

OLD DOMINION UNIVERSITY

An Introduction to Mechanical Engineering

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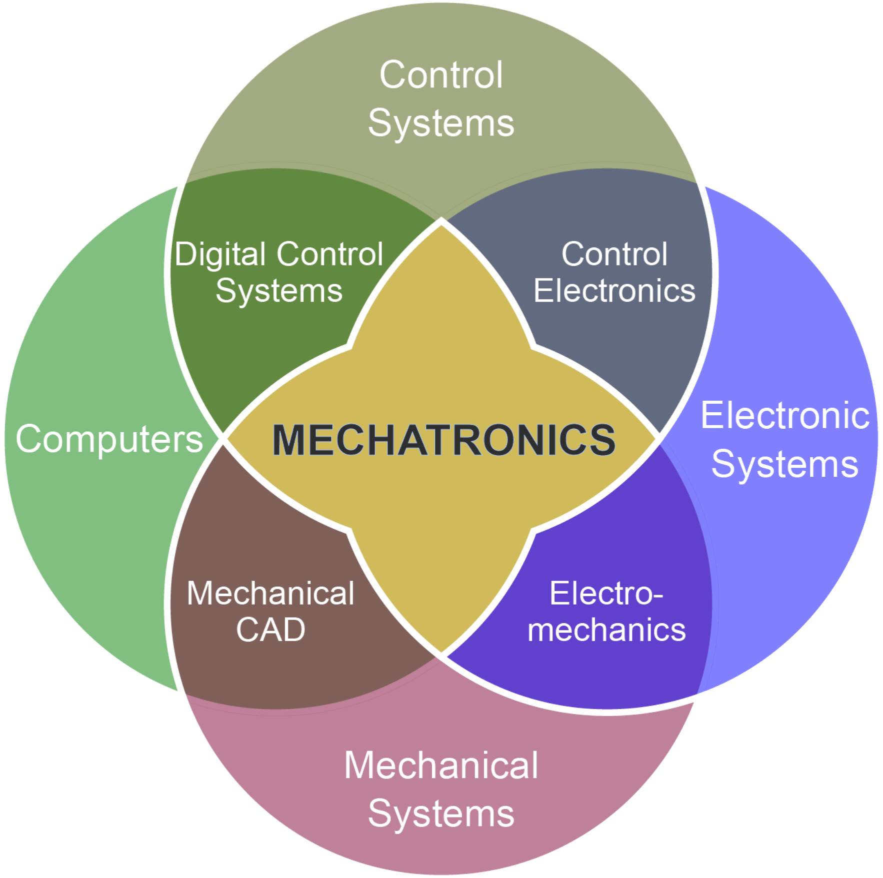
What is Mechanical Engineering ?

- Classical definition: An engineering discipline that encompasses the generation and application of heat and mechanical power and the design, production, and use of ***machines***.
- A ***machine*** is an apparatus using or applying mechanical power and having several parts, each with a definite function and together performing a particular task.
  - Pumps, compressors, internal combustion engines, wind turbines
  - Piping systems and pressure vessels, reactors, heat exchangers
  - Consumer goods and products: everything from coffee grinders to toothbrushes
  - Material handling equipment - conveyers, robots, production assembly lines
  - Vehicles - cars, trucks, heavy equipment, buses, aircraft, ships
  - Power generation equipment: wind power, hydroelectric, nuclear, geothermal

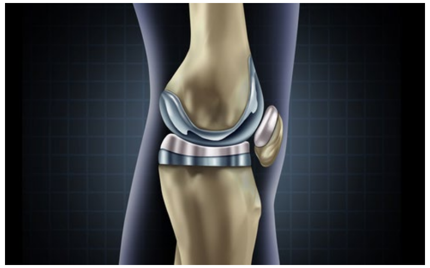
The Modern Era and Mechanical Engineering

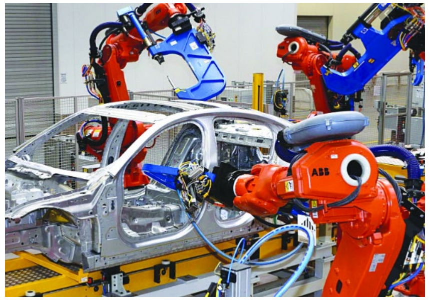
- We have discussed classical mechanical engineering applications but will now look at some new topics
- In engineering, boundaries between mechanical, electrical, and software engineers are increasingly blurry
  - As a new mechanical engineer you will need some knowledge in other fields
  - Mechanical engineering now has undergraduate courses called **Electro-Mechanical Systems** or *Mechatronics*
- As modern engineering becomes more precise both with measurements and computer simulations, understanding the error associated with solutions has become a focus
  - An undergraduate course of study should include **Probability and Statistics**



Typical Jobs of A Mechanical Engineer

- **Product Design:**
  - Designing products ranging from knee replacements to internal combustion engines to self driving cars, aircraft, bicycles, robots, drones and appliances
- **Research and Development:**
  - Researching new ideas and solutions that satisfy society's demands or improving or expanding older ideas and solutions
- **Manufacturing:**
  - Designing and building the machines and processes used for mass production of consumer products
- **Systems Management:**
  - Managing the operations of a large system, such as a manufacturing facility or a power plant
- **Energy**
  - Planning how energy is created, stored and moved in industries that produce and deliver electrical power, such as natural gas, oil and alternative energy



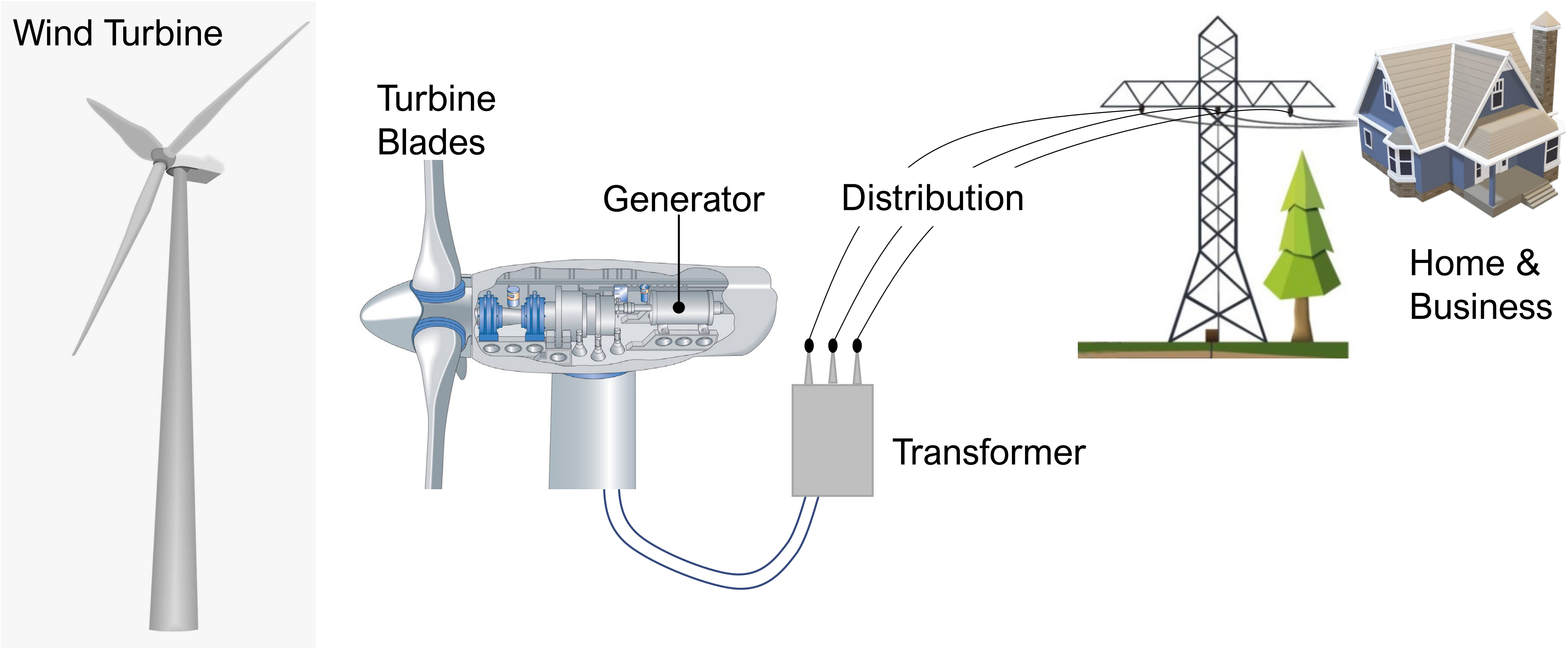


Wind Power Example

- In the next slides we will examine the role mechanical engineers play in the design, manufacture and management of systems for energy generation using wind
- Text in **BOLD** identifies relevant coursework from the undergraduate curriculum

