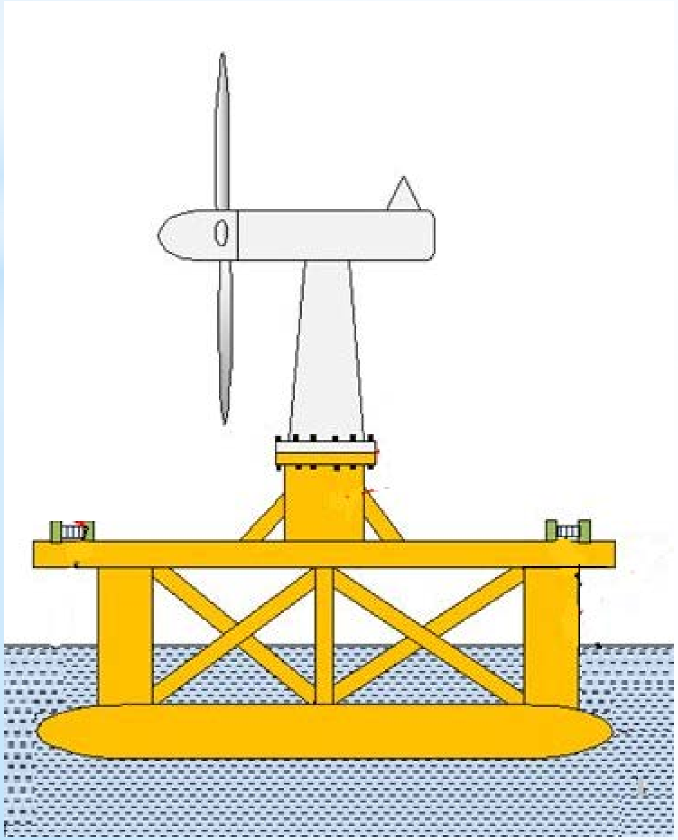
*Offshore Wind Turbine



Team 12

Jason Davis

Stephen Davis

Kevin Foppe

Margaret Gidula

Mark Price

Matthew Robertson

Nicholas Smith

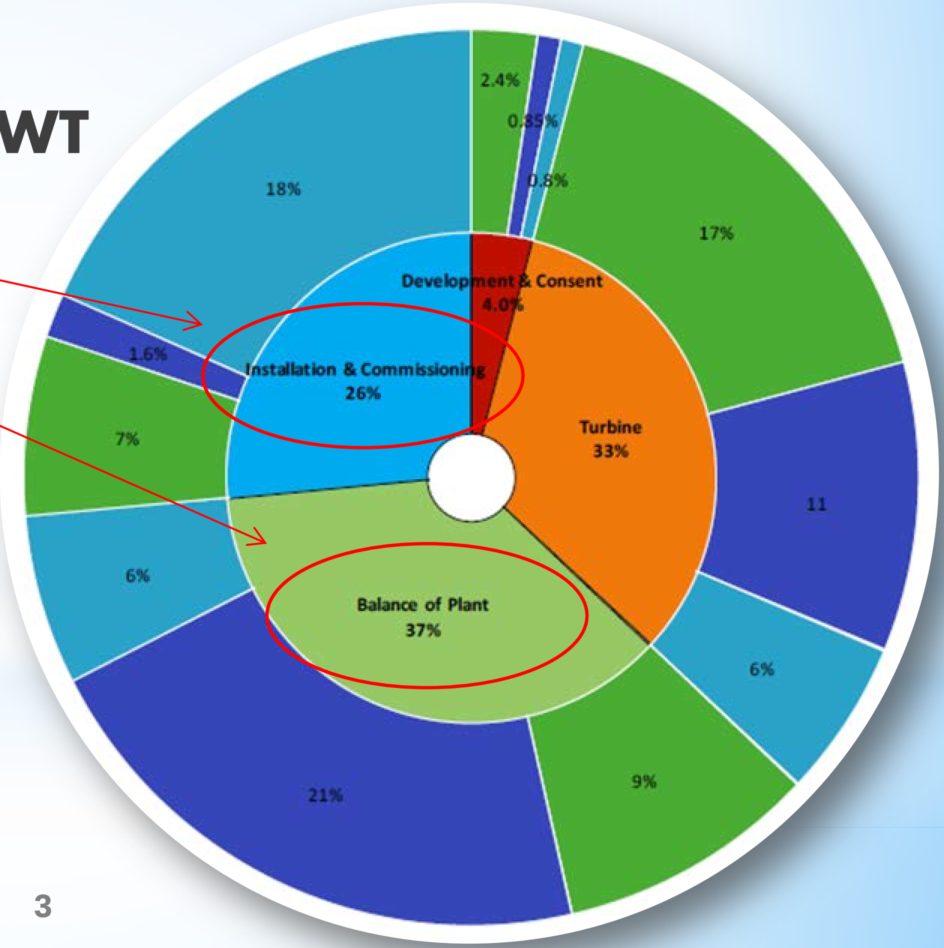
*Outline

* *Brief Overview
* *Detailed Design
* *Summary

Nick Smith

*Brief Overview

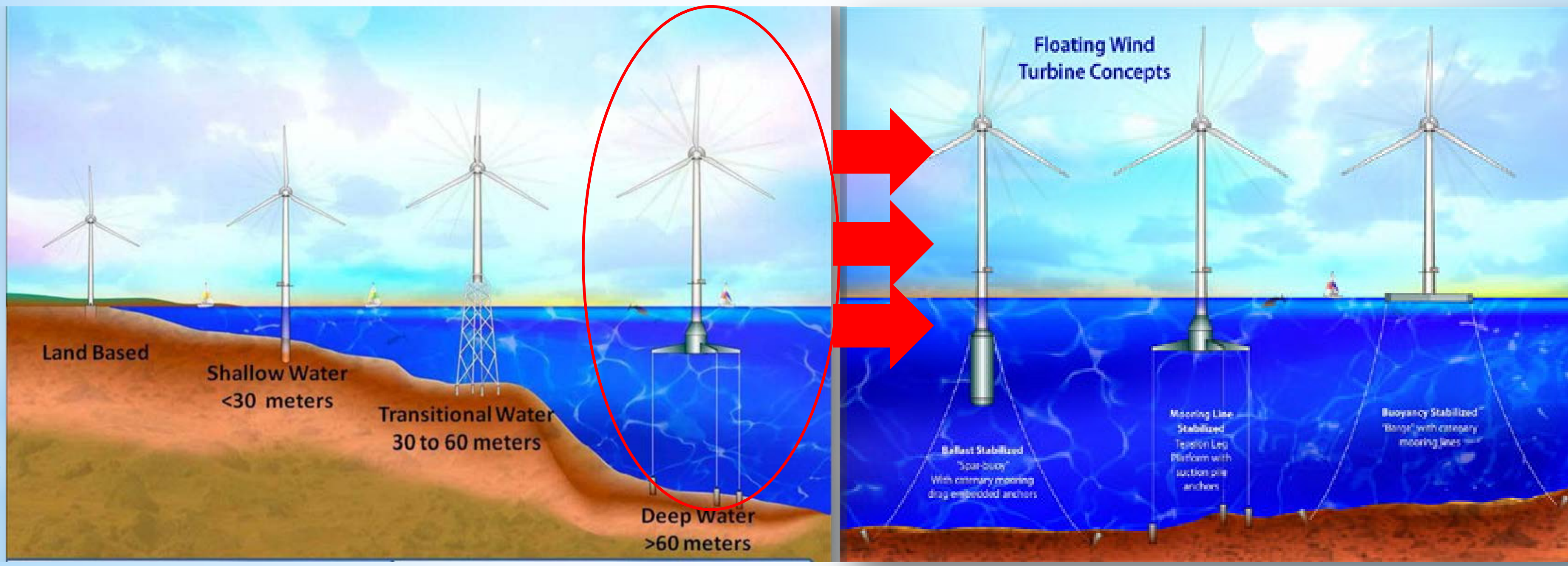
* **Goal: Reduce the cost of OWT**
  * **Construction – 24%**
  * **Foundation – 21%**



