ZIMITAR ROTOR MARKET & TEAM

VOLUME THREE: PUBLIC RELEASE SUMMARY

HIGH EFFICIENCY STRUCTURAL FLOWTHROUGH ROTOR WITH ACTIVE FLAP CONTROL

DOE AWARD NO: DE-EE0005492

DATE

16 May 2015

PUBLISHED BY

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EXECUTIVE SUMMARY

Each of the innovations that go into the Zimitar rotor has, in some way, been examined or physically tested by one or more of our technical leads. However, this was the first time that all of these innovations were included within a single design, and each innovation affects the others. For example, the location and size of the flaps also affects the sweep twist response of the blade. The rotor as it exists provides a highly cohesive preliminary design, with specific geometric and aerodynamic definition, and internal structural material layout, both for the compositie rotor, and the steel hub attachment. Components such as actuators and tendons are specifically identified, and their dynamic responses estimated. Detail on this is provided in Volume 1 – the key point here is that a well defined preliminary design has been created, though it is understood that rich opportunities for further advancement also exist.

Experienced wind engineers Mike Zuteck, Kevin Jackson, and Rick Santos form the executive management team and are the company's majority owners. Zimitar principals have had central roles in wind turbine blade advancements including sweep-twist adaptive rotors (STAR), flatback airfoils, and the evolution within the Sandia 9m blade research series, wherein aerosolve analysis yielded the lightest, strongest blade in that program, achieving near coupon stress levels in a full blade test.

Zimitar's technical principals are the core of both management and the board of directors. Thus there is a structure for technical decision making at the company level which can be relied on to implement required changes in the design focus. The project leads have all worked together for years and balance each other's strengths and weaknesses. In addition, Zimitar has created a consortium of technical, commercial, academic, fabrication, and industry specialists to supplement and extend its inherent capabilities.

A future task list has been been developed by the team, but prior experience has shown inherent uncertainty in the level of effort a given task will take. Certain research directions, like airfoils with controlled stall properties inboard to reduce its high wind power output, or outboard to take advantage of flap induced twist to further limit power, may prove to have powerful benefits and deserve considerable further effort. Modified or supplemental aerodynamic control devices may hold promise, and should be further examined. Only diving into the specifics can determine this, so further research must guide itself in the most promising directions.

Zimitar principals have determined that the best commercialization opportunities in the offshore market currently lie outside the USA. We recognize the need for strong partners in the challenge to bring a paradigm shift to one-piece rotor technology into today's large offshore turbine market. Our goal is to help a visionary company that is ready to leap forward in rotor technology get a big head start, and thereby move wind turbine economics into a market leading low cost realm that is currently out of reach.

TECHNICAL OVERVIEW & RISK ASSESSMENT

The technical work performed to date has shown that a much lighter and stiffer rotor can be produced using high-quality forms of fiberglass and typical steel casting materials through the paradigm shift to a structural one-piece rotor. The weight savings are larger than those from using carbon fiber for the main spars, without the higher cost, more demanding fabrication control, and lightning sensitivity that come with carbon fiber.

The work performed has not revealed any "show-stopper" limitations at 160m diameter and 6MW power; in fact, this structural concept appears more suited to scaling larger than the three blade upwind conventional architecture because of its lighter weight, that comes from efficient large inner rotor dimensions, and freedom from complicated load paths associated with mating with a circular pitch bearing at the root. There is no root or circular shape constraint; the shape can be whatever is structually most efficent and manufacturable.

Our technical work indicates the the flap system should provide both power control and fail-safe stopping. Comparison to the flap size of the final MOD-5 design, and the MOD-0/5 test rotor, shows the Zimitar flaps to have larger span, so it is likely they are conservatively oversized. This was intentional, we did not want to design into a technical box where optimistic assumptions would lead to expensive problems in further development for commercial application.

While our design work to date indicates the flaps should be a robust control technology, there are other aerodynamic devices that could be used to supplant or supplement them. All the virtues of the inner rotor design could be readily transferred to partial span pitch, which would rely on more conventional pitch bearings instead of flaps. Inboard rotor leading edge slats, as proposed for the Hawaii project, could be used to increase inboard rotor power, and augment stopping authority. Any of a wide range of devices currently being researched, such as deployable leading edge trips, could also be incorporated. Our work to date indicates these additional systems are not needed, but this overview would not be complete without mentioning these possible options.

Given that flaps remain the control strategy of choice for a structural one-piece rotor, the following is a short list of technical risks that must be investigated in further work. Zimitar does not have reason to think any of these are show stoppers, and is well placed to do further work on them. They are mentioned here to give a brief look at the kind of technical work still remaining.

Key technical risks are as follows:

- Flap flutter instability
- Flap binding when operated with deflected blade state
- Flap actuation system failure modes & effects
- Flap sensor system durability at sea

1 COMMERCIAL DEVELOPMENT CONSIDERATIONS

1.1 Offshore Wind Market Review

Navigant Consulting published an updated offshore wind market report [1] in October 2013 that summarized the development of the technology. We reviewed data from other recent market analysis reports in Volume 2: Section 4. Several references were summarized including: a 2013 report for the UK Crown Estate [2] that was used to obtain recent, relevant cost data for large offshore wind projects; a 2013 report by Fichtner and Prognos [3] that analyzed two different offshore development scenarios in Germany; a 2013 presentation from Roland Berger Consulting [4] that provided useful data on the market conditions and trends; a 2011 report by Deutche Bank [5] that reviewed the UK offshore wind energy market; another by van der Zwaan et al [6] that reviewed wind turbine offshore costs; and a 2010 report by Douglas Westwood [7] for the Norwegian government provided cost breakdowns for various offshore wind components.

The global market for offshore wind is currently centered in the North Sea. The consulting firm Roland Berger estimated that the European offshore market represented about 7 billion Euros in annual investment during 2013, as shown in Figure 1.1, with Asia Pacific investing 1.6 billion Euros. The European market was projected to increase to over 14 billion Euros by 2020 and Asia Pacific (China, Japan, & Korea) could generate another 4.8 billion Euros in annual investment by 2020. In contrast the North American market was expected to attract investment of about 1.6 billion Euros annually by 2020.

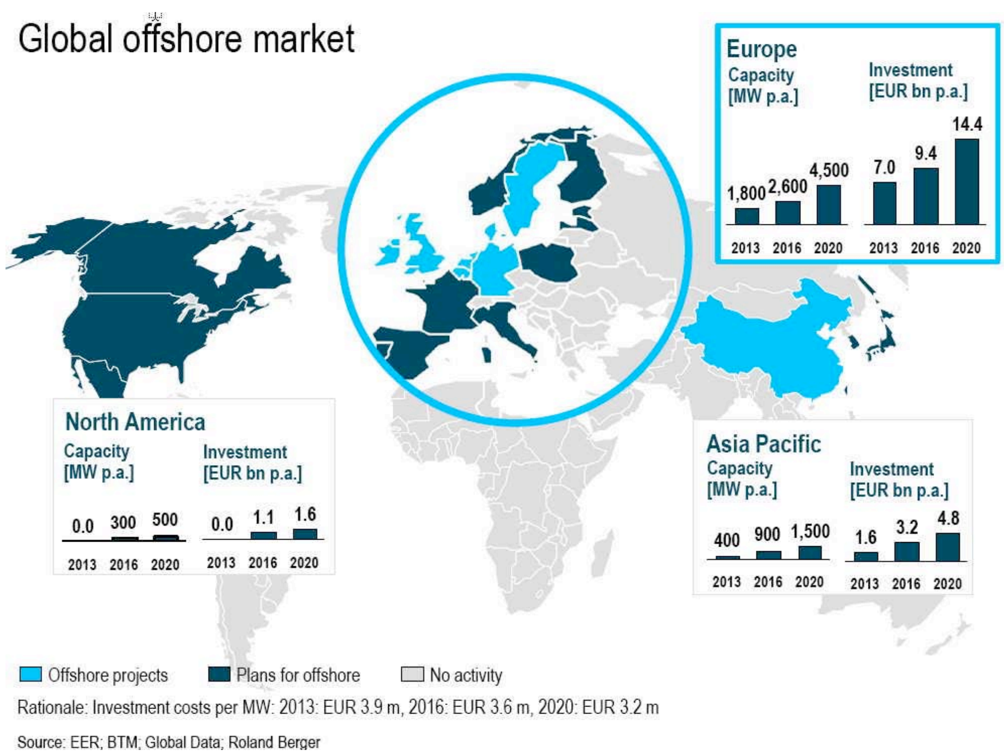
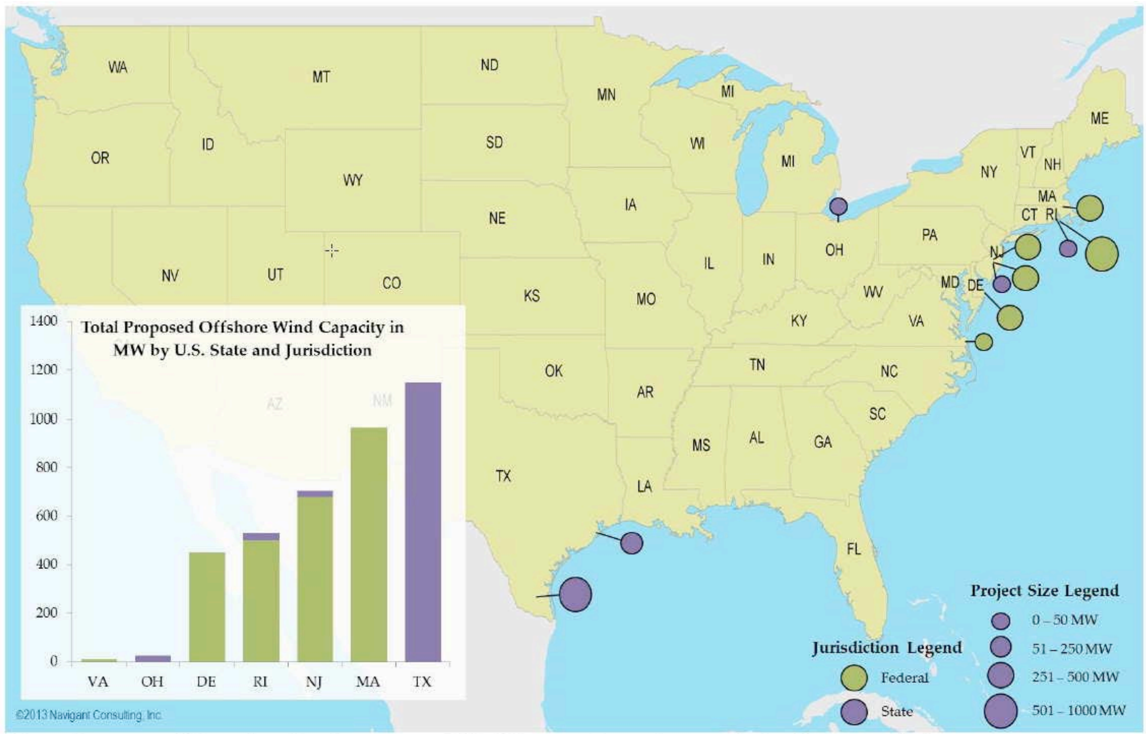


Figure 1.1 Estimate of the global offshore market presented by the consulting firm Roland Berger suggesting that Europe and Asia Pacific will dominate total investments.

