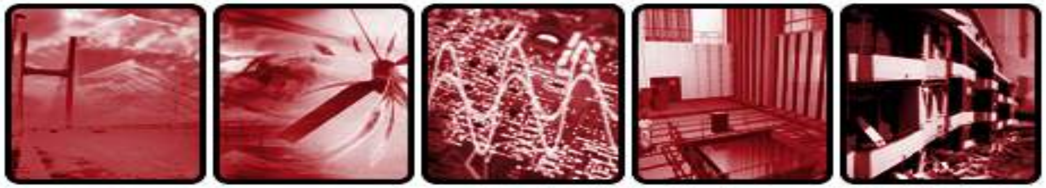
University of BRISTOL

Racing Aeolus 2011

The Bristol Entry



Overview

- The 2011 Team
- Review of last year's entry
- New features of 2011 vehicle
  - Improved turbine blades and hub
  - Updates to electric transmission & control system
- On-going work
  - Active variable pitch system
  - Shroud Development

The 2011 Race Team

- Clive Rendall (Faculty of Engineering Technician)
- James Baker (Electrical Engineering PhD Student)
- Ed Power (Aerospace Engineering PhD Student)
- James Teague (Electrical Engineering Undergraduate)
- Jon Steele (Electrical Engineering Undergraduate)
- Tom Pygott (Electrical Engineering Undergraduate)
- Drew O’Sullivan (Electrical Engineering Undergraduate)
- Hokyeom Kim (Mechanical Engineering Undergraduate)
- Roger Zhang (Mechanical Engineering Undergraduate)