Nick Smith

*Brief Overview

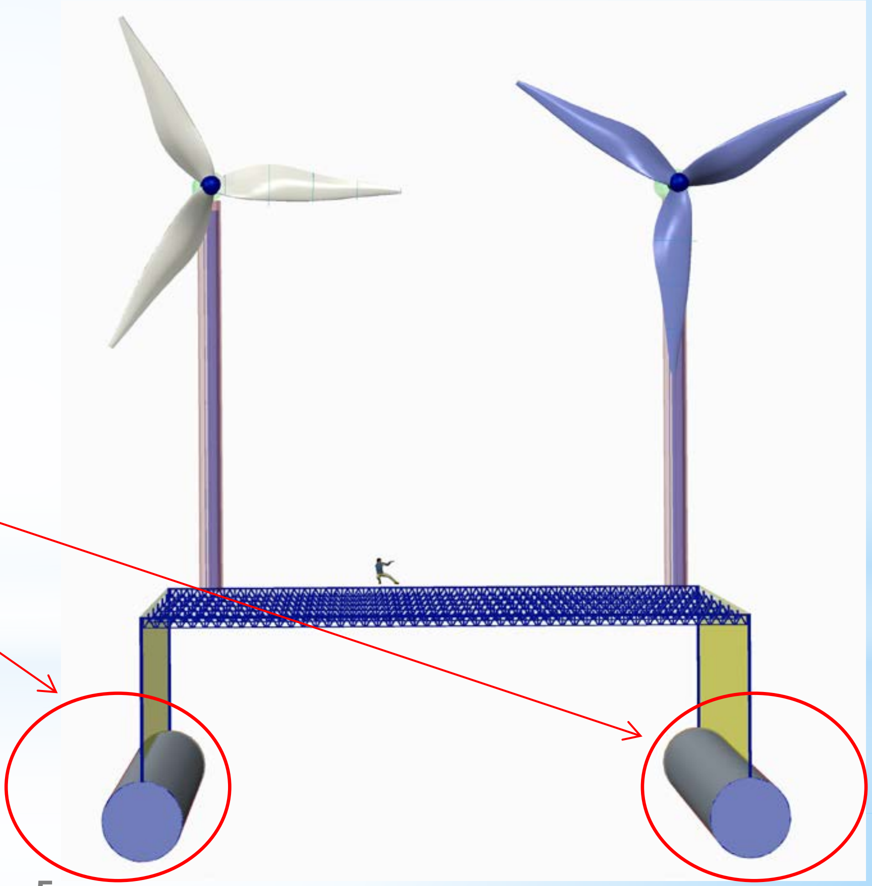
* **Existing Technologies are gradually moving due to better stronger winds offshore**



Nick Smith

*Brief Overview

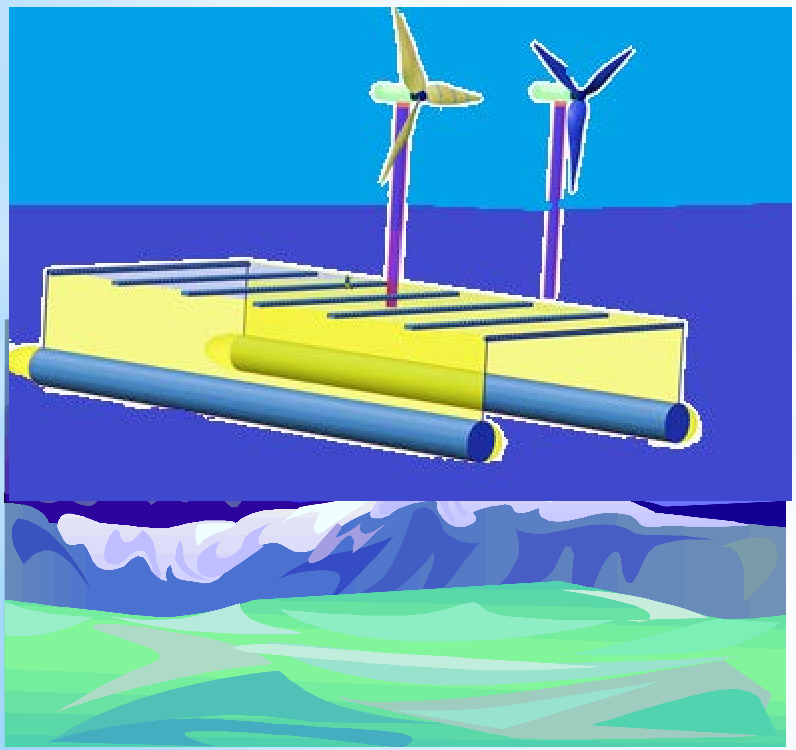
- *Innovations
  - *Twin tower design
  - *Autonomy
  - *Propulsion