Navigant summarized the status of the proposed U.S offshore wind sites in 2013, which is shown graphically in Figure 1.2. Texas currently has the largest amount of proposed offshore capacity, followed by Massachusetts, New Jersey, Rhode Island, and Delaware. There are currently no offshore wind plants operating in the United States and many of the proposed projects will not reach completion. Cape Wind has recently suffered major setbacks and is unlikely to be built. The 5 turbine, 30 MW Block Island Deepwater Wind project, scheduled to begin construction in 2015 and reach completion in 2016, is now on track to be the first US offshore wind project.



Note: One potential project (the Deepwater Wind Energy Center) spans federal waters off the coasts of Massachusetts and Rhode Island; this map splits its estimated 1,000-MW capacity between the two states.
Source: Navigant analysis

Figure 1.2 Proposed U.S. offshore wind energy projects in advanced development stages by jurisdiction and project size as summarized in 2013 by Navigant for DOE.

1.2 Offshore Wind Value

The value provided by offshore wind energy is strongly dependent upon the price for alternative sources, especially power derived from natural gas fuels. The reactor cooling failure and subsequent explosions at the Fukushima Daiichi nuclear station in 2011 have created new opportunities in Japan. At the time of this writing all the reactors in Japan are offline for safety reviews and the country has relied upon fossil thermal plants to replace the nuclear generation capacity that was lost. In 2014 the cost for Liquified Natural Gas (LNG) was about $16.50 per mmBtu in Japan, which was about $12.00 per mmBtu above U.S. costs of $4.50 per mmBtu, as shown in Figure 1.4. The price for natural gas imported to Europe has been about $11.50 per mmBtu, with Russia and Norway as the primary suppliers by pipeline.

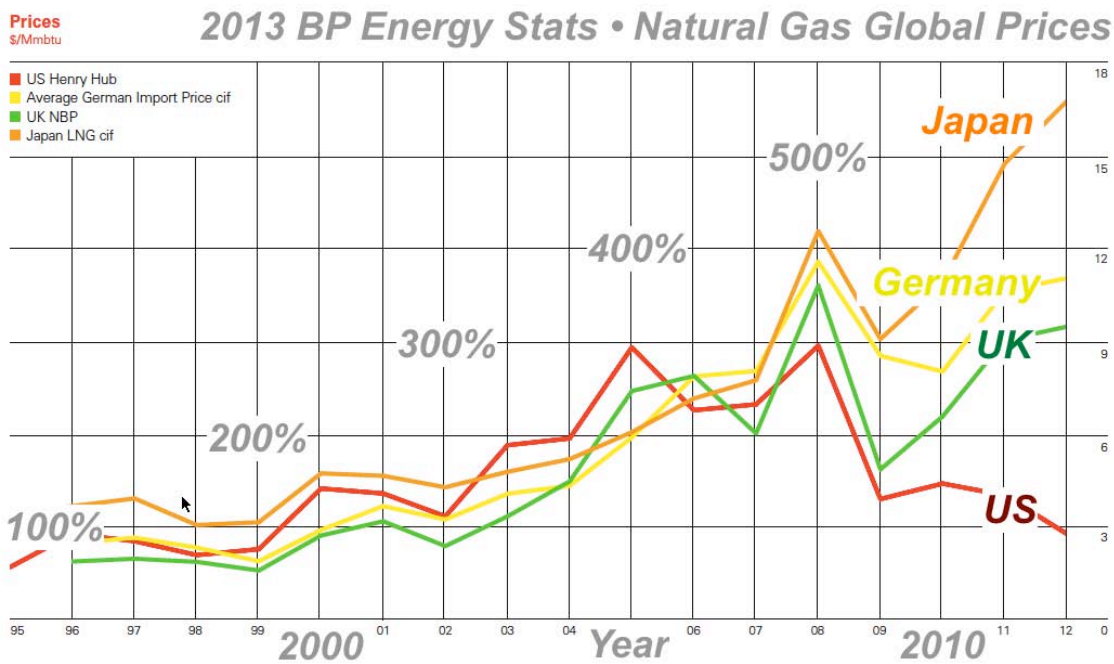


Figure 1.3 **Global prices for natural gas vary substantially depending upon the specific market location. The price for natural gas has recently been much lower in the U.S. than in Japan, the U.K, or Germany.**

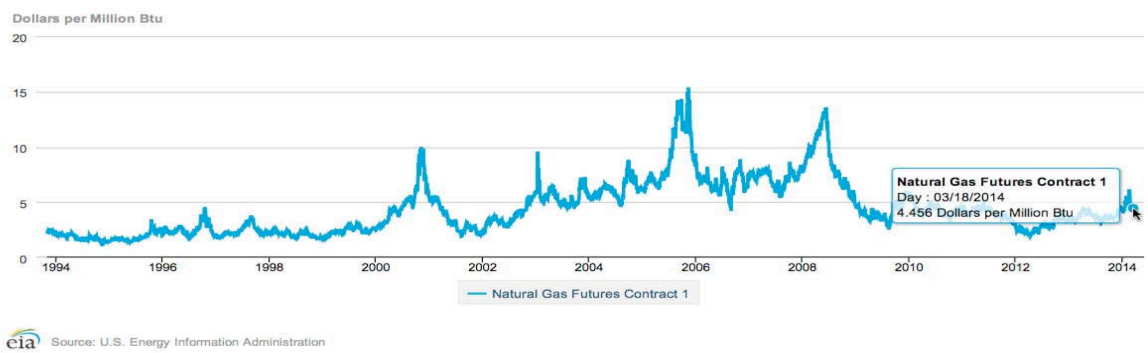


Figure 1.4 **Graphs of daily U.S. natural gas prices from the EIA website (NYMEX futures contract 1), showing large upward price fluctuations can occur rapidly and persist for long periods. Extreme cold weather in 2014 caused price spikes with current prices in the range of $4.50 per mmBtu and has been increasing since the recent low of 2012.**

The estimated cost to liquify and transport natural gas as LNG is currently greater than the cost of fuel in U.S. markets. The price spread for LNG loaded near Houston and delivered in Tokyo was estimated to range from $5.80 to $6.55 per million BTU in 2012, as seen in Table 1.1. This data indicates that a substantial price spread will remain between the fuel saving value of wind in the U.S. and in the key markets in Europe and Asia.

Table 1.1 The estimated cost for LNG deliveries to Japan assuming a range of fuel costs in Houston. These data show a cost spread between $5.80 to $6.55 per mmBtu for liquification and shipping.

(US$ per million BTUs)						
Houston	$2.00	$3.00	$4.00	$5.00	$6.00	$7.00
Energy cost (15%)	$0.30	$0.45	$0.60	$0.75	$0.90	$1.05
Capacity charge	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
FOB cost	$5.30	$6.45	$7.60	$8.75	$9.90	$11.05
Shipping	$2.50	$2.50	$2.50	$2.50	$2.50	$2.50
Japan	$7.80	$8.95	$10.10	$11.25	$12.40	$13.55

Source: Deutsche Bank Markets Research, *Global LNG*, 17 September 2012

The current unrest in Ukraine and potential sanctions by the European Union, seem certain to affect the price and supply of Russian natural gas to the European Union if economic sanctions are continued. Data published in the 2014 BP Energy Outlook show large natural gas imports to Europe by pipeline (Figure 1.5 and Figure 1.6), which may shift toward LNG if supplies from Russia are limited by economic sanctions. Most of the future LNG trade flows are anticipated to originate in the U.S., Australia, Africa, and Qatar, as shown in Figure 1.7. Overall these data suggest that the fuel savings value provided by offshore wind energy is presently three to five times higher in Europe and Asia than in the United States.

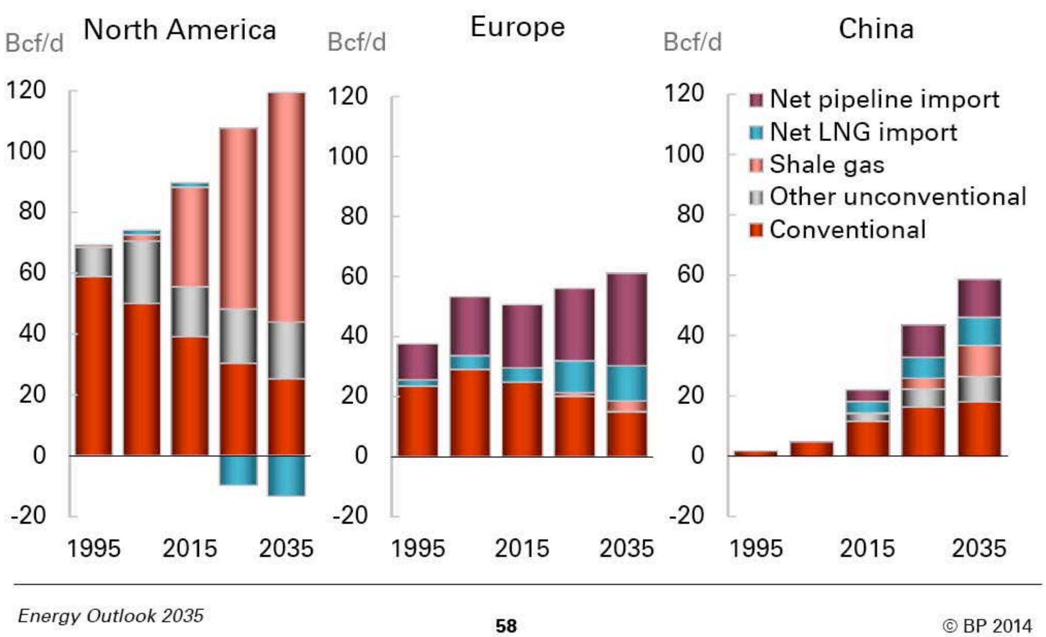


Figure 1.5 North American natural gas resources are relatively abundant and low cost relative to other major energy markets in Europe or China.

