Agent-based Simulation of Airborne Offshore Wind Farm Logistics as a System of Systems

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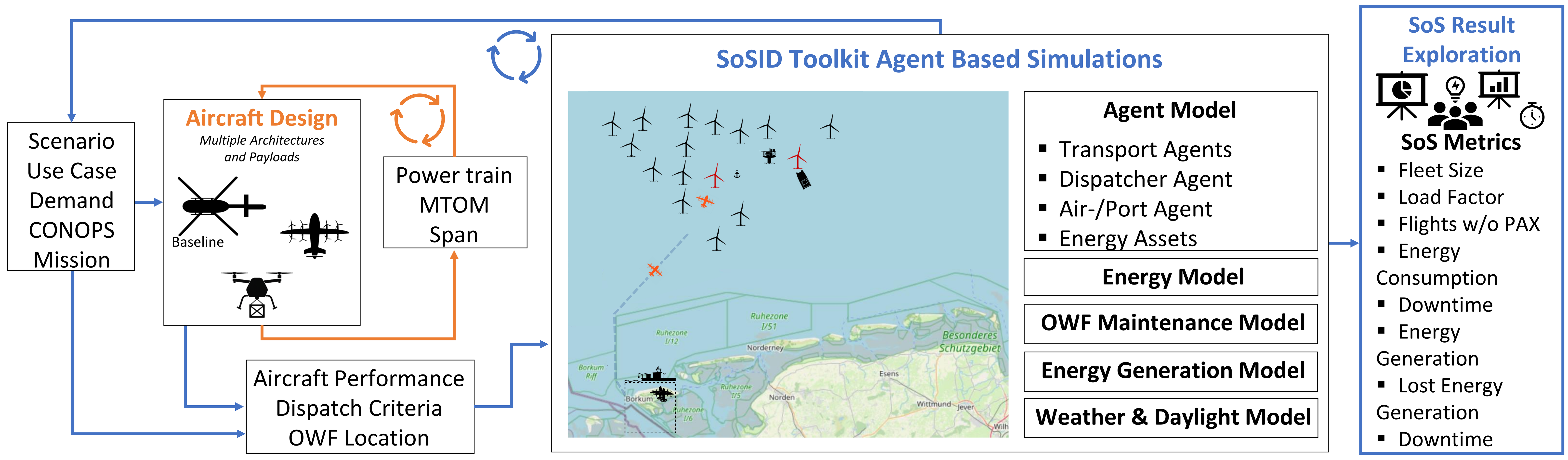


Figure 1: System of Systems Simulation Framework for Offshore Wind Farm Logistic Aircraft Design Using the System of Systems Inverse Design (SoSID) Toolkit

Airborne Offshore Logistics

Offshore wind farms (OWFs) are a key pillar of the energy transition, providing low-emission electricity worldwide. In the EU, the current 20 GW of installed capacity is targeted to triple by 2030 [1]. To maintain the growing number of wind farms with turbines of varying ages quickly, reliably, and with less dependence on sea conditions, and to respond swiftly to medical emergencies, helicopters are used alongside ships [2,3]. They hoist maintenance personnel and equipment directly onto the nacelle, eliminating in most cases the time-consuming transfer from crew transfer vessels (CTVs) and the internal climb within the turbine.

Figure 2: Hoisting Maneuver [4]

IAM for Wind Energy

Innovative air mobility vehicles already support inspections and serve as airborne cranes for maintenance work. With increasing range and payload of uncrewed, VTOL-capable systems with low emissions, new opportunities arise for OWF logistics. Operations traditionally performed by helicopters or CTVs can be flexibly supplemented when equipment is needed at short notice. Delivering items with Uncrewed Aerial Vehicles (UAVs) while transporting personnel by CTV could increase maintenance time and reduce turbine downtime [5]. Some aspects have been demonstrated in research projects and initial offshore operations, however the evaluation remains challenging due to operational constraints and aircraft limitations in the maritime environment.

