



BETTER SHIPS, BLUE OCEANS



Simulation of a feeder on a port to port mission

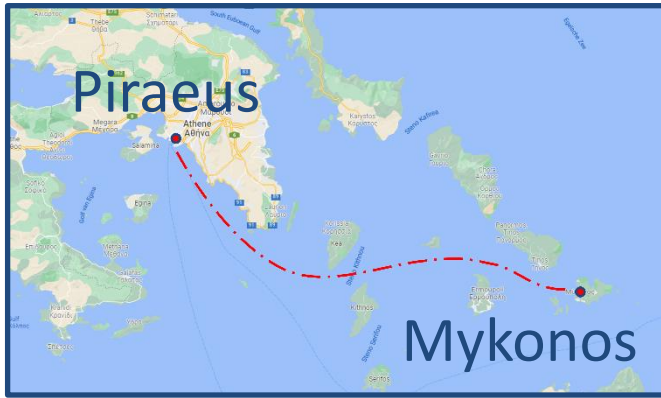
Ed van Daalen, Giorgio Iavicoli, Hans Cozijn, Bas de Kruif

MOSES

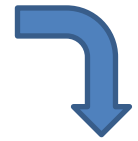
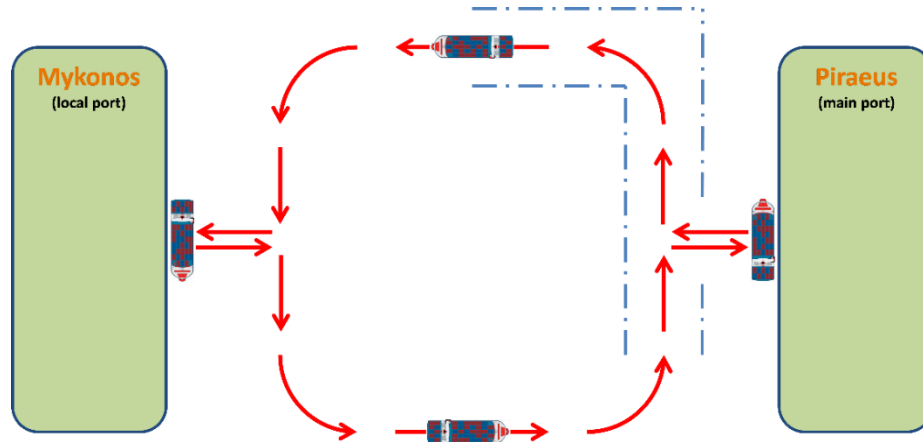
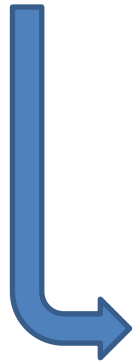


auto**M**ated vessels
and supply chain
Optimisation for
sustainable short **SEa**
Shipping

Autonomous sailing from port to port



full round trip Piraeus-Mykonos, autonomous ship
container feeder with azimuthing & tunnel thrusters
variable environment
different operational states
Divide and conquer:
multiple submodels → integration
multiple phases → transitions



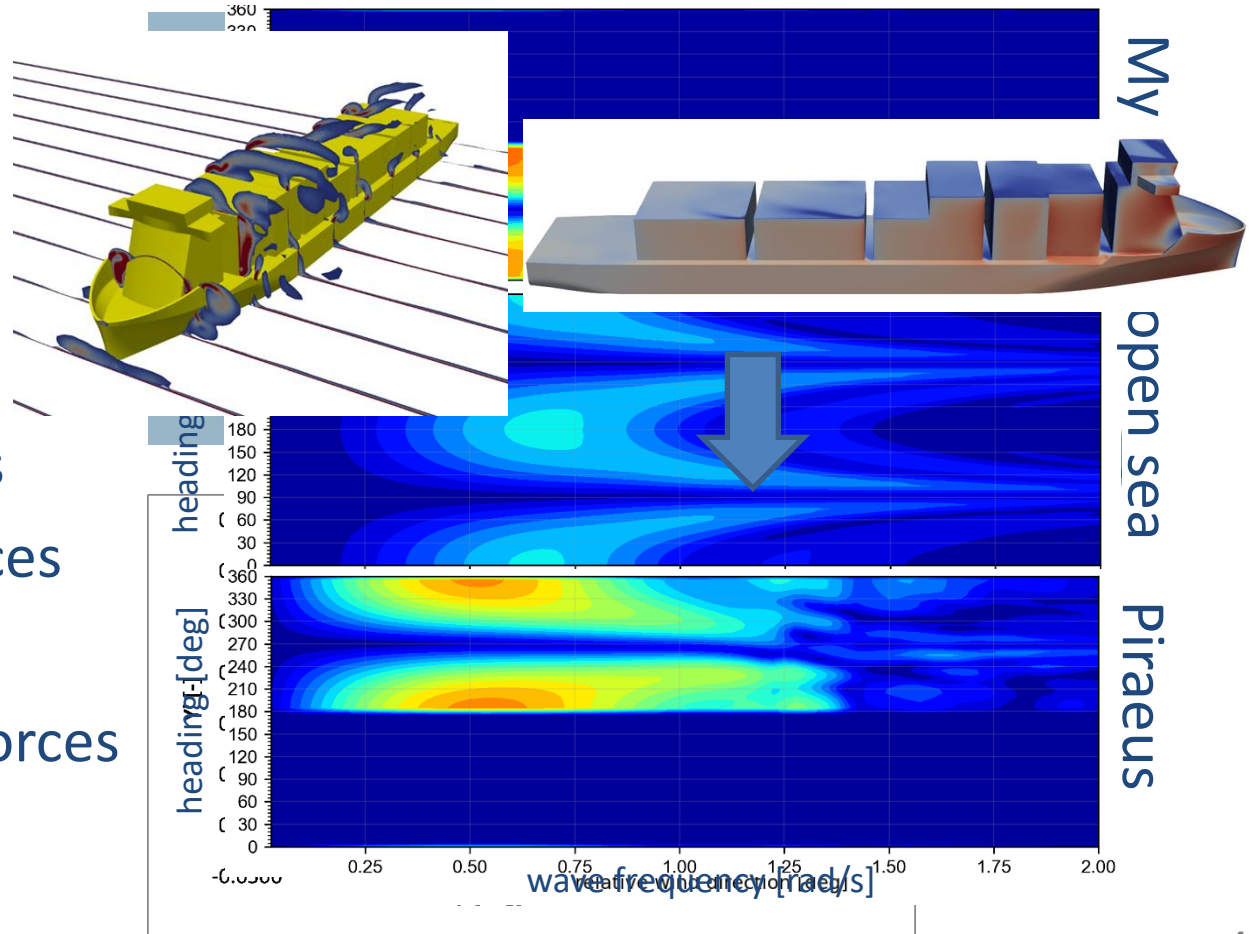
calculations
↓
simulations
↓
experiments