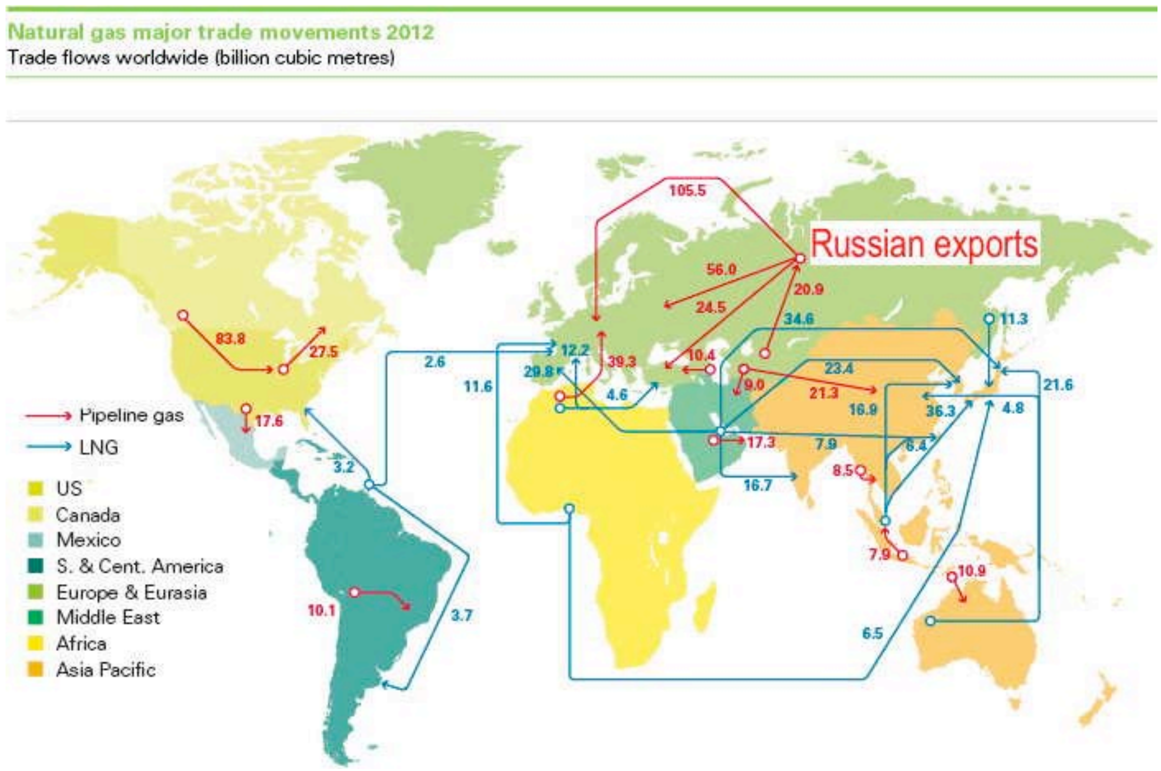


Figure 1.6 Natural gas trade movements in 2012 showed large exports from Russia to Germany by pipeline, which may be constrained by economic sanctions.

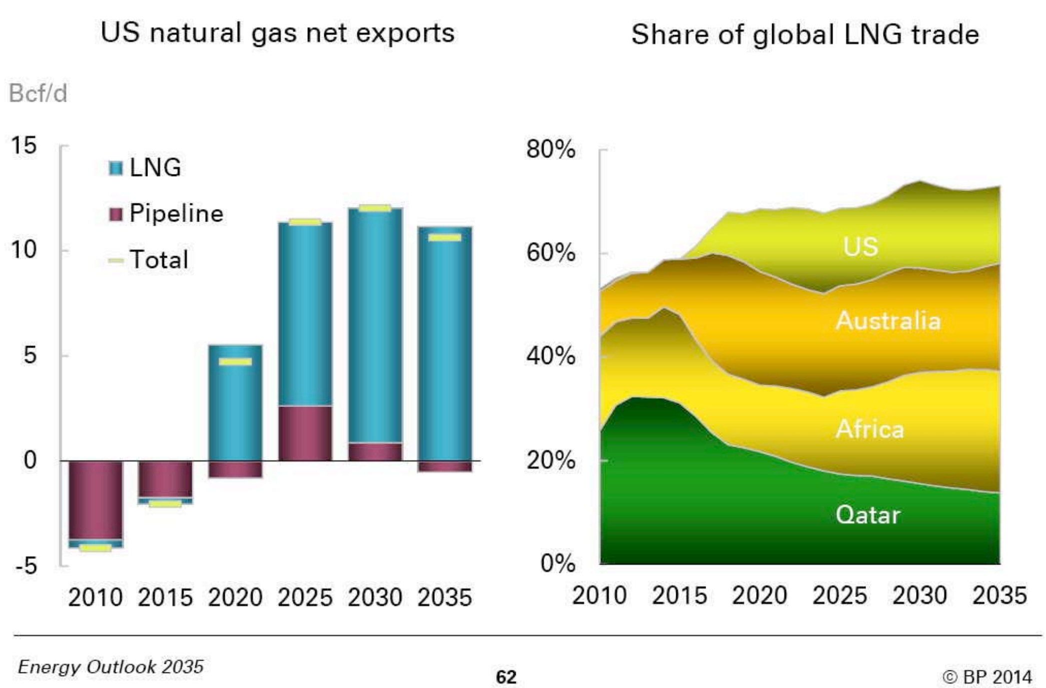


Figure 1.7 Gas imports to Europe and Asia are projected to rely upon large natural gas sources in the U.S., Australia, Africa, and Qatar.

The U.S. Energy Information Admistration (EIA) estimates the Levelized Cost of Energy (LCOE) for various energy sources annually (see Table 1.2). The 2013 EIA report showed that conventional wind energy on land was second only to natural gas powered generation systems in providing the lowest overall price, while offshore wind energy was the most expensive option. The EIA also estimated that variable O&M costs, which are largely fuel costs, represented over 70% of the total LCOE.

Table 1.2 Levelized cost of energy from the 2013 EIA report showing that U.S. land based wind has second lowest price after natural gas. Prices for LNG fueled electricity are much higher and the potential value of wind energy is much greater in Europe and Asia.

Levelized Cost of Energy 2013 EIA Report

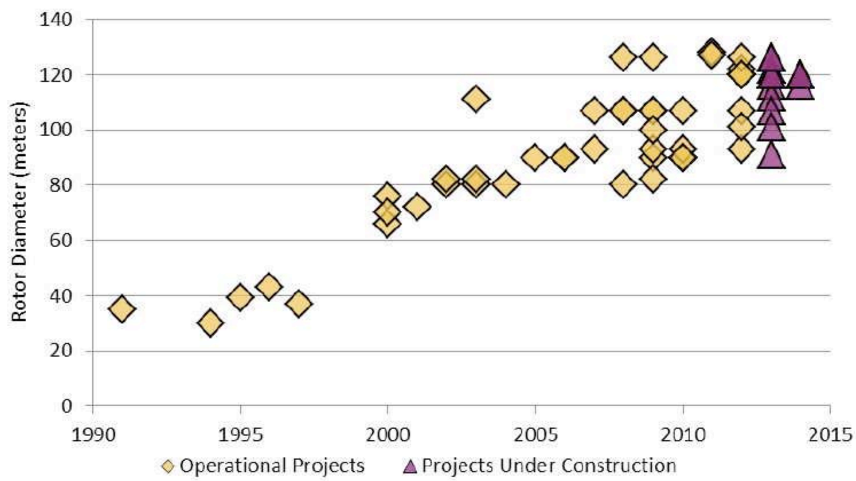
		U.S. average levelized costs (2011 $/megawatthour) for plants entering service in 2018				
Plant type	**Capacity factor (%)**	**Levelized capital cost**	**Fixed O&M**	**Variable O&M (including fuel)**	**Transmission investment**	**Total system levelized cost**
Fossil Fueled						
Conventional Coal	85	65.7	4.1	29.2	1.2	100.1
Advanced Coal	85	84.4	6.8	30.7	1.2	123.0
Advanced Coal with CCS	85	88.4	8.8	37.2	1.2	135.5
Natural Gas-fired						
Conventional Combined Cycle	87	15.8	1.7	48.4	1.2	Natural 67.1
Advanced Combined Cycle	87	17.4	2.0	45.0	1.2	Gas 65.6
Advanced CC with CCS	87	34.0	4.1	54.1	1.2	93.4
Conventional Combustion Turbine	30	44.2	2.7	80.0	3.4	130.3
Advanced Combustion Turbine	30	30.4	2.6	68.2	3.4	104.6
Non-Fossil Fueled						
Advanced Nuclear	90	83.4	11.6	12.3	1.1	108.4
Geothermal	92	76.2	12.0	0.0	1.4	89.6
Biomass	83	53.2	14.3	42.3	1.2	111.0
Wind	34	70.3	13.1	0.0	3.2	Wind 86.6
Wind - Offshore	37	193.4	22.4	0.0	5.7	Offshore 221.5
Solar PV	25	130.4	9.9	0.0	4.0	144.3

Our review of the global offshore wind industry suggests that successfully supplying markets in Europe and Asia will almost certainly be key to near term commercial success. The direct fuel-saving value provided by offshore wind generation could reach $150-200 per MWh in countries that purchase LNG from global markets, so offshore wind will become economically attractive much more quickly there.

1.3 U.S. Manufacturing Sites

The current U.S. situation for offshore wind has some historical precedent in the early 1980's when four small Danish companies (Vestas, Bonus, Nordtank, and Micon) rushed into newly emerging markets in California. Denmark provided a home market and some stablility supports, but wind companies moved quickly to take advantage of the opportunities for wind in California, that were unique at the time. Increasingly the United States should look to Europe and Asia as potential export markets for high value offshore wind products that are developed and manufactured here.

Commercial offshore wind projects have been installing wind turbines in the 120 meter diameter size in recent years, as shown in Figure 1.8. Several new designs have been installed in the 6 MW size by Siemens, Alstom, and Senvion, with rotors in the 150-154 meter size. Zimitar specifically targeted these newer WTGs as candidates for the Z160 rotor, because it can provide better performance on these machines for much lower rotor weight and cost.



Note: Rotor diameters are shown for the year each project reached completion. Multi-phase projects were combined to show a single rotor diameter and are reported for the latest year when turbines were added.
Source: Navigant analysis of data provided by NREL and BTM

Figure 1.8 Offshore wind turbine rotor diameter over time showing growth has reached about 120 m in commercial projects.

The Zimitar rotor system is a uniquely American design (see Figure 1.9) that has come of age with the commercialization of large offhore wind turbines with rotors over 150 meters in size. The scaling advantages of the structural flowthrough rotor show that it can reduce rotor blade weight by 40 tonnes at the 6 MW 160 m size, as shown in Figure 1.10. We currently estimate that weight savings for the 10 MW 200 m rotor scale would be approximately 66 tonnes for the rotor blades alone. Our analysis work has also identified large additional weight savings that result from improved structural efficiency in the steel components that attach the rotor composite parts to the main shaft of the wind turbine.

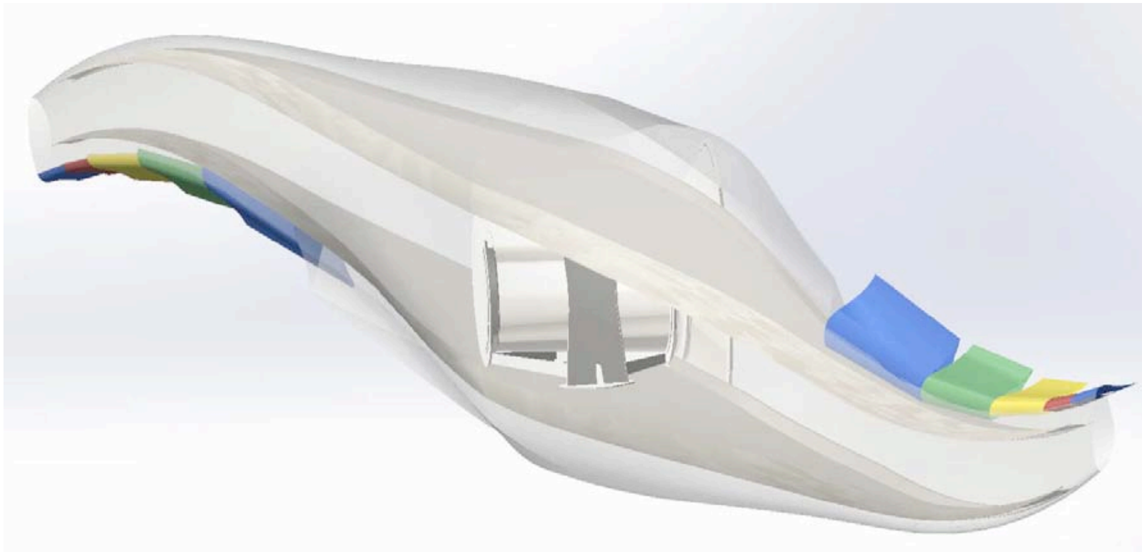


Figure 1.9 Semi-transparent image of the Zimitar 160 meter structural one-piece rotor with active flap control showing the double spar arrangement with internal attachment.