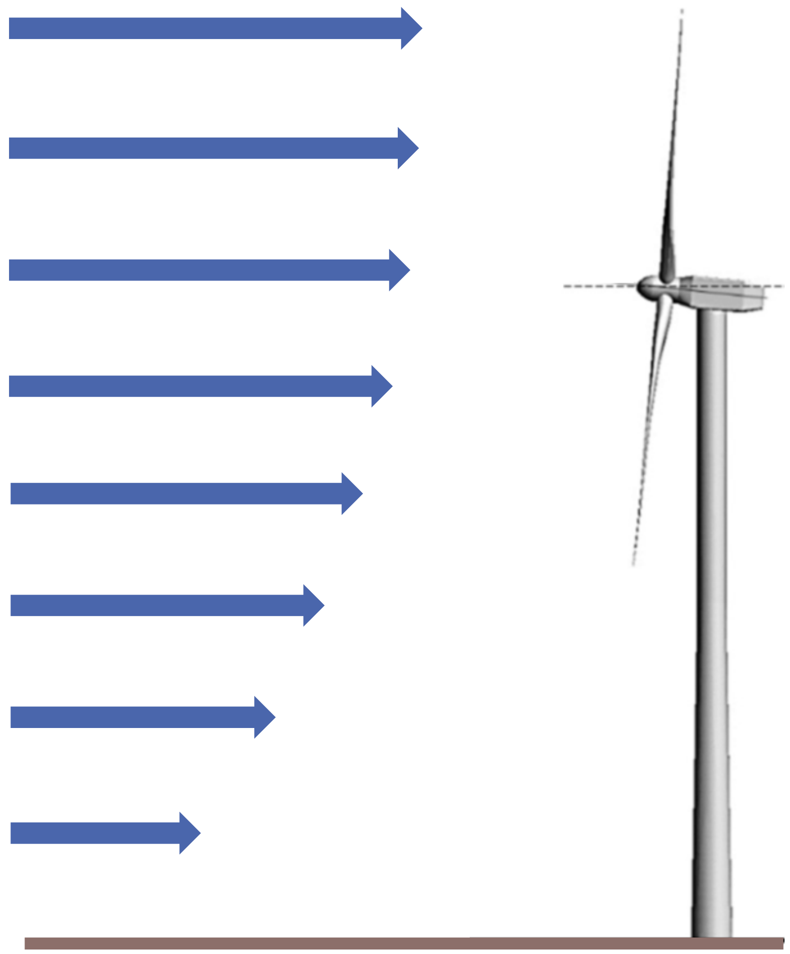
Mechanical Engineering of the Wind Turbine

- A wind turbine extracts energy from the movement of air in the atmosphere
- Here is the basic concept of operation:



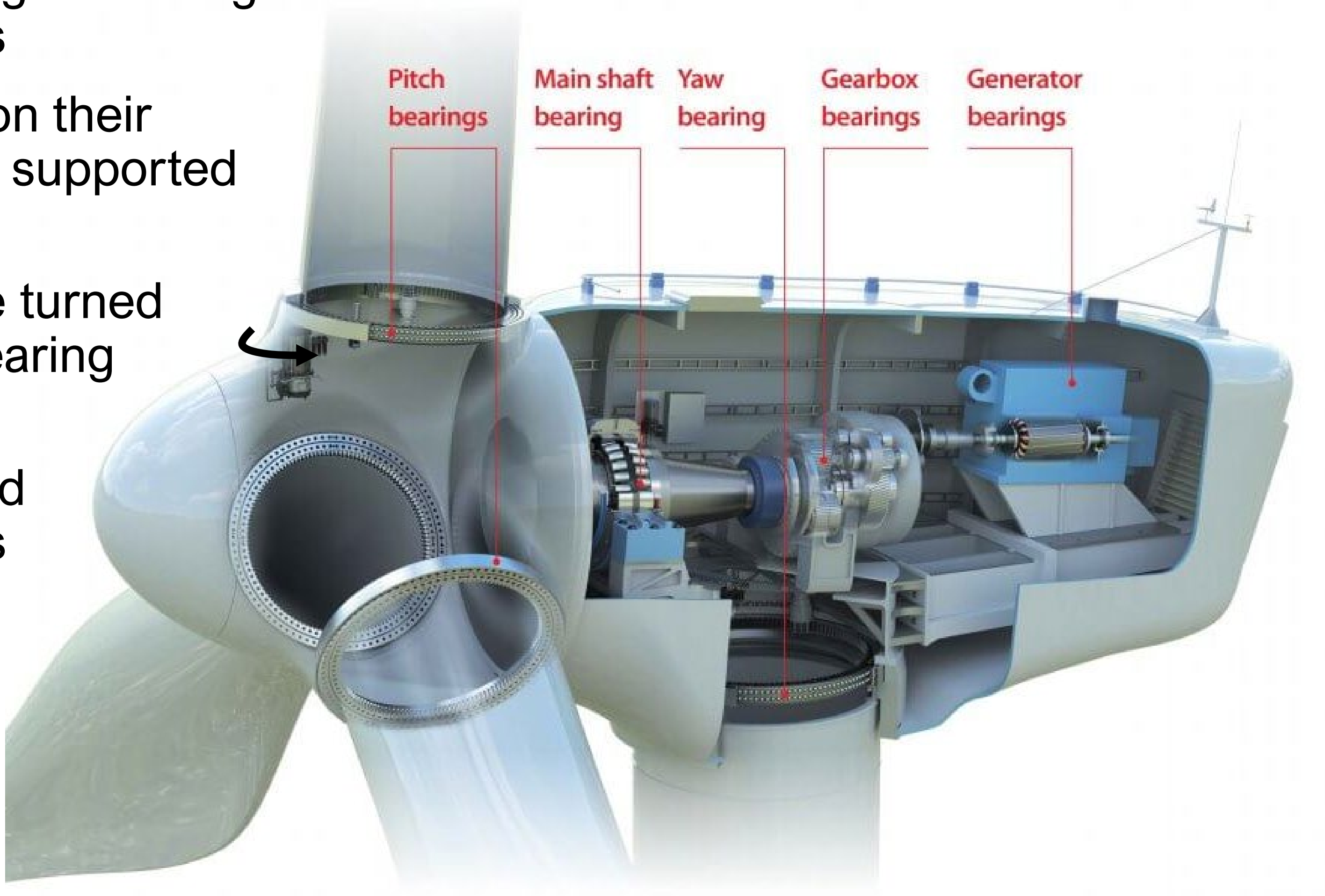
Wind Turbine Aerodynamics

- At a given location, wind velocity over the earth increases with height near the surface
- The change in velocity is due to skin friction from the air being in contact with the surface of the earth
- At the ground, the wind velocity is zero
- This layer where velocity changes is called the boundary layer and you will learn about it in **Fluid Mechanics**
- This is the reason wind turbines are mounted high above the earth
  - They generate more electricity in higher winds



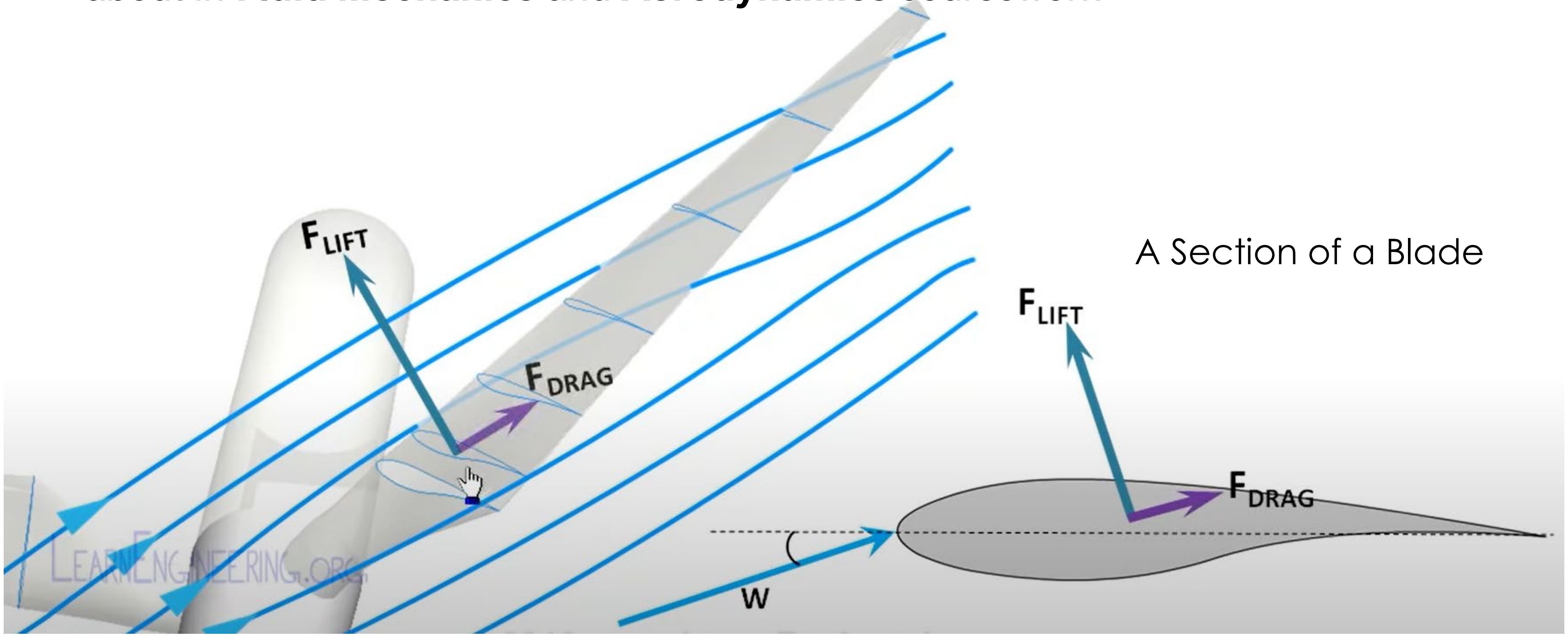
Wind Turbine Machine Element Design

- The rotor blades spin a main shaft at low speed that is supported by bearings
- The low-speed shaft drives gears in a gear box which in turn drives the generator; all have bearings
- The blades can be rotated on their axes to adjust pitch and are supported by their own bearings
- The whole assembly can be turned into the wind via the yaw bearing
- All of these devices have to be analyzed and designed to withstand the given loads over a long lifetime
- The design of these components requires courses like **Dynamics, Mechanics of Materials**, and **Mechanical Design**