Container feeder : external forces

$$\sum F = \frac{d}{dt}(m\dot{x})$$



- gravity forces
- hydrostatic forces
- manoeuvring forces
- wind forces
- wave excitation forces

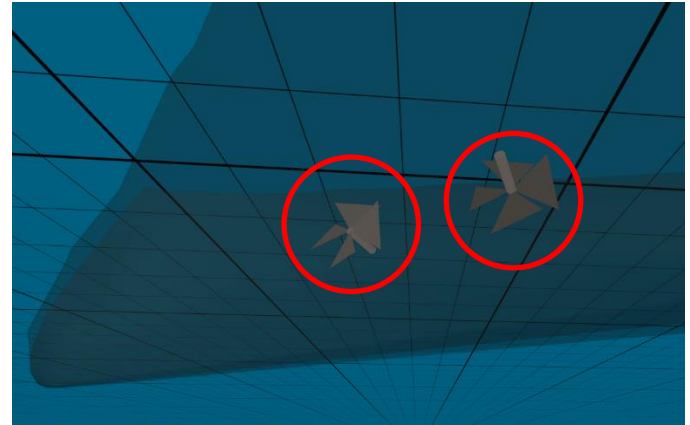


2 azimuthing thrusters



simulation

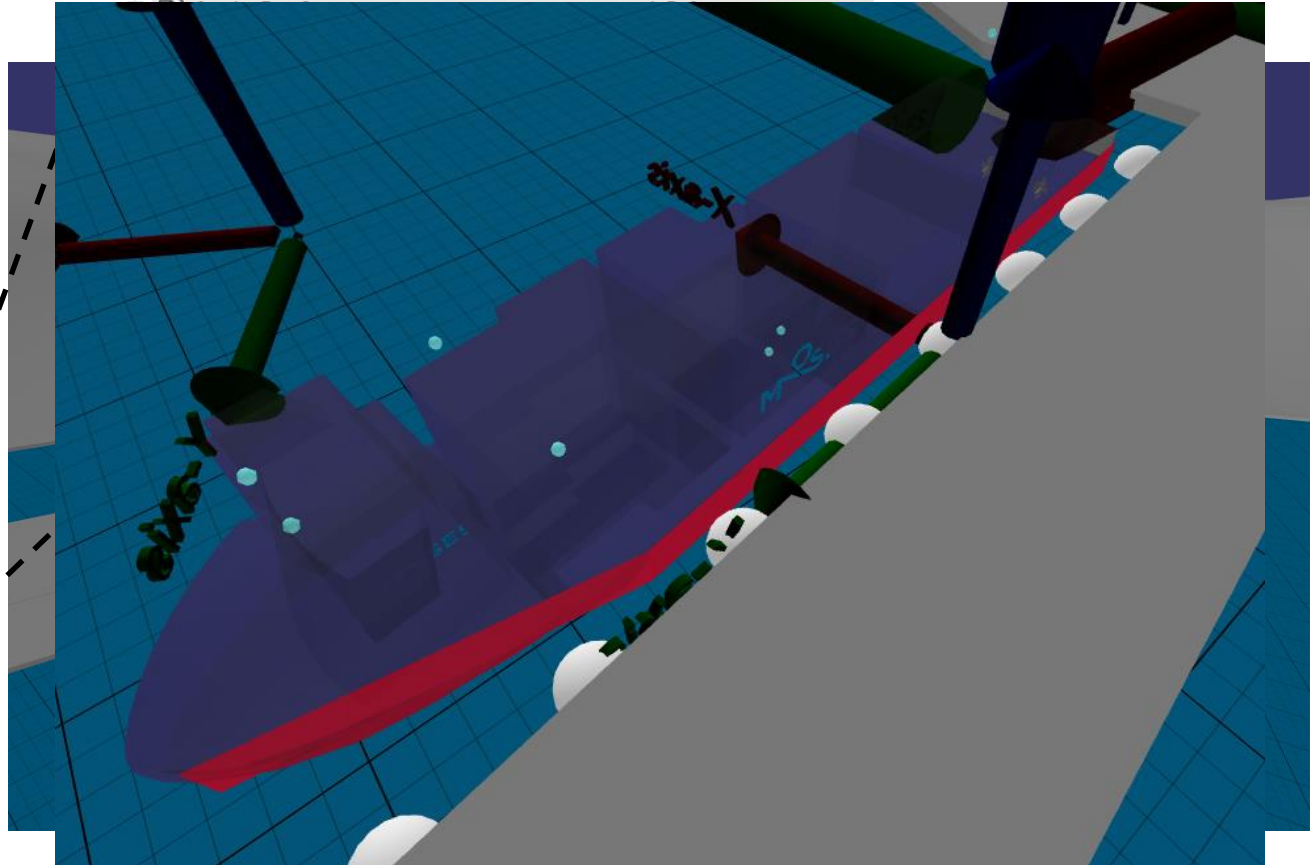
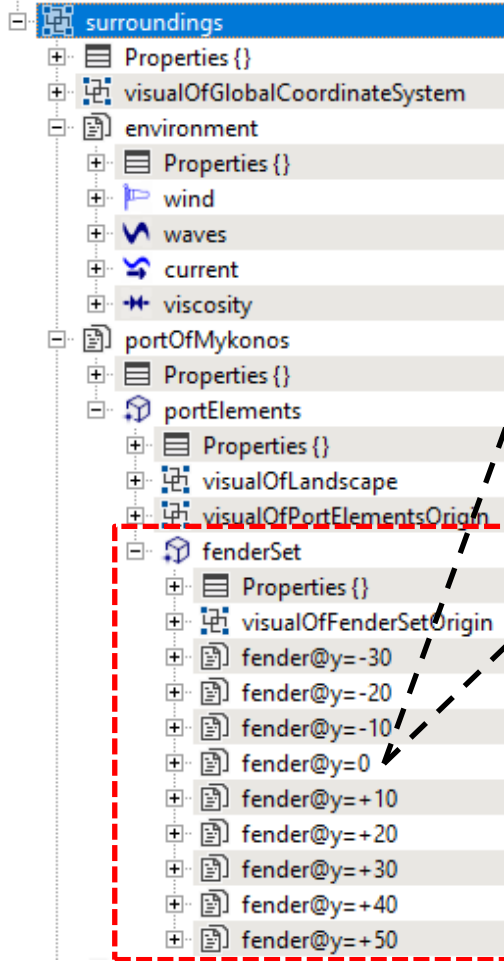
2 bow tunnel thrusters