System of Systems Approach

Given this complex situation, a system of systems (SoS) approach is appropriate, allowing the identified systems and their connections to be represented through agent-based modelling. Using the **DLR SoSID Toolkit**, simulations can be conducted to evaluate aircraft designs under varying operational conditions [6,7]. The following models were developed for this purpose:

- **Weather & Daylight Model:** Wind speeds/direction and significant wave height from NORA3 [8], sunrise and sunset times
- **Energy Generation Model:** Input of wind turbine data as a power curve, calculation using wind speed at hub height

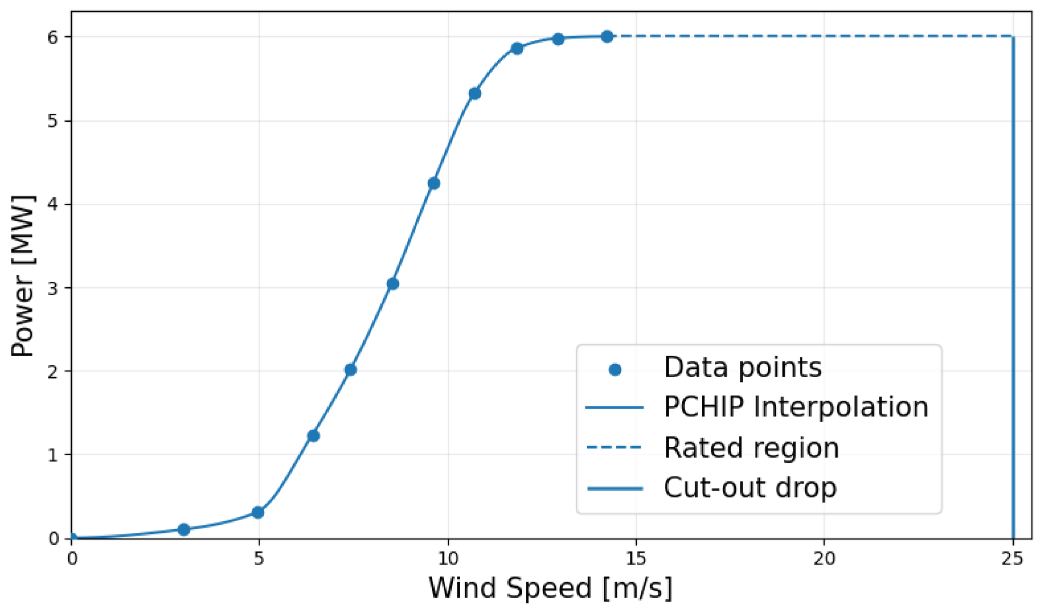


Figure 4: Exemplary Wind Turbine Power Curve

- **Maintenance Model:** Definition of maintenance cases with personnel and equipment requirements with forced or stochastic triggering

In order to approximate the energy requirements of the vehicles used, changes were also made to the existing **Energy Model**:

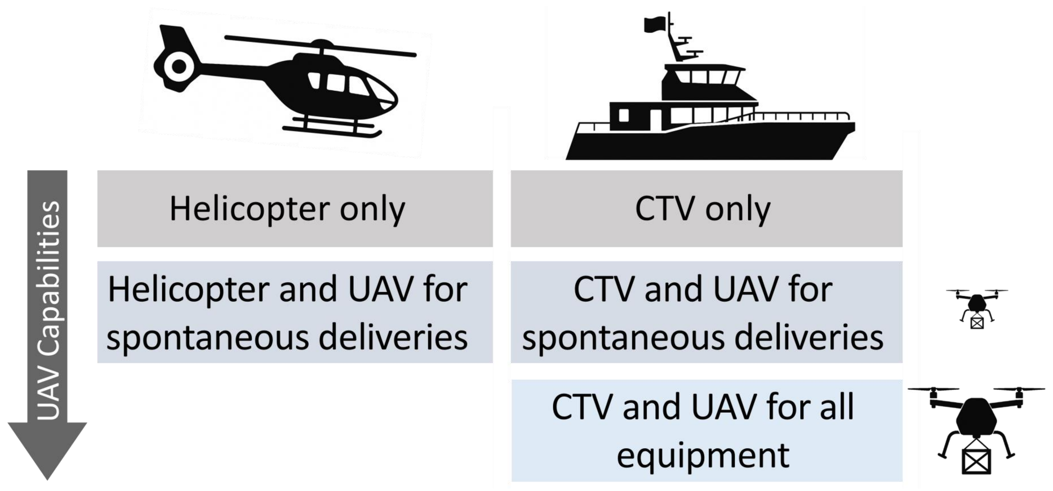
- Accounting for wind speeds for aircraft
- Performance model for ships factoring in wave heights

Simulation Parameters

Alongside UAV design, the fleet size represents a major influencing factor. Further important simulation parameters include the season, the distance to the mainland, and the scope and equipment needs of the maintenance activities.