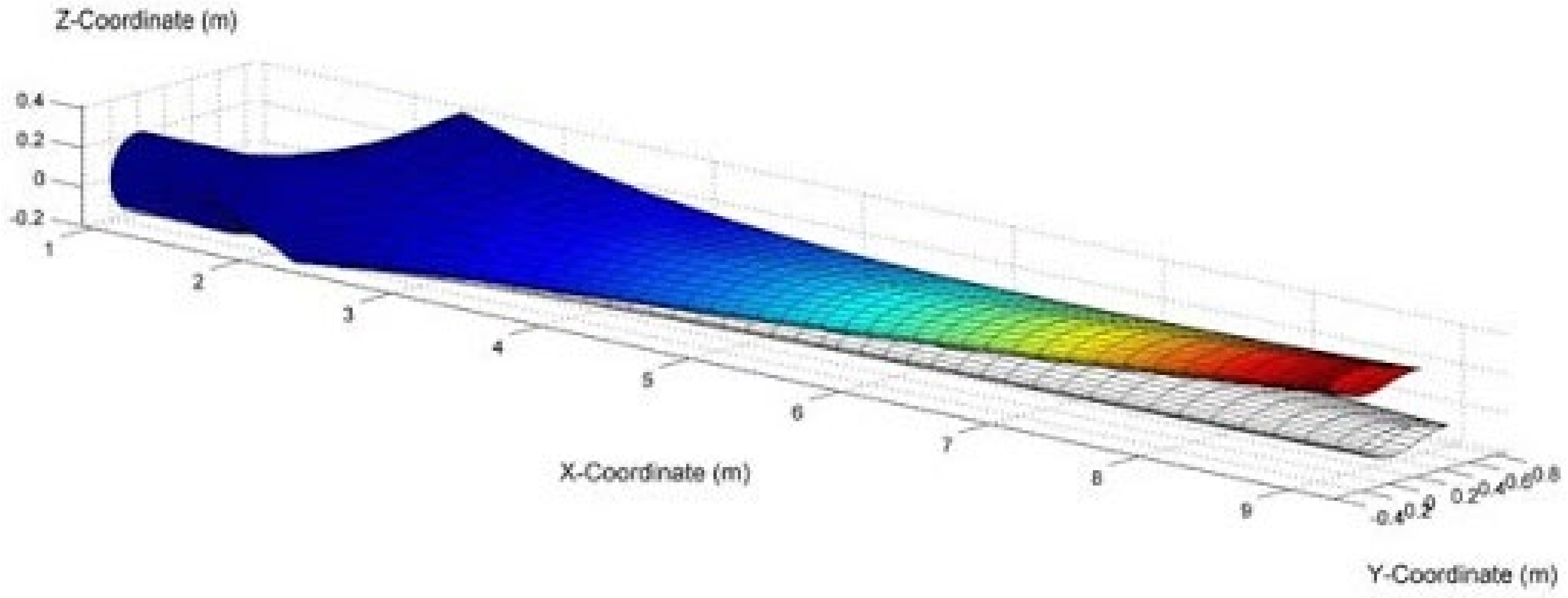
Blade Aerodynamics

- To understand the loads on the structure we first need predictions for the forces generated by the airflow over the blades
- The wind and blade rotation cause forces of Lift and Drag which you can learn about in **Fluid Mechanics** and **Aerodynamics** coursework



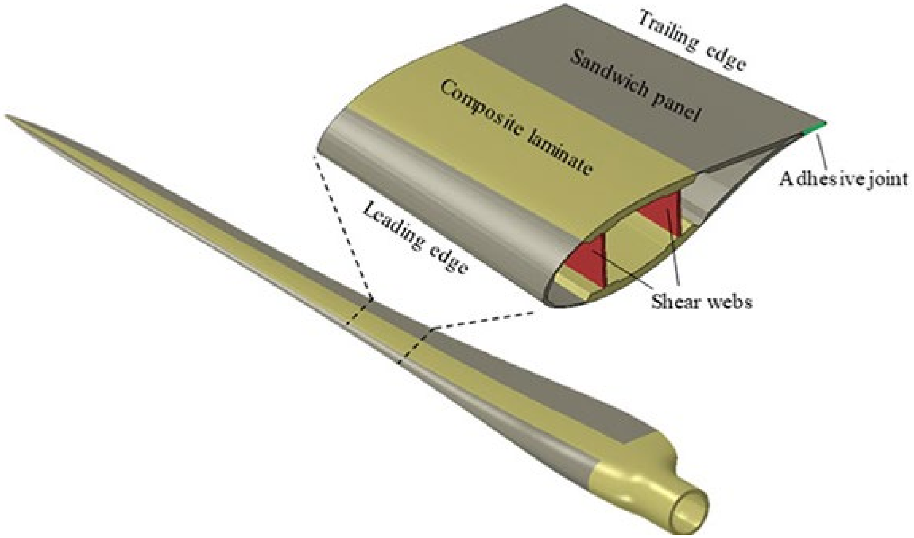
Blade Structure

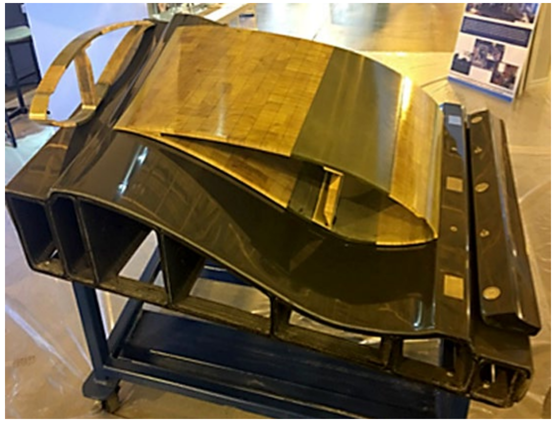
- If we know what loads are applied to the blade we can now investigate which materials are best to resist the loads
- Coursework in **Materials Science** and **Mechanics of Materials** will help us here
- Computer knowledge is essential in modern design; here is an image from a blade that was designed using a **Computer Aided Drafting** program then analyzed using a **Finite Element Method,** both courses in the undergraduate curriculum at ODU
- The image shows the deflection of the blade under wind loads



Composite Blade Manufacturing

- Now that the blade is designed, its time to manufacture it
- The mechanical engineer will design a blade mold that serves as the outer form
- Layers of composite fabric and resin will make up the structure and be laid into the mold to cure
- Expertise here comes from knowledge of **Composite Materials**



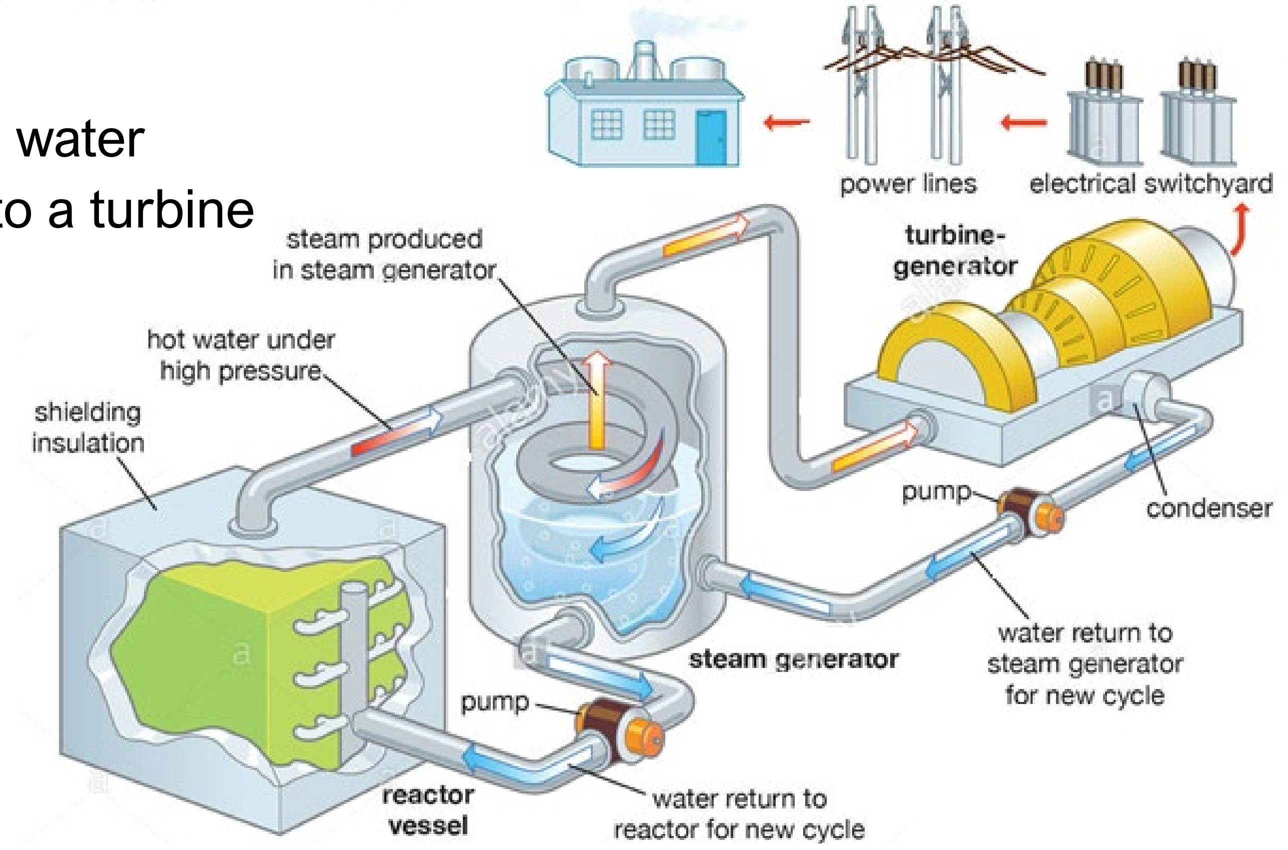


Nuclear Power Example

- In the next slides we will examine the role mechanical engineers play in the design, and management of systems for energy generation using nuclear power
- Text in **BOLD** identifies relevant coursework from the undergraduate curriculum