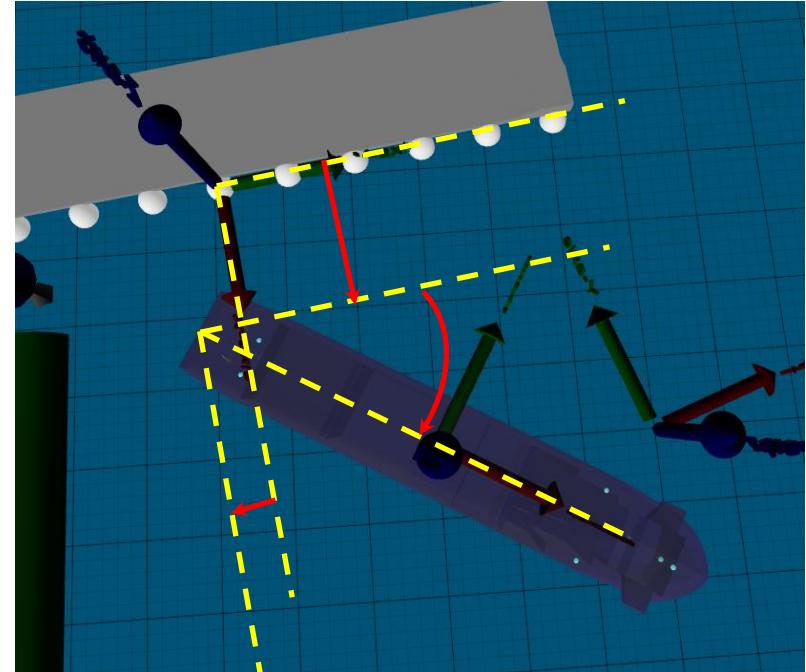
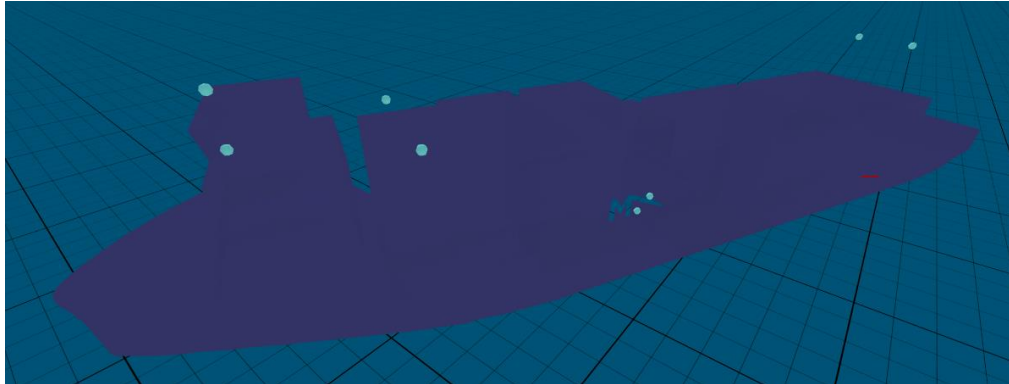
scale model



Surroundings : environment and ports



- motion sensors : logging, navigation, evaluation of criteria
- wave probe : criteria
- 'pose relative to' : (un)docking