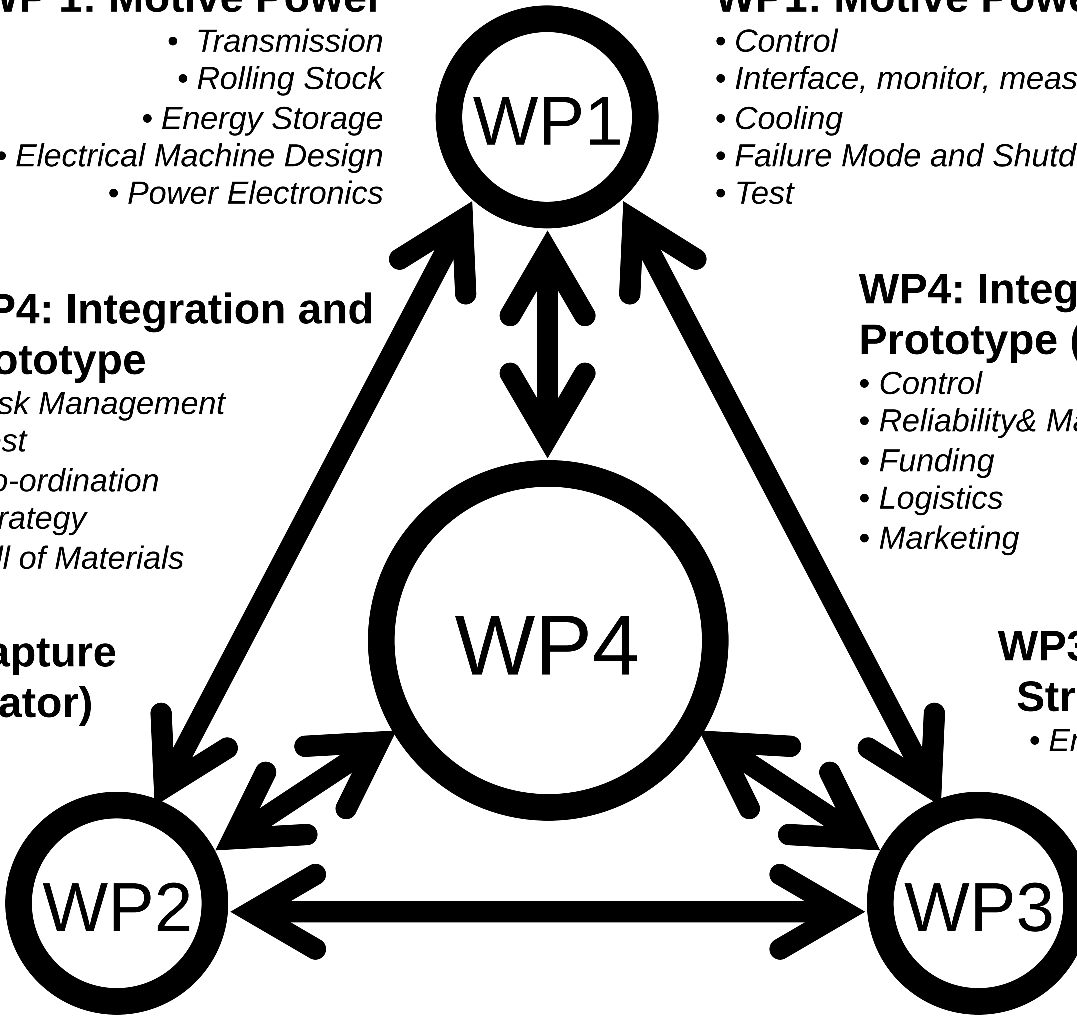
Work Package Outline for Aeolus

WP 1: Motive Power
- *Transmission*
- *Rolling Stock*
- *Energy Storage*
- *Electrical Machine Design*
- *Power Electronics*

WP1: Motive Power (cont.)
- *Control*
- *Interface, monitor, measure*
- *Cooling*
- *Failure Mode and Shutdown*
- *Test*

WP4: Integration and Prototype
- *Risk Management*
- *Test*
- *Co-ordination*
- *Strategy*
- *Bill of Materials*

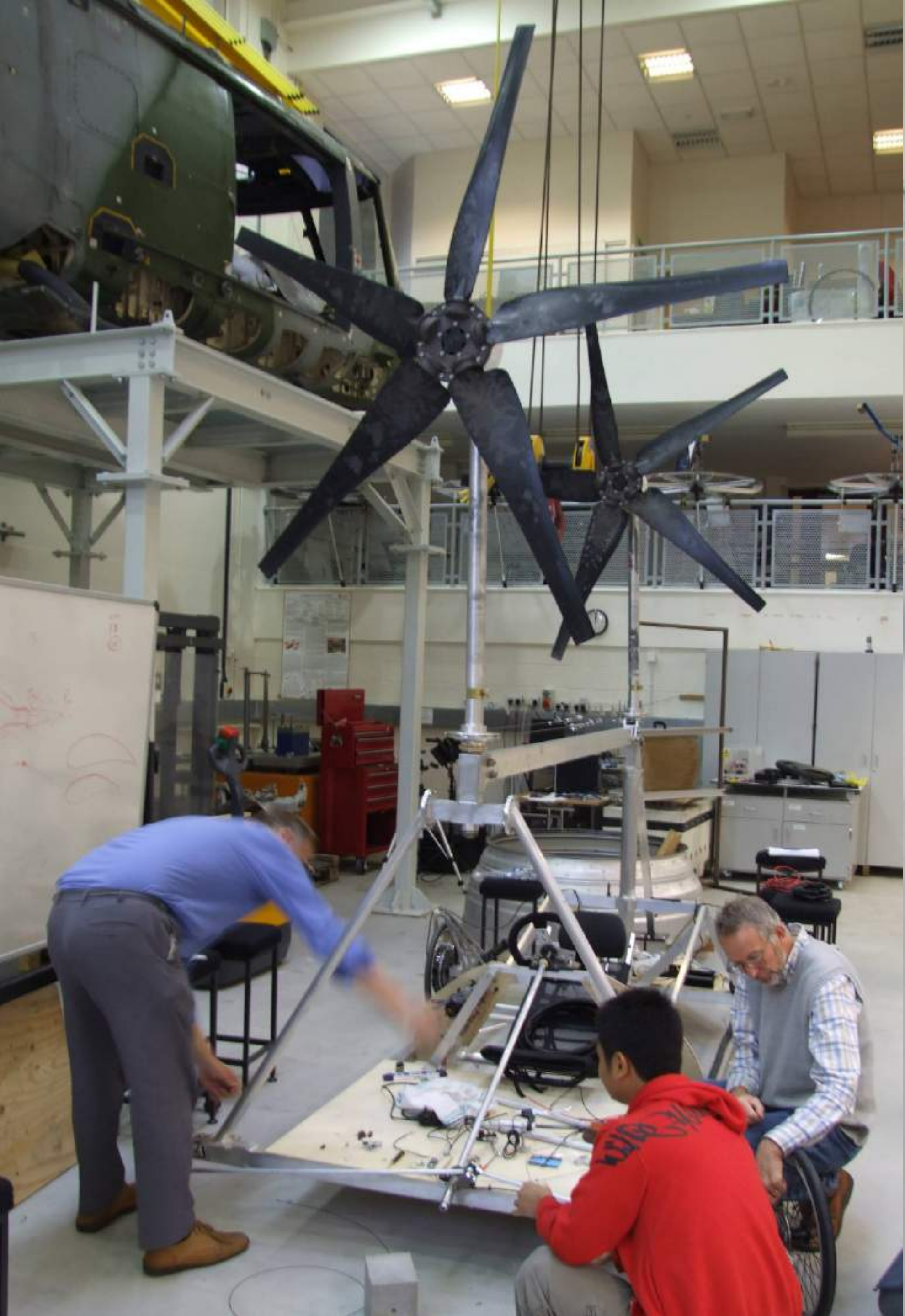
WP4: Integration and Prototype (cont.)
- *Control*
- *Reliability& Maintenance*
- *Funding*
- *Logistics*
- *Marketing*



