WARP™ Solar/Wind Power: Green, User-Friendly & Cost Effective for the New Millennium International Power Markets

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ABSTRACT

The Wind Amplified Rotor Platform (WARP™) system is a highly effective and versatile modular wind amplifier power design. WARP is intended to enhance use of proven wind turbines, albeit with lower risk and more reliability, using much simpler, smaller size and lower cost turbines. Hence, WARP systems can be easily packaged to any power size by virtue of its modular amplifier building blocks. Plus, WARP can operate integrally and synergistically in baseload fashion with fossil fired power plants like gas turbines, micro-turbines and diesels while reducing fuel consumption - hence pollutants - by over 50% to 70%. In other words, this renewable power technology is *not* intended as an "us (renewable) versus them (fossil)" power system; rather it is a complementary technology with excellent economy and environmentally 'green' characteristics to serve a variety of markets.

Having spent over $1.5 million, a convincing technology knowledge base has been prepared through research and development with Rensselaer Polytechnic Institute (RPI) under New York State Energy Research (NYSERDA) support. Also, independently sponsored research has been conducted overseas, including CFD analyses at the Technical University, Graz, Austria and recently initiated wind tunnel tests in Denmark. These have corroborated results generated by RPI scale model wind tunnel test. A pre-prototype test unit was built and operated, and yielded significant data, though limited due to a force majeure 100 year storm. Also prepared were preliminary application systems engineering designs and analyses, and detailed independent cost estimations and application cost-of-energy calculations. The latter included use of the EPRI TAG method for a US DOE proposal submitted by Raytheon that projected cost of energy (COE) in the $.02 to $.04/kWh range. Due to recent research findings and patented design improvements, WARP COE is projected lower yet.

WARP technology is now either under licensing discussions, negotiations and/or commitment in various fields-of-use and geographic locations around the world.

WARP SYSTEM DESCRIPTION

WARP is being recognized as a breakthrough in wind power technology which can synergistically circumvent a myriad of drawbacks of today's conventional large bladed windmills and of fossil fuel power plants (Ref. 1-5).

The WARP system configuration, consisting of stacked amplifier modules on a core tower (Ref. 6-11), differs dramatically from the traditional single, large-diameter horizontal-axis windmill rotor mounted on a tower. Yet this globally patented wind power design employs the latest technology developments of today's conventional high-efficiency horizontal-axis wind turbines (HAWT) without their inherent large rotor and gearbox risks. Unlike conventional wind turbines, which stress ever larger diameter rotors for increased energy capture, a WARP system, using an aerodynamic windframe building-block technology, focuses on wind speed amplification and multi-tasking use of its aerodynamic toroidal structure.

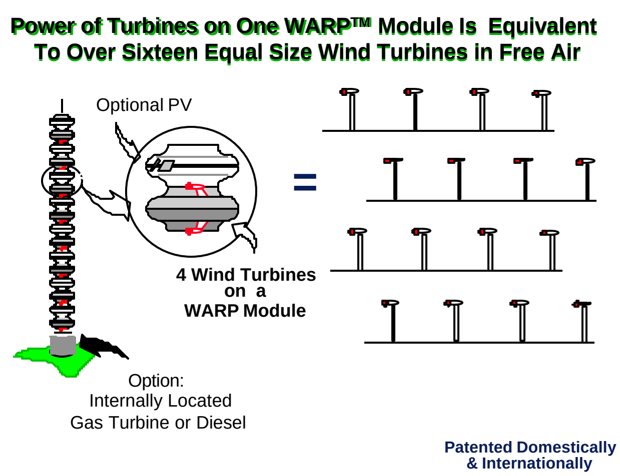

Fig. 1 WARP Wind Power System Performance

WARP wind amplifiers both boost turbine performance plus provide other functional and structural benefits such as passive yawing to face turbines into the wind and strengthening the core tower via ring stiffening with the alternating static modules. WARP is also an “open” system, meaning it can use any type of wind turbine.