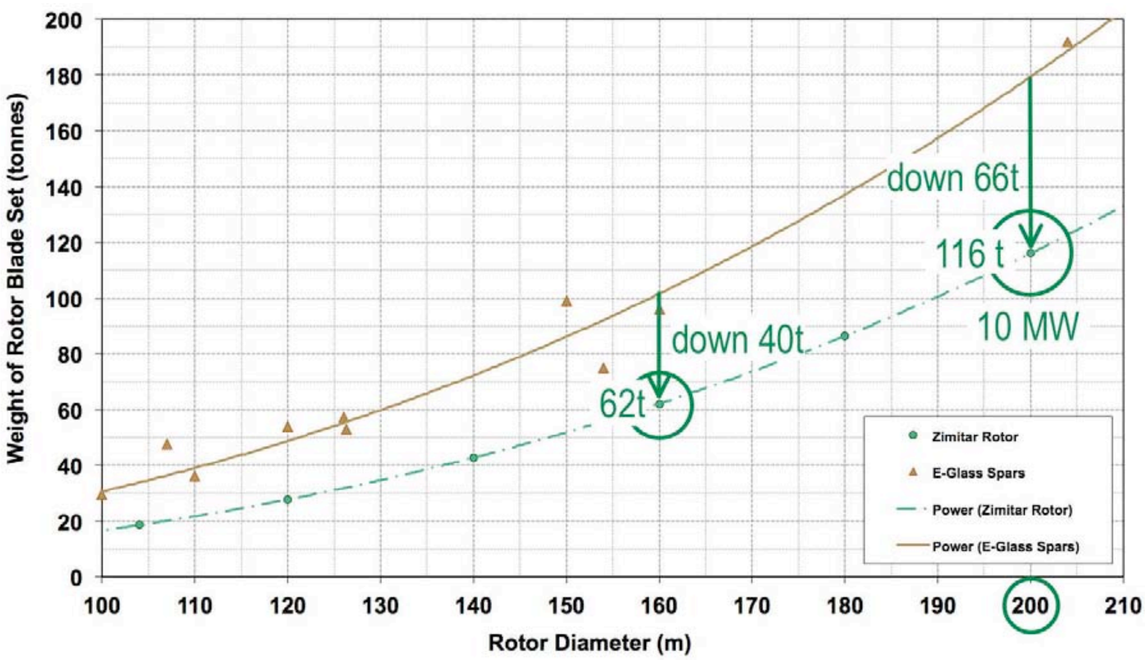


Figure 1.10 The Zimitar rotor weight savings was estimated to be 40 tonnes at the 6 MW 160 m scale and 66 tonnes at the 10 MW 200 m diameter. Additonal weight savings derived from the rotor hub connection are expected to be similar in magnitude.

The Zimitar rotor design is an innovative technology that has the potential to dramatically reduce the rotor blade and hub weight in large offshore wind turbines. Our preliminary design study work has shown the structural flowthrough rotor could be a key design breakthrough needed to get high performance, ultra-large wind turbines at the 10 MW 200 meter scale. Annual energy production at this turbine size is summarized in Figure 1.11 and net capacity factors range from 43% in 8.5 m/s sites to 53% in 10.5 m/s resource locations.

Annual Energy Production

	Hub Height Mean Wind Speed (m/s)	8.50	9.00	9.50	10.00	10.50
Assuming 85% Net-to-Gross	Annual Net Capacity Factor	43.0%	46.0%	48.7%	51.0%	53.0%
Rayleigh Wind Distribution	Gross Specific Energy (MWh/MW)	4434	4742	5016	5257	5464
	Gross Annual Energy (MWh)	44342	47419	50162	52567	54636

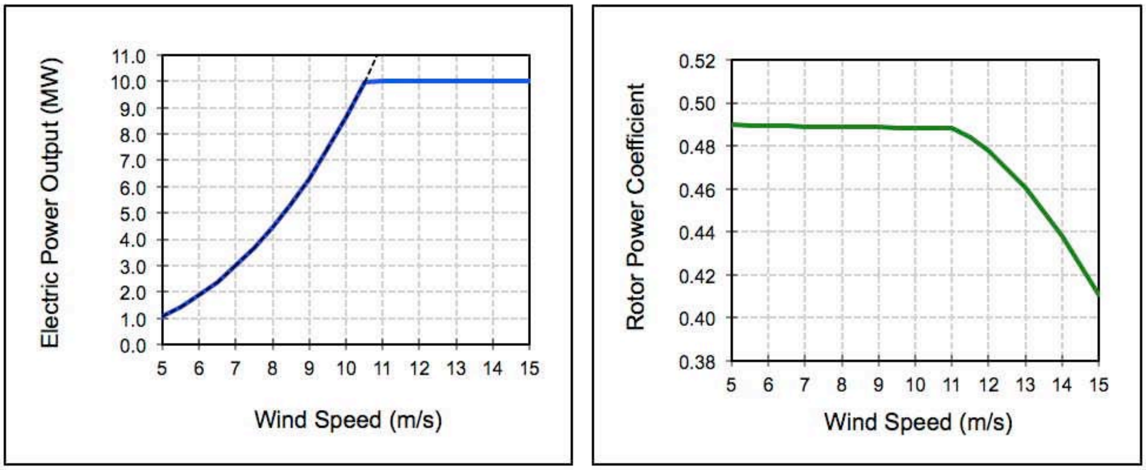


Figure 1.11 Estimated annual energy production for a Zimitar rotor with a 10 MW power rating and 200 meter rotor diameter.

1.3.1 Atlantic Coast – Manufacturing Site #1

During our preliminary design study we identified three potential U.S. based manufacturing sites, and currently believe the Narragansett Bay region in Rhode Island has the best potential for manufacturing the Zimitar rotor blades (see Figure 1.12).

There is a long history of wind turbine blade manufacturing in the Providence area and the geographic location of the maritime industrial site at Quonset is well suited to serve Atlantic markets in Europe and the U.S. Blade production at TPI Composites started in Warren, Rhode Island the early 1980's for U.S. Windpower. Since then there has been a continous growth in manufacturing experience, and in addition to the Warren facility, TPI now produces wind turbine blades at factories located in Newton, Iowa, Fall River, Massachusetts, Ciudad Juarez, Mexico, Taicang, China, and Izmir, Turkey.

Project leaders Jackson and Zuteck have been collaborating on wind turbine blade projects with TPI Composite since the mid-1990's. During that time we also built strong working relationships with Clear Carbon & Components, located in Bristol. We have had discussions with Quonset Development regarding potential for large scale manufacturing at their site. NREL has a large blade test center in Boston that could also provide resources to support large rotor testing in the future.

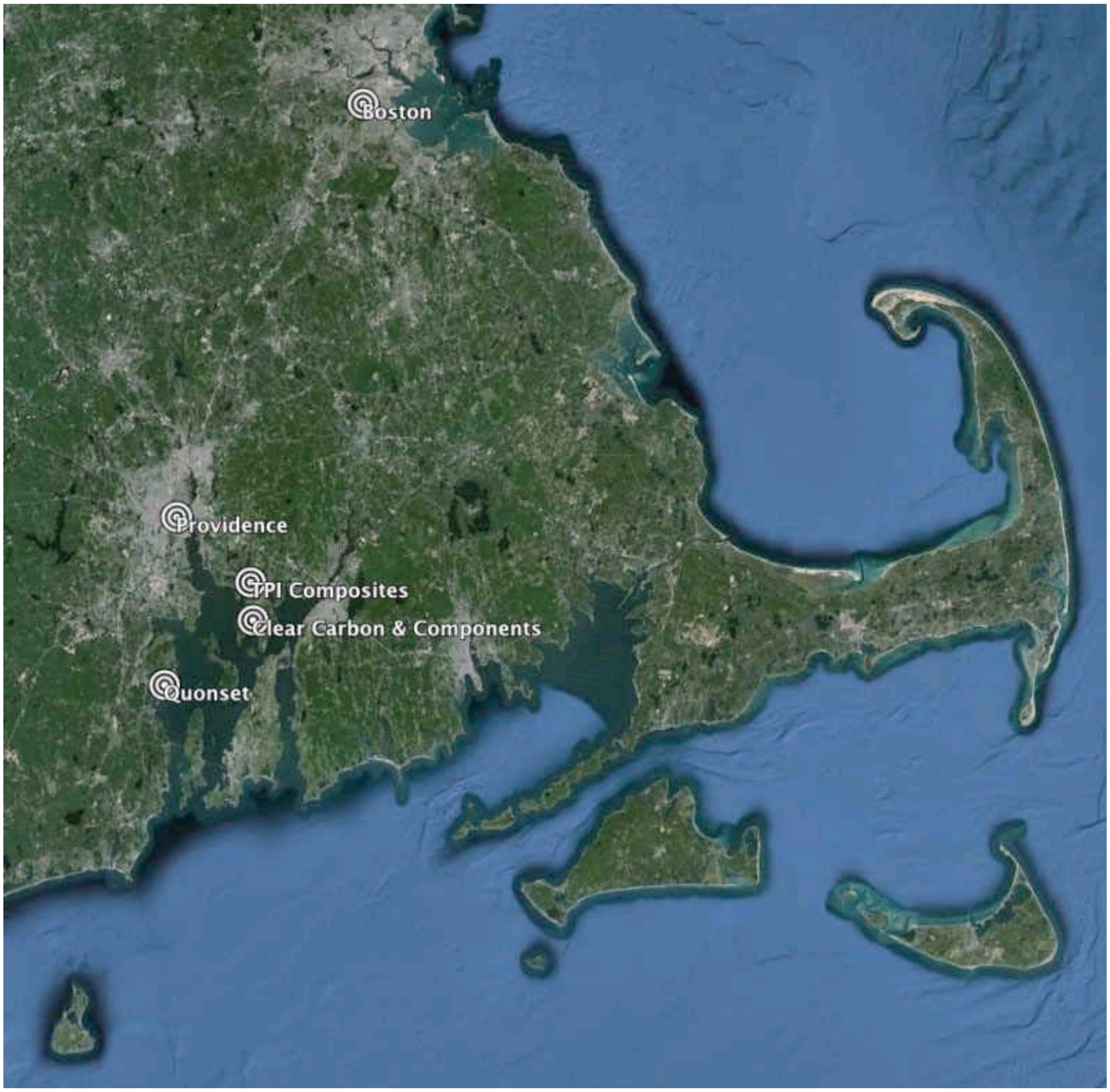


Figure 1.12 Team members TPI Composites and Clear Carbon & Components are located in the Narragansett Bay region, which also has a large potential rotor manufacturing location at Quonset.

Quonset was originally the location of a Naval Air Station and has now been returned to civilian use. The site is managed by a commercial development company and they have been actively working to attract offshore wind manufacturing and installation support activities at Quonset. There are rail facilities and large areas available for blade production and loading, as shown in Figure 1.13. Transport ships leaving Quonset can reach U.S. offshore wind sites in a matter of hours and can be in European harbors in about 10 days, as depicted in figure 1.14.

