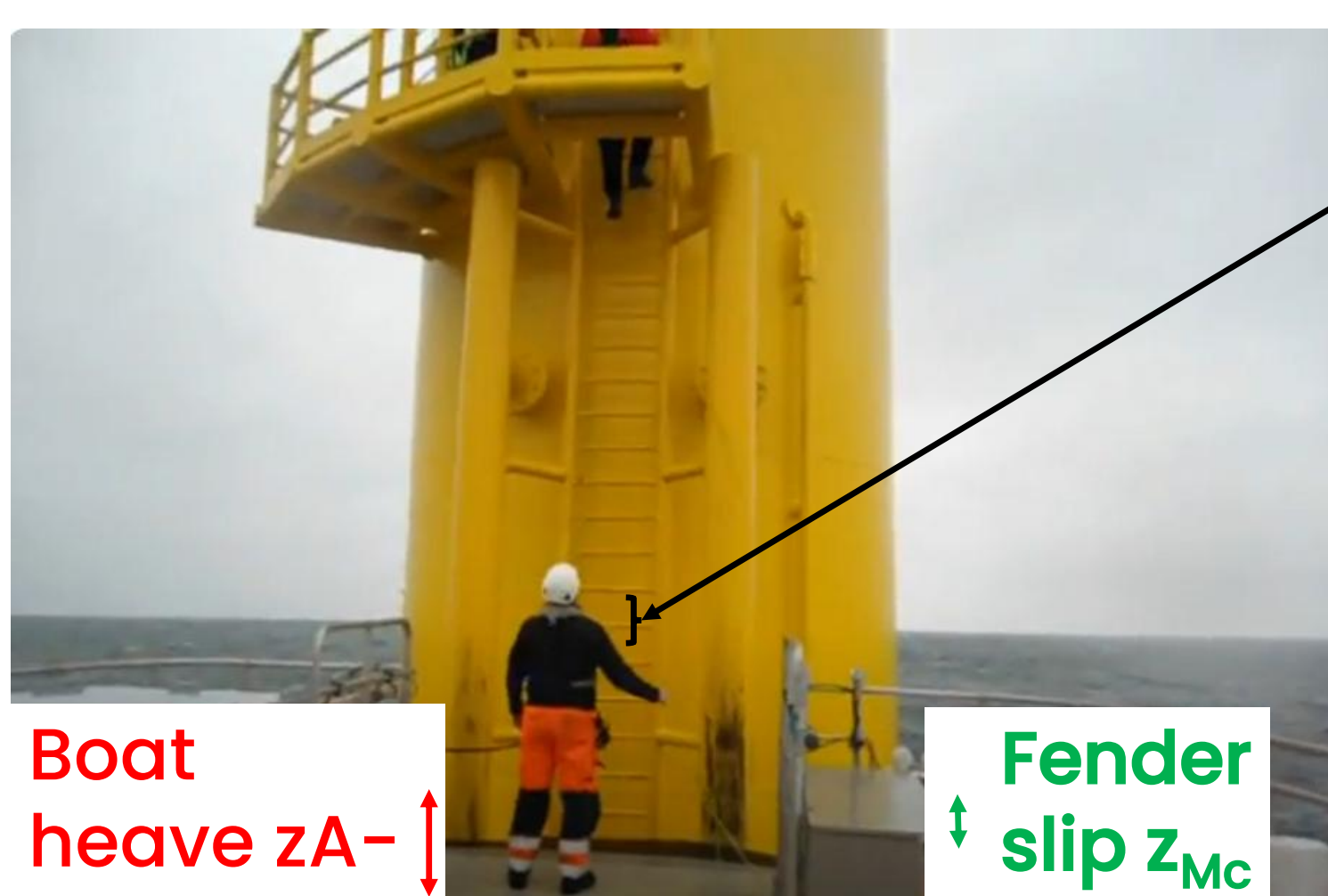


# Berthing Vessels Against Wind Turbines In Real Sea State

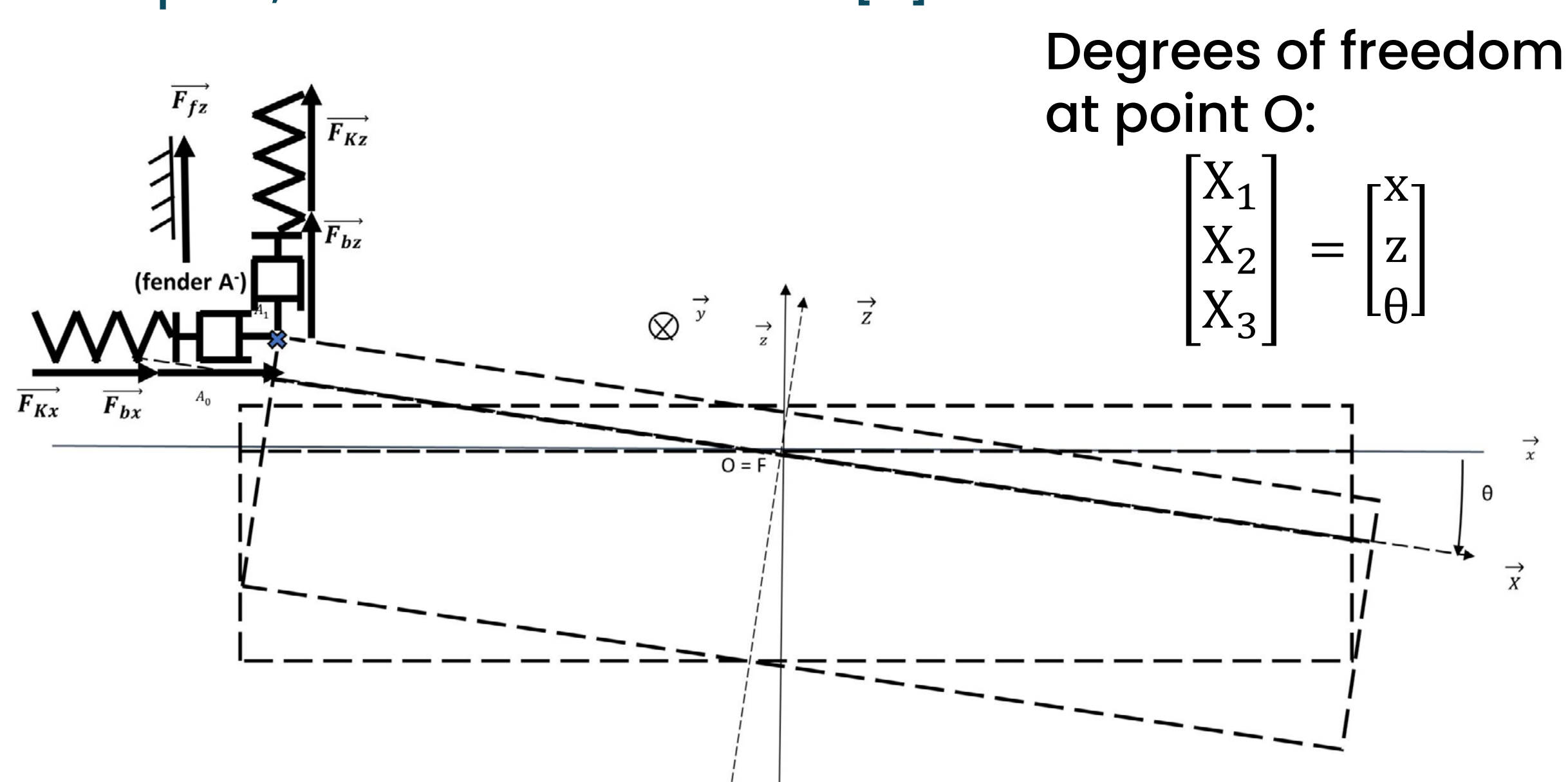
## Introduction

Criterion [1] : 95% waves pass with no fender slip > 1 ladder rung



## Method

Boat/monopile contact: horizontal & vertical springs & dampers, vertical friction force [2]



Loads & responses of a boat in irregular seas (ie. real sea) [3]

$$\sum_{j=1}^3 \left\{ [I_{ij} + I_{a ij}(\infty)] \ddot{X}_j + \int_{-\infty}^t \dot{X}_j R_{ij}(t-\tau) d\tau + K_{ij} X_j \right\} = \mathcal{R} \left\{ \sum_{k=1}^n F_{i,km} e^{-i(\omega_k t + \delta_k)} \right\}$$

$$\text{with } R_{ij}(t) \stackrel{\text{def}}{=} \frac{2}{\pi} \int_0^\infty B_{ij}(\omega) \cos(\omega t) d\omega, I_{a ij}(\infty) \stackrel{\text{def}}{=} I_{a ij}(\omega_t) + \frac{1}{\omega_t} \int_0^\infty R_{ij}(\tau) \sin(\omega_t \tau) d\tau$$

