MARIN

BETTER SHIPS, BLUE OCEANS

Autonomous sailing from port to port

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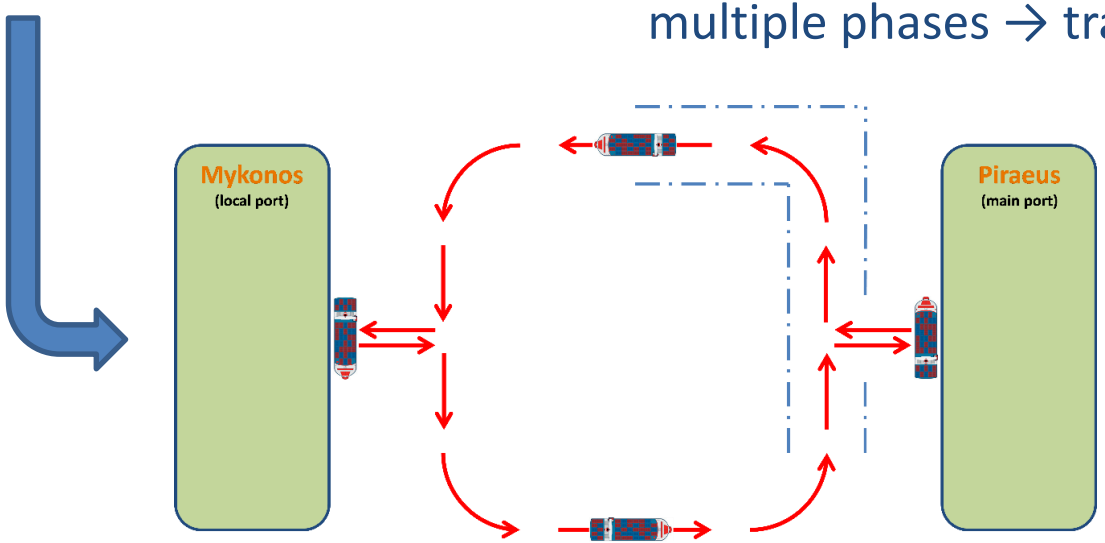
EU MOSES project

autoMated vessels and supply chain Optimisation for sustainable short SEa Shipping

Autonomous sailing from port to port – How ?