Nick Smith

*Brief Overview of Manufacture

* Constructed in Dry Dock

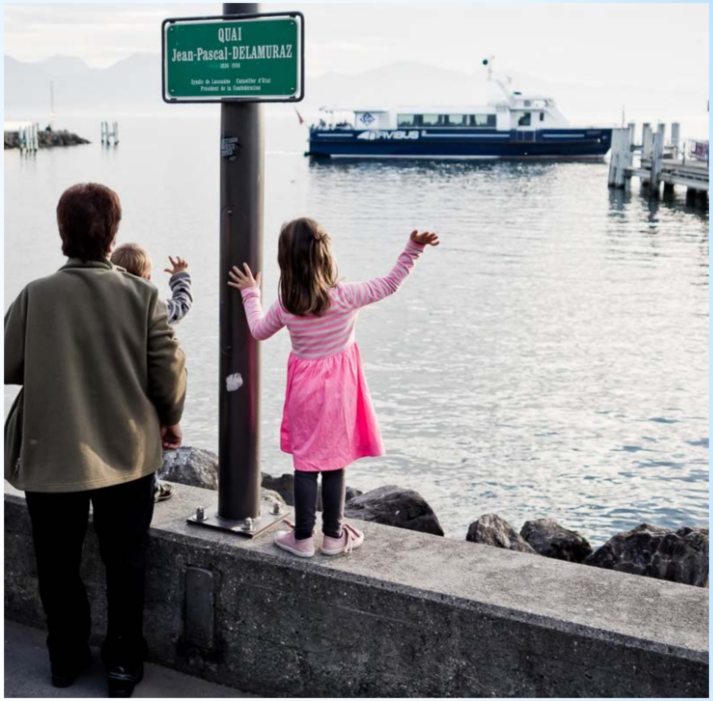


* Placed in harbor

Nick Smith

*Brief Overview of Manufacture

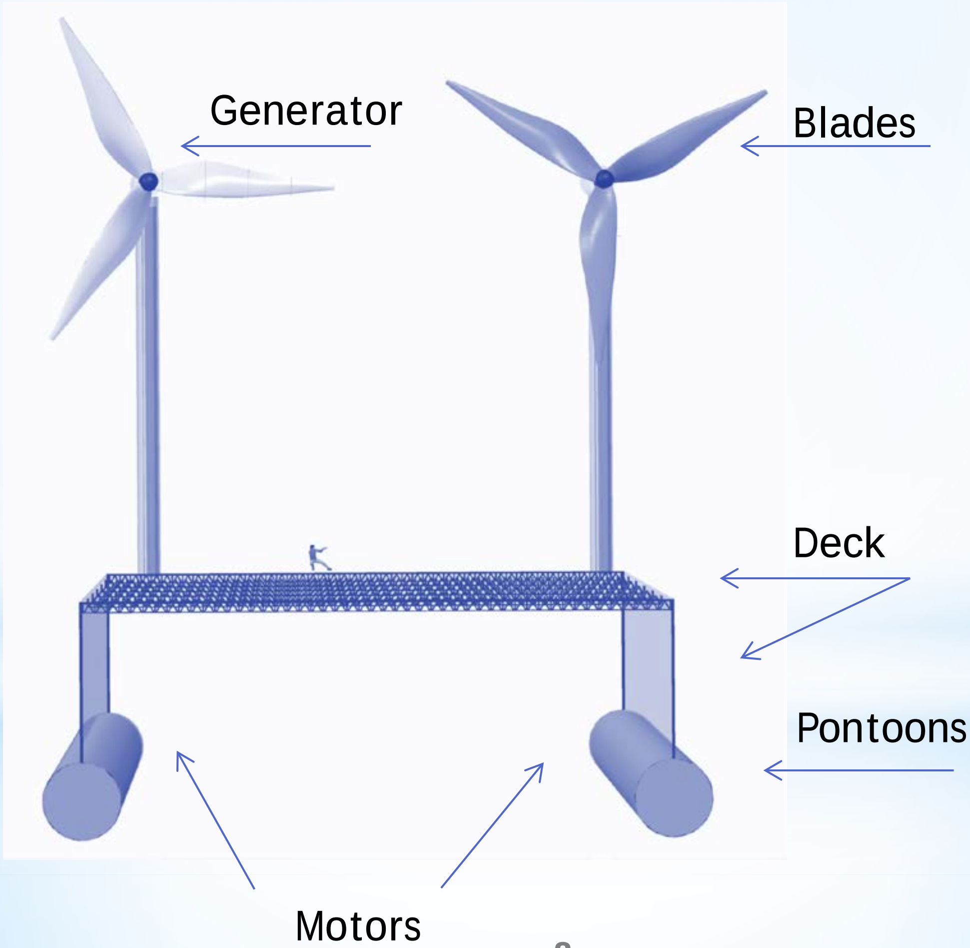
- Sent off to Coordinates



- Thrusters Stop & Turbine Starts

Kevin Foppe

*Navigation of Turbine Components



Kevin Foppe

Innovations: Propulsion for Deployment

- Two Engines Required
  - Total Force

$$F_{thrust} = F_{d,total} = F_{d,air} + F_{d,water}$$

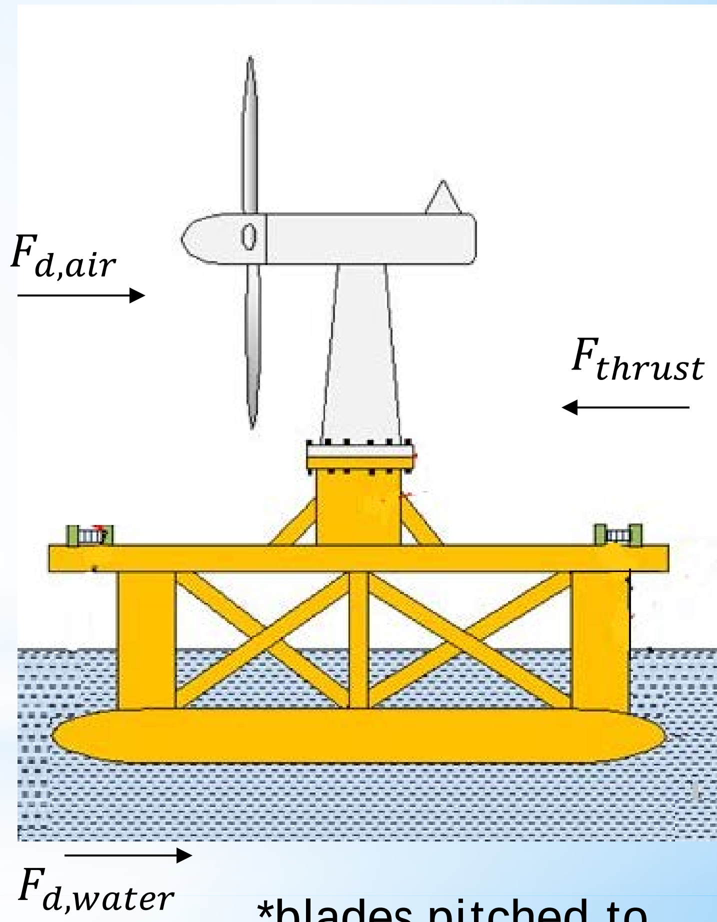
$$= \frac{1}{2} C_d v^2 A_c p_{\ air} + \frac{1}{2} C_d v^2 A_c p_{\ water}$$

$$F_{d,air} \approx 1.81\ N \ll F_{d,water} \approx 83\ kN$$

$$F_{d,total} \approx 83.35\ kN$$

  - Power per motor

$$Power = \frac{F_{thrust}}{2} * v \approx 213.4\text{kW} = 286\ \text{HP}$$



*blades pitched to zero

Kevin Foppe

*Motor Selection

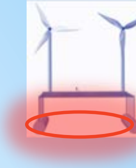
- *Two 300HP LINCOLN 1800RPM 449TS TEFC 3PH MOTOR
- *Total Enclosed Fan Cooled
  - *Better Protection from penetration
- Weight ≈ 3000 lbs.