WP2: Energy Capture (Blade to Generator)
- *Transmission*
- *Power Electronics*
- *Control*
- *Blade Topology*
- *Failure & Shutdown*
- *Aerodynamics*
- *Aero-structural*
- *Test*

WP3: Lofting and Structures
- *Ergonomics (Man/Machine Interface)*
- *Topology*
- *Space Frame Design*
- *Cockpit*
- *Aero-structural*
- *Dynamics*
- *Test*

Review of 2010 Vehicle




Key Features

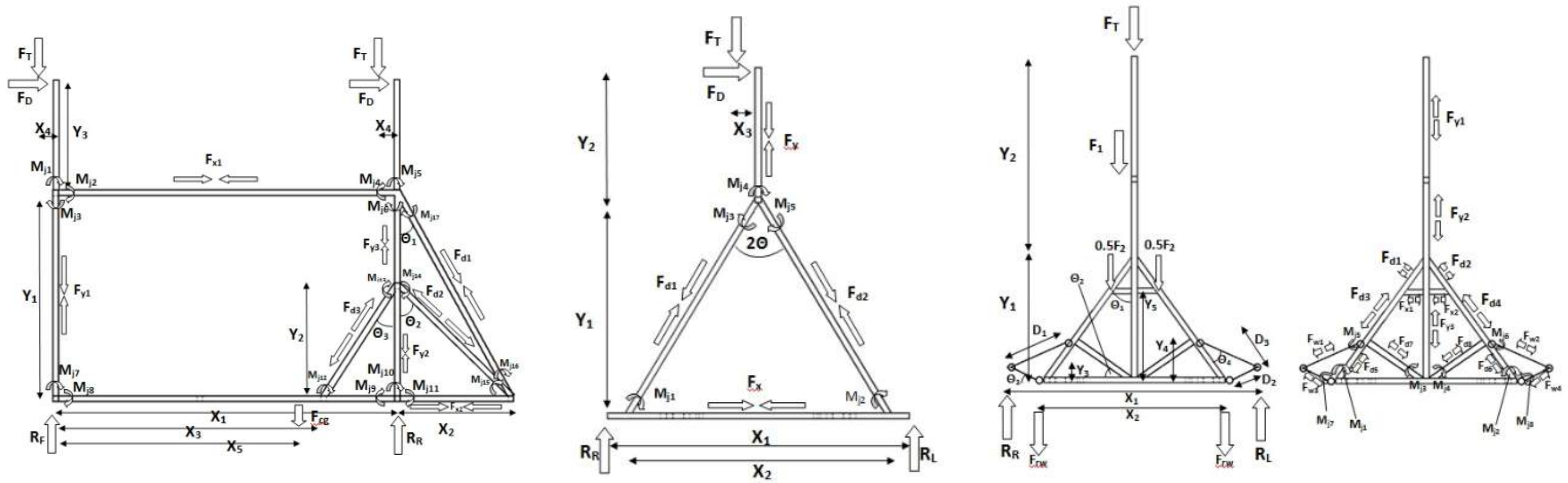
- Twin rotors to achieve max turbine swept area of $4m^2$
- Off-the-shelf turbine blades
- All-electric drive-train
  - 2 x 1kW generators
  - 2 x 1kW rear-hub mounted motors