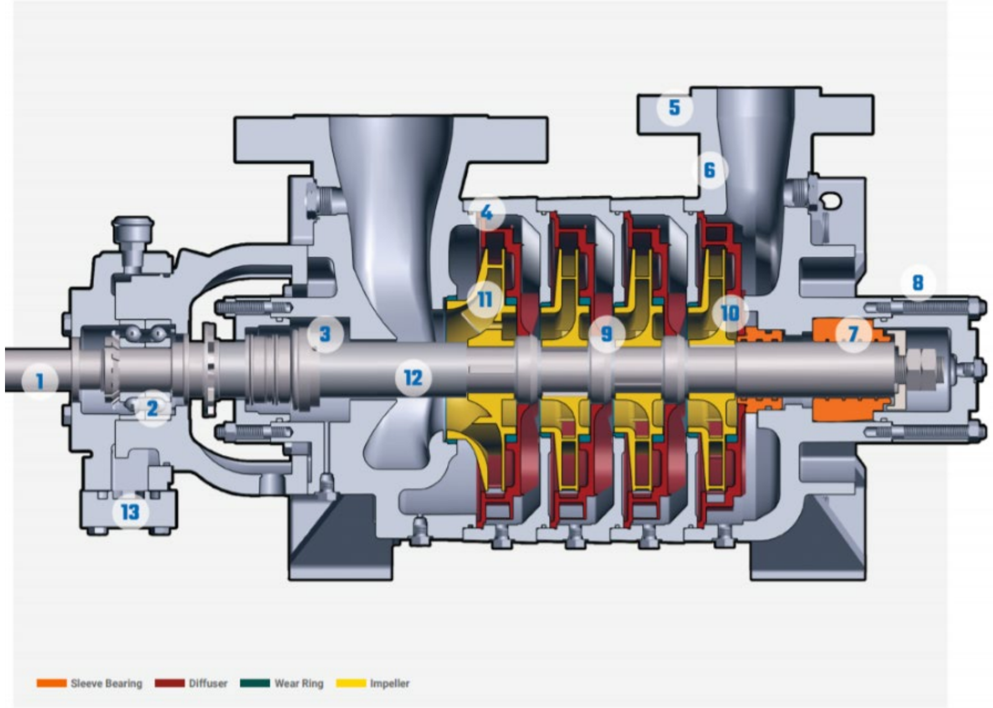
Nuclear Power Plant

- The basic operation of a nuclear power plant involves many systems designed by mechanical engineers
- Here is how it works:
  - An atomic fission reactor heats water
  - Steam is generated and flows to a turbine
  - The turbine drives a generator
  - Steam condenses to water after passing through the turbine
  - Water is returned to a steam generator by pumps for reheating



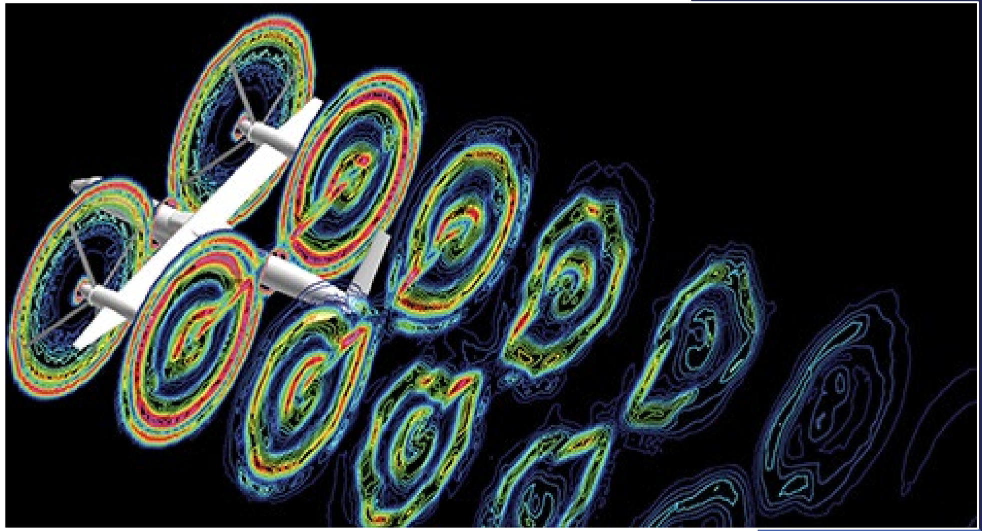
Nuclear Power Plant

- The theory behind the thermal cycle water undergoes is a topic in two courses in **Thermodynamics**
- The course **Heat Transfer** discusses the design of heat exchangers such as the one used to transfer heat from high pressure water lines to steam in the steam generator vessel
- **Fluid Mechanics** will cover the sizing of pumps
  - The pump shown at the right features staged impellers to increase pressure



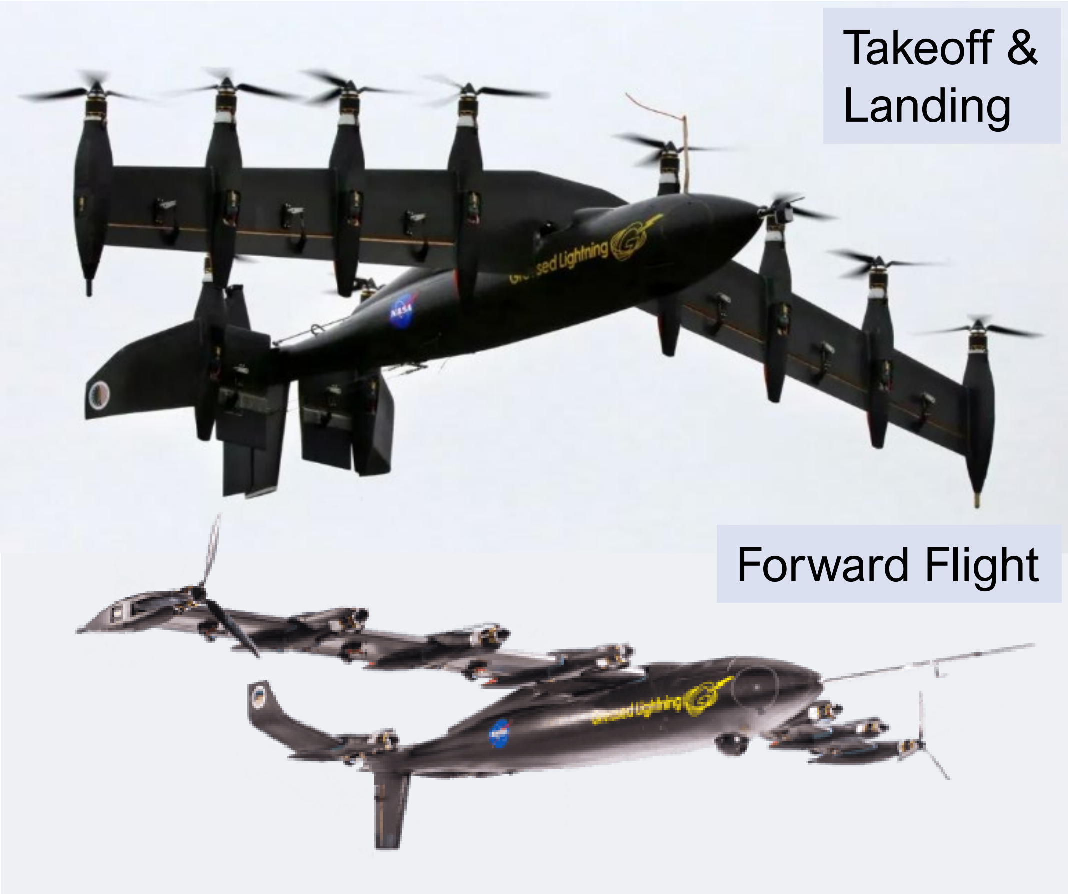
Propeller Performance Measurement Example

- In the next slides we will examine the role mechanical engineers play in the design, manufacture and use of instruments for aerodynamic measurements on propellers
- Text in **BOLD** identifies relevant coursework from the undergraduate curriculum