WARP Performance

A WARP uses a multiplicity of robust small diameter, high power wind turbines on many identical vertically integrated, multi-use wind amplifier modules. The amplifier modules speed up the wind well over 50% to 80% (VAF=1.5-1.8) averaged over a rotor, depending on module configuration and stacking aspect ratio (Ref. 11). Typically standard wind turbines 1 to 3 meter in diameter (d) (i.e.; aircraft propeller-size) are used. For example, ***the impact of only a 65% wind speed-up with WARPs is 450% more power and energy due to the cubic effect of wind speed on power output***. This is enhanced by WARP system height which accesses higher winds aloft and by gearless direct drive and shrouded turbines. WARP capture area can thus be less than for comparable power conventional windmills.

10kW to 50 kW per WARP rotor may be generated (depending on site wind and module height) by small WARP turbines at rated wind speed. Turbines are now a commodity, not a complex and costly foci as giant rotor-heads are on conventional wind turbines. ***WARP power capacity from kilowatt levels to multi- megawatts can now be tailored easily without the need for expensive rotor re-design and re-tooling***, as with single large rotor-head windmills. Instead, multiple WARP modules, each having common rotors which direct-drive common stock generators of specified capacity, are stack arrayed on a common tower to achieve desired system power capacity.

Fortuitously also, ***optimum WARP rotor rpm just matches generator speed eliminating needs for gearboxes***. Each WARP amplifier module also serves as support for the wind turbines, as yaw means and as protective housing for core support tower and other internal sub-systems.

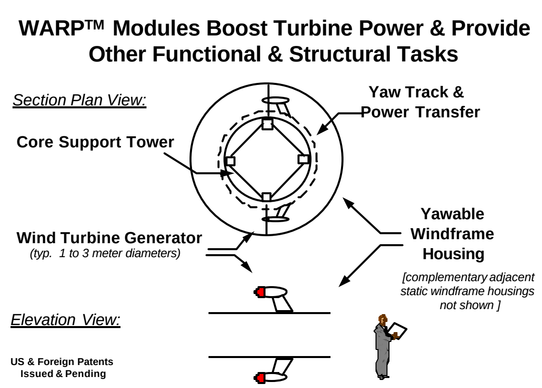

Fig. 2 WARP Modules Provide Multiple Duties

WARP Solar & Fossil Incorporation Options

A "smart” WARP tower configuration can also uniquely and economically add ~10% more power with photovoltaic cells (PV) using common WARP structure. Thereby both wind and solar energy are convertible. Since over 50% of conventional PV system cost normally resides in structural support, piggybacking PV cells on common WARP system structure makes PV thereon much more cost effective. When PV cells are embedded on WARP amplifier panels, very economic capture of both wind and sun can exist.

More important is that a ***WARP can synergistically co-locate within it relatively clean burning state-of-the-art high efficiency fossil fuel power plants such as gas turbines, micro-turbines or gas diesels***. By operating such fossil units in conjunction with a WARP wind system, about 50% to 70% in fuel savings can be realized with comparable reduction in pollution. This permits effectively ‘green’ baseload power generation in stand-alone manner.

Substantial fuel savings have been demonstrated in the past using rudimentary arrangements of conventional wind turbines and diesel sets. Even in small grid systems, where degree of wind capacity penetration has been a limiting factor, over 40% fuel savings are shown possible (Ref. 12). With availability of new electronic controllers for wind-diesel systems, major wind penetration as percent of a micro-grid is no longer projected to be a problem (Ref. 13).

WARP Mass Production & Customization

WARPs’ simple and relatively small sub-components are well suited for low cost volume production, plus ease of transportation, erection and servicing. Therefore, WARP system cost and/or cost of energy have been determined to be attractively low and competitive (Ref. 6, 14).

Mass production has long been recognized as an effective means of reducing a product’s unit cost (Ref. 14). It has enabled manufacturing companies around the world to produce high-quality products that leverage the economies of scale based on division of labor and automated, standardized components and processes. The principle drivers are the learning curve and the bulk purchasing power afforded by large quantity of identical components.

The modular WARP systems design is ideally suited to provide standardized sub-components and modular repetitive sub-assemblies for mass production and procurement benefits. Capturing the efficiencies of mass customized WARP wind power plant design is an approach that stems from years and well over $1 million in R&D by

ENECO with Rensselaer Polytechnic Institute and the New York State Energy Research & Development Authority (NYSERDA). Noteworthy is that a ***single shape panel can form the entire exterior structure of a WARP system***, hence, a large portion of the system. Along with repetitive tower and turbine sub-assemblies this clearly lends itself to mass production economy of scale.