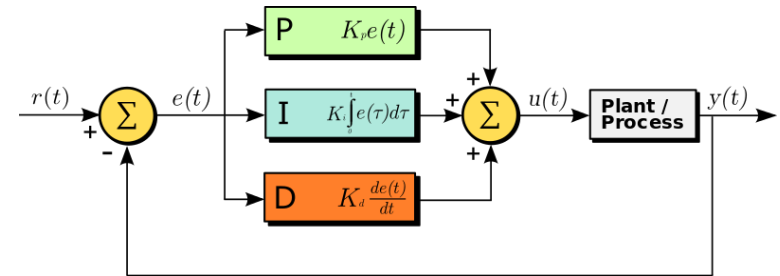
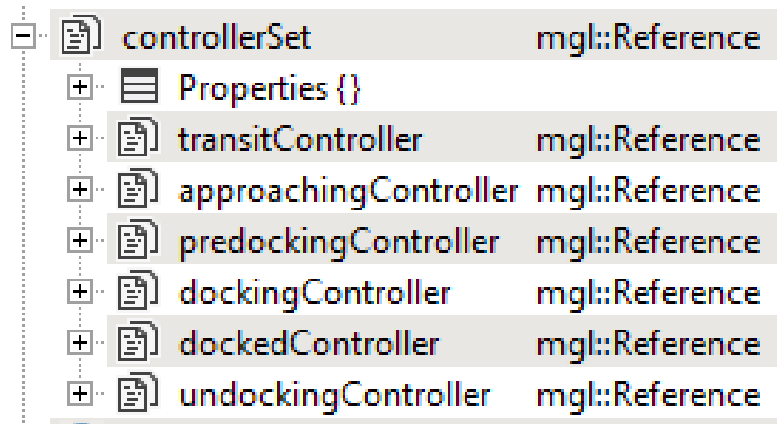
Each phase has its own controller.

For example:

The `transit` phase has an autopilot controller, based on waypoints.

The `docking` phase uses PID controllers for surge, sway, yaw.

The required forces are handed over to the allocation.



distribute required surge & sway forces and yaw moment over available actuators with minimal use of power

→ constrained optimization problem

$\min \sum_i P^{(i)}$ with

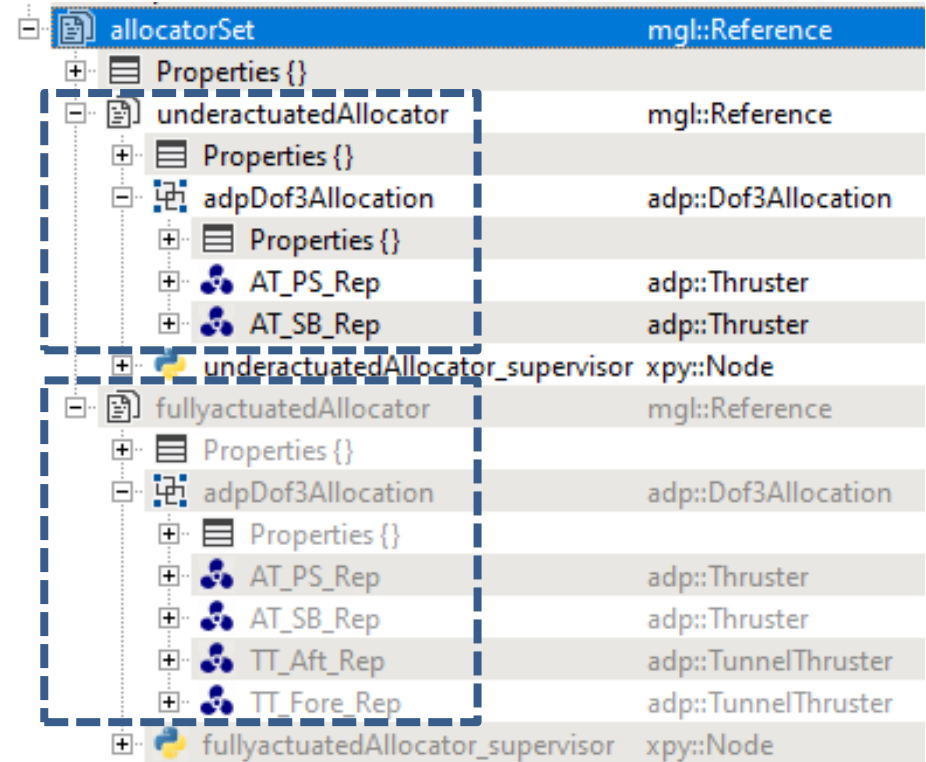
$$\sum_i F_x^{(i)} = F_x^{(req)}, \sum_i F_y^{(i)} = F_y^{(req)}, \sum_i M_z^{(i)} = M_z^{(req)}$$