Dispatching and Scheduling

Five operational strategies were identified:



All strategies are subject to specific boundary conditions, with daylight being particularly important, as personnel may only be transferred to or from installations during sunlight. UAVs are generally not allowed to fly at night.

Initial Results

First results demonstrate the potential of drones and the relevance of further in-depth investigations on uncrewed aerial logistics.

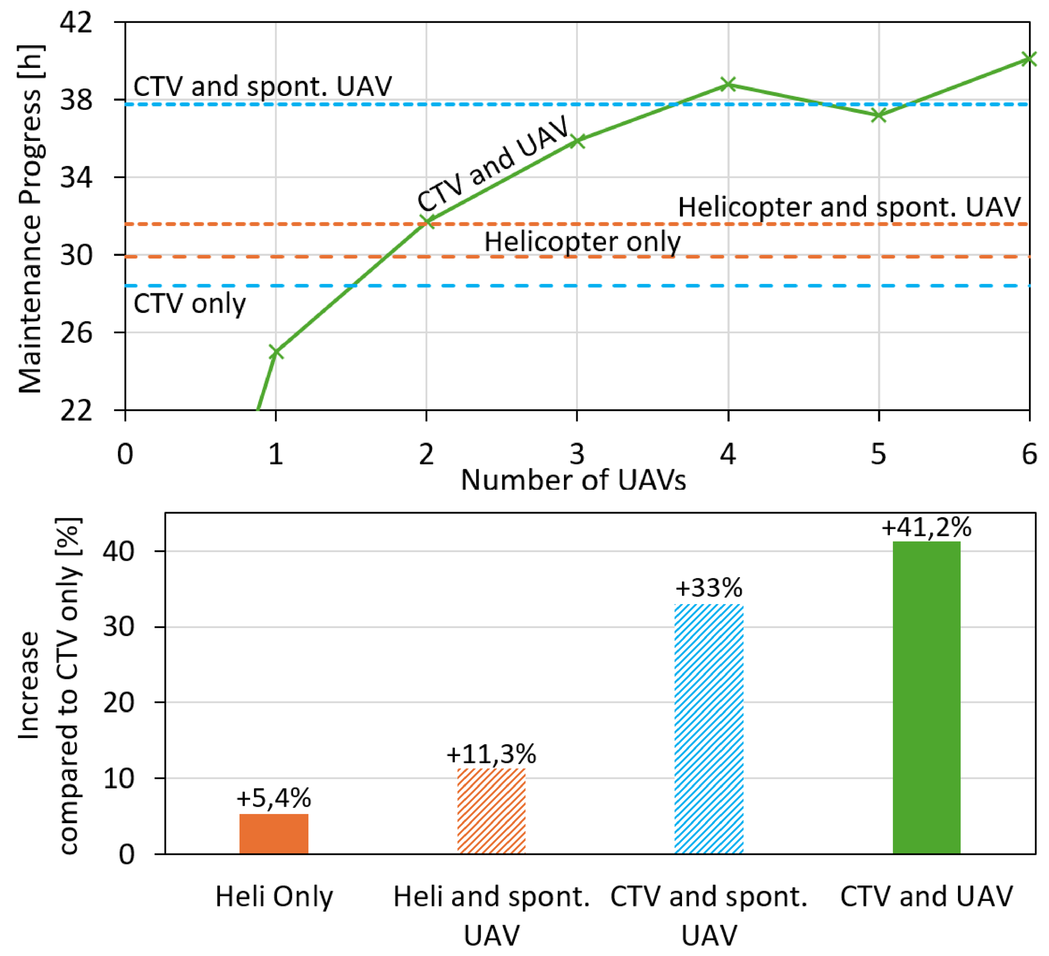


Figure 5: Initial Simulation Results for a First Test Case

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