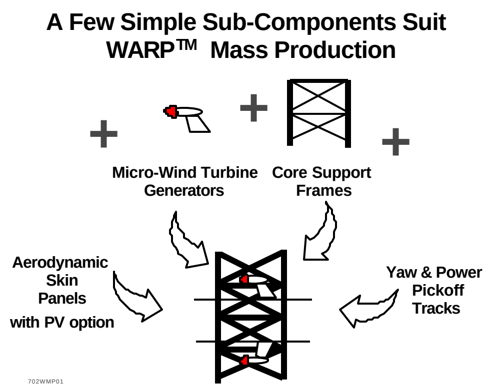

Figure 3. WARP is Readily Volume Produced

WARP ENVIRONMENTAL BENEFITS

WARP environmental benefits are obviously significant when compared to traditional fossil fired power plants. However, WARPs also have improved features relative to traditional large rotor windmills. Despite their non-airpolluting energy generation, today's typical large bladed windmills have some other nagging environmental concerns and safety risks and liabilities. These include large unsightly land sprawl, bird kill, noise, blade safety, potential effluent of hydraulics or gearbox transmission fluid and telecommunication/TV interference due to the need for metallization on their large blades for lightning protection purpose. WARP systems virtually avoid all these problems. Some of the key environmental attributes are briefly discussed below. These and others are presented in more detail in Ref. 15.

Land Use Reduction:

A WARP wind farm needs about an order of magnitude less land for an equal quantity of energy generated by a conventional windmill wind farm. It also has a more attractive appearance. Land reduction comes from large energy capture capability per tall installed units and the smaller unit spacing needs as a result of shortened downstream flow perturbation from its small rotors. The ability to deploy WARP structures much taller than possible with conventional windmills is a paramount benefit. WARPs as tall as any HDTV tower can be readily built.

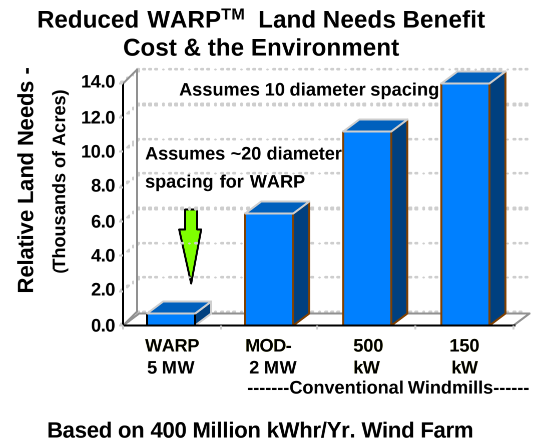

Fig. 4 WARP Reduces Land Requirements

Lower Noise & No EMI Interference:

Far field noise is calculated to be substantially lower from a WARP power plant due to much higher RPM and gearless operation of its wind turbines. High frequency noise is known to dissipate more rapidly with distance compared with low frequency noise emitted from large bladed turbines. Large rotor noise is due largely to blade-tower shadow interaction and gear noise. Also, many rotors on a WARP system will give highly uncorrelated source noise compared with the correlated noise of a single or a few large bladed windmills. This gives rise to better noise abatement characteristics.

Electro-magnetic (EMI) interference for TV and tele-communications will be avoided by WARP systems. This stems from WARP rotor blades avoiding the need for metalized content required by large bladed wind turbines for purposes of lightning protection. WARP lightening protection comes from tower apex lightning arrestors.

Bird Kill Avoidance:

Avian mortality (bird kill) is a major concern, especially to the Audobon Society which has highlighted this problem in the US as a result of the hundreds of birds of prey, including dozens of golden eagles, killed by large bladed windmills in California windfarms. This environmental problem is judged to be avoided with WARP systems because birds can easily discern building-type structures such as a WARP plus evade small high speed rotors.

Reduced Risk & Better Safety:

WARP wind turbines are highly reliable due to their relative simplicity and robustness. Absence of gearbox requirement by rotors directly driving mature product generators improves reliability. WARPs can also either partially or fully shield its rotors from adverse weather conditions and provide desirable blade containment means.