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

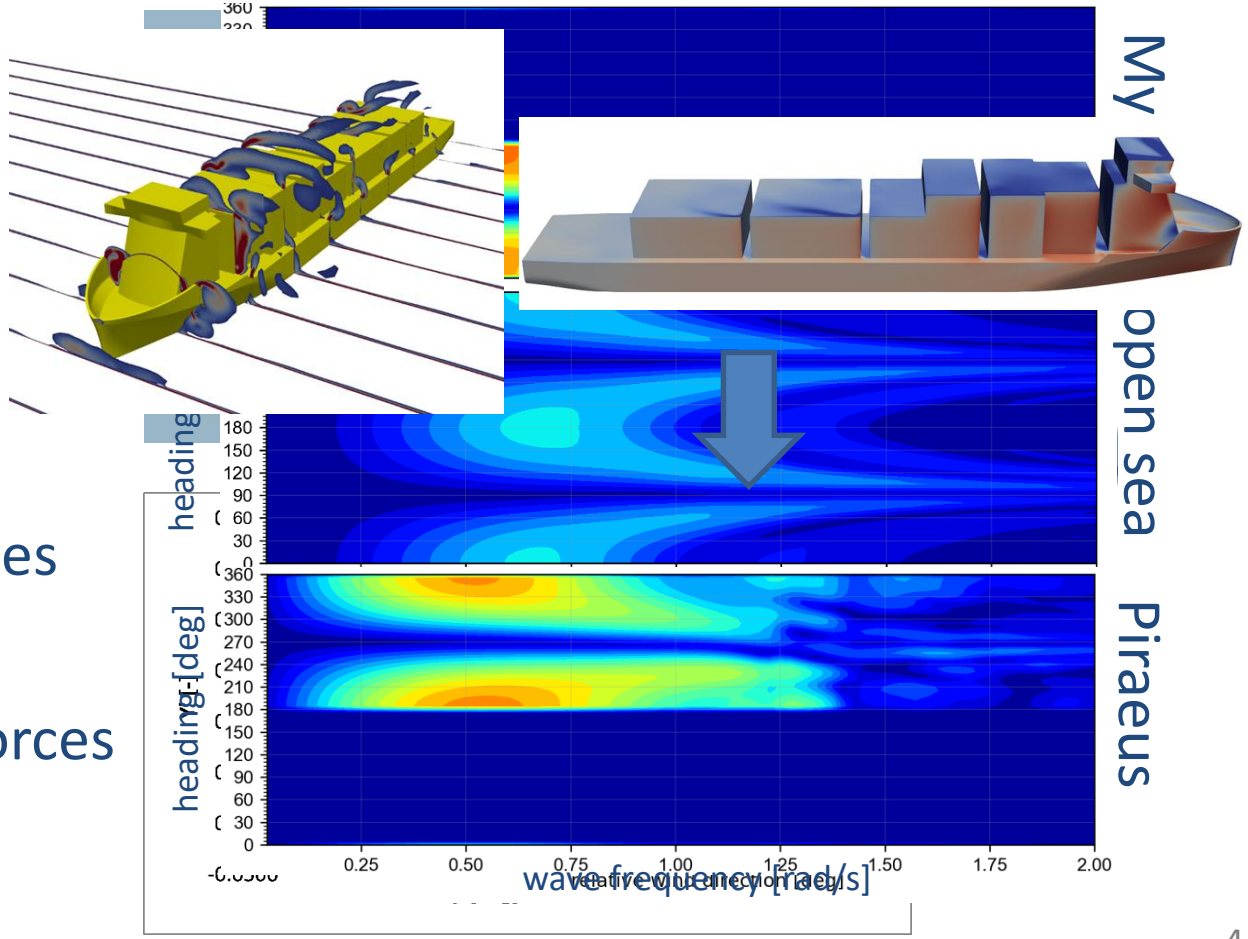


calculations
⇩
simulations
⇩
experiments

Container feeder : external forces

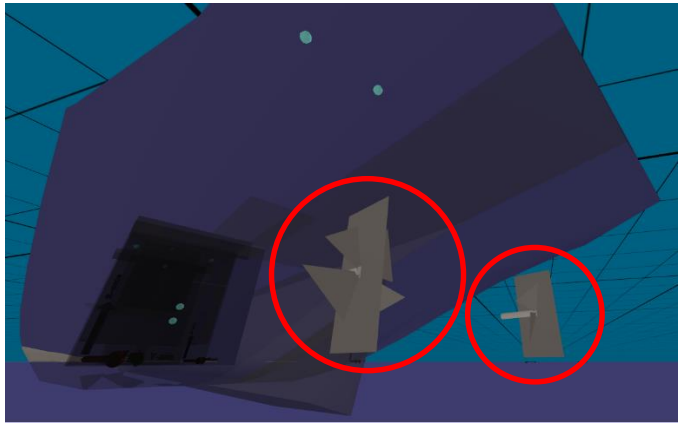
$$\sum F = \frac{\mathrm{d}}{\mathrm{d}t}(m\dot{x})$$