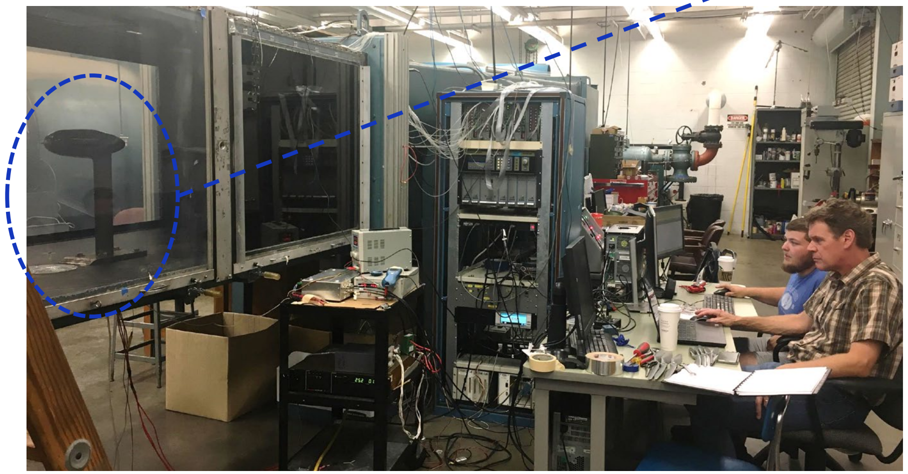
Aircraft Propeller Performance

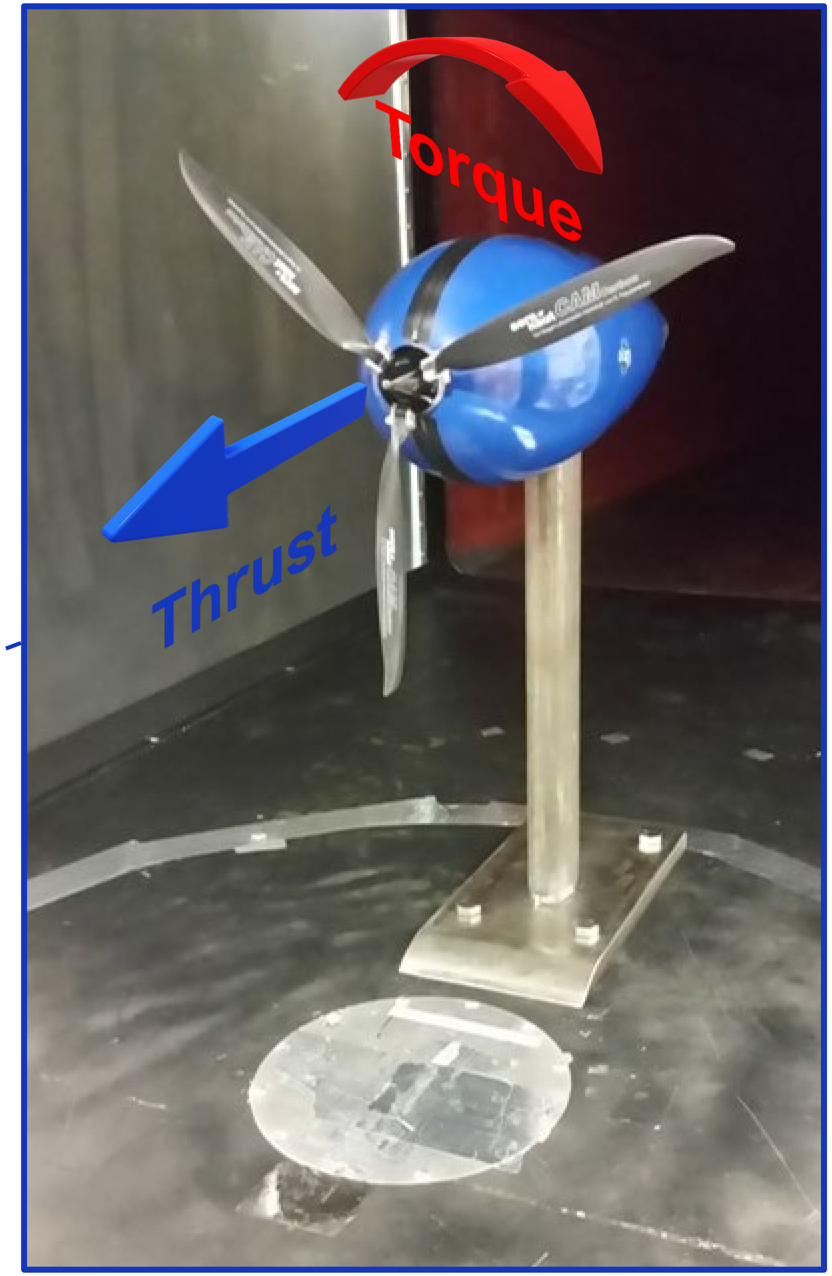
- An example that illustrates the multi-dimensional nature of modern mechanical engineering. Several years ago ODU developed a measurement capability to determine propeller performance for the NASA unmanned aerial vehicle called the Greased Lightning
- This aircraft features a tilting wing and tail to allow vertical takeoff and landing (VTOL)
- It uses 10 electric motors and propellers for VTOL
- For forward flight, it uses as few as two motors on the wing tips for maximum efficiency



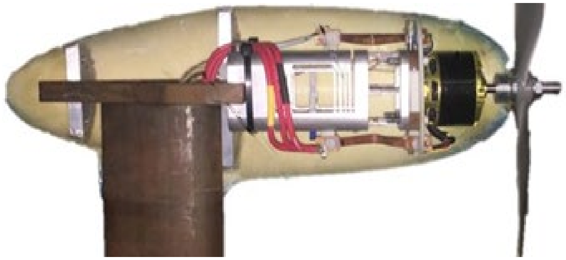
Propeller Performance

- To understand propeller performance we need to measure:
  - The force of thrust and torque
  - The rotation rate of the prop (revolutions per second)
  - The airspeed of the airplane
- We do this in a wind tunnel – a closed duct with known wind speed