Motor

*Innovations: Autonomy Package

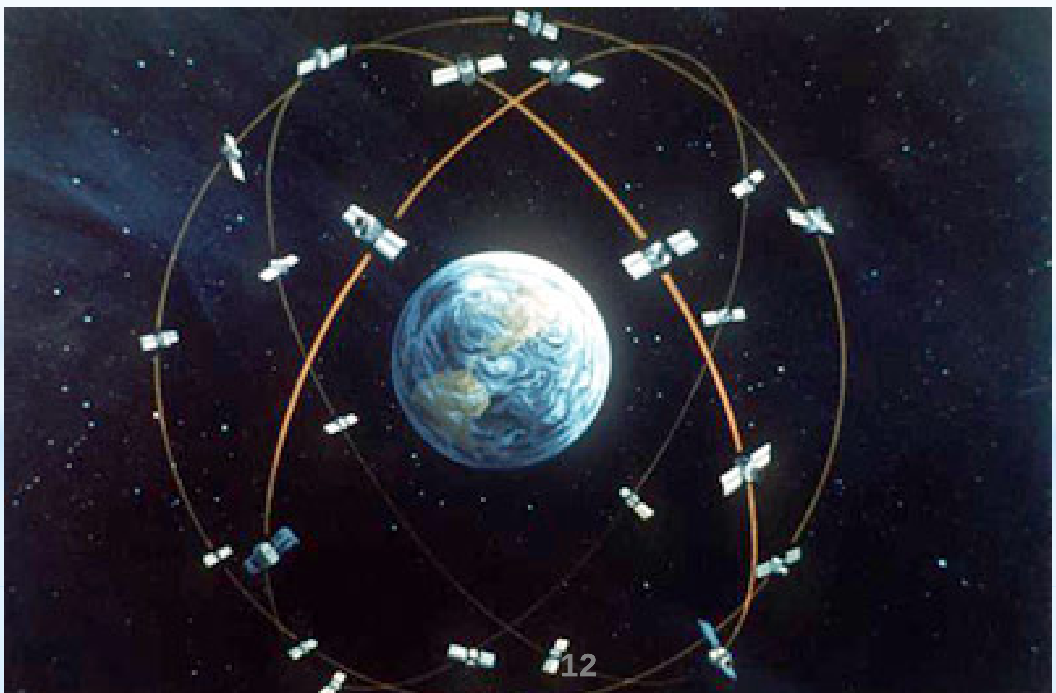
* Four main stages:
  * GPS
  * Power Stage
  * Controller
  * Filter Stage

Stephen Davis



*GPS

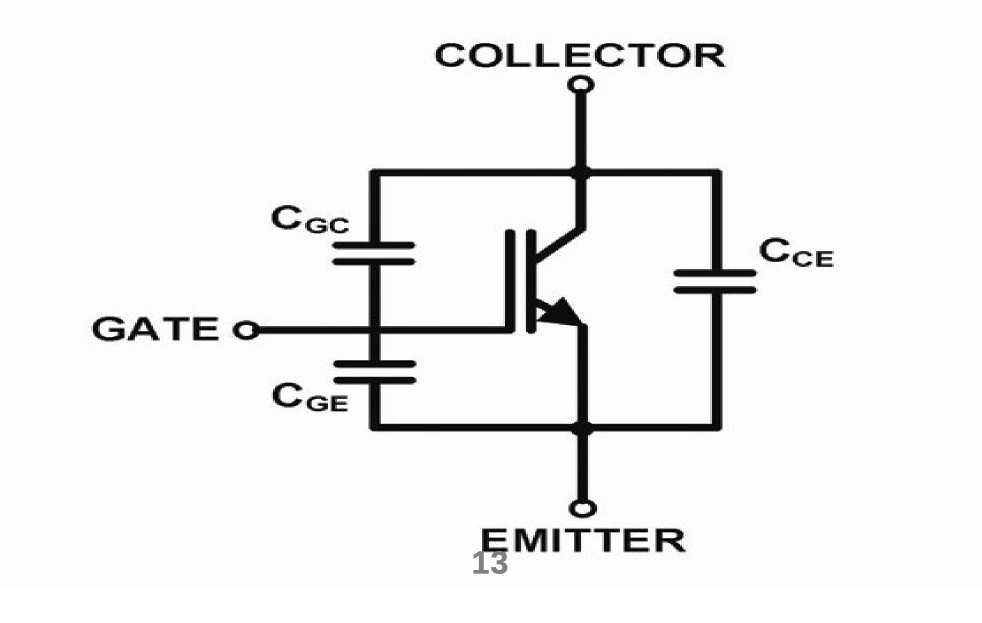
* Communication hub on land will send signal to the wind turbine giving it route to take
* Hardware onboard will interpret the signal and give the controller instructions



Stephen Davis

*Power Stage

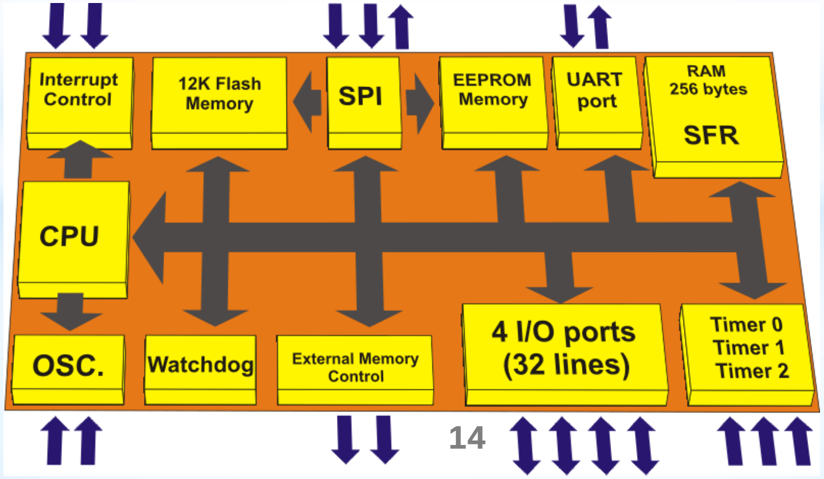
* Semiconductor switch arrays that connect to the motor (made of IGBTs)
* Within the arrays six different switches grouped into three pairs.
* During commissioning each bridge will be connected to a phase of the 3-phase AC motor.
* During operation the connection to the motor is closed using relays