Shut-down of one WARP module due to a component failure will not jeopardize the rest of the system which can remain operational. A fail safe feature also exists because when a failure is initiated on any one wind turbine (e.g. bearing or generator seizure), the module assembly automatically yaws the turbines out of the wind and parks the module. Service personnel safety is enhanced due to convenient and protected interior access to all sub-components. This is particularly important when operating in hostile weather conditions. Operation under extreme icing is also safely afforded due to both rotor shielding and inherent self-sustaining tower anti-icing capabilities. This contrasts with perilous large rotor imbalance and ice shedding events possible with conventional windmills.

Effluent Absence

In the absence of gearboxes and other transmissions on WARPs, no anticipated harmful chemicals such as transmission or hydraulic fluids are present to be spilled.

Fuel Savings & Air Pollution Reduction:

Within a WARP one can synergistically *co-locate & co-generate* relatively clean burning state-of-the-art high efficiency fossil fuel power plants such as gas turbines, micro-turbines or gas diesels. By operating such fossil units in conjunction with a WARP wind power system for distributed baseload use, about 50% to 70% in fuel savings can be realized with comparable reduction in air pollution.

Dual-Duty Resource Conservation:

WARP has dual-use capability apart from power generation when employed, for example, as a wireless telecom tower, as a transmission tower, on a off-shore oil platform or in building penthouse function. Thereby it provides very attractive economics because a large portion of system structure cost is assignable to non-power host use.

All together, WARP systems are projected, therefore, to better meet or exceed the requirements of increasingly stringent environmental regulations relative to both solo fossil power plants and large, single rotor windmills.

WARP MARKETS, USE & COSTS

Major application markets and fields-of-use for WARP systems are available world-wide for the globally patented WARP technology. The European Union , like the US, is now in the process of deregulating energy services. The shift offers new opportunities to make money: Revenue in Europe's electricity and natural gas markets totals more than $270 billion a year, comparable to the US market. Each EU country presents a different opportunity for utilizing wind power. Clean and affordable, especially in the offshore with suitably economic technology, wind is the answer to the appalling growth of pollution in the EU.

Large markets are projected for electric utility integrated wind power. The American Wind Energy Association (AWEA) predicts 48,000 MW of new wind generating capacity globally by the year 2007 as reported in Power Engineering in June of 1998. The European Wind Energy Association (EWEA) has targeted 40,000 MW by the year 2010 and 100,000 MW by the year 2020. Denmark alone is targeting 50% of its energy from wind by 2030.

Although the Asian economic setback has slowed the demand for power, the pace for clean power development will continue there. According to the Aug. '97 Oil & Gas Journal, the Pacific Rim nations lead in clean power projects under active consideration with 121,000 MW, Europe with 40,000, Latin America with 40,000 and Africa and the Middle East with 26,000. India's power growth demand is predicted at 126% by 2010 (Lynton, 1997) and it has been a major growth market for wind power until recently. China has reported viable wind power potential of over 150,000 MW.

Major petroleum firms such as ENRON, BP and Shell have taken note of these market prospects. They have recently acquired or are now initiating acquisition of wind and solar energy technology in anticipation of profiting from this future market trend. In fact, Cor Herkstroeter, Chairman of Shell has stated that "in 50 years, Shell could be 50-50 oil and renewables". Related may be the requirement by the petroleum industry to decommission many hundreds of oil platforms at sea. 450 such platforms are slated for removal from the North Sea alone over the next 20 to 30 years at enormous cost. The prospect of extending their usefulness as wind power platforms could save the oil firms hundreds of millions of dollars. The Kyoto Conference on Global Warming and resulting protocols further stimulate the trend toward renewables of which wind is most cost competitive despite cited certain drawbacks of current windmills.

WARP application versatility and economy opens profitable and beneficial opportunities. WARP applications can range from traditional utility scale wind farms and distributed commercial or village power units, to highly cost effective dual-use applications such as wireless telecommunication towers, electric power transmission/distribution towers, high-rise building integrated WARP 'penthouse' units, and offshore petroleum industry platforms. Particularly attractive are autonomous floating offshore marine WARP power plants. These permit inclusion of water desalination as a concurrent option with power generation. (Drinking water is known as the next global resource in crises) Numerous other WARP niche applications are possible such as on navigational aids, agricultural silos, high mast lighting, remote environmental/forrest fire monitoring sations, etc. with very economic dual use (see Fig, 7)

Below are dipicted some key applications and associated cost estimates.