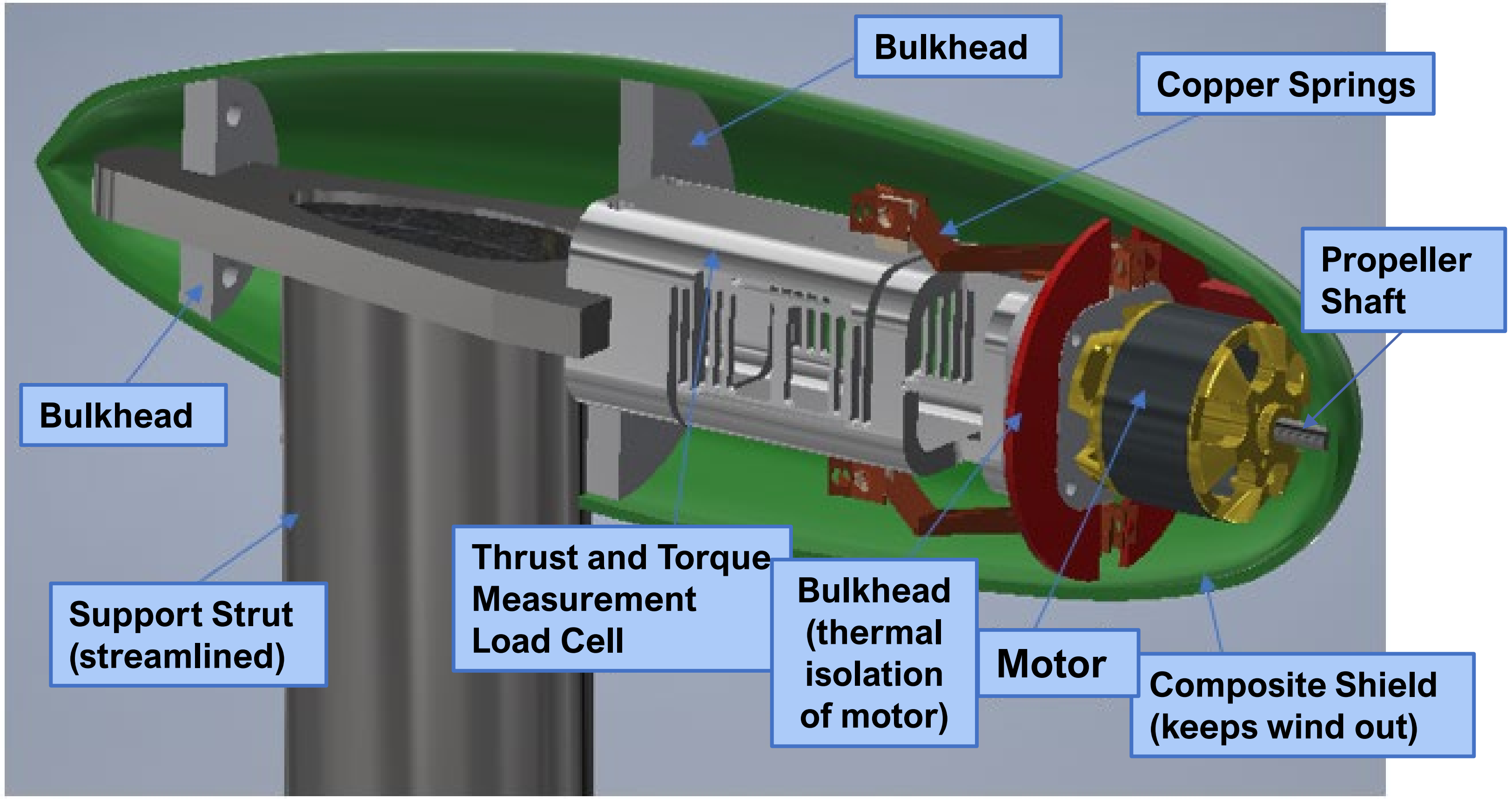




The Propeller Test Stand

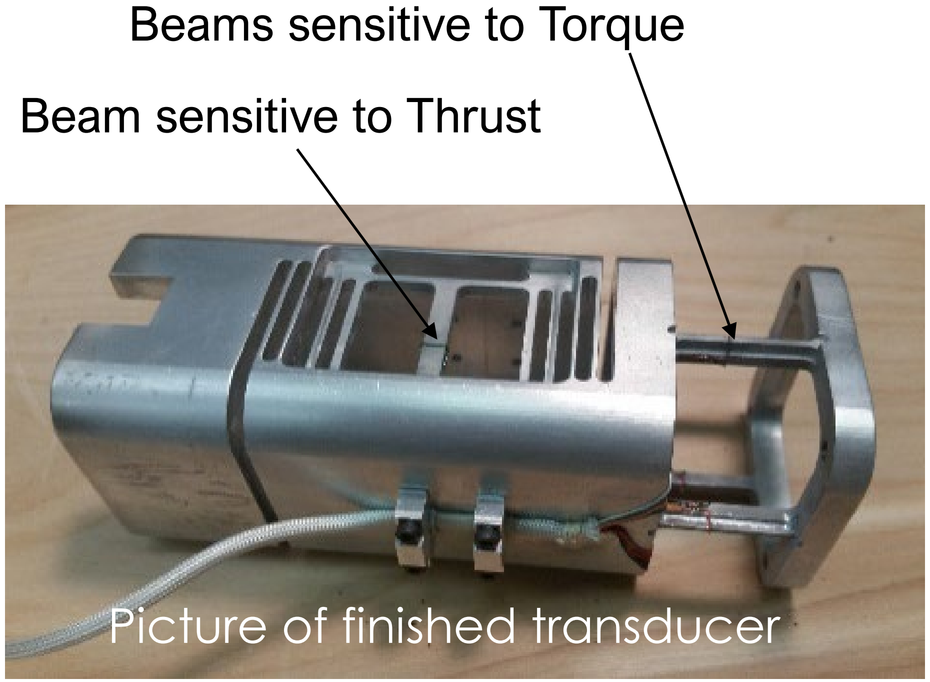


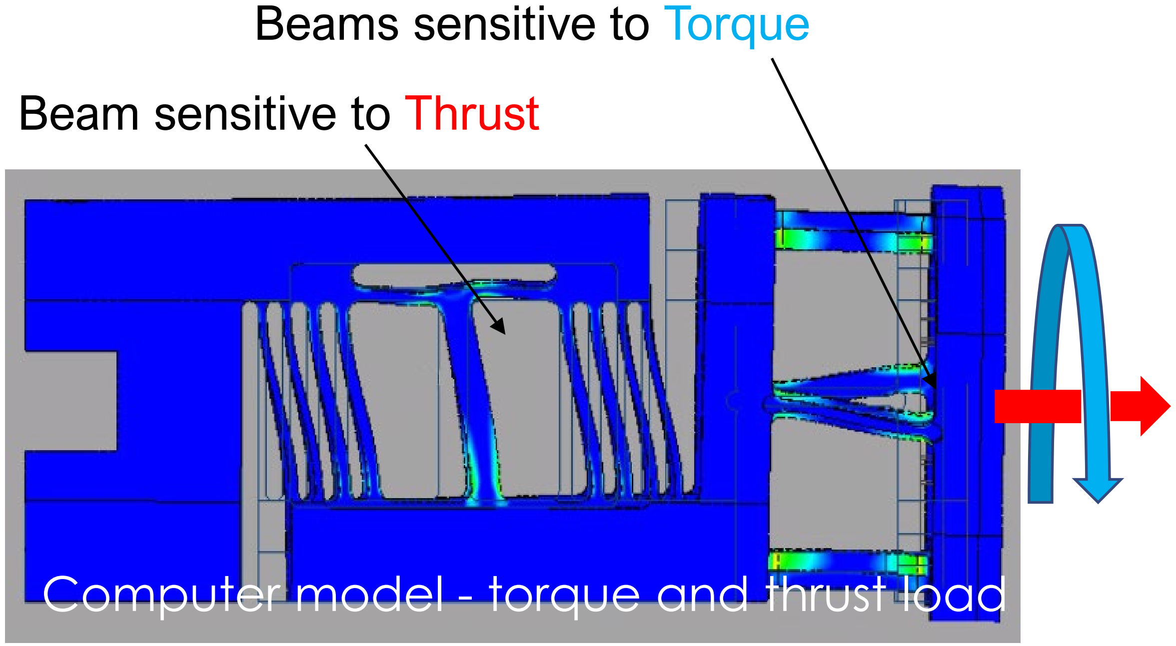
- Here is a CAD model of the test stand designed at ODU with student engineering help
- Relevant courses: **CAD, Mechanics of Materials, Electromechanical Systems**



The Thrust-Torque Load Cell Design

- The load cell is an electro-mechanical sensor – a transducer
- Loads (Thrust and Torque) are sensed by small beams that deflect
- Relevant courses here are **Mechanics of Materials** and **Finite Element Methods**

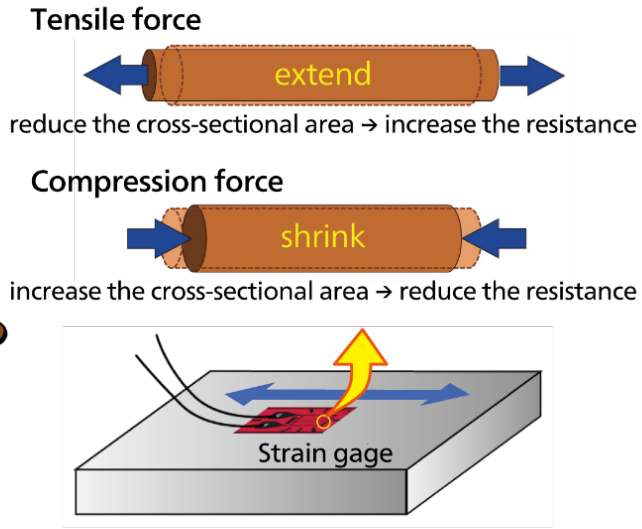


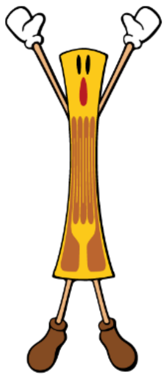


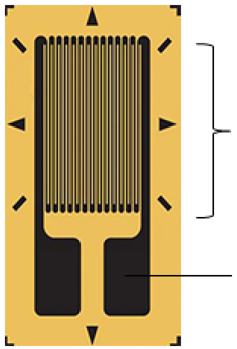
Deflection is Exaggerated

Instrumentation Design: Electro-Mechanical Devices

- How do we design an instrument to measure force and torque ?
  - One popular method is to use strain gages with mechanical elements like beams
- A strain gage is a piece of thin film with a very thin wire arranged in a long serpentine shape called a grid
- The strain gage is bonded to a metal surface
- As the metal is under load, the gage wire length changes and so does the resistance
- Relevant courses here are **Mechanics of Materials, Electromechanical Systems**

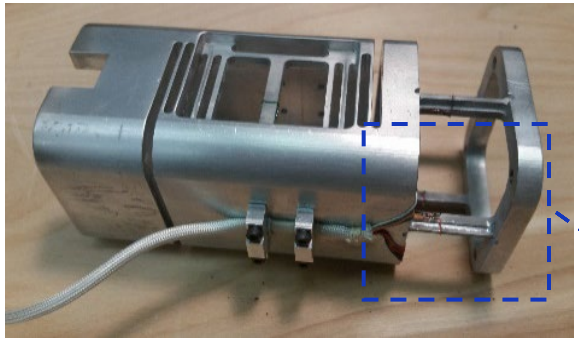


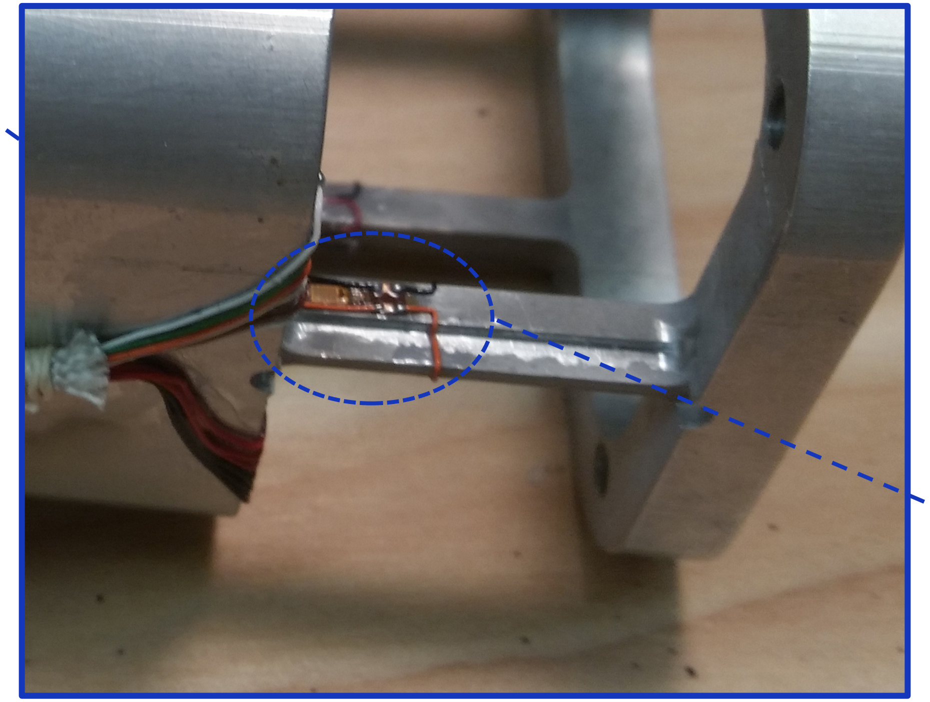


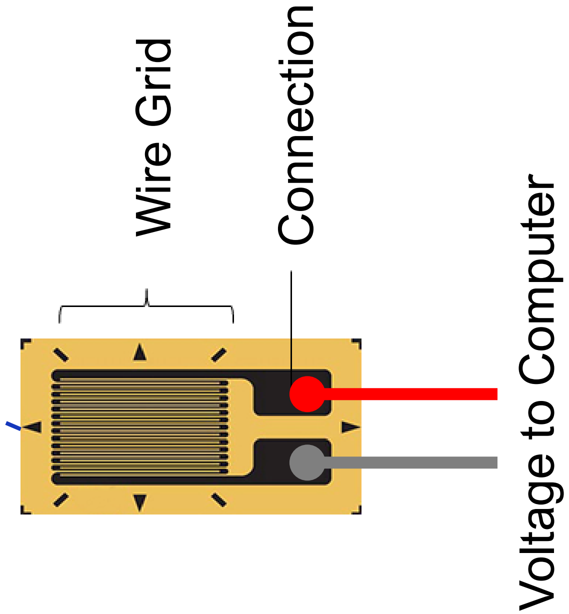


Instrumentation Design: Electro-Mechanical Devices

- Glue the strain gage to the beams that bend most with applied Thrust and Torque
- Connect them to a special circuit and now: Thrust is proportional to Voltage







