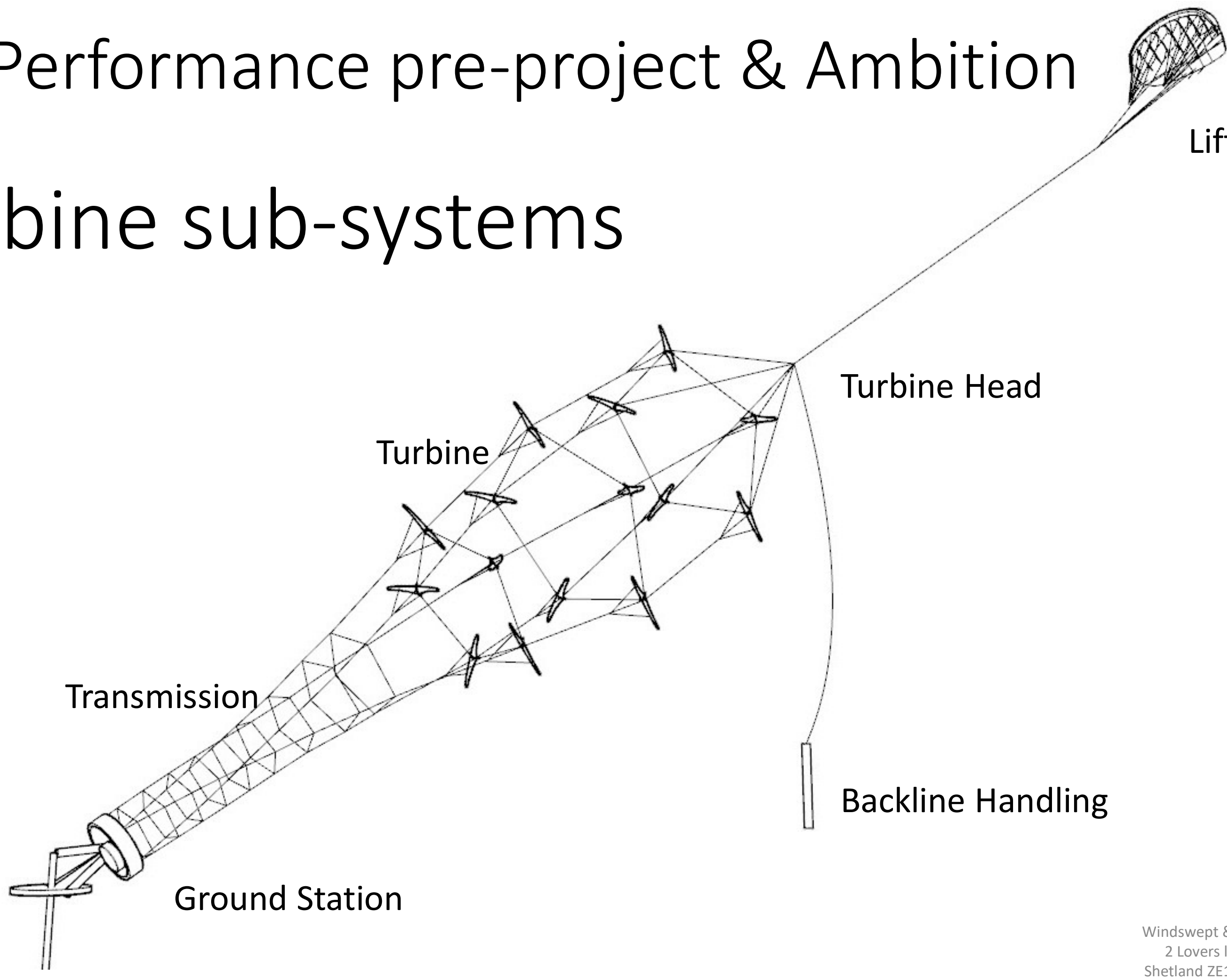
Baseline Performance pre-project & Ambition