Twin Rotor Design Strategy

- Maximum vehicle dimensions restrict turbine swept area to 3.141m^2 (width limit = 2m)
- Wind direction not always aligned with the main-axis of the vehicle
- Some energy can be recovered as swirl from the front turbine to the rear
- Some redundancy of components

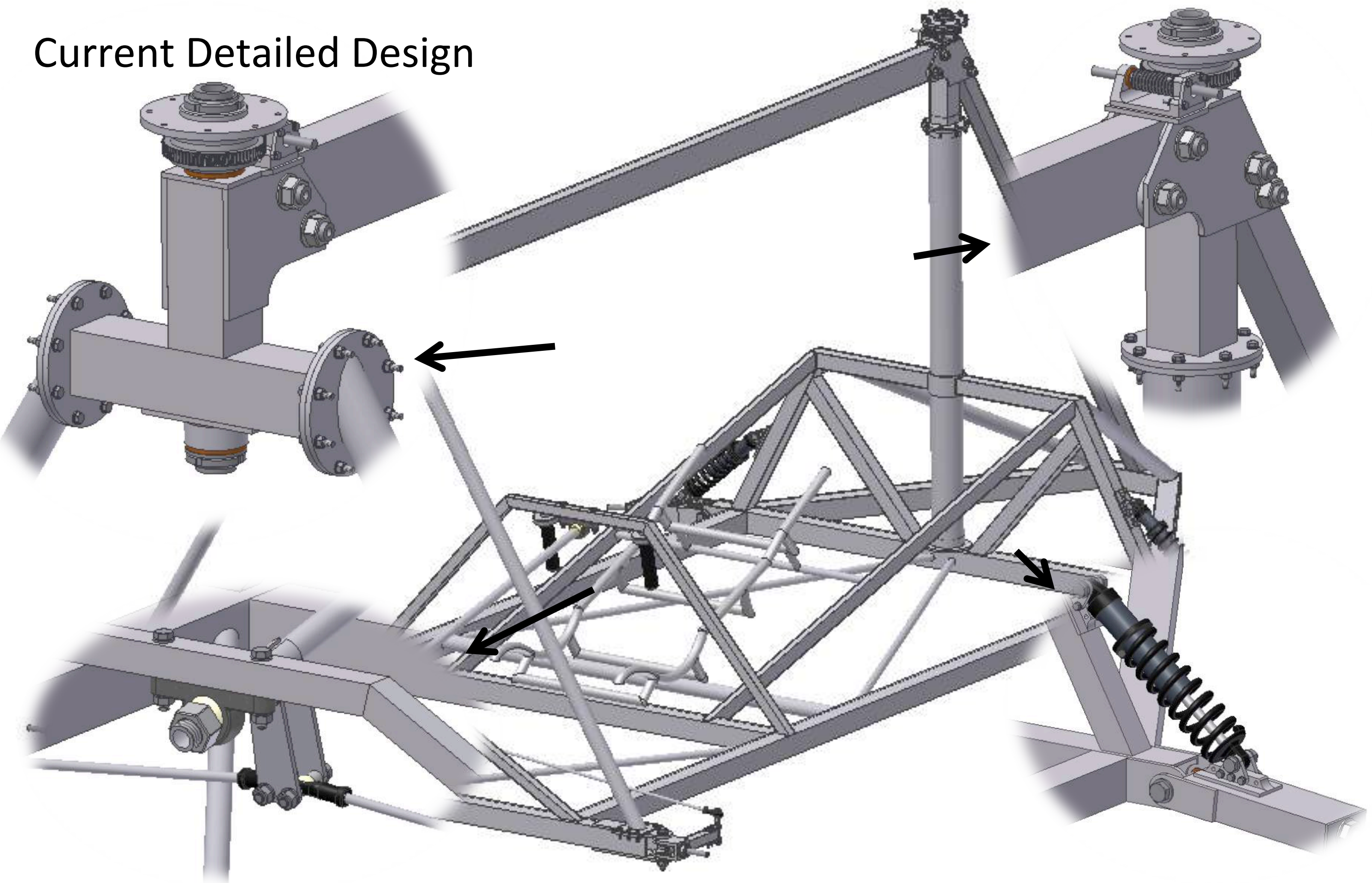
2010 Vehicle: Frame

- Student project developed an aluminium frame and mechanical subsystem interface designs
- 2011 frame remains unchanged, but recognised that composite structure and aerodynamic cowling would be beneficial for future vehicle development