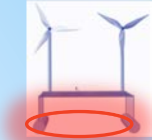
Stephen Davis

*Controller

- *Controller turns the IGBT switches on and off.
  - *(can turn the on and off up to 32,000 times per second)
- *Main components of controller: Digital Signal Processor(DSP) and Safety processor(SP)
- *DSP- Controls torque and charge behavior
- *SP- monitors acceleration and the motor currents consistency.



Stephen Davis

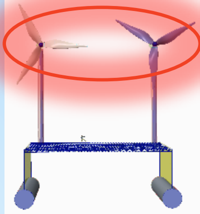


*Filter Stage

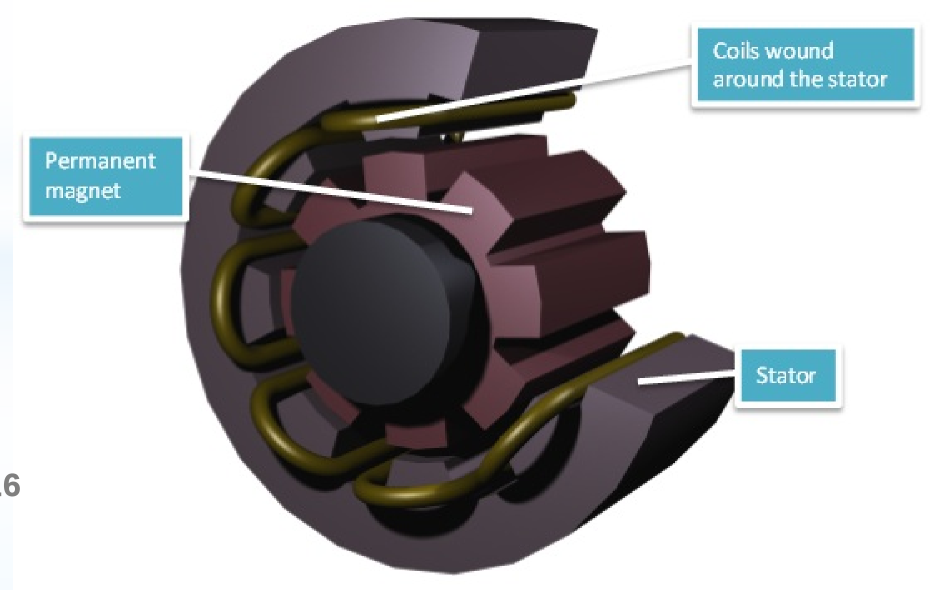
* *During operation the electrical power components create noise.
* *To help filter out this noise, inductors are placed between the IGBTs to help filter out the noise and any unwanted interference

Stephen Davis

*Generator



* Using two Permanent Magnet Generators
* Power Output – 100 Kw
* Start up speed – 3 m/s
* Rated rotational speed – 50 rpm
* Survival speed – 40 m/s
* Weight – 2400 Kg



Stephen Davis

*Programming

- *All programming will be done in C
- *Due prohibiting factors with GPS the small scale will be using timing delays.

Stephen Davis

One of Motors Code:

```
int motorPin = 9;

void setup()
{
  //Set the PWM Motor pin as an output
  pinMode(motorPin, OUTPUT);
}

void loop()
{
  //Increase Motor Speed from 0 -> 255
  for (int i=0; i<=255; i++)
  {
    analogWrite(motorPin, i);
    delay(10);
  }

  delay(10000); //Hold
  //Decrease Motor Speed from 255 -> 0
  for(int i=255; i>=0; i--)
  {
    analogWrite(motorPin, i);
    delay(10);
  }
 delay(10000); //Hold
for (int i=0; i<=255; i++)
  {
    analogWrite(motorPin, i);
    delay(10);
  }

delay(5000); //Hold

  for(int i=255; i>=0; i--)
  {
    analogWrite(motorPin, i);
    delay(10);
  }

  delay(5000); //Hold
  for (int i=0; i<=255; i++)
  {
    analogWrite(motorPin, i);
    delay(10);
  }

  delay(10000); //Hold

  for(int i=255; i>=0; i--)
  {
    analogWrite(motorPin, i);
    delay(10);
  }

  delay(10000); //Hold
}
```

Mark Price

*Pontoons

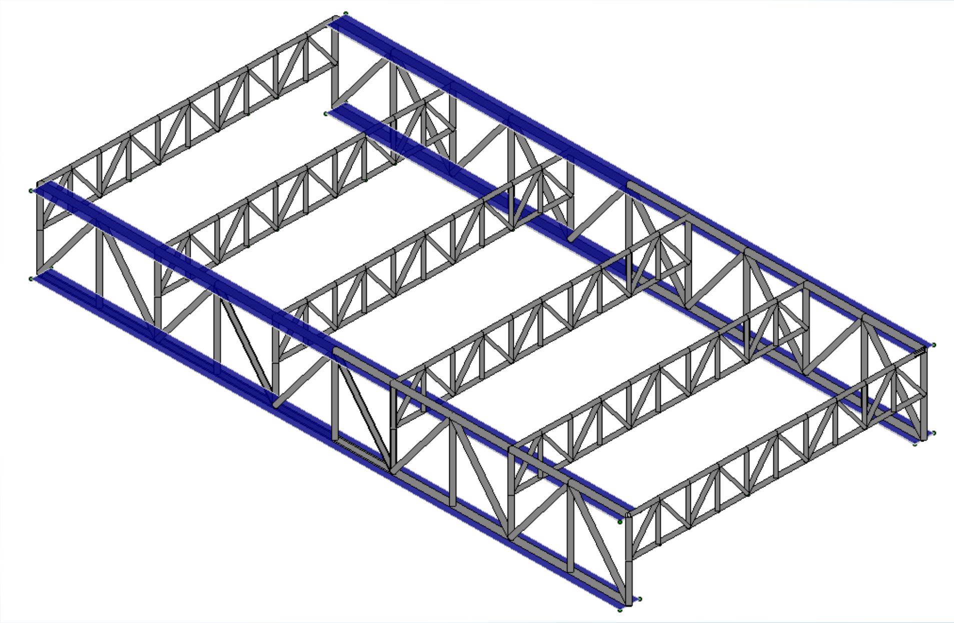
* Two A618 Grade 1 Steel Galvanized Pontoons
* Modeled as Cylinders
  * For design simplicity