Grid-tied WARP Systems:

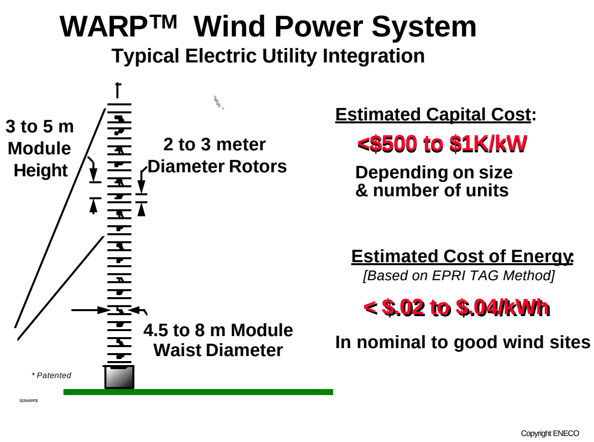

Fig. 5 Land Based WARP for Grid-tied Wind Farms

The WARP costs shown in the figures are based on US labor rates. Over 80% of WARP cost resides in general construction and component content because of the absence of complex, costly and sophisticated large rotor heads as on conventional windmills. Thus, when accounting for much lower labor cost in other countries where at least 50% to over 80% of WARP sub-systems can be readily fabricated and assembled for local deployment, the cost can drop dramatically. This can aid the local economy and local market access.

Sample Rated Performance Potential:
Assumes: ~2 m diameter turbines; d/D=0.42; H/d=1.66; VAF=1.7; Cp=0.34max/rotor; 0.14 wind shear; 10 m base

Site Mean Wind:	Vr/Va	WARP kW (100 m tower*)	WARP MW (400 m tower*)
• 13 mph	2.1	500	4.6
• 15 mph	2.2	800	6.2
• 18 mph	2.4	2000	14.0

* guyed like HDTV towers
Vr=rated wind speed; Va=ave. wind speed

Much interest has developed recently in marine-based offshore wind power plants. For example, Denmark's largest electric utilities state they will build 4000 MW of offshore wind plants. The UK plans 5000 MW of offshore wind power installations according to the BWEA, and the Netherlands has embarked on its initial offshore wind power units. Japan has been assessed to have offshore wind installation potential within several miles of its shore that would exceed its annual electricity needs (Ref. 16).

The reason for attempting to access offshore winds is fairly obvious. The best wind resources exist offshore. Plus numerous other potential benefits abound such as no land cost, zoning (NIMBY), visual and noise issues. However, with conventional large bladed windmills the opportunity is limited to the shallow waters of about 5 meters due to otherwise prohibitively high costs of support platforms. Offshore WARP systems can have significant cost and technical advantages here (Ref.17, 18, 19). A *single WARP unit* installation has been assessed as follows. Economy of multiple unit volume production had not been included and would likely drive these costs lower.

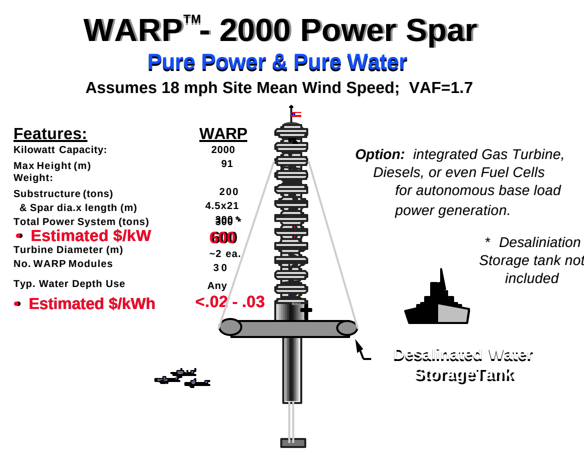

Fig. 6 WARP s Can Be Cost Effective in Deep Water

Aside from the general advantages of offshore wind power, WARP Power Spar type units can be transported fully assembled to site as well as easily removed and relocated.