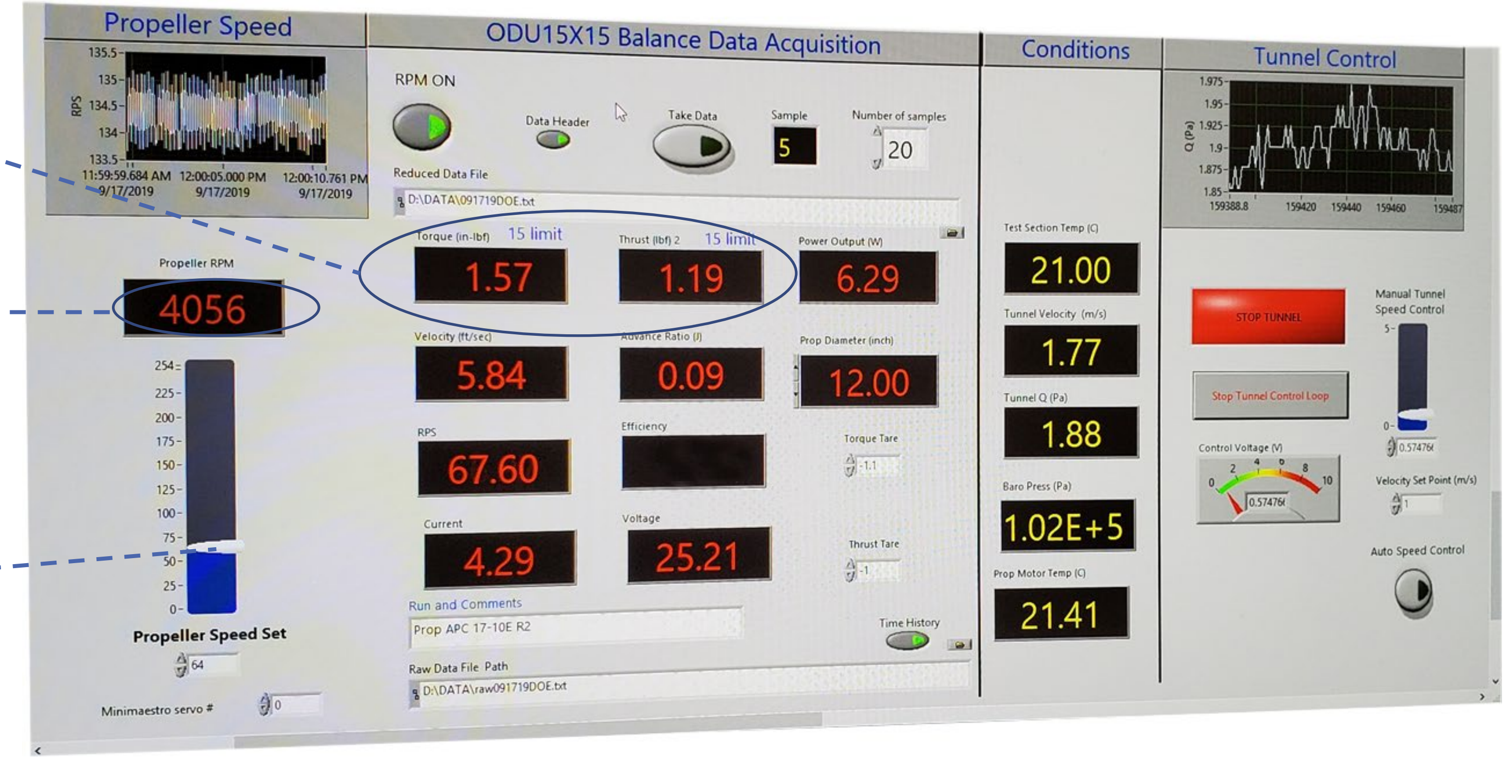
Using the Computer

- To record the propeller torque and thrust, we use a computer
- Voltages are digitized in an Analog to Digital converter
- A program is written to display and file all the quantities measured

Thrust and Torque Displayed

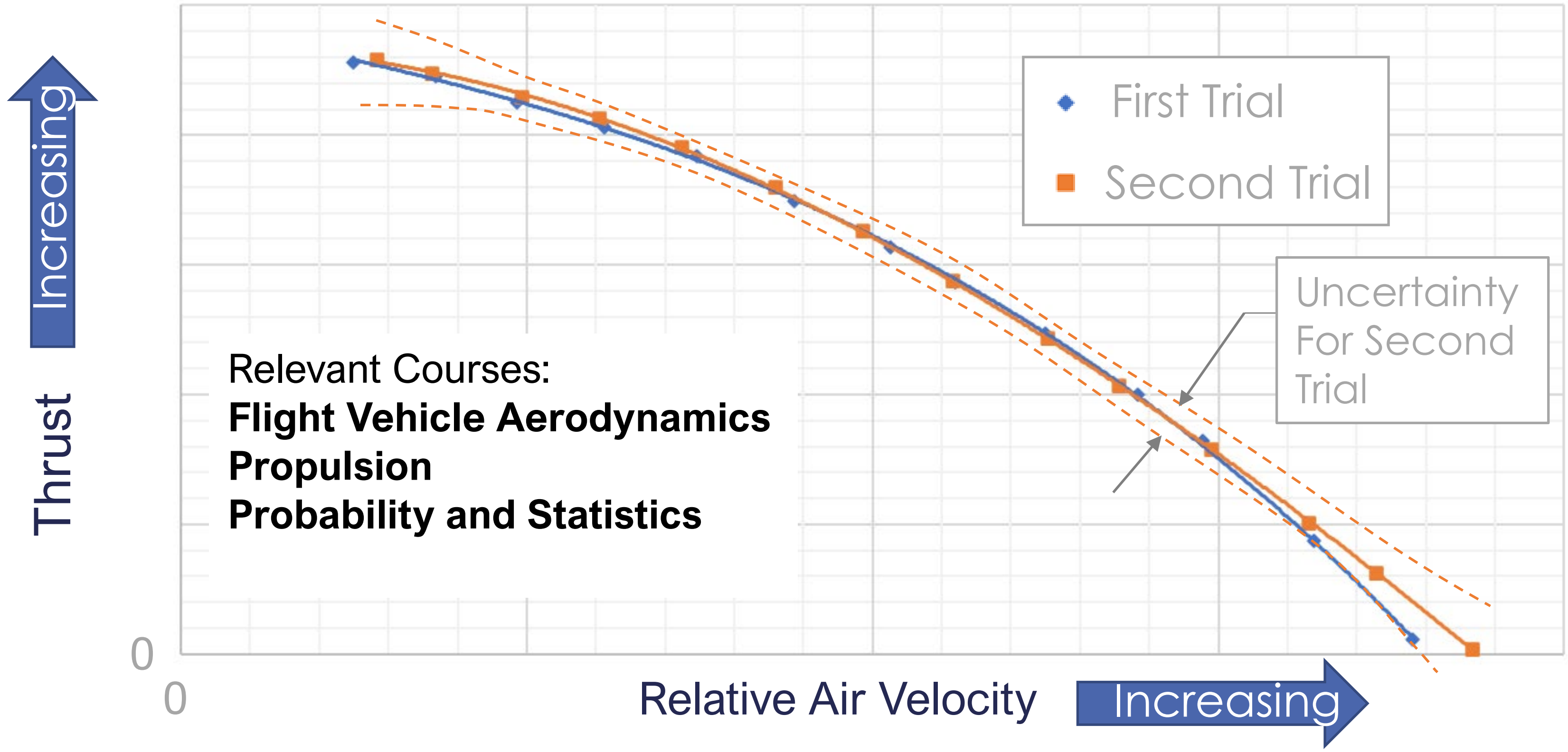
Propeller Rotational Speed

Control for Propeller Speed



Reporting Results

- Here is a plot showing thrust of a propeller from data recorded in the wind tunnel
- We build a mathematical model that fits the data and graph the curve
- We use statistics to compute error or uncertainty in our results – helps us compare
  - Here the blue line is the first trial, orange the second
  - The dashed lines indicate the uncertainty – Trials 1 & 2 are identical from a statistical test