- Volume of water to displace = 590m^3
- Diameter of 4m
- Length of 60m
  - Capped ends
- Ballasted to control buoyancy and stability

Matt Robertson

*Deck- Truss Framing

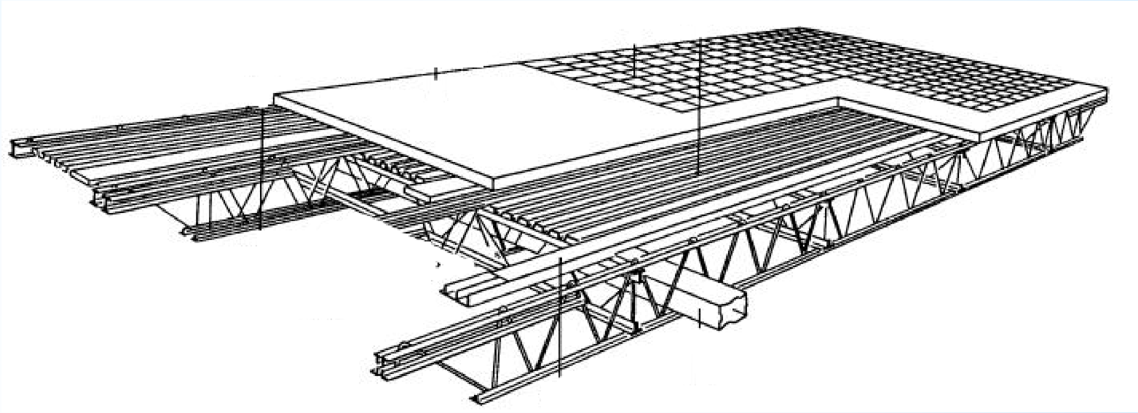
- *Beam-trusses rest directly on the pontoons
  - *Round HSS16x0.625 members
  - *A500 Grade B Steel
  - *Yield Stress = 42 ksi
- *Connections pinned within the trusses
- *All other connections are continuous welds
- * Plates are 2.5 inches thick using A36 steel with Yield stress =36ksi

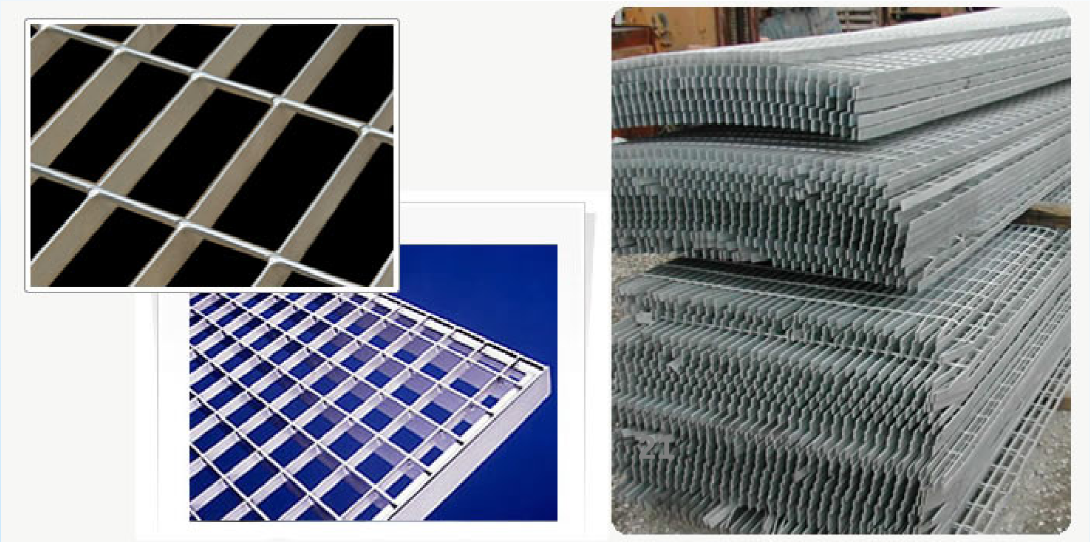


Matt Robertson

*Deck- Flooring

* 60x30 m metal grating
* Provides little structural support
* Provides accessibility for maintenance





Towers

- Purpose :
  - Support Nacelle and Blades
  - Carry loads generated by rotation

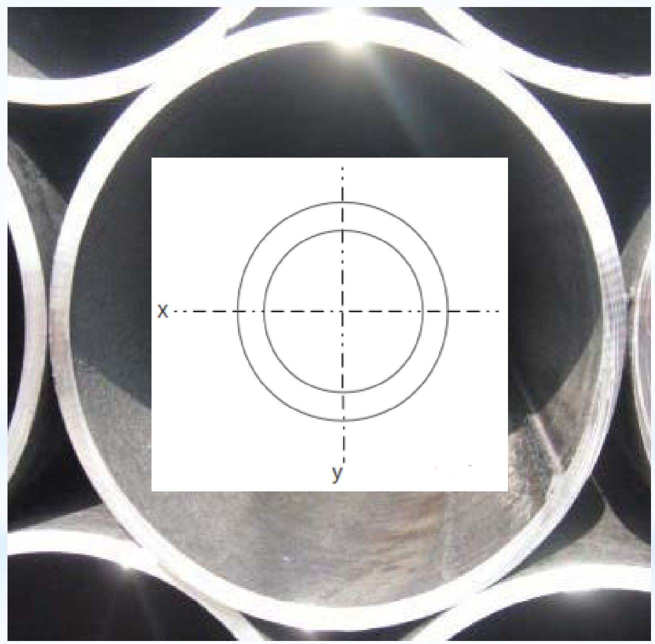
- Design Options:
  - Steel Column
  - Lattice Tower

Margaret Gidula

Design Criteria and Selection

Criteria:

- 20 m tall
- 2 towers
- Required yield strength= 345 Mpa
- Meet ASCE 7 Standards



Selection

- Steel Column
- Galvanized A618 Grade 1
- 2 feet diameter
- ½ inch thick
- 8,635 lbs