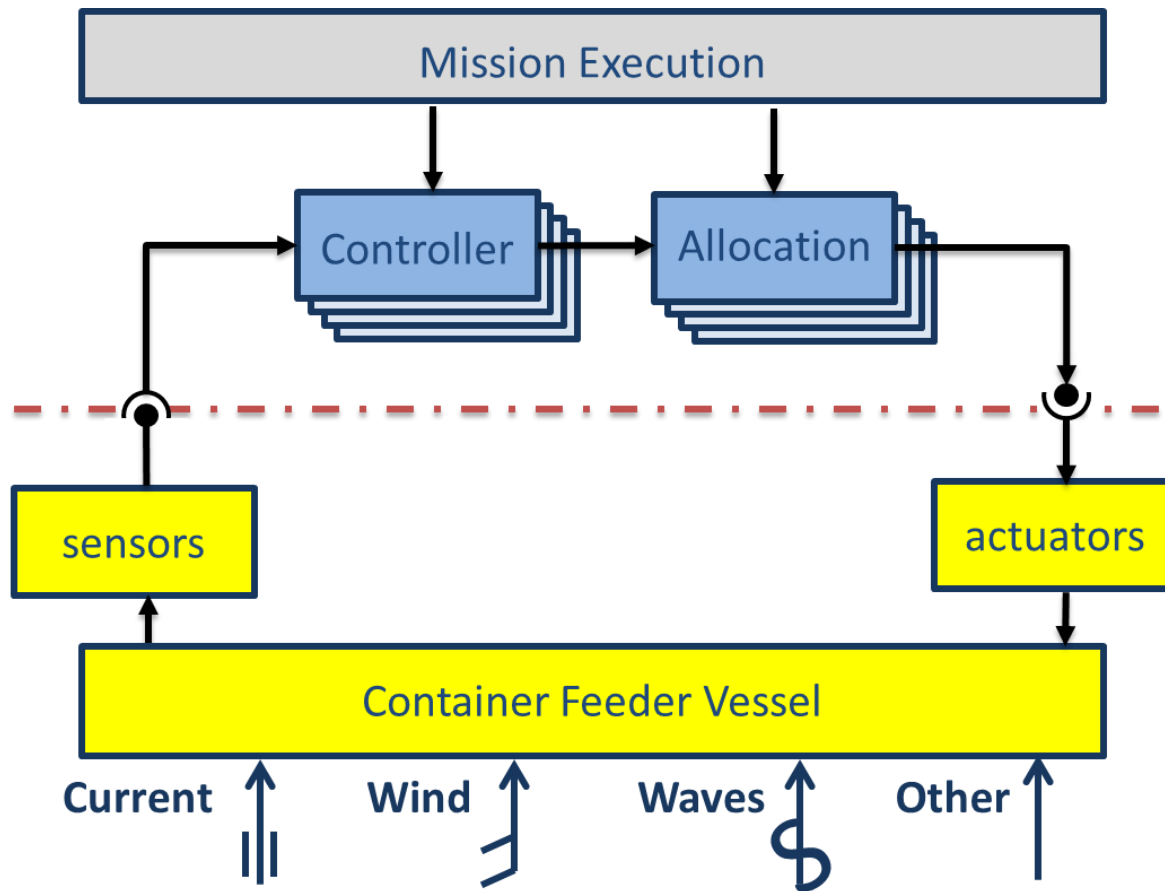
under-actuated

- azimuthing thrusters only

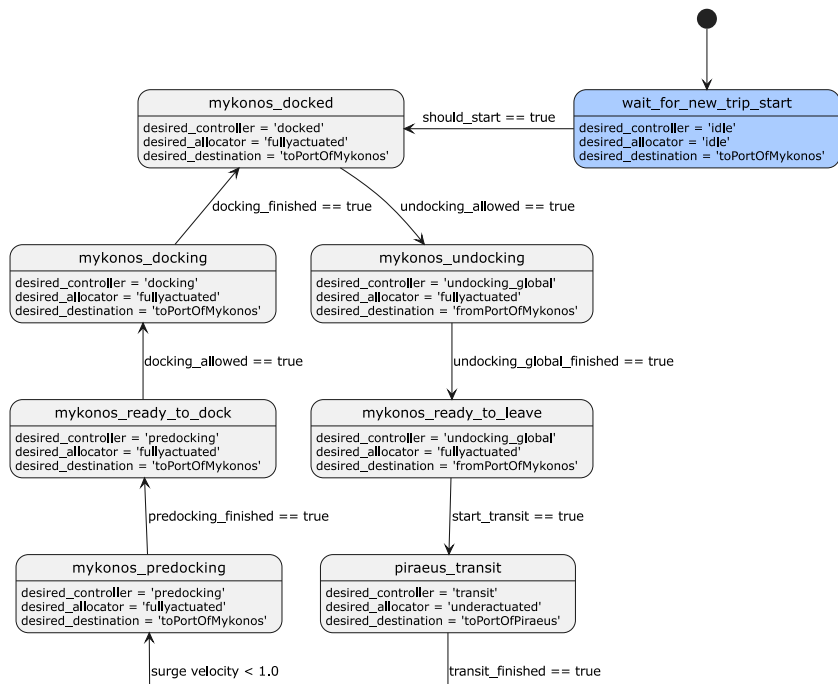
fully actuated

- azimuthing and tunnel thrusters





State diagram

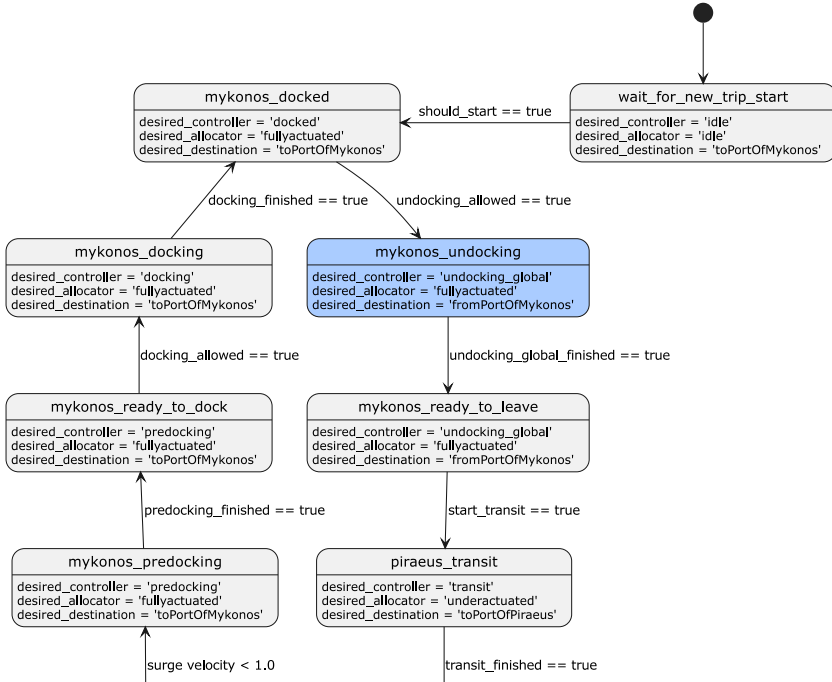


start up:

- no control
- no allocation
- port environment

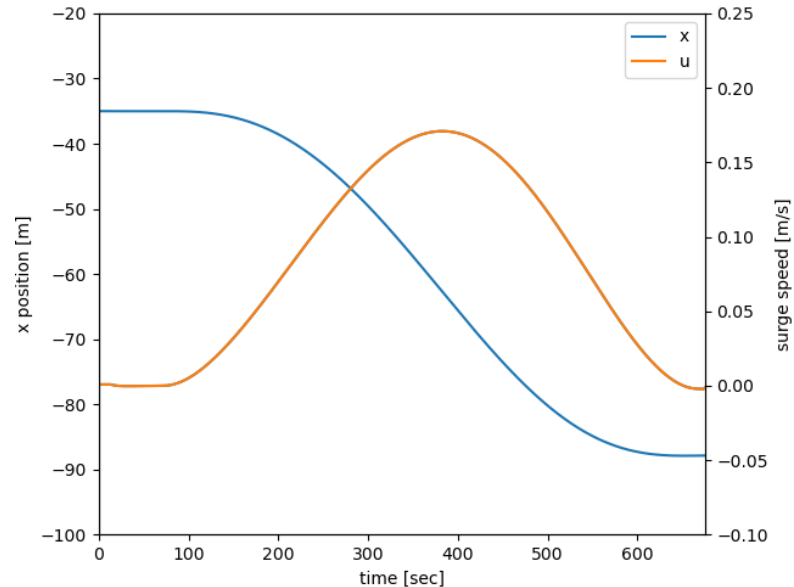


State diagram

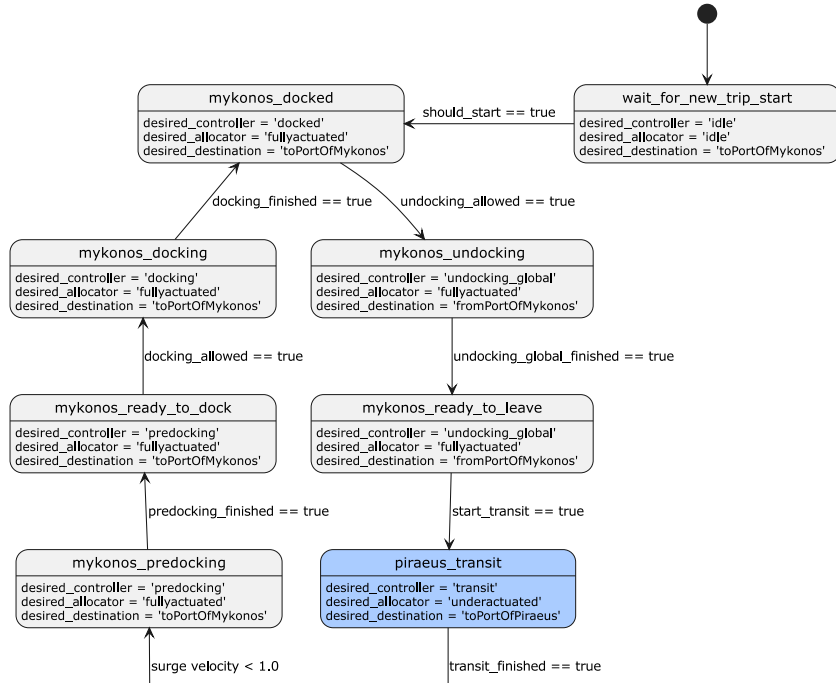


undocking:

- no control → DP control
- no actuators → fully actuated
- pose to undock

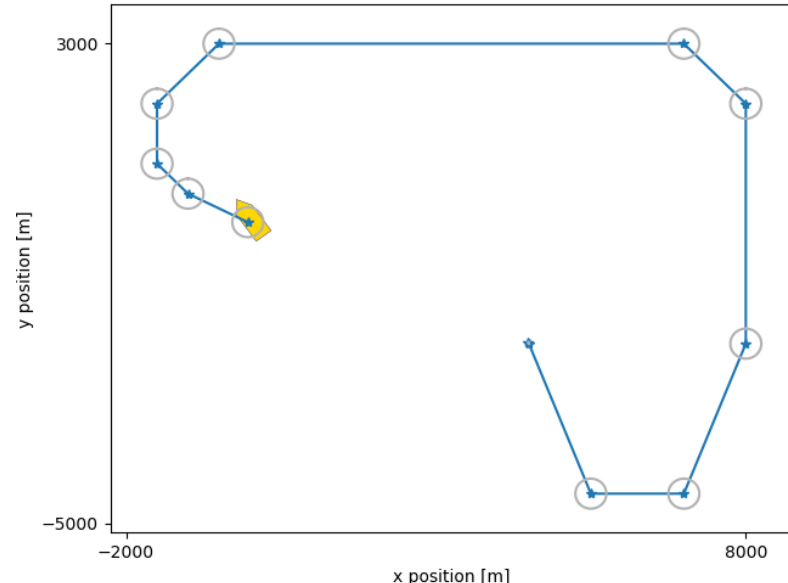


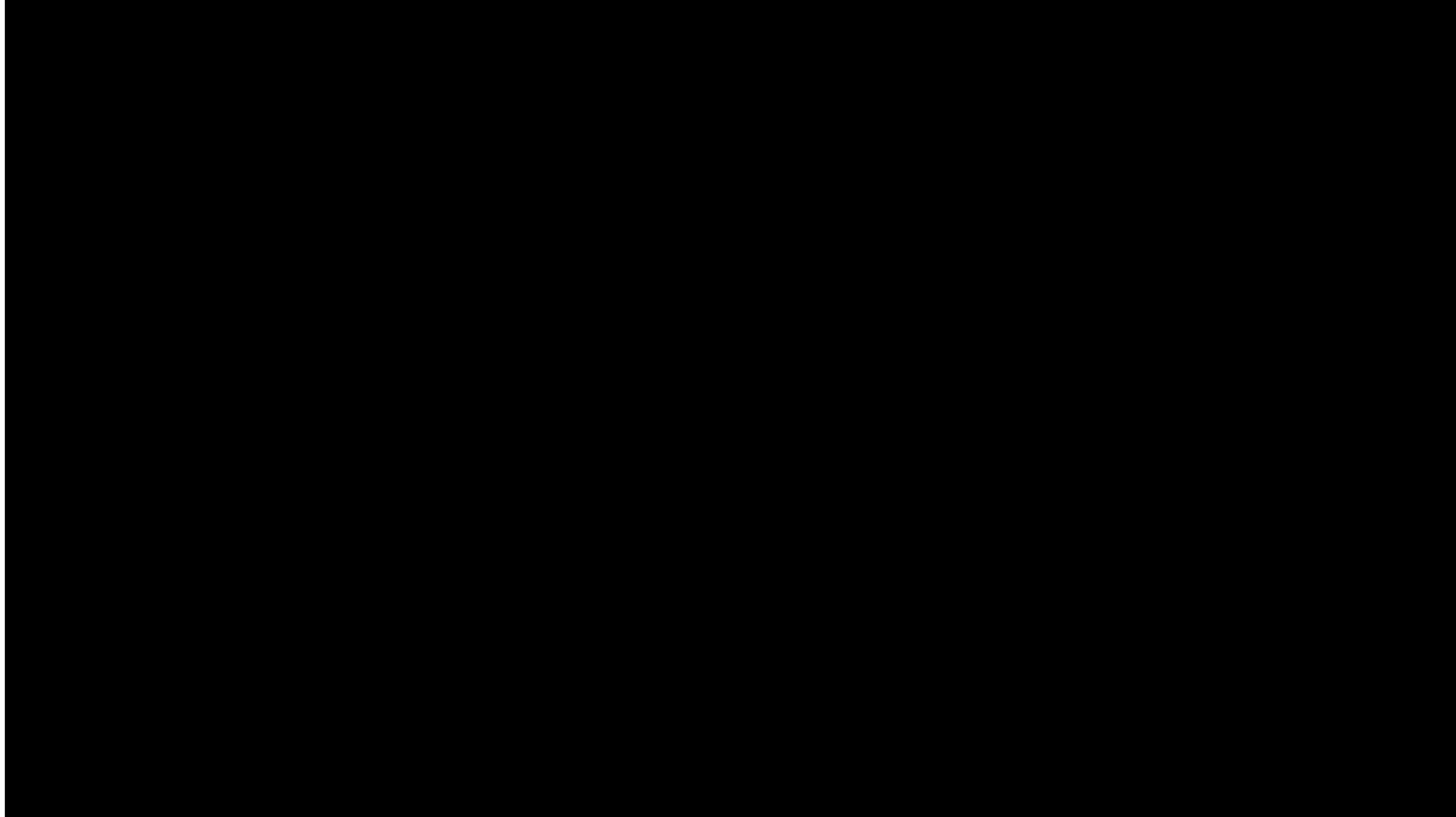
State diagram



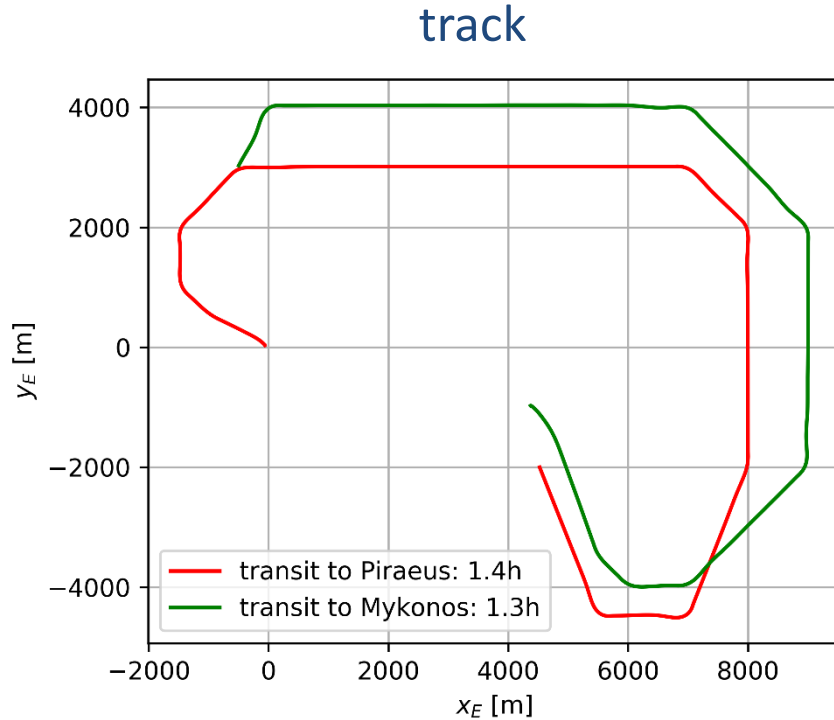
transit:

- DP control → autopilot
- fully actuated → under actuated
- pose → waypoints
- harbour → open water

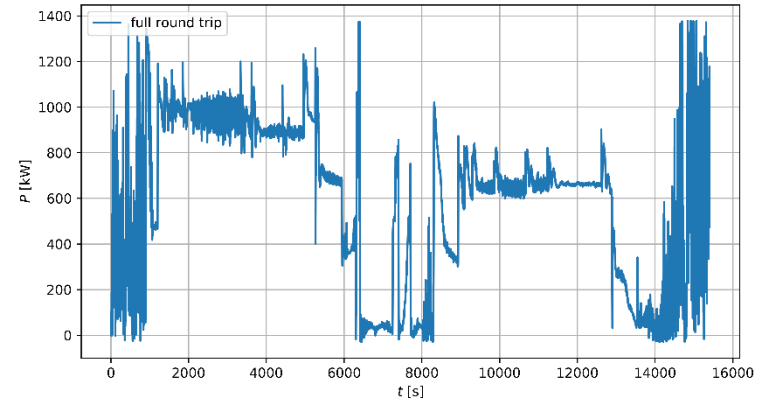




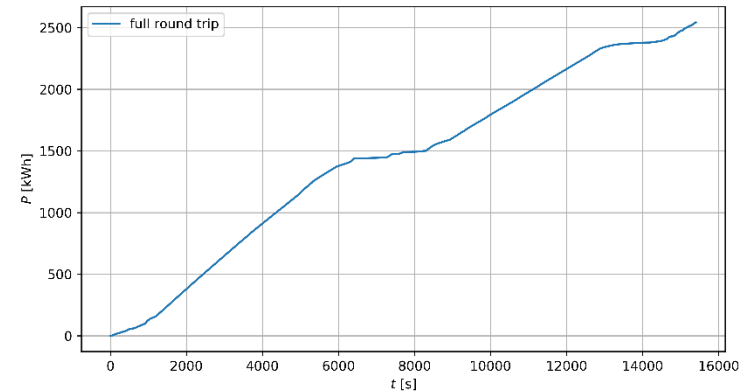
Results : shortened round trip



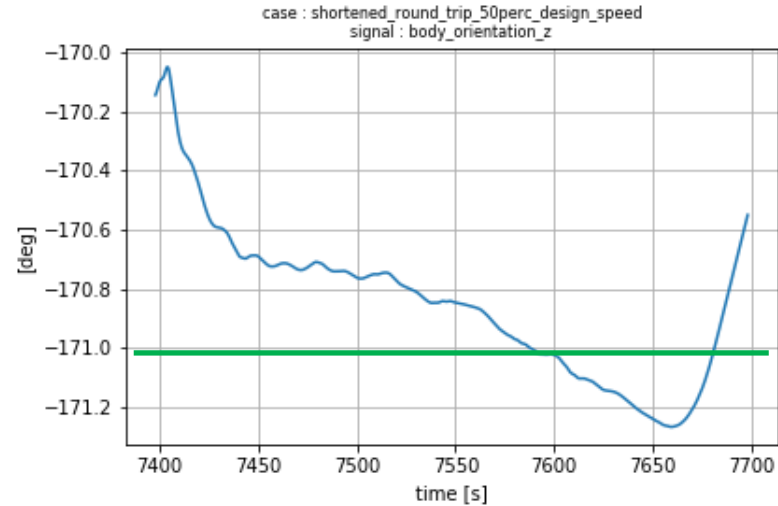
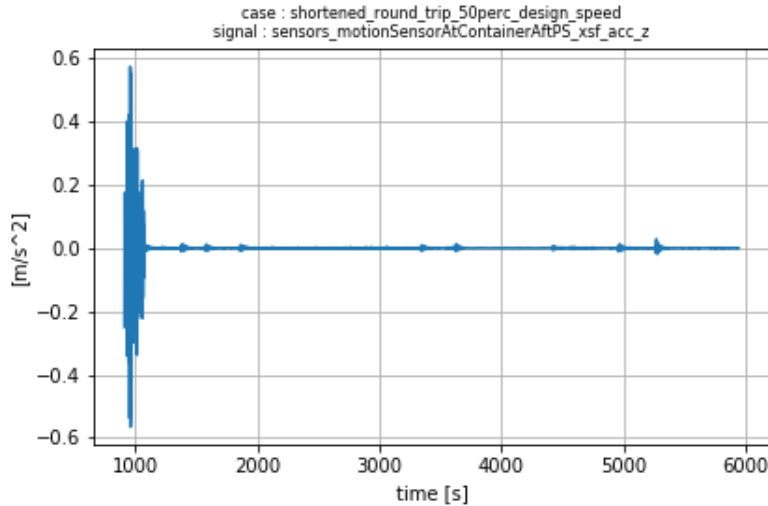
propulsion power



energy consumption



Results : evaluation of criteria (examples)



phase	criterium	SPI*	result
transit	vertical acceleration @ containers	$a_z < 7.83\text{m/s}^2$	OK
docked	heading error	$\Delta\psi < 2 \text{ deg}$	OK

* Specific Performance Indicator

- divided operation and project phases to sail from port to port
- each task solved in ‘calculation’ phase
- all tasks combined in ‘simulation’ phase
- integral solution tested in ‘experimental’ phase
- smooth sailing in operation of ship and project

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THANK YOU.



Experiments - validation