Kite Turbine sub-systems



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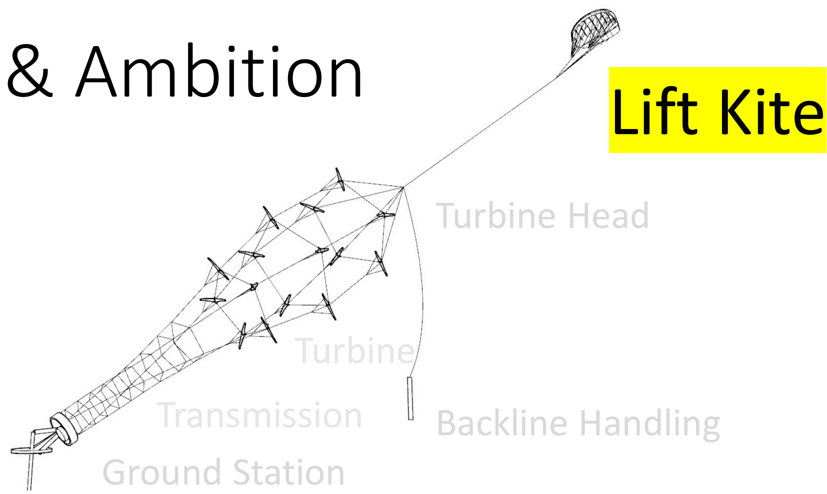

Initial State - TRL 3 Some basic concept prototypes and models have had an initial field trial Others are still only conceptual. Analogous products exist elsewhere in AWES.

Target State -TRL 5 prototype proven to work reliably in real world.

The Lift Kite was always hand launched and landed. - Automating this functionality is a key part of the project.

The kite was mostly a mechanically autonomous KAP lift foil. - Flight controls will be added to the lift kite.

Short tests of battery powered RC servo bridle winding steering systems had run successfully.

- An improved kite steering system will be developed with a flight controller, onboard charging, communications, rtk GPS and novel steering.

The steering ran on basic IMU sensing with bluetooth control - Steering algorithms will be enhanced with field wifi and operational mode awareness for reliability and safety.

Steering was occasionally set to the prevailing wind with twin anchor lines to steering bridles - Full azimuth operation and bank angle control will enable operation throughout the wind window in changing wind conditions.

Concepts with 3 lines from the turbine head have been dismissed as too hard to re-gather, balance and maintain electrically

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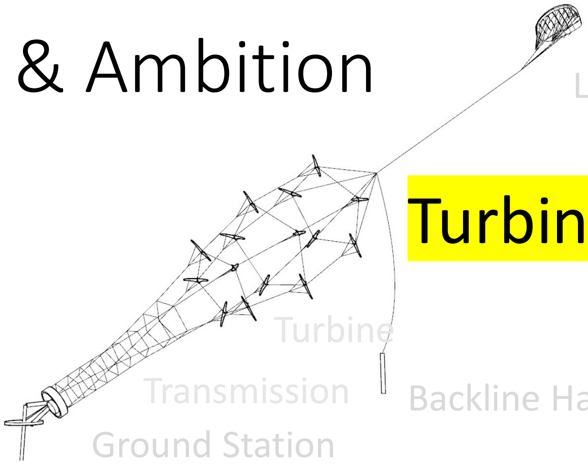

Initial State TRL 3

The turbine head has been constructed from adapted skate wheel and axle configurations. No smarts included.

The system has run both ways - with simple through axles holding the turbine tip whilst the rim held the top lift line steady and with the turbine on the rim and the axle steadied by the lift and backline. This second configuration is preferred.

No attitude, speed, power, monitoring, communications, control or autonomous connection functional

Target State TRL 5

The new turbine head will be capable of communicating rtk gps position and line tension data to aid ground station alignment and backline handling. The turbine head will be able to be attached and detached from the lift-line/ back-line whilst in the launch and land stages and positioned in the head of the backline handling bot. Power will be battery sourced for this project but will develop to backline power or sourced from the thrust bearing.