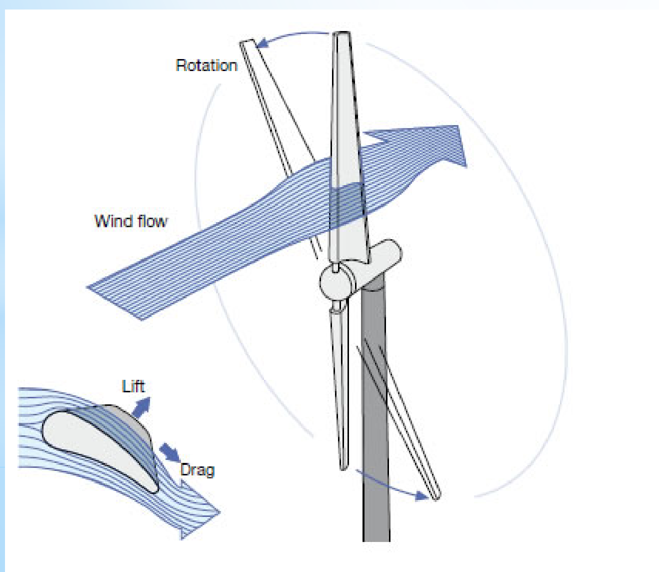
Nick Smith

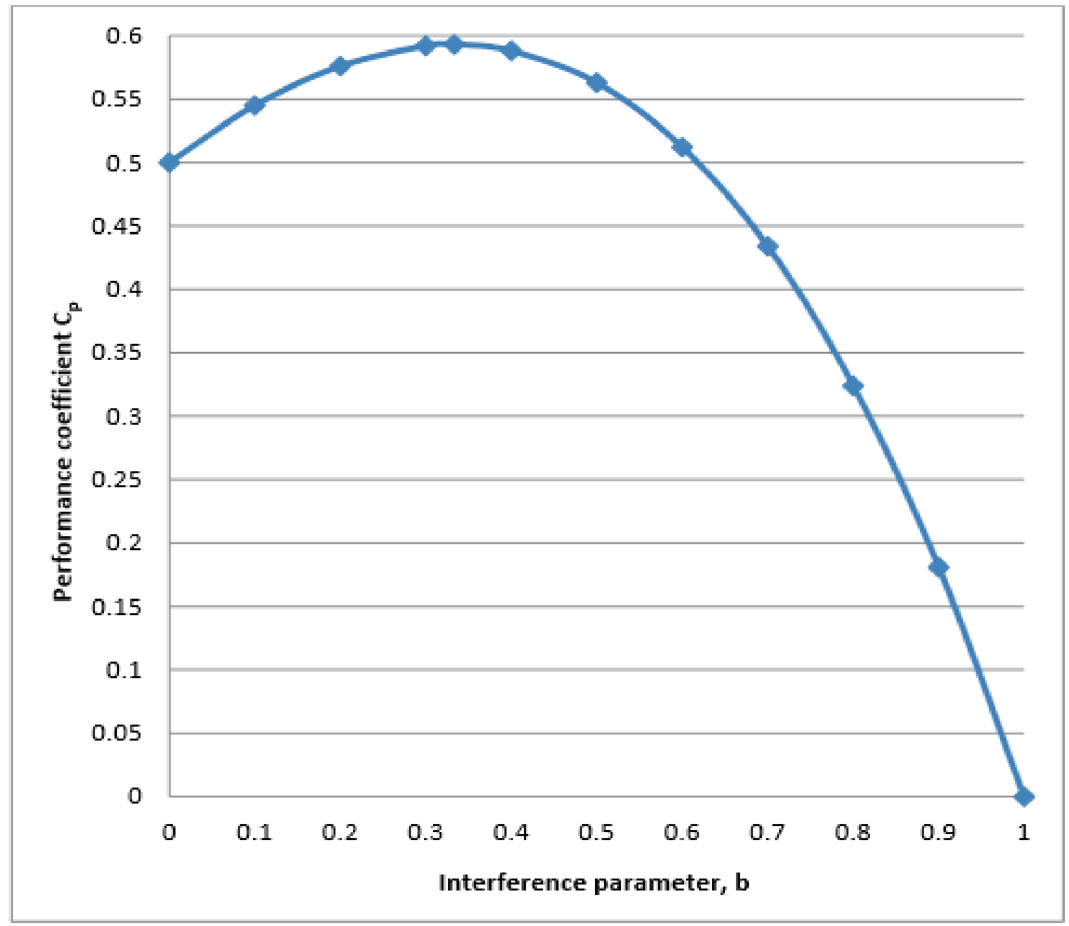
*Purpose of Turbine Blade

* Convert Wind Energy

$$Power = \frac{1}{2} * \rho_{air} * V^3 * A_c * C_p$$

  * ρ = Air density
  * V = Wind speed
  * A = Blade area (cross section)
  * C = Power Coefficient





b	0.0	0.1	0.2	0.3	1/3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_p	0.500	0.545	0.576	0.592	0.593	0.588	0.563	0.512	0.434	0.324	0.181	0.00

Nick Smith

*Turbine Blade Details

* Three-Blade Configuration
  * Gyroscopic balance
  * Better efficiency

Property	Value
Max rotational speed	19 rpm
Blade composition	Epoxy glass fiber + carbon fiber
Length per blade	9 m
Mass per blade	1,200 kg

Rotor Size and Maximum Power Output	
Rotor Diameter (meters)	Power Output (kW)
10	25
17	100
27	225
33	300