Figure 1.13 Quonset is well suited to offshore blade manufacturing, with access to rail and large docks that provide access to Narragansett Bay.

Figure 1.14 Transport of rotors from Quonset to the North Sea is about 3700 nautical miles.

1.3.2 Pacific Coast – Manufacturing Site #2

We have also been reviewing the potential for large scale offshore blade manufacturing in Mare Island, California. This location was the site of the first U.S. Navy shipyard on the Pacific Coast and has been converted to civilian uses, as shown in Figure 1.15. The site has many large docks and shipways, while the drydock facilities are also functional and potentially useful. Zimitar set up a permanent office nearby (Figure 1.16) in Benicia, and we successfully used this location as a base to attract other wind related activity to the area, including engaging the California Maritime Academy, which was a significant a cost-share participant in research and design efforts.

Figure 1.15 Mare Island was the site of the first U.S. Navy shipyard on the Pacific Coast. The site has been converted to civilian uses and has potential for large scale blade production.

Figure 1.16 Cal Maritime is located in Vallejo next to Mare Island and is the only maritime academy on the Pacific Coast. Zimitar has set up its main office nearby in Benicia, which also has excellent port and rail access that could support blade manufacturing.

Mare Island has the potential to supply blades to the Japanese market, which could grow rapidly if political and safety concerns from the Fukushima disaster continue to prevent reactors from going back on line. Transport of blades to Japan will require about 12 days (see Figure 1.17).

Figure 1.17 Transport of rotors from Mare Island to Japan is about 4400 nautical miles.

1.3.3 Gulf Coast – Manufacturing Site #3

For several years we have discussed manufacturing of large wind turbine blades at Ingalls Shipyard in Pascagoula, Mississippi with Ingalls Shipbuilding. Representatives of our team visited the site, and met with the business development manager. Ingalls is a major shipyard and currently does most of its work for the U.S. Navy. There is interest in diversifying work at the shipyard, but the existing cost structure does not fit commercial needs. We will use this site as a model for our Gulf Coast manufacturing location (see figures 1.18 and 1.19), but have also identified suitable facilities in the vicinity of Corpus Christi, Texas.

Figure 1.18 The Ingalls Shipyard in Pascagoula, Mississippi is a major potential manufacturing site on the Gulf of Mexico.

Figure 1.19 Transport of rotors from Pascagoula, Mississippi to the North Sea is about 4700 nautical miles.

1.4 Candidate Offshore Wind Turbines

During preliminary design we reviewed the key design parameters for the baseline offshore wind turbine, which was a Siemens 3.6 MW with a 107 meter diameter rotor. We identified a target rotor size of 160 meters for a 6 MW generator rating and found three potential candidate wind turbines from three different Original Equipment Manufacturers (OEMs): 1) the Siemens 6.0 MW, 2) the Alstom 6.0 MW, and 3) the Senvion 6.2 MW. This section provides a short summary of the technical features of these wind turbines.

1.4.1 Siemens 3.6 MW 107 m - Baseline

The Siemens 3.6 MW 107 m wind turbine was used as the baseline for cost of energy analysis. This model has been widely installed in offshore applications and uses a geared drive train as shown in Figure 1.20.

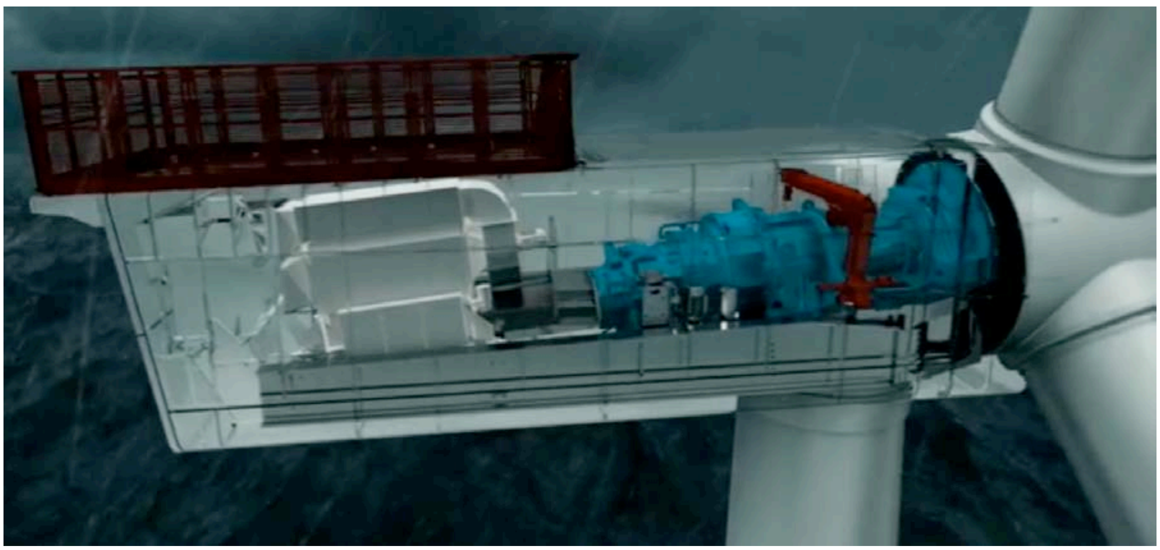


Figure 1.20 Drawing of the Siemens 3.6 MW nacelle and geared drive train.

1.4.2 Siemens D6 Series 6 MW 154m

We consider Siemens to be a leading potential OEM candidate to commercialize the Zimitar rotor. During the Preliminary Design effort we focused on the Siemens 6 MW 154 m diameter offshore wind turbine as the primary candidate for the Z160 rotor. September 2013, Mike Zuteck presented the Zimitar concept in a meeting we hosted at Cal Maritime and spoke afterward with Henrik Stiesdal (then Siemens Wind Chief Technology Officer). Stiesdal expressed interest in the Zimitar project, even though he had reservation about them making a leap this big. We followed up with a meeting at the Siemens Wind R&D office in Boulder in November.

Stiesdal has expressed his belief in the commerical imperative for design innovations, and in a recent video presentation expressed his belief that the direct drive 6 MW platform would become the new standard for the Siemens offshore wind product line. Computer renderings of the Siemens 6 MW 154 are provided in Figure 1.21, Figure 1.22, and Figure 1.23, with specifications in Table 1.3.

Figure 1.21 A computer model image of the Siemens 6 MW 154 m offshore wind turbine, which uses a direct drive generator.

Figure 1.22 Images from a semi-transparent model of the Siemens 6 MW 154 m wind turbine nacelle, showing the yaw drives, interior electrical cabinets, and the helicopter deck.

Figure 1.23 Image from a semi-transparent model of the Siemens 6 MW 154 m wind turbine nacelle, showing the yaw drives, interior electrical cabinets, and the helicopter deck.

The direct drive system has the significant benefit of reducing the total parts count in the drive train. Our work in preliminary design on the Zimitar 160 rotor has shown large potential weight and cost savings are possible, with the added benefits related to installation of a one-piece rotor, reduced fastener count (about 600 fewer pitch bearing bolts to torque), and simplified helicopter access to offload crew and spare parts.

Table 1.3 Specifications for the Siemens 6 MW 154 offshore wind turbine.

Rotor	
Type	3-bladed, horizontal axis
Position	Upwind
Diameter	154 m
Swept area	18600 m²
Speed range	5-11 rpm
Power regulation	Pitch regulation with variable speed
Rotor tilt	6 degrees
Blade	
Type	Self-supporting
Blade Length	75 m (B75)
Aerodynamic profile	Siemens proprietary airfoils, FFA-W3-XXX
Material	GRE
Surface gloss	Semi-gloss, <30 / ISO2813
Surface colour	Light grey, RAL 7035
Aerodynamic brake	
Type	Full-span pitching
Activation	Active, hydraulic
Load-Supporting Parts	
Hub	Nodular cast iron
Main shaft	Nodular cast iron
Nacelle bed plate	Nodular cast iron
Mechanical brake	
Type	Hydraulic disc brake
Canopy	
Type	Totally enclosed
Surface gloss	Semi-gloss, 25-45 / ISO2813
Colour	Light grey, RAL 7035
Material	Fire retardant GFRP with integrated EMC shielding

Generator	
Type	Synchronous, PMG, Direct Drive
Grid Terminals (LV)	
Nominal power	6000 kW
Voltage	690 V
Frequency	50 Hz
Yaw system	
Type	Active
Yaw bearing	Externally geared
Yaw drive	Electric gear motors
Yaw brake	Passive friction brake
Controller	
Type	Microprocessor
SCADA system	WPS
Controller designation	WTC 3.0
Tower	
Type	Cylindrical and/or tapered tubular
Hub height	Site-specific
Corrosion protection	Painted
Surface gloss	Semi-gloss, 25-45 / ISO2813
Colour	Light grey, RAL 7035
Operational data	
Cut-in wind speed	3-5 m/s
Nominal power at	12-14 m/s
Cut-out wind speed	25 m/s
Maximum 3 s gust	70 m/s (IEC version)
Weights (approximately)	
Towerhead mass	360,000 kg

1.4.3 Alstom 6 MW 150 m

The members of our team engaged in early stage conversations with Alstom R&D engineers in the U.S. and at the design office in Barcelona. Rick Santos, Zimitar Chief Engineer, worked in Barcelona for several years and has maintained personal and business relationships with the company. This past year Santos and Jackson worked with Alstom on advanced rotor research topics and had interactions with U.S. engineering staff in Richmond, Virginia, and with engineers in Barcelona.

Alstom has devoted considerable effort and funding to the development of their 6 MW 150 m direct drive offshore wind turbine, which has a fixed mainshaft spindle that supports the rotor hub, as shown in Figure 1.24. This rotor support arrangement is somewhat uncommon within the wind industry, but has become a discriminating marketing feature that Alstom calls "pure torque". It is noteworthy that: 1) the Zimitar rotor is well suited to the pure torque connection and 2) a fixed spindle was used by GE in the original 7.2 MW flowthrough rotor design that started the historical lineage of the Zimitar rotor design approach.

Alstom was awarded a DOE offshore wind grant to develop an advanced control system for floating platforms. The much reduced tower head mass from a lightweight Zimitar rotor design would have a synergistic effect on the floater structure by significantly reducing the amount of required bouyancy. We believe the relatively flat thrust characteristics of the Zimitar rotor above rated power would also be an advatage to a floating configuration.