2010 Vehicle: Frame

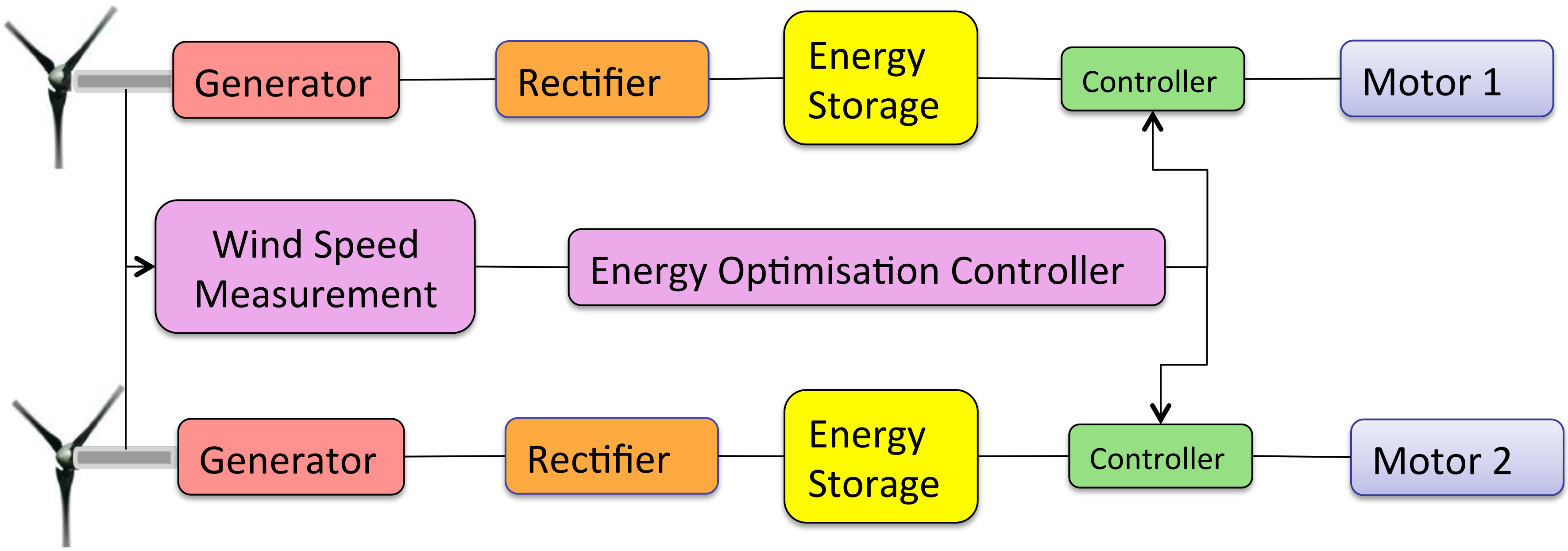
Current Detailed Design



2010 Vehicle: Drivetrain

- Dual independent channels
- Infinite gear ratios (Electric CVT)
- Lossless clutch
- All-electric in-house design based upon PIC micro-controllers
  - Overcomes current and usage limits imposed by off-the-shelf design
  - Lightweight, maintainable and reconfigurable

2010 Vehicle: Drivetrain




BOTH

2010 Vehicle: Safety Features

- Both wheels and turbines fitted with electric and mechanical braking systems
- Turbine
  - Mech – Fail-safe sprung loaded brake
  - Electric – Passive and active overspeed detection will operate without power supply (failsafe)
- Wheels
  - Mechanical disc brakes
  - Ability to run motors in shorted “generate” mode

2010 Race Outcomes

- Design functioned
  - First team to build an "all-electric" design that worked (all other teams used mechanical drive-trains)
  - First UK entry to build a working design
- Given award for innovative nature of design
- Placed last in race
- Poor weather conditions (low wind speeds + rain)
- Huge value of seeing other designs/experience

Design Successes

- Aluminium frame very robust and weather-proof
- Easily removable turbines essential
- Flexibility of programmable electric drive-train
- Completely different to existing designs