Nick Smith

*Turbine Blade Pitch Control

* Tip Speed Ratio

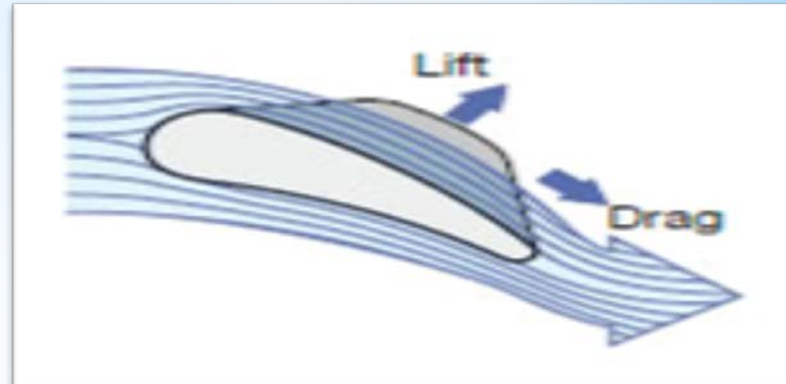
$$TSR = \frac{\Omega R}{V}$$

  * V = Wind velocity
  * R = Blade radius
  * Ω = Angular rotational speed

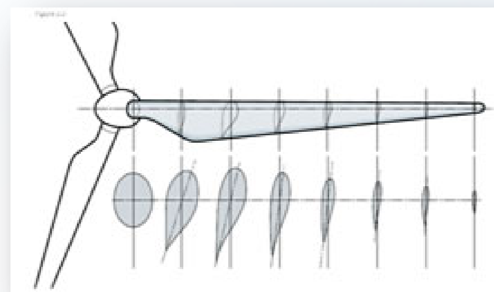
* 9m blade -> $TSR \approx 12$

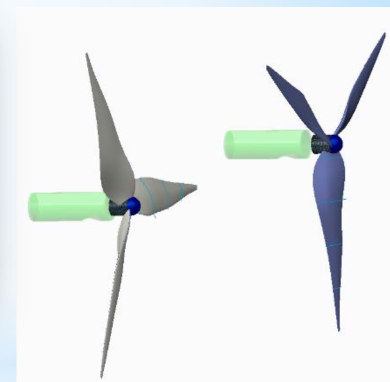
Nick Smith

*Turbine Blade Pitch Control

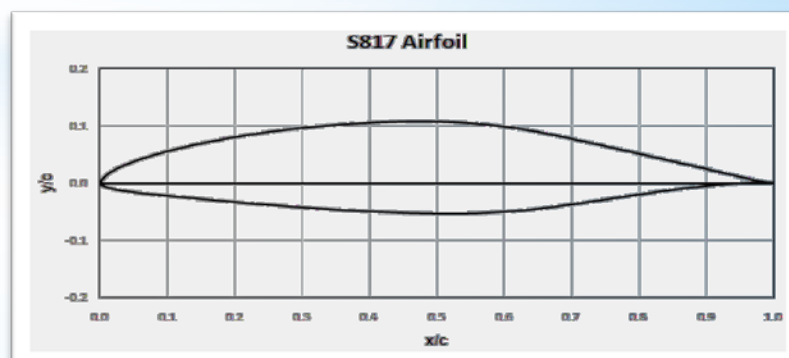


- *Blade Forces
  - *Lift and Drag
  - *Angle of Attack





- *NREL S817
  - *Optimum for small diameter turbine



Nick Smith

*Total Cost

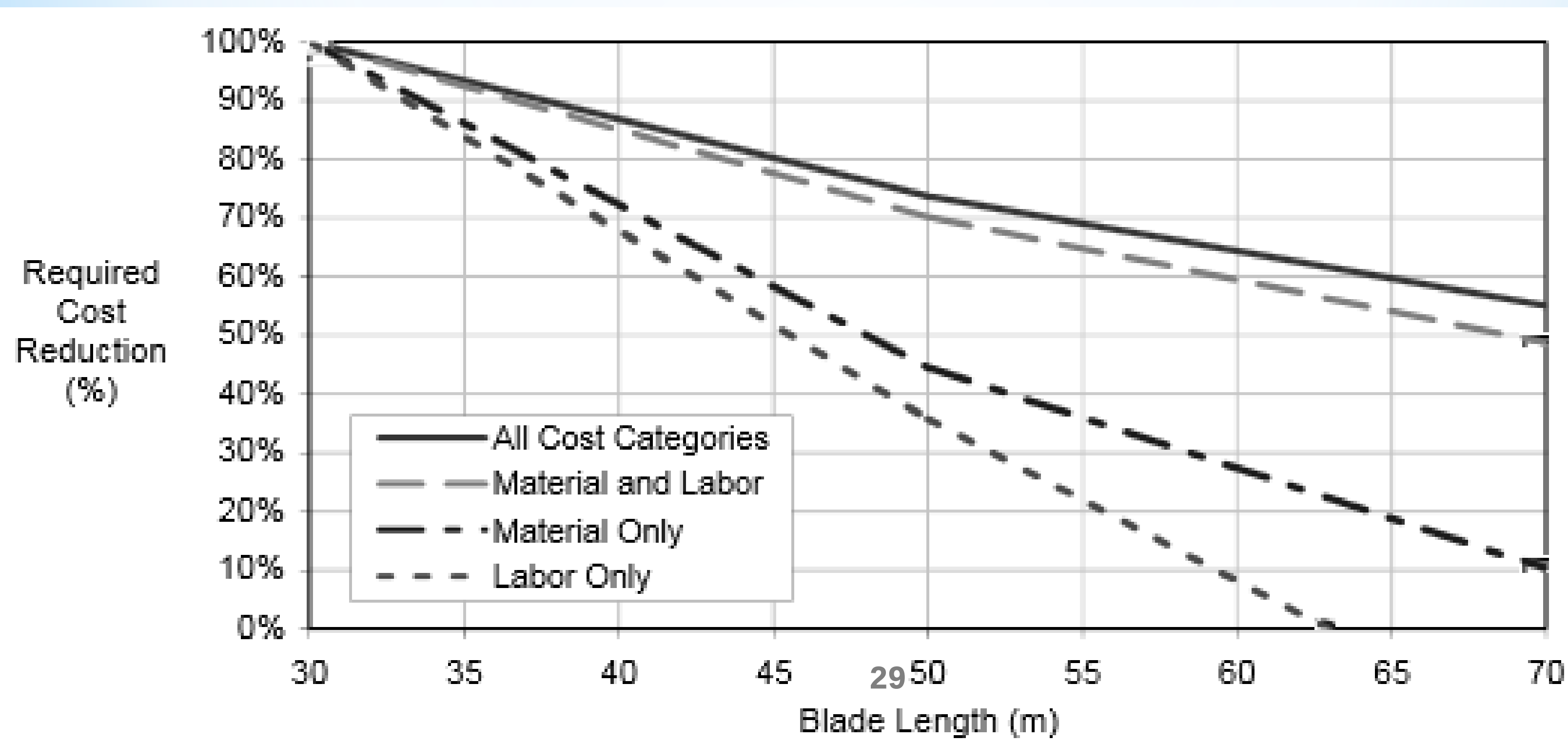
- Blades and Nacelle……………$ 5,300
- Propulsion Engine…………………$ 18,398
- SWATH……………………………………$ 1,000,000
- Generator………………………………$ 5,000 +

TOTAL = $ 1,028,693 + Labor

Nick Smith

*Reducing Material Cost

- *Material and labor provide the largest cost
- *CFRP cost $10/pound (2013)[2]
  - *$150/pound (2000)[2]



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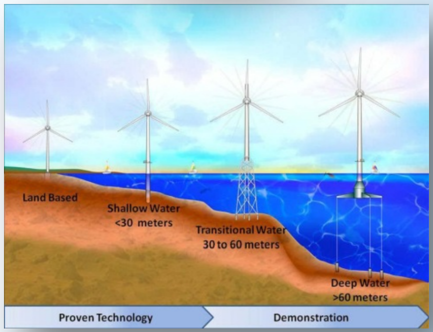
*Summary

* Goal
  * Reduce the cost of OWT
* Existing Technologies
* Innovations
  * Twin tower design
  * Autonomy
  * Propulsion



*References

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QUESTIONS?