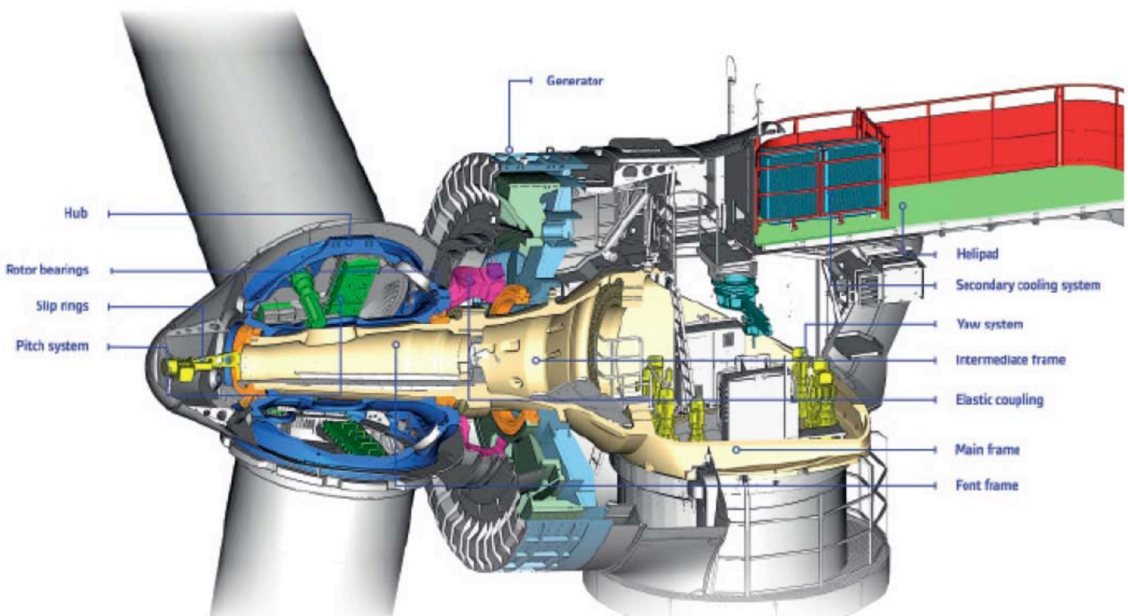


Figure 1.24 Side view cutaway drawing of the Alstom 6 MW 150 wind turbine.

Key specifications for the Alstom 6 MW 150 wind turbine are summarized in Table 1.4.

Table 1.4 Key specifications for the Alstom 6 MW 150 wind turbine.

OPERATING DATA	
Wind Turbine Class	I-B IEC-61400-1 / IEC-61400-3
Rated power	6.0 MW (net after transformer)
Cut-in wind speed	3 m/s
Cut-out wind speed (10 minutes average)	25 m/s
Grid frequency	50 / 60 Hz
ROTOR	
Rotor diameter	150.95 m
Blade length	73.5 m
Rotor swept area	17,860 m^2
Rotor speed range	4 - 11.5 rpm
Tip speed	90.8 m/s

1.4.4 Senvion 6.2MW 152m

Senvion (formerly Repower) has upgraded its most recent offshore wind turbine offering to the new 6.2 MW 152 m (see Figure 1.25 and Table 1.5). Members of our design team have been working with the Senvion U.S. support engineering office in Denver, Colorado and we plan to visit their design engineering office in Hamburg, Germany during the summer of 2015.

Figure 1.25 Drawings of the Senvion 6.2 MW 152 m offshore wind turbine.

Table 1.5 Key specifications for the Senvion 6.2 MW 152 wind turbine.

Type class: **Hub height 112m, 114m:** **Onshore: IEC IB, IEC IIA** **Hub height 100m, 117m:** **Onshore: WZ4** **Offshore: IEC IB, IEC S**	Type class: **Hub height 121m:** **Onshore: IEC S** **Hub height 124m:** **Onshore: WZ4** **Offshore: IEC S**
Rated power: **6.15 MW**	Rated power: **6.15 MW**
Rotor diameter: **126 m**	Rotor diameter: **152 m**
Hub height (m): **Onshore: 112m, 114m, 100m, 117m** **Offshore: 85-95m (site specific)**	Hub height (m): **Onshore: 121m, 124m** **Offshore: 95-110m (site specific)**
Rotor speed: **6,9 - 12,1 min^{-1} (+15%)**	Rotor speed: **6,4 - 10,1 min^{-1} (+15%)**
Power control: **Electrical pitch system – pitch and speed control**	Power control: **Electrical pitch system – pitch and speed control**

1.4.5 Envision 3.6MW 128 m

The Envision 3.6MW 128m diameter turbine is not a direct candidate for the Zimitar rotor due to its small size and power rating, but its rigid hub, two blade configuration is similar to the Zimitar rotor in that the inner rotor does not feather, and all aerodynamic control comes from the outer part, albeit by partial span blade pitch rather than flaps (see Figure 1.26).

Figure 1.26 Photo of the Envision 3.6 MW 128 m offshore wind turbine

It appears that the Zimitar one-piece rotor hub and attachment design could be adapted to provide a lighter inner rotor, with more freedom to optimize the aerodynamic shape of the inner rotor, and the root region of the partial span blades. This may be a particularly interesting path forward for larger rotors shippable on land, if one envisions hub and blades all in the 50-60m length range. During work on the MOD-5, it was recognized that spanwise joints to add afterbodies or noses were relatively easy to accomplish, since the load flows mostly parallel to those joints. It was the chordwise joints between spanwise sections that were dificult. But if the spanwise sections are bolted together at the pitch bearings, assembly is no more complicated than installing blades on a hub, in fact, with a two blade design, it can all be done on the ground and readily lifted into place. There may be markets where the Zimitar one-piece inner rotor coupled with Envision's partial span pitch has an advantage over all competing options. The much lighter inner rotor could add even more value for offshore floaters, where tower head mass is a design driver.

2 ENGINEERING DESIGN TEAM QUALIFICATIONS

2.1 Kevin Jackson, Ph.D., Principal Investigator, Project Manager

PROFESSIONAL EXPERIENCE

Kevin Jackson began his wind energy career during graduate study at the University of California in 1982. In 1985, he began to provide engineering consulting services to California's emerging commercial wind power industry. Over the years, Dr. Jackson has managed a variety of wind turbine repair, retrofit, and performance enhancement projects. He has been responsible for blade geometry definition and structural design, drive train component analysis, yaw system design, and tower structural analysis. He has also completed dynamic and fatigue analyses using measurements obtained from field testing of wind turbines.

Dr. Jackson has worked extensively with field test data sets gathered from operational turbines. He began as a key participant in field testing of Micon 65 and 108, Enertech 40 and 60, Mitsubishi 250, Wind Eagle 300, and NedWind 500 wind turbines. Interpretation of these massive data sets has been a major focus of effort, and Dr. Jackson developed computational tools to speed processing and enhance analysis accuracy. This work included development of an improved methodology for evaluating fatigue damage rates and estimating the lifetime of wind turbine equipment. He has developed methods for scaling design loads from existing test data for use in the analysis of similar turbines for which no test data are available. He has also developed analysis tools for wind turbine performance assessment using site SCADA data. This software has been used to calculate power curves, expected energy, and revenue for large wind plants.

Dr. Jackson has worked extensively in support of owners and wind site landowners on issues related to the safety, reliability, quality, and performance. In this work he has often conducted engineering investigations, tests, and analyses leading to the preparation of technical reports and recommendations. On several assignments Dr. Jackson has been asked to render expert opinions and provide oral testimony relating to the mechanical engineering aspects of wind turbines and commercial power generation facilities. Projects in this area have included evaluation of warranty issues, review of turbine energy production, failure analyses, and other aspects of wind technology assessment. Recent engineering efforts have included USW 56-100, Mitsubishi 250, 600, & 1000, Vestas V47, V80, V90, V100, NEG Micon 750 & 900, Zond/Enron 750 & 1.5, Gamesa G87, Bonus 1.3 & Siemens 2.3, GE 1.5 & 2.5, RePower 2.0, and other megawatt-scale wind turbines.

EDUCATION

Ph.D.	Mechanical Engineering, University of California at Davis, 1989.
M.S.	Mechanical Engineering, University of California at Davis, 1984.
B.S.	Mechanical/Aeronautical Engineering, University of California at Davis, 1982.

SELECTED PUBLICATIONS

K. Jackson, M. Zuteck, C.P. van Dam, “Sweep-Twist Adaptive Rotor Blade: Final Project Report”, Knight & Carver Wind Group, SAND2009-8037, January 2010.

K. Jackson, C.P. van Dam, and D. Yen Nakafuji, "Wind Turbine Generator Trends for Site Specific Tailoring," Wind Energy, 2005.

K. Jackson, M. Zuteck, C.P. van Dam, K.J. Standish, and D. Berry, "Innovative Design Approaches for Large Wind Turbines," Wind Energy, Vol. 8, No. 2, 2005, pp. 141-171.

K. Jackson, "Scaling Wind Turbine Fatigue Design Loads", Proceedings of the 1994 ASME Conference, New Orleans, January 1994.

K. Jackson, "Deriving Fatigue Design Loads From Field Test Data", Proceedings of the Windpower '92 Conference and Exposition, Seattle, October 1992.

D. W. Bernadett and K. Jackson, "Teetering Three-Bladed Rotors Through the Use of Multi-Axial Suspension", Proceedings of the Windpower '92 Conference and Exposition, Seattle, October 1992.

K. Jackson, "Load Estimation Methods for Advanced Wind Turbines", Proceedings of the Windpower '89 Conference and Exposition, San Francisco, September 1989.

K. Jackson, "Mechanical Design and Load Estimation Methods for Advanced Wind Turbines", Doctoral Dissertation, Department of Mechanical Engineering, University of California at Davis, June 1989.

K. Jackson, "Dynamic Response of Active Yaw Drives", Proceedings of the Windpower '88 Conference and Exposition, Honolulu, September 1988.

K. Jackson and P.G. Migliore, "Design of Wind Turbine Blades Employing Advanced Airfoils", Proceedings of the Windpower '87 Conference and Exposition, San Francisco, October 1987.

SYNERGISTIC ACTIVITIES

Founder and Board Member of the California Wind Energy Collaborative (CWEC). CWEC was established in February 2002 and works in close cooperation with industry, state and federal agencies, and other institutions on wind energy issues in California.

Co-teach short courses for technicians working in the field of wind energy and for the general public a course on small wind energy systems. Provide wind energy guest lectures at UC Davis and the California Maritime Academy.

Worked with TPI Composites on DOE sponsored wind turbine blade design project (Blade System Design Study). Worked with Knight & Carver on DOE sponsored Low Wind Speed Turbine blade design study (LWST).

Provide engineering support for a variety of large wind turbine owners and operators including: NextEra, Terra-Gen Power, enXco, and BP Wind.

2.2 Michael D. Zuteck, Principal Investigator, Rotor Designer

PROFESSIONAL EXPERIENCE

Mr. Zuteck has pursued rotor research and design as an independent consultant in the field of wind energy since 1977. He proposed to Sandia the concept of a sweep twist blade design, provided the initial study analysis of engineering feasibility, was the lead designer for the effort to reduce this design to practice, helped guide build by Knight & Carver, and verification atmospheric and fatigue testing. He also provided key design guidance and analysis for the Sandia 9m research blades including the CX-100, TX-100, and flatback BSDS blades fabricated by TPI Composites, and also supported subsequent testing of these blades. He supplied the initial structural design concept and analysis for a variable diameter extensible blade. These projects are all within this decade.

Also within this decade Mr. Zuteck provided field failure examination and analysis of blade problems including surface cracking, structural cracking, web debonding, lightning, tower strike, spar/shell debonding, root bond failure, and even bullet hole spar damage. This work covers a wide range of modern blade types and sizes, and provides background on the difficulties encountered with current blades. This work lead to expert deposition testimony in one case, and outside wind, to litigation support for a helicopter crash.