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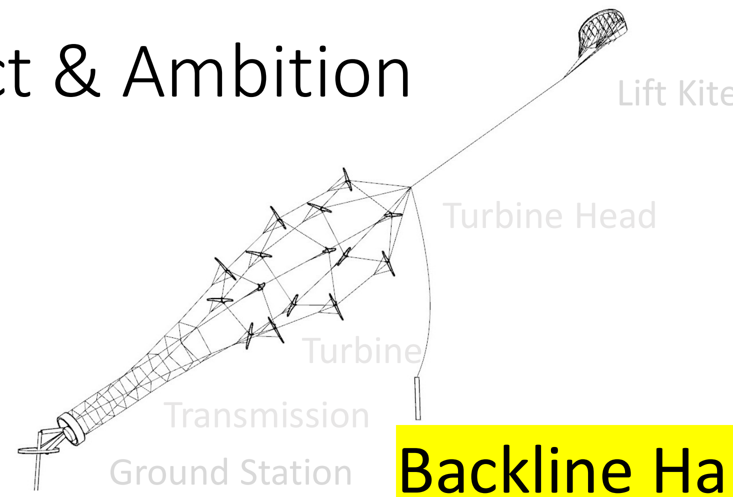
Initial State TRL 3

The Backline Handling has been limited to manual handling with occasional use of twin lines from the ground to the turbine head & lift line connection point - to limit azimuth drift under an unsteady lifter.
A straight line ground "horsetrack" backline anchor system has been trialled
The backline has been tested with bungee to remove the potential for slack to wrap around in the case of torque transfer to the lift line.
The backline has been manually tested for turbine stalling



Backline Handling

Target State TRL 5

Automating the roles of the human field operator poses challenges. The backline has several main roles.
1) To maintain vertical tension at the head which limits the lifted height of the turbine. 2) To pull the turbine head around the field for alignment, stalled launch and land. 3) To connect and disconnect the turbine head to the backline. 4) To provide an emergency anchored backline for preventing breakaway in case of full transmission failure.

The solution has to be able to move in the area around the ground station perimeter. The device requires accurate positioning, coordinated with data on the position of the lifter, turbine head and ground station. The device is required to launch and recover the lift kite and turbine system repeatedly. The device will have to control backline payout length and a positive working backline tension. The device will control turbine-head connection state and effective location. The device should be able to maintain an anchored ground connection. The mechanisms will demonstrate functionality with oversight and an ability to adopt fuller automation.

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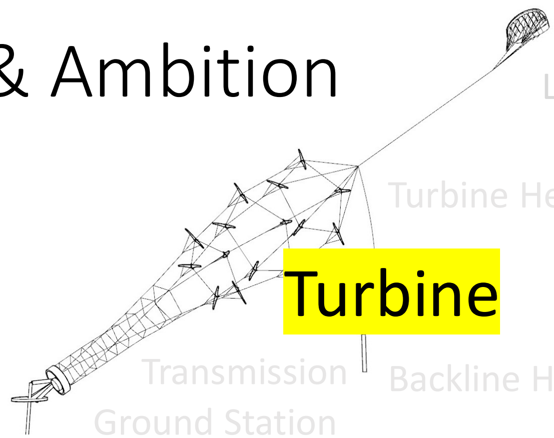


Initial State TRL 4

Our early turbines mostly exploited the cheap and easy fix nature of ram air kites attached to varied forms of ring support system.

A shift in design to rigidised foam profile wings resulted in the best AWES Power/Weight test efficiency to date.

A first description of the turbine system performance was achieved through collaboration with University of Strathclyde.