Stand-Alone WARP Systems:

Stand-alone WARP systems are essentially identical to grid-tie except that they co-operate with fossil power units such as gas turbines, micro-turbines, or diesels co-located internally in a WARP. Such "hybrid" or co-generation systems are ideally suited for remote village power, industrial and other commercial installations, including factories, farms, and commercial facilities and resort hotels that are removed from a grid or are at the mercy of unreliable grid systems. The economics can look very favorable because operation and maintenance (O&M) and fuel use cost (typically 35% of operation) for the fossil power units is greatly reduced. Additionally, the low capital cost of such fossil units (typically from below $300/kW to $450/kW) can be cost effectively absorbed by WARP systems which can cost from below $500/kW to under $1K/kW. In many regions of the world either no electricity exists today or cost of $.25 [twentyfive cents] to $.80/kWh is not uncommon. In stand-alone mode, WARPs should be able to deliver electricity at a small fraction of that in sites where moderate to good winds exist.

Dual-Use WARP Systems

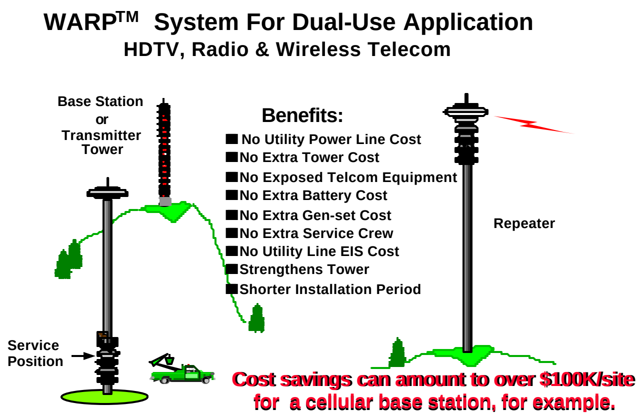

Fig. 7 WARPs In Very Cost Effective Dual-Use Mode

SUMMARY

WARP technology is shown to be extraordinarily versatile, efficient and cost effective. It is a timely technology for use in the new millennium wherein clean and sustainable energy is of critical importance as mankind endeavors to struggle with new energy needs, battles environmental pollution and deals with the threats of global warming.

Key WARP benefits are:

- High energy recovery from amplified wind;
- Minimal capitalization requirement;
- Mass production of few small discrete parts;
- Low O&M due to simple, robust dynamic components;
- Easy power capacity tailoring via modularity;
- Multiple small, low risk turbines for high availability;
- User-friendly assembly, erection and servicing;
- Easy parts shipment and/or system towing;
- Self-preserving anti-icing & lightning protection;
- Good structural & environmental characteristics;
- Many fields-of-use including in any depth water;
- Much lower land use with high energy recovery/acre;
- Ability to incorporate gas turbine power plants.

The synergism of these benefits bring attractively low cost clean energy and excellent return on investment.

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He has served as President and CEO of Alfa Laval AB subsidiary Chemap, Inc., Vice President and General Manager of GNA Industrial Furnaces, Inc. and of Wellman Thermal Systems Corporation, and Manager of Business Planning and Project Engineering Manager, Combustion Engineering, Inc. He served in the U.S. military as one of the youngest battery commanders of Hawk surface to air missiles.

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Professor Olson is on several boards including the Connecticut World Trade Association, the Antiquarian Landmark Society, the Plastics Molding Technologies in Slovakia and the United States. He is listed in the Marquis's Who's Who in the World, American Education, Finance and Industry, Young Leaders, and in the East editions since 1992.

Prof. Olson earned his Bachelor of Arts from C.W. Post Center of Long Island University and has his Master of Business Administration from the Roth Graduate Business School of Long Island University. He is completing his doctoral studies at Columbia University in International Managerial Economics and Education. Contact: Tel: 860 548-2431; Fax: 860 547-0866; e-mail: polson@rh.edu

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His professional career has included aerospace industry rotary wing R&D for advanced helicopters, prop-fan aircraft propulsion and wind power systems, as well as space propulsion rocket engine development. Specific conventional wind power development experience includes the 4 megawatt 250 foot diameter Hamilton Standard wind turbine built for NASA and U.S. Department of the Interior, the Kaman Aerospace 50 kW Vertical Axis Wind Turbine (VAWT) built for Sandia Laboratories and a 150 foot wind turbine blade for the U.S. DOE. He served as a Presidential Intern at the NASM under former Apollo 11 Astronaut Michael Collins.

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