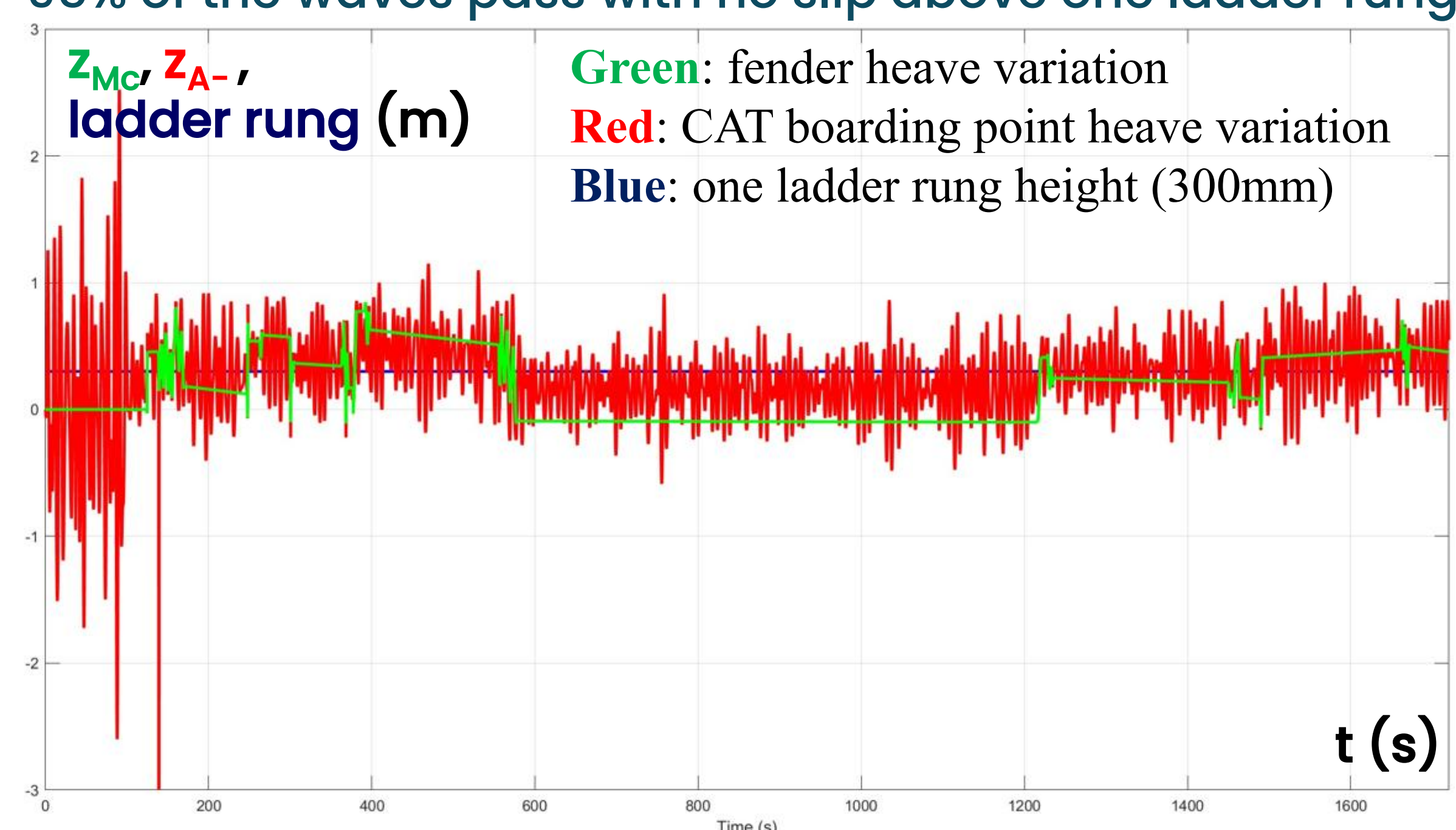
Equations ruling fender mass  $m_*$  motion at point  $M_c$  (2)