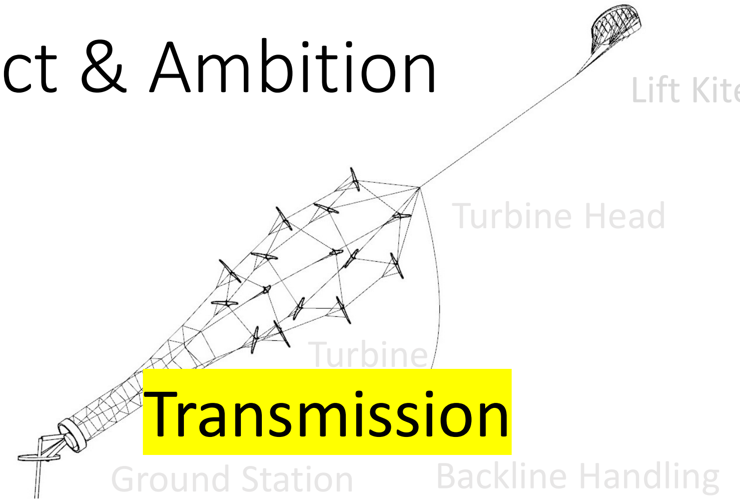
Target State TRL 6

The new turbine will be modularly constructed in order to test network layer scaling performance. Turbine layers will be able to be flown alone or stacked together. The expected mechanical power of 3 stacked rotors after transmission is 10kW in 11m/s wind at 30deg elevation.

Each blade fuselage and rod connection will be more interlocked than previous models to maintain blade bank angle relative to the rotation plane on launch. A more solid connection also suits the less temporary portable nature of a 10kW system.

Data on rotor attitude and rotary position should be transmitted to the field communication system at ~1kHz. A single sensor system set to the centre of the rotor should suffice.

Baseline Performance pre-project & Ambition



Initial State TRL 4

Several variations of transmission have been tested and characterised at W&I.

The unique dynamic properties of Tensile Rotary Power Transmission were described in Oliver Tulloch's PhD.

W&I have prefer the more dynamic ring to ring TRPT in preference to rod to rod style TRPT due to the handling and efficiency benefits

Target State TRL 6

The new transmission will be modularly constructed in order to test length vs altitude variation performance.

Each polygon ring will be formed from bar section carbon fibre bonded into the nodes.
Transmission line tabs will also be bonded into the nodes.

The transmission will not use a centre line nor retracting lines.

Data on certain transmission rings attitude and rotary position may be transmitted to the field communication system at ~1kHz. A single sensor system set to the centre of the ring should suffice.

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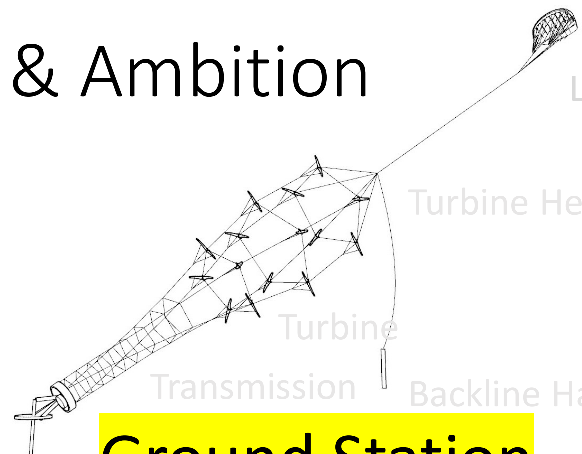

Initial State TRL 3

The Ground Stations have had passive azimuth alignment with elevation tracking predominantly being set pre-flight, manually.

The generation system used torque control mode over FOC on 500W rated BLDC motors. Control came from a basic human interface combined in an algorithm with data from anemometer, onboard tension sensing and the speed controller

Target State TRL 5

The ground station will have positional data from Lifter, turbine head, transmission and backline handler. This will allow the ground station to assess transmission compression levels to be used in governing an optimal regen controller.
The new ground station will actively align the PTO axis with the airborne turbine head relative Az & El position.
The ground station will monitor line tension on each transmission line in order to recognise transmission condition and efficiency.
The ground station will monitor the base plate anchor – ground height to ensure anchoring is maintained.
The ground station will monitor wind condition to ensure appropriate generation state.