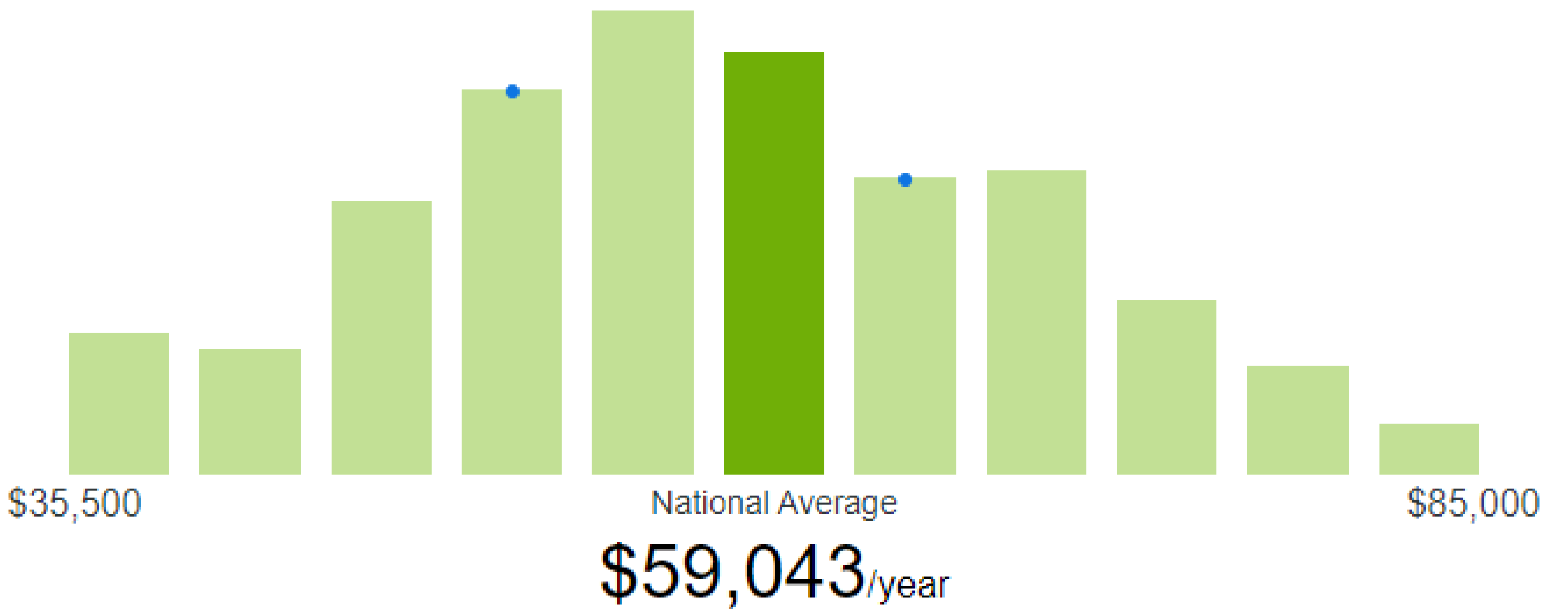


Relevant Courses:
Flight Vehicle Aerodynamics
Propulsion
Probability and Statistics

Expectations

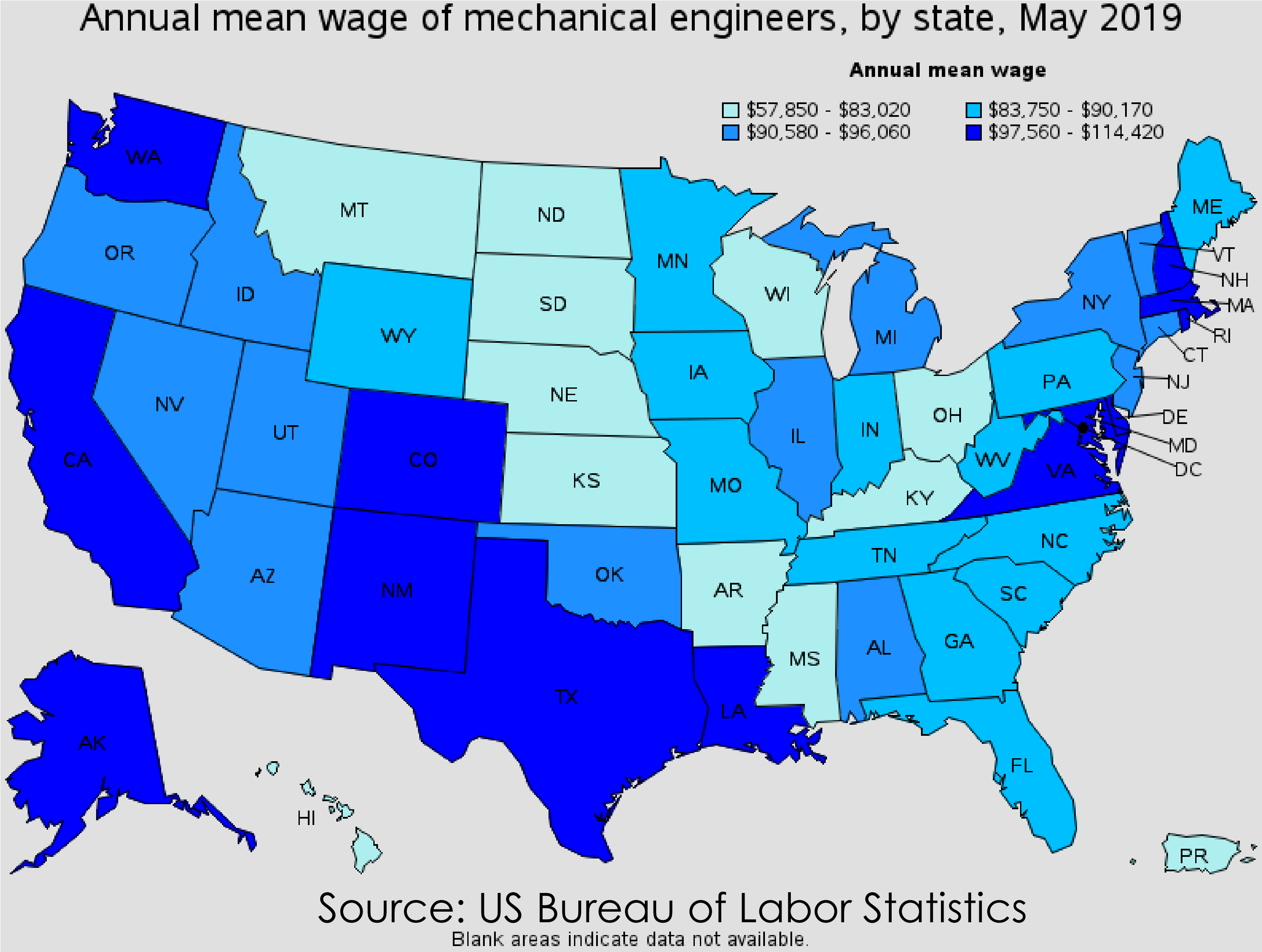
New Mechanical Engineering Graduate Salaries

- National average salary in the USA for a new graduate of Mechanical Engineering

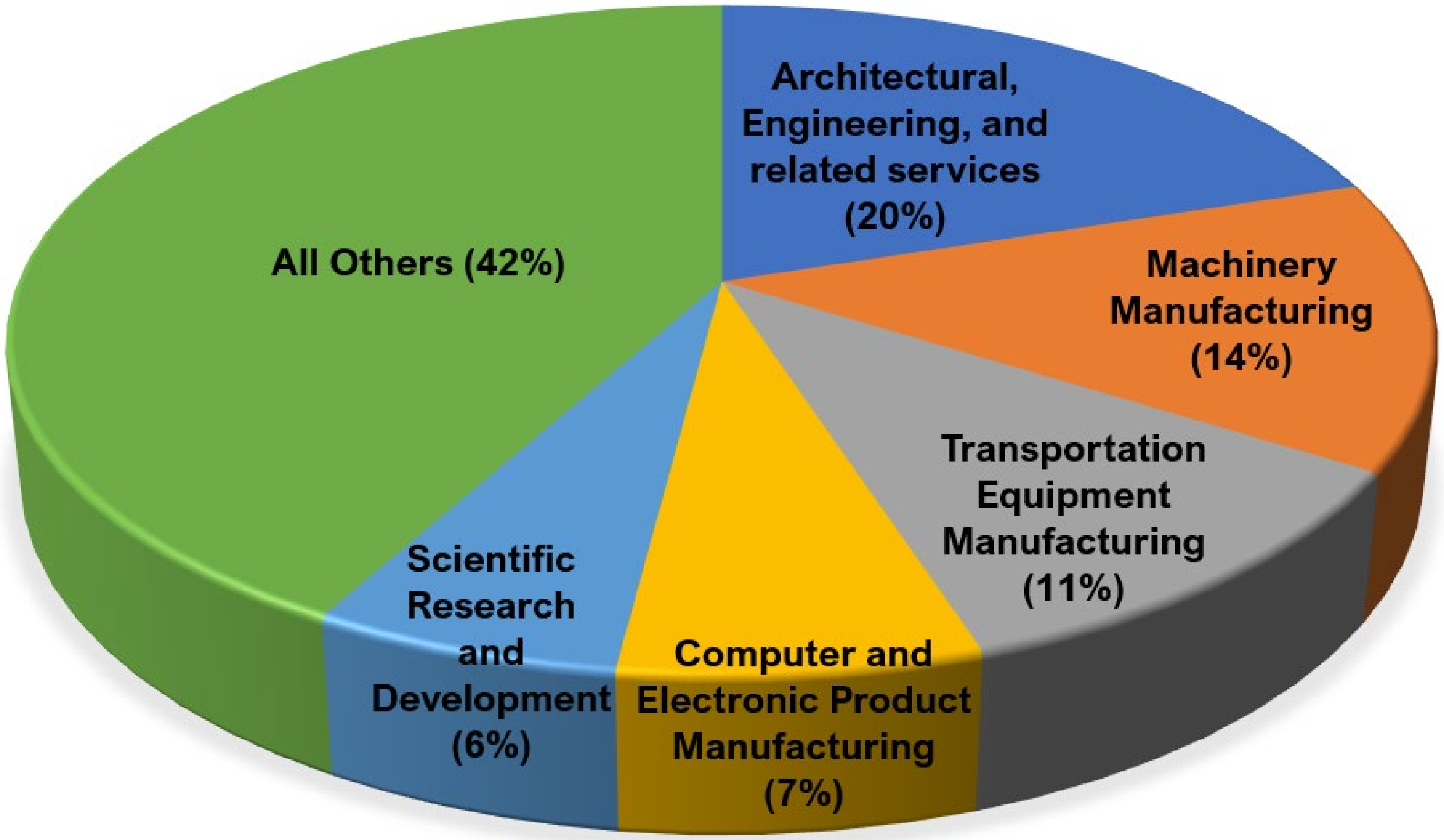


Source: Ziprecruiter.com

Average Mechanical Engineering Salaries in USA



Mechanical Engineering Employment in the USA



Source: US Bureau of Labor Statistics

Resources at ODU

https://www.odu.edu/mae