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

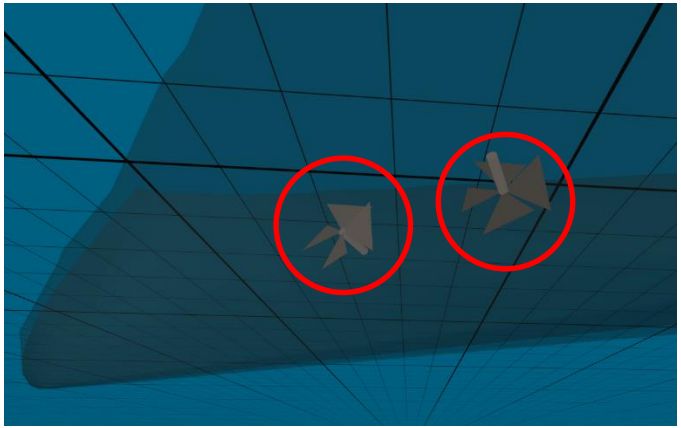


Container feeder : actuators

2 azimuthing thrusters



2 bow tunnel thrusters

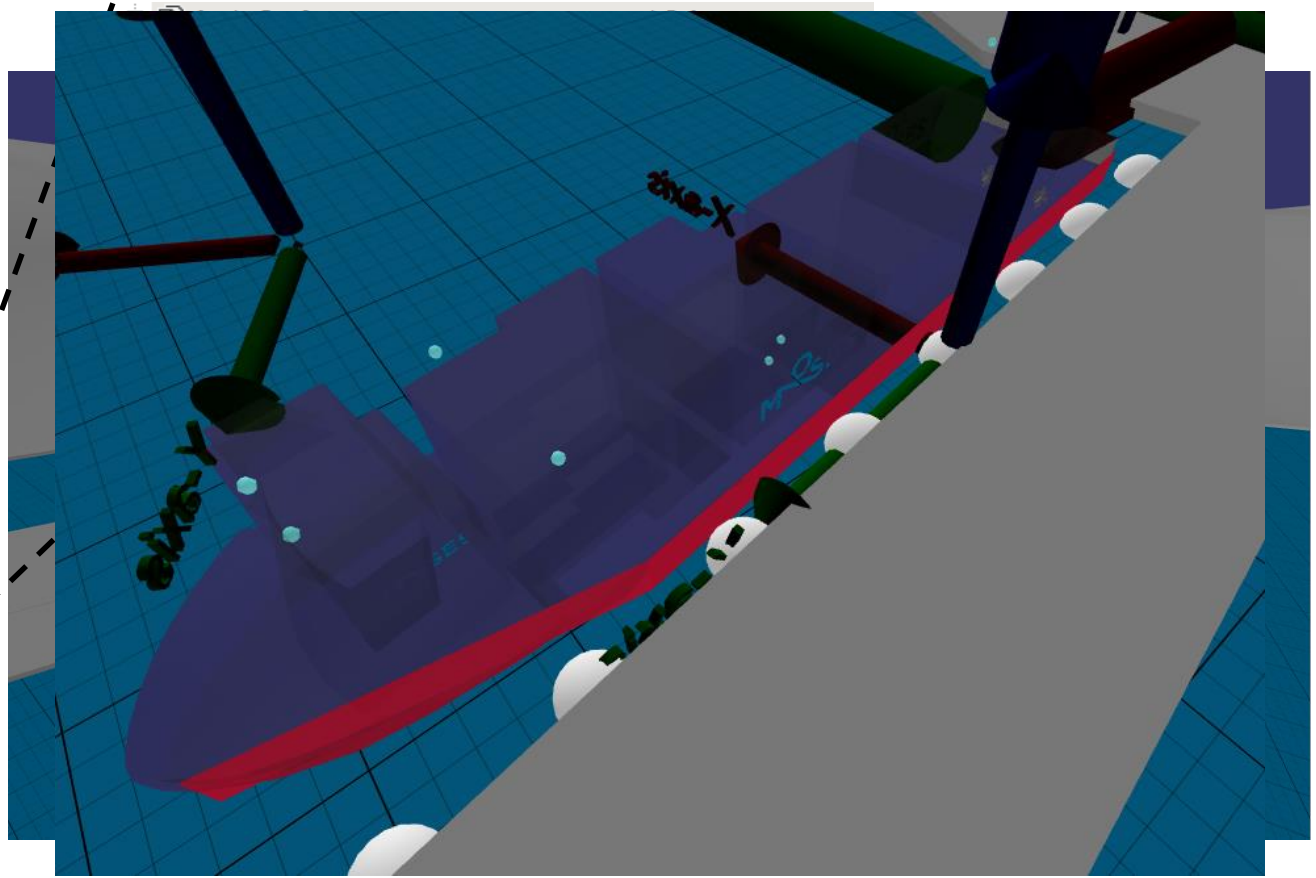


simulation

scale model

Surroundings : environment and ports

- surroundings
  - Properties {}
  - visualOfGlobalCoordinateSystem
  - environment
    - Properties {}
    - wind
    - waves
    - current
    - viscosity
  - portOfMykonos
    - Properties {}
    - portElements
      - Properties {}
      - visualOfLandscape
      - visualOfPortElementsOrigin
      - fenderSet
        - Properties {}
        - visualOfFenderSetOrigin
        - fender@y=-30
        - fender@y=-20
        - fender@y=-10
        - fender@y=0
        - fender@y=+10
        - fender@y=+20
        - fender@y=+30
        - fender@y=+40
        - fender@y=+50

