# Title

Optimized Additive Manufacturing for Vertical-Axis Wind Turbines

# Summary

We propose creating a method for developing efficient vertical-axis wind turbines using genetic algorithms and additive manufacturing.

# Classified

* No

# Description

We propose a system for using genetic algorithms and additive manufacturing to create efficient wind turbines for electricity generation on a small footprint. This project would leverage our existing additive manufacturing techniques and advanced simulation capabilities to contribute to a problem of global importance.

Windmills have been used since at least Ancient Greece to capture the wind and put the energy in that wind to productive work. Especially over the last 20 years, windfarms, fields of windmills, have been built to produce electricity and decrease reliance on fossil fuels. However, modern windmills are typically spun on an axis parallel to the airflow. To increase power generation, larger blades are used. However, larger blades demand larger height to ensure sufficient clearance vis-á-vis the ground as the mill spins.

It is also possible to construct a windmill on a vertical axis, where the axis of rotation is perpendicular to the ground, and therefore the airflow. This is similar to the anemometers seen atop weathervanes. Vertical-axis turbines require a smaller footprint for energy generation, allowing denser placement of windmills and makes feasible smaller installations overall. However, like all built systems, the design of a vertical-axis windmill is limited to what we can construct.

Additive manufacturing gives us an edge in creating. Commonly called 3D printing, additive manufacturing been shown for creating objects and constructs not possible through traditional manufacturing techniques. These objects can have unique and nearly arbitrary shape, design, and are typically light-weight while maintaining strength. Applying this technology to windmill manufacturing will allow us to create a windmill not possible except via the 3D printer.

The final part of this project's puzzle is the use of genetic algorithms to create the windmill design. Genetic algorithms start with a collection of potential solutions to a problem, test them each, and take the top handful as "winners." The criteria for testing may be speed, size, or some other metric at the researcher's discretion. The winners are then randomly recombined with each other to create a new generation of potential solutions. The process repeats. After many generations, optimized solutions are found, similar to the evolutionary processes seen life.

We will use genetic algorithms to test a sample of potential vertical-axis windmill designs. Rather than manufacturing each, we can simulate their performance using fluid-dynamics and modeling airflow to estimate efficiency. The top performers will be randomly recombined with each other and the new generation evaluated. Once one-or-more potential final solutions are found, they can be 3D printed and tested under real-world circumstances.

This project has the ability to be a game changer at both the micro- and macro-levels. At the micro-level, small and efficient power generation systems can be used by our sponsors when deploying mobile units. These units, when relying on tradition fossil fuel-based power generation systems, increase risk with supply-chain management and risks associated with managing flammable and explosive consumables. Small footprint deployable wind systems are unlikely to completely supplant fossil fuel-based generation, but can reduce dependence and increase flexibility on the front lines. This scenario can play out in both military and disaster response contexts.

At the macro-level, we can contribute a solution to resolving the existential risks associated with global climate change. Small footprint windmills are installable in areas where traditional horizontal-axis windmills could never fit, including footprints as small as townhome roofs. Advancing the state of the art in power generation will not, along solve the climate change problem, but can be a piece of a larger solution adoptable globally.

# Potential for Impact

This project can impact at both the micro- and macro-levels. At the micro-level, small and efficient power generation systems can be used by our sponsors when deploying mobile units to the field. At the macro-level, we can contribute a solution to resolving the existential risks associated with global climate change.

# Novelty of Your Idea

This proposal is novel in its complexity space. Genetic algorithms have been used to create optimized products before and additive manufacturing has been used to create unusual products before. In 2013, Preen and Bull[1] attempted something similar, but only used five generations because each model was actually printed. Our decision to use simulation to evaluate fitness gives us more flexibility to test more options and allow for more evolution steps, on the order of thousands.

1. https://link.springer.com/article/10.1007/s12065-014-0116-4

# Significant Technical Challenge

There is a significant technical challenge in creating the model used to to evaluate the fitness of each design as created. As noted in the Description, we may evaluate fitness based on several different criteria, but selecting evaluation criteria is challenging, as different criteria lead to different outcomes. The overall challenge is to select a balanced approach that leads to an efficient, lightweight, inexpensive solution that still meets the power output requirements.

# Collaboration

This project will draw on …

# Technical Soundness of Approach

Preen and Bull demonstrated the technical soundness of the overall process. For us, the radical departure is the airflow simulation study and this is an area where APL has significant background due to our work in aerospace engineering. Accordingly, we believe our approach is both feasible and likely to succeed.

# Consistency with APL's Mission

This project aligns with the APL VSE's by focusing on solving national and sponsor problems. Specifically, this project aligns with VSE strategy focus areas 5("Contribute strategically to national issues…") and 7 ("Become a model organization for innovation…"). Our proposal expands an innovative approach for creating vertical-axis wind turbines using advanced computing technologies for modeling and simulation that APL is known for.

This project will provide two critical benefits for APL. First, we can push the edge of what can be produced using additive manufacturing. While useful for one-off part creation and prototyping, we can demonstrate our ability to use advanced methods for creating the initial designs to print. Second, we will be able to reach into and establish credibility in a new field, energy, using our core strengths of modeling and simulation to show our abilities in the field.

# Team Lead (optional)

* James Howard, ITSD

# Collaborators (optional)

* Bill Woodcock, REDD

# Technical Categories

* Electro-mechanical
* Electrical and electronics engineering
* Modeling and simulation

# Other Categories:

* N/A

# Budget requested (up to $50k)

* $50,000