Earlier in his career, Mr. Zuteck had key technical responsibility for rotor system design in many projects which include: two NASA research rotor systems, many commercial rotor designs with thousands of blades produced, the DOE/NASA/GE 400' diameter multi-megawatt Mod-5A design study, and the Westinghouse 142' dia., 600 kW. turbines. He served as structural consultant on the SERI advanced airfoil composite blades, and was co-recipient of the 1990 American Wind Energy Association Technical Achievement Award for that work. He is the originator of the airfoil tower concept that received study both here and abroad. He provided blade designs for both the AOC and AWT NREL supported wind turbines, led the design of an innovative flap control retro-fit for the Westinghouse turbine, and was a contributor on the ERS and NPS blade designs.

He has worked with both US Department of Energy, and National Academy of Sciences panels that set energy research directions in the aerodynamics and materials areas. He provided lead consulting on a two year SBIR sponsored materials research program to advance the strength and fatigue data for wood/epoxy wind turbine materials, and has also supported the Montana State research program for fiberglass blade composites.

Mr. Zuteck contributed input at an FAA meeting to help define certification requirements for powered lift vertical takeoff aircraft. He has worked with a helicopter blade company on innovative blade design, and solving problems with existing blade designs. He did the detailed structural design and aerodynamic concept for a state of the art aerobatic wing, and key tradeoff and optimization, and some detailed design, for the Formula 40 trimaran Adrenalin, which was successful in professional European circuit racing. He designed the Tornado catamaran that took the Silver medal in the 1976 Olympic games.

Mr. Zuteck also has ten years experience in aerospace. He served as part of the Apollo lunar landing team, and received the astronaut's special Snoopy award for his unique landing radar predictions during the pioneering landings in mountainous lunar terrain. He created the attitude dependent on-orbit aerodynamic drag model for the space shuttle, and also authored the automatic data-editing technique which pre-processed drop-out prone tracking data used by the Manned Spacecraft Center.

EDUCATION

M.S. Physics, University of Illinois, 1972

B.S. Physics, Massachusetts Institute of Technology, 1967

SELECTED PUBLICATIONS

S. Larwood, M. Zuteck, "Swept Wind Turbine Blade Aeroelastic Modeling for Loads and Dynamic Behavior", Windpower 2006,

http://flight.engr.ucdavis.edu/~smlarwood/documents/Larwood_Windpower_2006.pdf

K. Jackson, M. Zuteck, C.P. van Dam, K.J. Standish, and D. Berry, "Innovative Design Approaches for Large Wind Turbines," Wind Energy, Vol. 8, No. 2, 2005, pp. 141-171,

http://www.sandia.gov/wind/abstracts/030723A.pdf

D. Griffin, M. Zuteck, et al, "Development of Prototype Carbon-Fiberglass Wind Turbine Blades: Conventional and Twist-Coupled Designs." *2004 ASME Wind Energy Symposium*, *Reno, NV*, *5-8 January 2004*. American Society of Mechanical Engineers; pp. 1-12.

http://www.aiaa.org/content.cfm?pageid=406&gTable=Paper&gID=13763

M, Zuteck, "Adaptive Blade Concept Assessment: Curved Planform Induced Twist Investigation", SAND2002-2996, October 2002, http://sandia.gov/wind/topical.htm#ADAPTIVE

M. Zuteck, "Hawaii Zuteck Rotor Project Compilation of Reports", NREL/SR-500-26086, November 1998,

http://nsdl.org/resource/2200/20061005024309501T

D. Spera, J. Esgar, M. Gougeon, M. Zuteck, "Structural Properties of Laminated Douglas Fir/Epoxy Composite Material", NASA Reference Publication 1236, DOE/NASA/20320-76, May 1990 (hardback book)

T. Stroebel, C. Dechow, M. Zuteck, "Design of an Advanced Wood Composite Rotor and Development of Wood Composite Blade Technology", DEO/NASA/0260-1, NASA CR-174713, December 1984

SYNERGISTIC ACTIVITIES

Worked with TPI Composites on DOE sponsored wind turbine blade design project (Blade System Design Study). Worked with Knight & Carver on DOE sponsored Low Wind Speed Turbine blade design study (LWST).

Provide engineering support for a variety of large wind turbine owners and operators including: NextEra, Terra-Gen Power, enXco, and BP Wind.

2.3 *Richard Santos, Ph.D., Dynamic Loads and Controls*

PROFESSIONAL EXPERIENCE

Richard Santos is a wind turbine engineer with a broad range of international experience in design and control of wind turbines, capable of contributing to wind turbine design from inception through International Electrotechnical Commission (IEC) Type Approval. Dr. Santos has a strong background in wind turbine dynamics and control with experience designing and implementing control systems for POC variable-speed and individual blade pitch control. He has provided key expertise for certification of POC turbines, resulting in over twenty certification design reviews including blades, hub, mainshaft, bearings, brakes, bedplate, generator housing and tower. He holds B.S. and M.S. degrees in aerospace/mechanical engineering from Syracuse University and a Ph.D. degree in aerospace engineering sciences from the University of Colorado with a focus on damage mitigating control of wind turbines. His doctoral research focused on advanced controls for damage mitigating control of wind turbines.

EDUCATION

Ph.D. Aerospace Engineering Sciences, University of Colorado at Boulder, 2007.

M.S. Aerospace /Mechanical Engineering, Syracuse University, 1990.

B.S. Aerospace /Mechanical Engineering, Syracuse University, 1987.

AWARDS/HONORS

Best Poster Paper, European Wind Energy Association Conference, *Dynamic Tuning of Aeroelastic Wind Turbine Models*, 2007.

SELECTED PUBLICATIONS

Santos, R., Development and Simulations of Tower Damping System for ECO74 Wind Turbine using MSC/ADAMS, June 2007.

Santos, R., Dynamic Interaction of Global Wind Turbine Dynamics with Structural Subcomponents, AWEA Conference Paper, 2007.

Rossetti, M., Gudyol, M, Santos, R., Dynamic Tuning of Aeroelastic Wind Turbine Models, EWEA Poster Paper, 2007.

Santos, R., INF-3199 Summary of ARTEMIS System Identification Software, January 2007.

Santos, R., INF-3197 Location Study of Sensors for Individual Blade Pitch Control, February 2007.

Santos, R., INF-3198 Sensors for Individual Blade Pitch Control on ECO80 II Wind Turbine, February 2007.

Santos, R., Result from the IEA Round Robin Mechanical Loads Testing, AWEA Conference Paper, April 2002.

Derrick, J., Link, H. and Santos, R., Evaluation of a Hydraulic Yaw Damper on the AOC 15/50 Wind Turbine, AWEA Conference Paper, April 2002.

Musial, W. and Santos, R., Non-Linear Finite Element Buckling Analysis of a Pultruded Wind Turbine Blade, AWEA Conference Paper, June 2001.

Butterfield, S., Musial, W. and Santos, R., The Load Rose Method of Estimating Multi-Axial Fatigue Spectra for Wind Turbine Components, AWEA Conference Paper, June 2000.

2.4 Thomas Nordenholz, Ph.D., Flap Actuator System

PROFESSIONAL EXPERIENCE

Thomas Nordenholz is a professor of mechanical engineering at The California Maritime Academy, a campus of the California State University specializing in marine engineering and transportation and other maritime-related fields, and located on the San Francisco Bay.

Since CMA is an undergraduate institution, Dr. Nordenholz has mostly been focused on teaching undergraduate mechanical engineering courses, the improvement of ME education, and curricular development. Since joining the faculty of CMA in 1998, Dr. Nordenholz has been teaching a wide variety of ME courses, including fundamental mechanics courses (statics, dynamics, mechanics of materials, fluid mechanics), upper division mechanics courses (mechanical/materials laboratory, vibrations, advanced mechanics), computer programming, circuits, and controls.

Dr. Nordenholz began his interest in wind energy about seven years ago, when he met several members of this team. Since then Dr. Nordenholz has been acquiring knowledge and skills in wind energy engineering, created and taught a new course in power engineering (with a wind energy component), developed a laboratory course to study various power systems, and installed and instrumented a small wind turbine system to be studied in this course. Dr. Nordenholz has also created a minor within the ME program that focuses on power generation (traditional and renewable sources) and includes these courses as well as others. Dr. Nordenholz plans to continue these efforts with the aims of placing CMA's students into the wind energy industry, involving them in research projects, and utilizing the unique resources of the maritime academy to study, develop, and support the emerging offshore wind industry in the US.

EDUCATION

Ph.D. Mechanical Engineering, University of California at Berkeley, 1998.

M.S. Mechanical Engineering, University of California at Berkeley, 1995.

B.S. Mechanical Engineering, State University of New York at Buffalo, 1990.

SYNERGISTIC ACTIVITIES

Dr. Nordenholz is a member of ASME and ASEE (American Society of Engineering Education) and is the Principal Investigator and lead faculty advisor for the Cal Maritime Collegiate Wind Competition Team. This competition, organized and sponsored by NREL and taking place at the 2014 AWEA Windpower Conference, involves teams of college students designing and building a small wind turbine, developing an associated business plan, and delivering presentations on wind industry market issues.

2.5 Raymond Chow, Ph.D., Aerodynamic Modeling

Professional Experience

Raymond Chow is an aerodynamicist with over a decade of experience performing high fideltly computational fluid dynamics simulations over a wide range of problems. He has an extensive background with wind turbine aerodynamics and active aerodynamic load control devices. He actively conducts and supervises academic research in numerical methods, CFD, and wind tunnel experimentation as a postdoctoral scholar. He also acts as a consultant to the energy industry. He has conducted various aerodynamic performance analysis studies, design evaluations, and technology surveys for various wind turbine manufacturers.

Dr. Chow has conducted many computational studies focused on the NREL Phase VI and the NREL 5-MW rotors. He has worked as a contractor with Eloret Corp for the NASA Advanced Supercomputing division at NASA Ames. There he developed computational methods and performed simulations of accidental solid rocket booster ignitions inside the Vehicle Assembly Building at Kennedy Space Center. He also developed automated scripts to generate overset grids systems to model complex, multi-body 3-D geometry. He created the high fidelity computational grid for the flame trench of Launch Pads 39A/B at Kennedy Space Center for validation and development of the next generation launch vehicles.

Education and Training

Ph.D. Mechanical and Aerospace Engineering, University of California at Davis, 2011.

M.S. Mechanical and Aeronautical Engineering, University of California at Davis, 2006.

B.S. Mechanical and Aeronautical Engineering, University of California at Davis, 2004.

Synergistic Activities

Continued collaborative research with Sandia National Laboratories focused on developing wind energy technologies. Projects in the past included active aerodyanmic load control in the form of microtabs and microjets, development of the blunt trailing edge or flatback airfoil design, and 3-D rotor modeling of inboard flow separation on rotors and various methods to allieviate separation. The current active research project is focused on developing a numerical transition model of surface roughness and soiling with in a high fidelty 3-D CFD framework.

Awards/Honors

National Defense Science and Engineering Graduate (NDSEG) Fellow - Army Research Office and American Society of Engineering Education, 2004-2007.