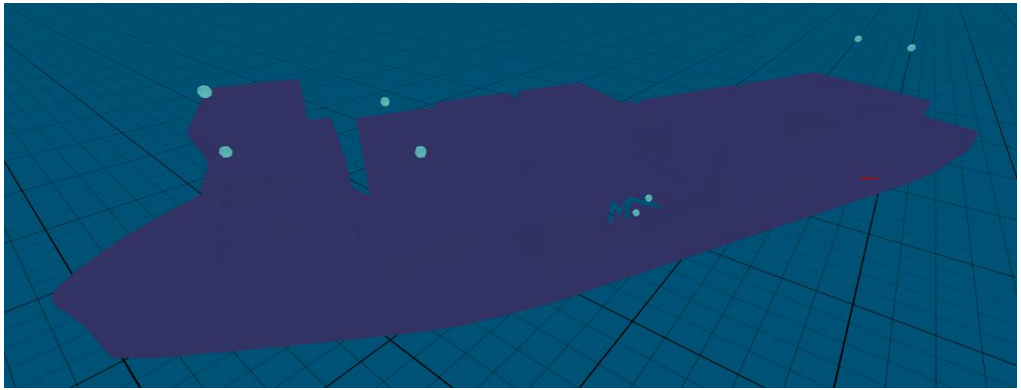


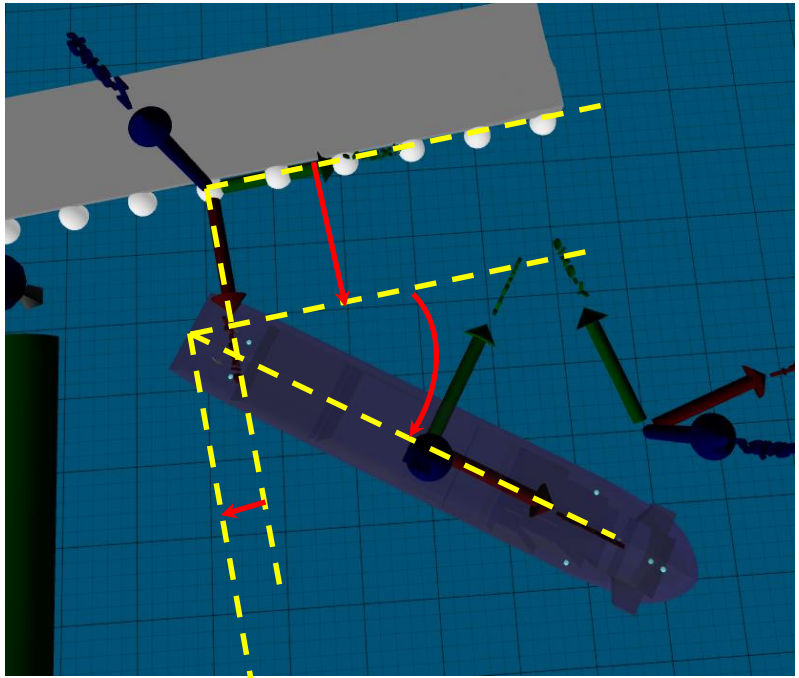
Sensors

motion sensors : logging, navigation, evaluation of criteria

wave probe : criteria

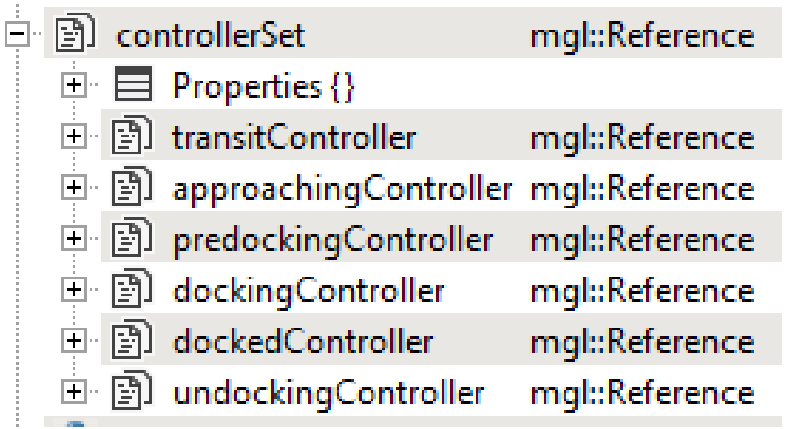
`pose relative to’ : (un)docking

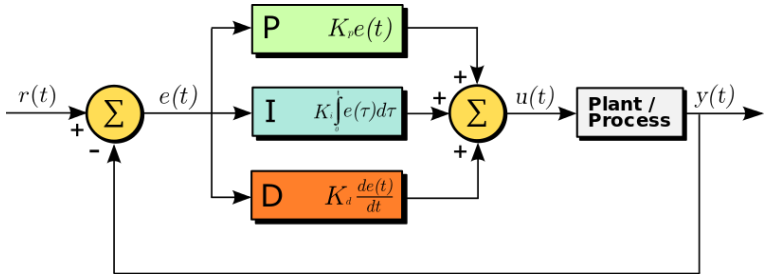




Control

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.





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

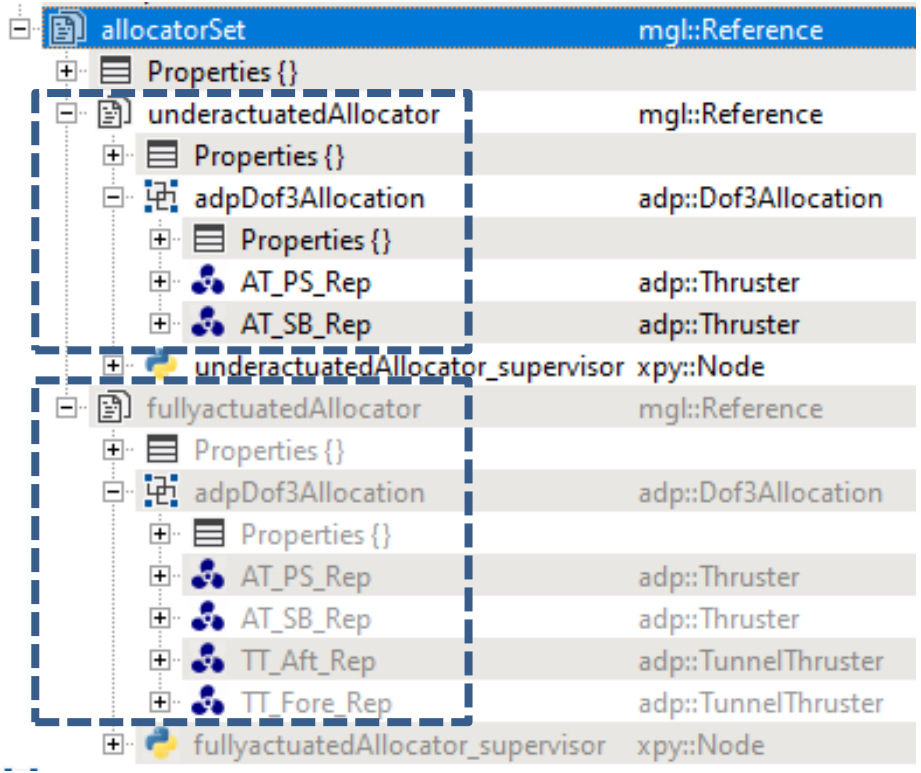
$$\sum_i F_x^{(i)} = F_x^{(req)}, \sum_i F_y^{(i)} = F_y^{(req)}, \sum_i M_z^{(i)} = M_z^{(req)}$$