$$m_* \cdot \ddot{z}_{M_c} = F_{fz} - F_{Kz} - F_{bz}$$

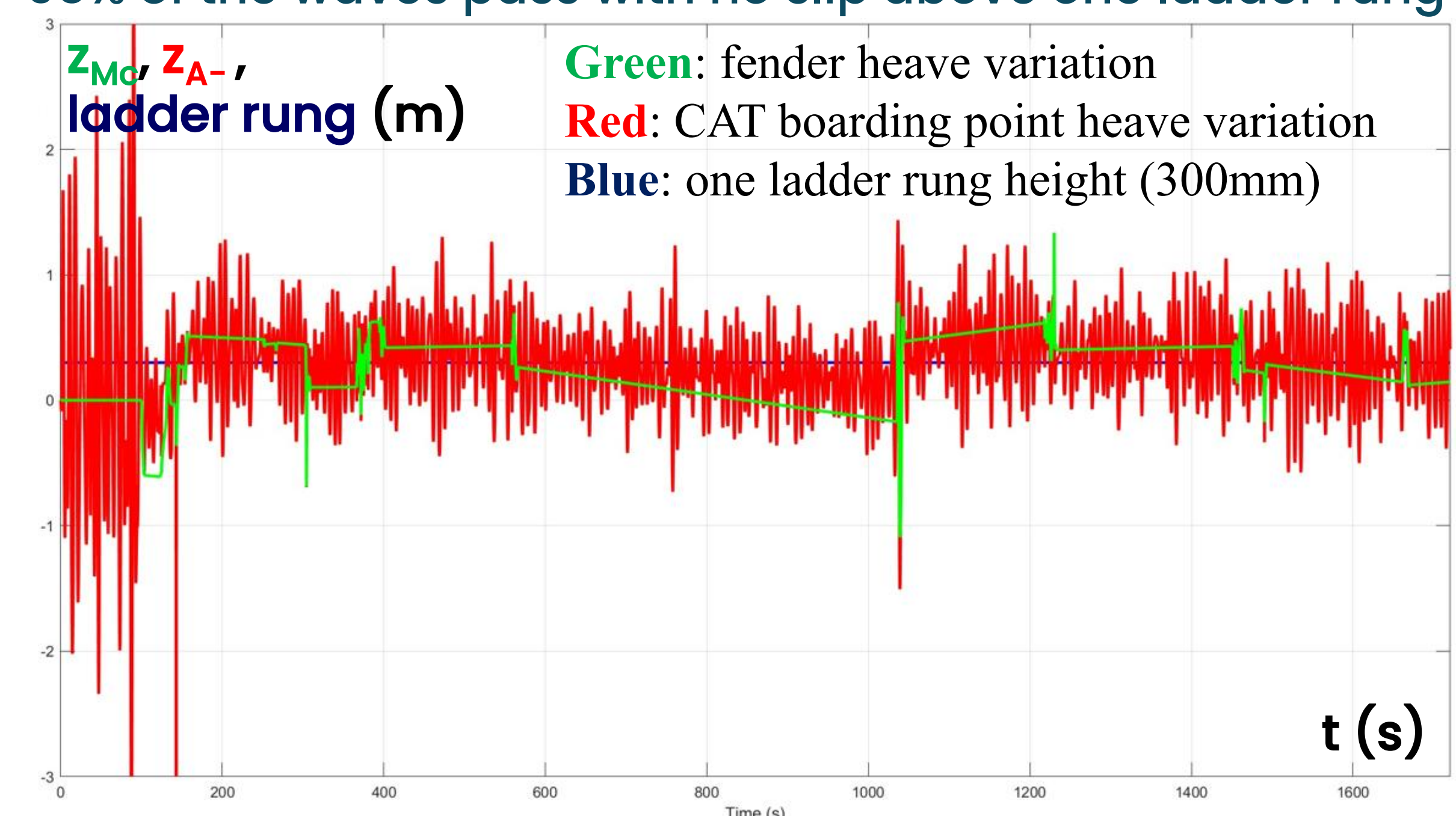
**References:** [1] Carbon Thrust (2017): Crew Transfer Vessel (CTV) Performance Plot (P-Plot) Development. Notice to the Offshore Wind Energy Sector <https://www.carbontrust.com/media/674745/carbon-trust-p-plot-development-re-searchsummary-june-2017.pdf>, [2] AUESTAD Oyvind, GRAVDAHL Jan, PEREZ Tristan, SORENSEN Asgeir, & ESPELAND Trygve (2015): "Boarding control system for improved accessibility to off-shore wind turbines: Full-scale testing", Control Engineering Practice, 45, pp. 207-218, <https://eprints.qut.edu.au/95577/>, [3] Bernard Molin (2023), Offshore Structure Hydrodynamics, CAMBRIDGE, ISBN 978-1-00-919804-2, [4] Nere G. Skomedal and Trygve Halvorsen Espeland (2017) Cost-effective Surface Effect Ships for Offshore Wind, FAST 2017 conference, Nantes, France. ESNA AS, KRISTIANSAND S, NORWAY, 7.

## Results

For a 1,5m significant wave height & 7,5s peak period, approx. 95% of the waves pass with no slip above one ladder rung



For a 2m significant wave height & 7,5s peak period, less than 95% of the waves pass with no slip above one ladder rung



## Conclusion : safe boarding criteria

| Wave length / boat length                                                            | 0     | 1,85    | 14 |
|--------------------------------------------------------------------------------------|-------|---------|----|
| CAT CTV 27m [4] 2017 benchmark                                                       | 2m Hs | 1,5m Hs |    |
| Wave length / boat length                                                            | 0     | 1,86    | 14 |
| CAT CTV 27m 2025 non linear calc., irregular sea (either kinetic or static friction) | 2m Hs | 1,5m Hs |    |

**Next step :** extend study to the case of a floating wind turbine