Selected Publications

Blaylock, M., Chow, R., and van Dam, C.P., "Comparison of Pneumatic Jets and Tabs for Active Aerodynamic Load Control," *Journal of Wind Energy*, published online Jun. 2013. [doi: 10.1002/we.1638]

Cooperman, A.M., Chow, R., and van Dam, C.P., "Active Load Control of a Wind Turbine Airfoil Using Microtabs," *Journal of Aircraft*, vol. 50, no. 4, Jul. 2013, pp. 1150-1158. [doi: 10.2514/ 1.C032083]

Chow, R., and van Dam, C.P., "Computational Investigations of Inboard Blunt Trailing Edge Modifications on the NREL 5-MW Rotor," *Journal of Wind Energy*, vol. 16, no. 3, Apr. 2013, pp. 445-458. [doi: 10.1002/we.1505]

Chow, R., and van Dam, C.P., "Verification of Computational Simulations of the NREL 5-MW Rotor with a Focus on Inboard Flow Separation," *Journal of Wind Energy*, vol. 15, no. 8, Nov. 2012, pp. 967-981. [doi: 10.1002/we.529]

Chow, R., and van Dam, C.P., "On the Temporal Response of Active Load Control Devices," *Journal of Wind Energy*, vol.13, no. 2-3, Mar.-Apr. 2010, pp. 135-149. [doi:10.1002/we.370]

Chow, R., and van Dam, C.P., "Unsteady Computational Investigations of Deploying Load Control Microtabs," *Journal of Aircraft*, vol. 43, no. 5, Sept.-Oct. 2006, pp. 1458-1469. [doi:10.2514/1.22562]

2.6 John Lee Wamble, Rotor & Flap Actuator Modeling

PROFESSIONAL EXPERIENCE

Lee Wamble brings over fifteen years of work experience as an electrical engineer plus another three years as an electrical technician. Going beyond the typical EE areas of interest his expertise extends into the domains of mechanical engineering and physics, with deeper knowledge in magnetics, electromagnetics, power generation, acoustics and vibration analysis. From 2009 to 2012 he led the design of a new, unique and proprietary form of direct drive permanent magnet generator for wind turbines, an effort that included the successful deployment and field testing of a 100 kW prototype in southern California. From 2003 to 2009 he led an engineering team developing linear drives, generators and magnetic bearings for the transportation sector, and winning a million dollar four year federal grant to develop magnetic levitation technology. Prior to 2003 Mr. Wamble worked in diverse engineering disciplines including three years with an aerospace company designing and building factory automation tooling, a year with a consumer electronics firm both developing products and improving manufacturing, and a year with a manufacturer of professional sound equipment designing electro-acoustic transducers for commercial and military applications. Prior to and during his formal engineering education he worked as an electrical technician on commercial, industrial and residential projects, and his readiness to don the coveralls and turn a wrench continues to the present day. Mr. Wamble is the primary inventor on multiple patents both issued and pending and has considerable experience with the processes and strategies of intellectual property protection.

EDUCATION AND TRAINING

B.S. Electrical Engineering, University of Washington, 1993.

SYNERGISTIC ACTIVITIES

Ongoing development of direct drive modular generators for the wind energy sector.

2.7 John Cole, Rotor & Flap Actuator Modeling

PROFESSIONAL EXPERIENCE

Mr. Cole's brings to the Zimitar team a broad base of high technology engineering experience across multiple industries. In the area of mechanical and systems engineering Mr. Cole participated in the design of automated production lines for high volume medical disposable devices, including line layout and throughput studies. He optimized the design of electronic circuits for an intra-arterial blood gas analyzer. He worked with vendors to develop prototype machines for producing DNA micro arrays and participated in the design of a next-generation automated transit system, including vehicle design and ergonomics, magnetic levitation, motor design and power electronics and control electronics design. Mr Cole led an engineering team in the design and implementation of an upgrade to a single axis tracker for a 25MW solar array.

In the area of software engineering Mr. Cole developed control systems architectures and programs for high-volume production lines, co-developed the control software architecture and fundamental algorithms for an advanced automated transportation system, and wrote code for controlling DNA micro array synthesizers, including algorithms for performing optical pattern recognition and robotics. He also developed CRM/ERP/Ecommerce systems by customizing an Oracle Database and writing Java scripts.

In the area of manufacturing engineering Mr. Cole developed manufacturing procedures and wrote manufacturing instructions for assembling and testing complex systems ranging from medical devices to missile guidance systems.

In the area of quality engineering Mr. Cole developed Failure Modes and Effects Analysis for the design and manufacturing of numerous complex systems including gyro-stabilized optical seeker units for guided missiles. He established statistical process controls for the manufacturing of these systems as well as for the manufacture of high volume medical disposable devices. He conducted Design of Experiments to optimize the design of critical assemblies in a high volume medical disposable devices.

Mr. Cole also brings to the Zimitar team project management and leadership experience in a variety of areas. He managed the development of an advanced automated transit system from concept to subsystem prototype and full scale demonstration. Mr. Cole co-founded an advanced wind turbine company and led an engineering team in the development and deployment of a 120 kW prototype wind turbine and led the design of the follow-on prototype. He raised over $1 million in seed funding for the company. Mr. Cole managed the manufacturing development and rollout of several next generation DNA and RNA micro array designs as well as the development of an extremely complex automated piece of equipment that builds newly synthesized DNA coated wafers into fully packaged micro arrays. Mr. Cole began his leadership experience as an officer in the U.S. Army, where he trained and led soldiers in combat exercises in numerous worldwide locations.

EDUCATION AND TRAINING

B.S. Chemistry United States Military Academy

Synergistic Activities

As a consultant to the renewable energy industry, Mr Cole has experience in designing utility scale solar projects and wind turbine systems. Most relevent to this project is his experience participating in the mechanical design of the subscale STAR blade and his extensive filed experience in the repair and upgrading of large wind turbine blades.

2.8 Clark Foster, Flutter Detection System

Professional Experience

He held position at the Boeing Military Aircraft as a wind tunnel design engineer. Projects included design of yaw head to support full size ALCM in AEDC 16 x 16 transonic tunnel. Supported the fabrication, test, mating with ALCM and operation. Activity involved structural design of critical component in high dynamics environment. Transferred to commercial aircraft division an worked at BTWT on variety of dynamic models including rotor systems (Osprey V22 wind tunnel model). He is familiar with aero elastic structures.

Recent project involved emergency revision to large wind threatened structures at 43MW solar power installation. Original system included flat panels on compliant structure and subject to both base line wind loads and oscillating loads from cyclic separation and attachment of airflow. Collaborated on design, installation and test of new triangular truss structure to reduce compliant and avoid the cyclic loading. Solution implemented across entire solar power installation.

Co-builder of experimental aircraft – 1997 Pulsar N460GM; Re-built Pitts S1 aerobatic biplane N1PH; Upgraded Lazer N81337 aerobatic mono plane. These aircraft are subject to control surface flutter and require understanding of aero elastic phenomena to operate safely.

Education and Training

University of Washington -1977 Bachelor of Science – Mechanical Engineering

Registered Expert Witness with the SEC

USPTO listed in the top 25 Prolific Inventors with over 137 US patents. See: (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/inv_prol.pdf top of page 3)

Licensed as Professional Engineer, State of Washington 1982 #20314

Private Pilot's License Certified Assistant Aerobatic Judge

Member ASME (American Society of Mechanical Engineer)

Solid works CAD Trained

Synergistic Activities

He was team member developing an advanced segmented variable speed generator. Project included specification development, design, fabrication, assembly, lab test followed by instalation on a wind turbine and field testing over a year includiing winds exceeding 80 mph.

2.9 Robert Kamisky, Lab & Field Test Engineering

Professional Experience

Since 2010 Rob Kamisky has been an independent consulting providing engineering support for the wind energy industry. Projects have included research, development and demonstration of advanced turbine and blade concepts, field testing and measurement, failure analysis and mitigation, static blade testing and small turbine certification. He began work in wind energy in 2004 as a graduate student at the University of California, Davis where he was a research assistant at the California Wind Energy Collaborative. For his Master's thesis he installed, instrumented and analyzed a 1 kW wind turbine on the UC Davis campus and coordinated the development of a small wind turbine short course. After graduating, he spent two and a half years with Frontier Wind as the Engineering Manager and Lead Project Engineer where he oversaw a technology development and demonstration project that resulted in the deployment of a field test rotor on a 750 kW wind turbine in November of 2009. From 1998 to 2004, Mr. Kamisky focused on automotive engineering with the Hybrid Electric Vehicle Research Center at UC Davis and Battery MD, a small battery system engineering firm in Sacramento.

Education

M.S. Mechanical Aeronautical Engineering, University of California at Davis, 2007.

B.S. Mechanical Engineering, University of California at Davis, 2007.

Synergistic Activities

Mr. Kamisky has worked closely with the Zimitar engineering team members since 2007 on several successful wind turbine RD&D projects.

Organize and co-teach short courses for technicians working in the field of wind energy and for the general public a course on small wind energy systems.

Formed WINDprove Inc. to provide engineering support for wind turbine owners and operators.

2.10 Eric Jacobson, Lab & Field Test Support

Professional Experience

In 1989, Eric began his career in renewable energy working as a maintenance technician for a small wind farm in North Palm Springs, CA, where he installed and maintained ESI-80 and Vanguard wind turbines. He received his B.S. in Business Administration in 1994 from Southern Oregon University. In 1995, he worked with the engineering team at Advanced Wind Turbines in Tehachapi, CA, testing and developing the AWT-26 wind turbine. Following the AWT-26 development project, Eric worked as a Senior Research Technician at the National Renewable Energy Laboratory (NREL) for six years where he provided loads, performance, acoustic, and safety and function testing support for a wide variety of wind turbine development projects. He has tested components on many machines, including the Siemens 2.3MW, GE 1.5MW, Mitsubishi 1 MW, Zond Z750 kW, Mitsubishi 600 kW, AWT 26m, AOC 15/50, Bergey 50 kW and Bergey 10 kW machines. While working at NREL, Eric became a licensed electrician in 2002. He was also selected by his peers as the National Wind Technology Center's employee of the year for 2003. In 2004, Eric began to provide technical consulting services to the wind turbine industry, specializing in laboratory and field testing support.

EDUCATION & TRAINING

B.S. Business Administration, Southern Oregon University, 1994

JOURNEYMAN ELECTRICIAN – State of Colorado, LIC # 104856. 2001.

HIGH VOLTAGE ELECTRICAL SAFETY - National Technology Transfer, Inc. – OSHA Safety Division. 1999.

AWARDS/HONORS

NATIONAL WIND TECHNOLOGY CENTER: 2003 Outstanding Individual Award – December, 2004

NATIONAL WIND TECHNOLOGY CENTER: Employee of the Month – January, 2003

NREL: TEAM OF THE QUARTER, JANUARY 2000 – Certification Loads Testing Team

WIND TECHNOLOGY CENTER: TEAM OF THE YEAR 1999 – Technicians

3 REFERENCES

1. Hamilton, B., et al., "U.S. Offshore Wind Market and Economic Analysis", Navigant Consulting, DOE Award DE-EE0005360, October 17, 2013.

2. The Crown Estate, "Offshore Wind Cost Reduction Pathways", May 2013.

3. "Cost Reduction Potentials of Offshore Wind Power in Germany", Fichtner and Prognos, August 2013.

4 Roland Berger Consulting, "Offshore Wind Toward 2020: On the Pathway to Cost Competitiveness", April 2013

5. Cotter, L.,"UK Offshore Wind: Opportunity, Costs & Financing, DB Climate Change Advisors, Deutche Bank Group, November 2011.

6. Van der Zwaan, B, Tinoco, R., Lensink, S, van den Oosterkamp, P., "Evolving Economics of Offshore Wind Power", Cost Reductions from Scaling and Learning", May 2011.

7. Douglas Westwood, "Offshore Wind Assessment for Norway: Final Report", March 2010.