under-actuated

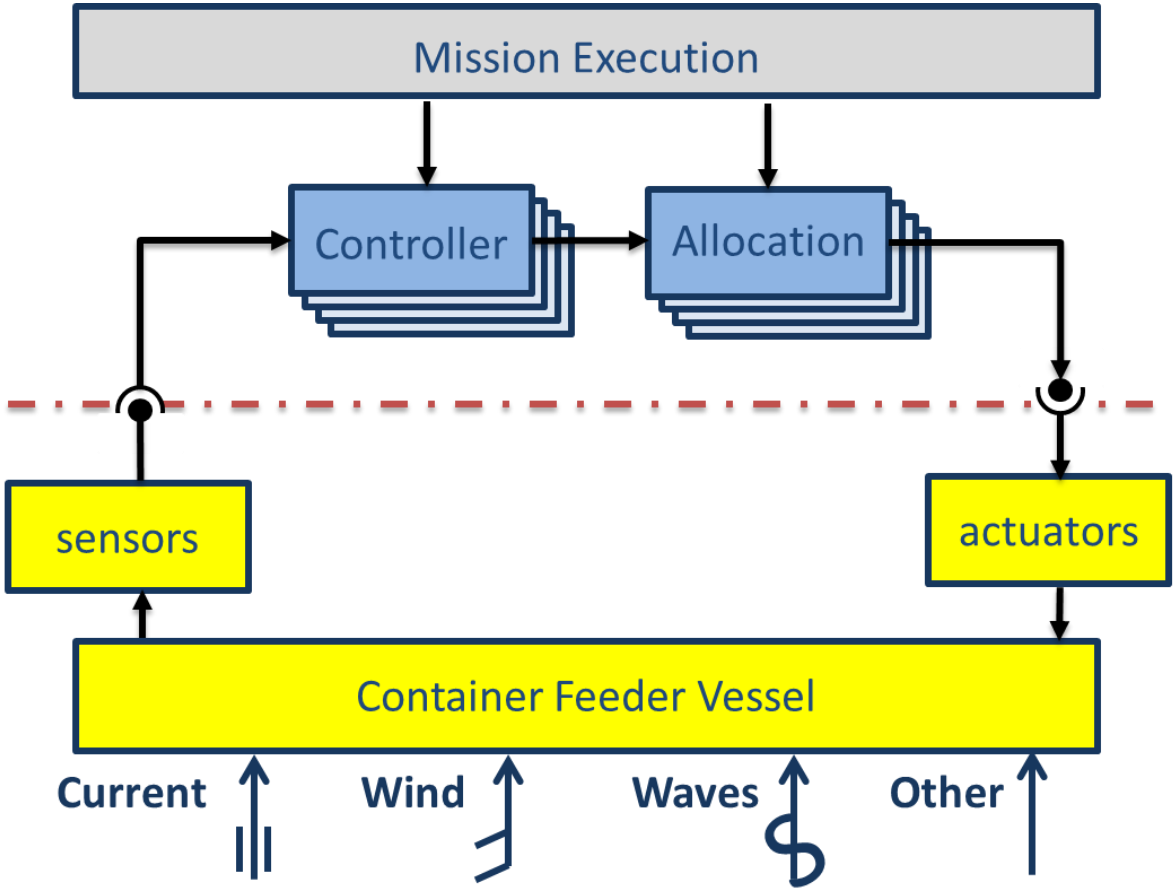
- azimuthing thrusters only

fully actuated

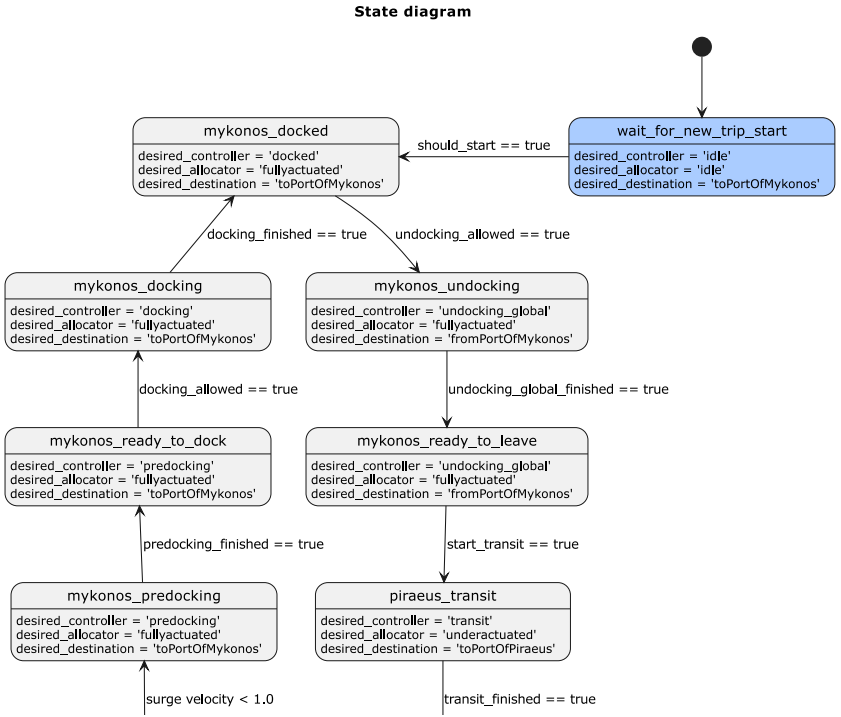
- azimuthing and tunnel thrusters



Simulations - framework



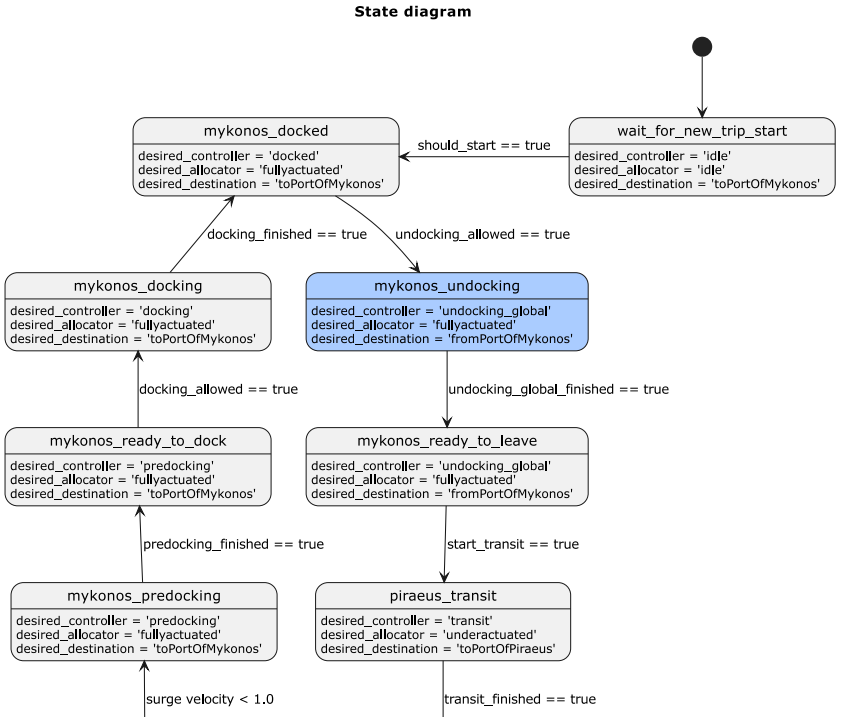
Simulation - idle



start up:

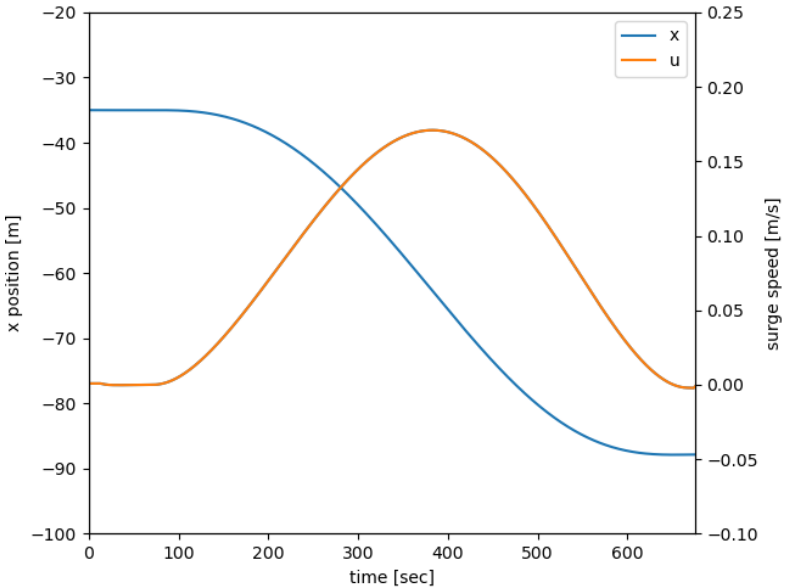
- no control
- no actuators
- harbour environment

Simulation - undocking

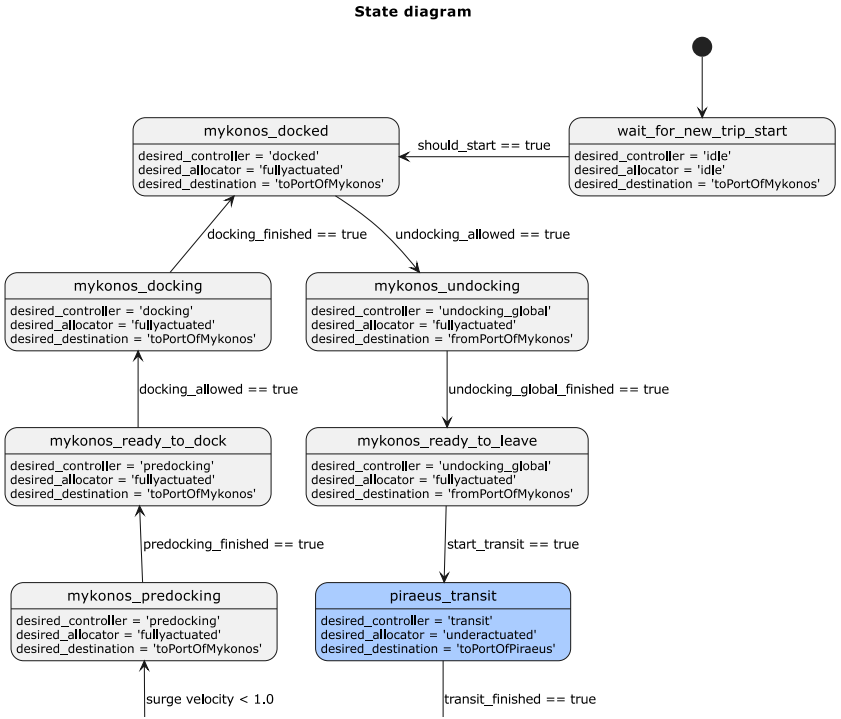


undocking:

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

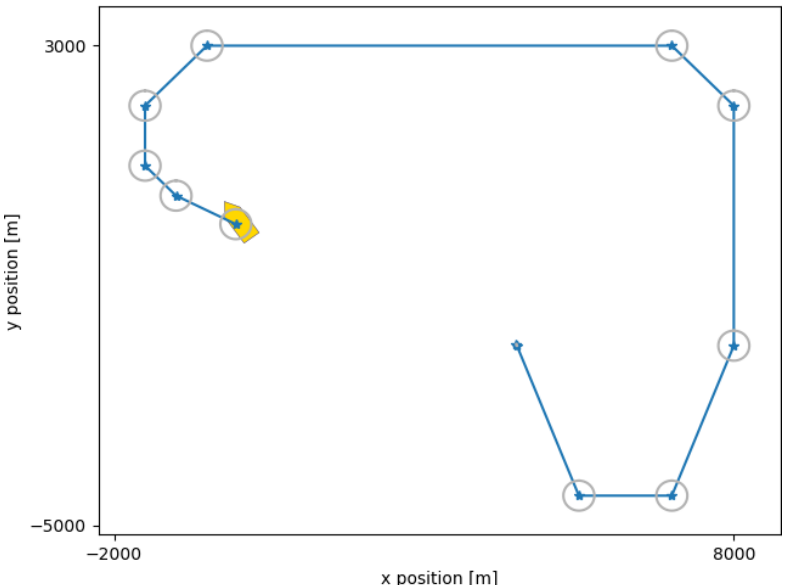


Simulation - transit

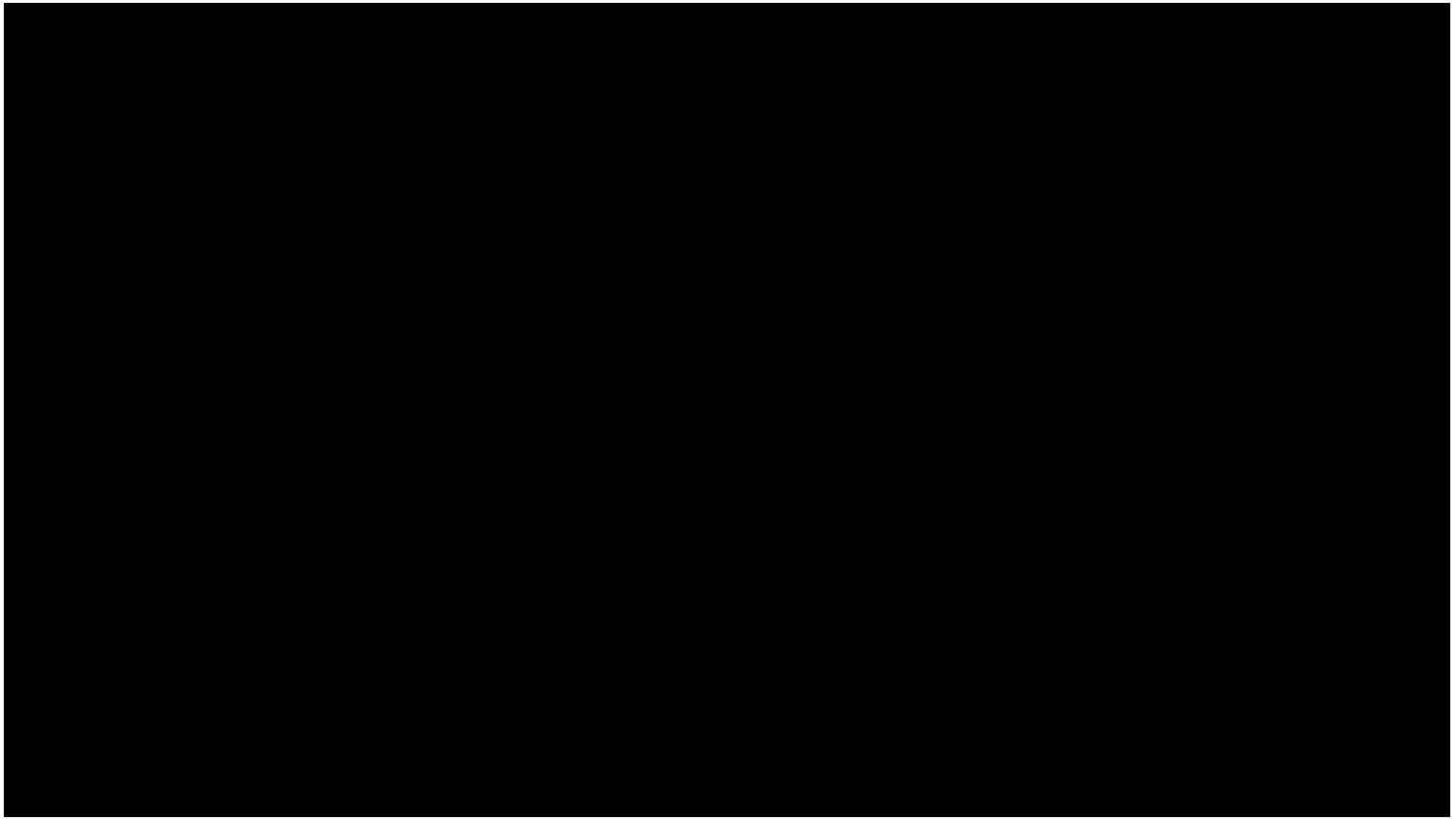


transit:

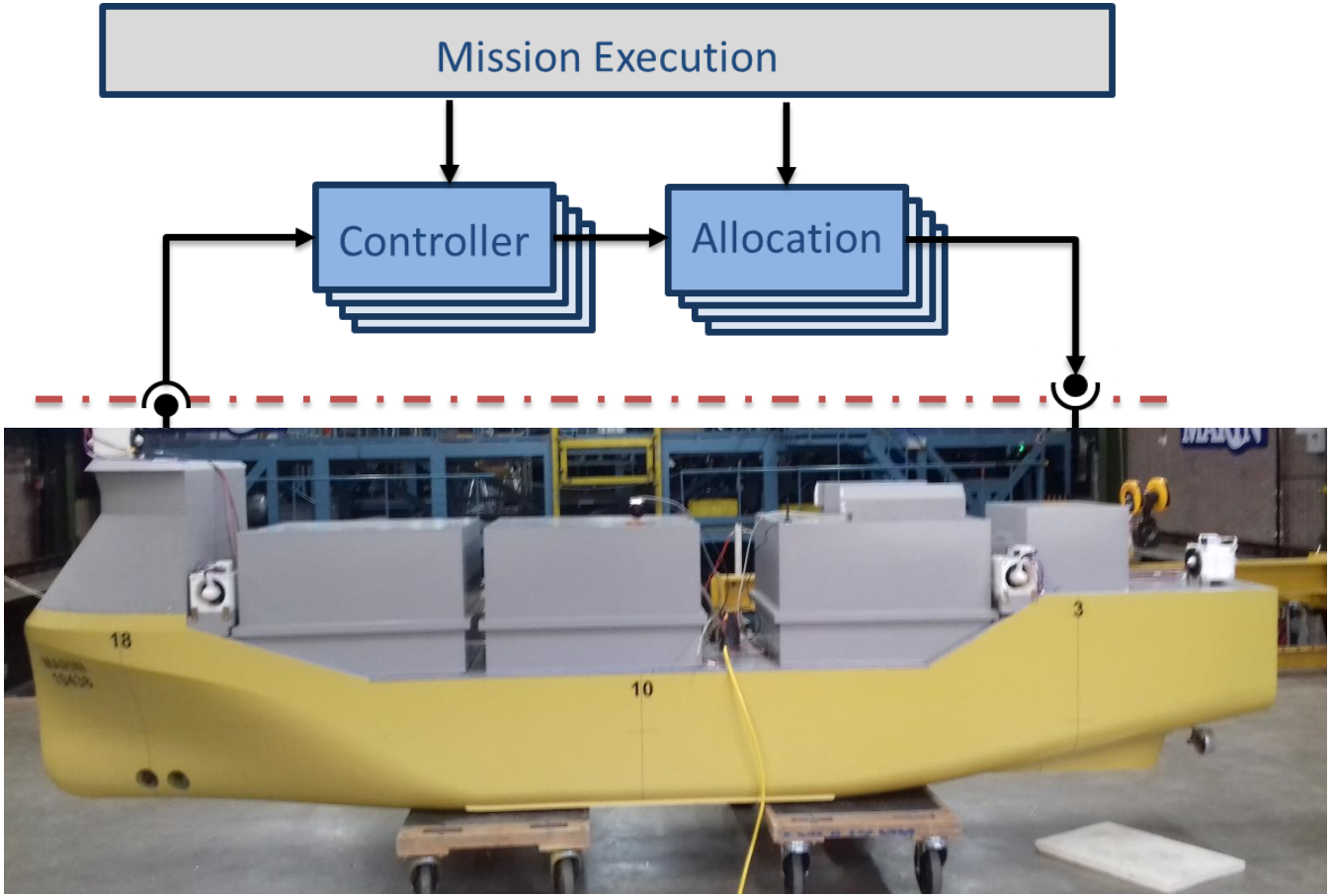
- DP control → autopilot
- fully actuated → under actuated
- pose → waypoints
- harbour → open water



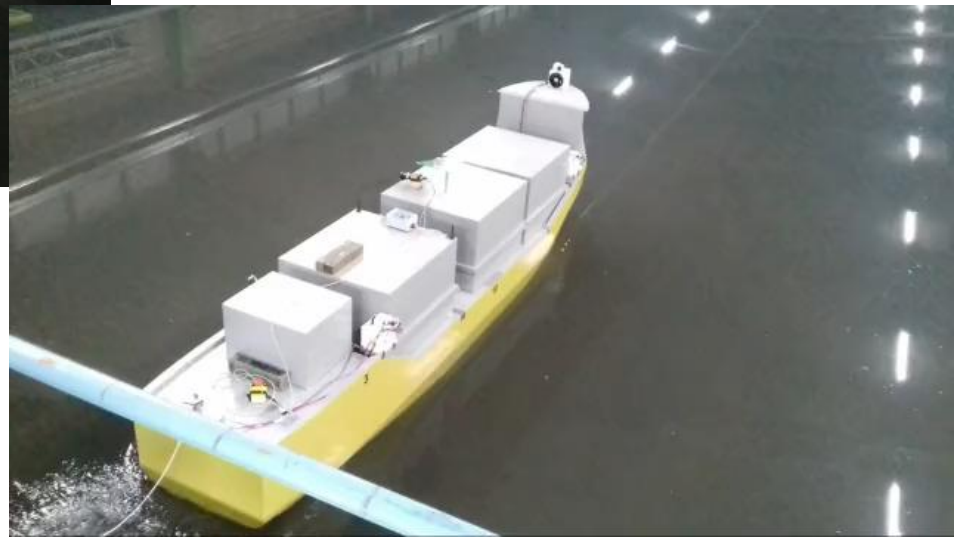
Simulation - results



Experiments - changes



Experiments - validation



Summary

- 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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