Design shortcomings

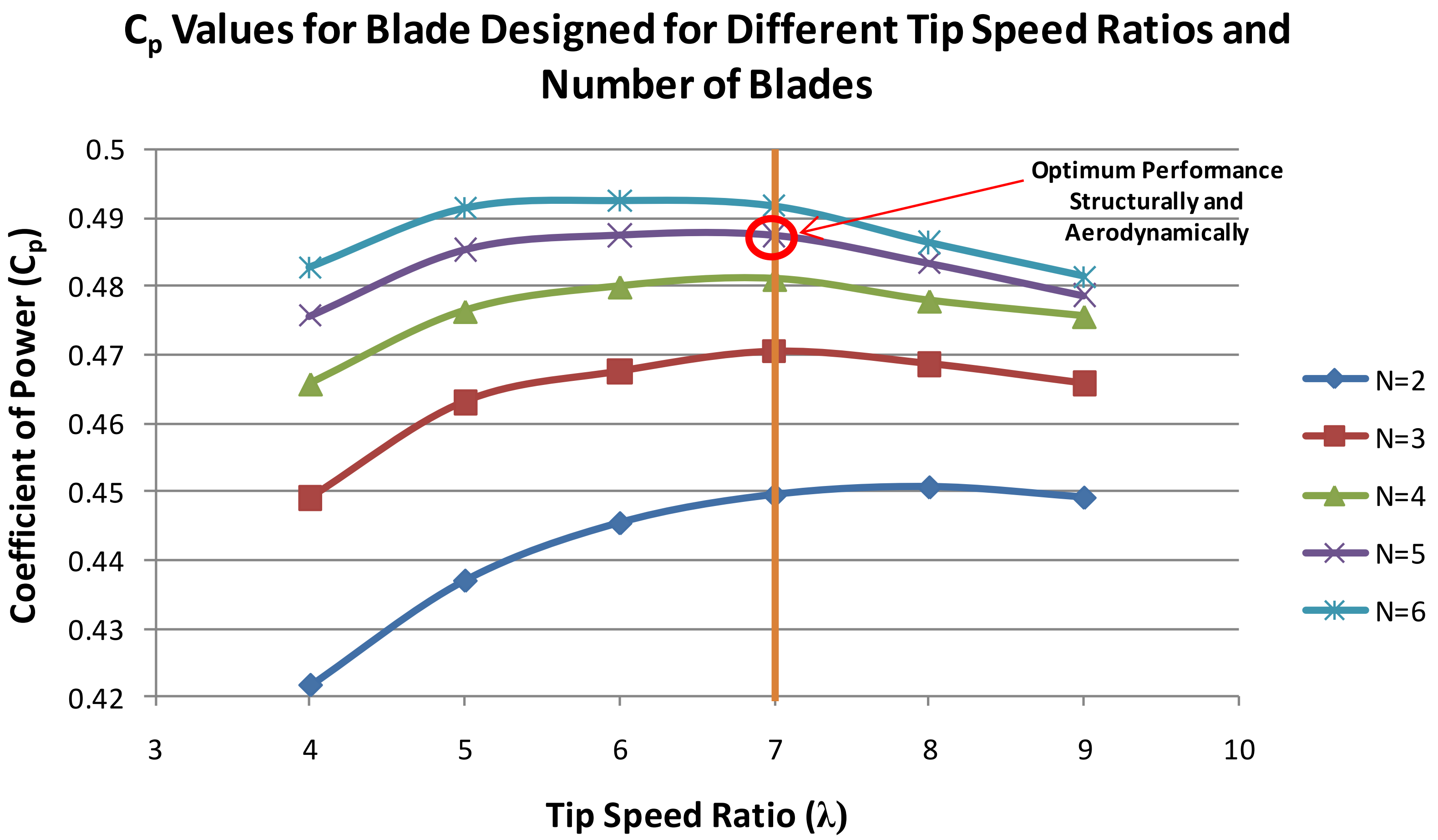
- Electric drive-train
  - Not noise or weather resistant
  - Low efficiency at low vehicle speeds
  - Can't "pre-charge" turbine
- Turbines
  - Too high a thrust/torque ratio under race conditions
  - Very slow and difficult to reconfigure for difficult conditions
- No data-acquisition systems
- Safety features not completely fail-safe

The 2011 Entry

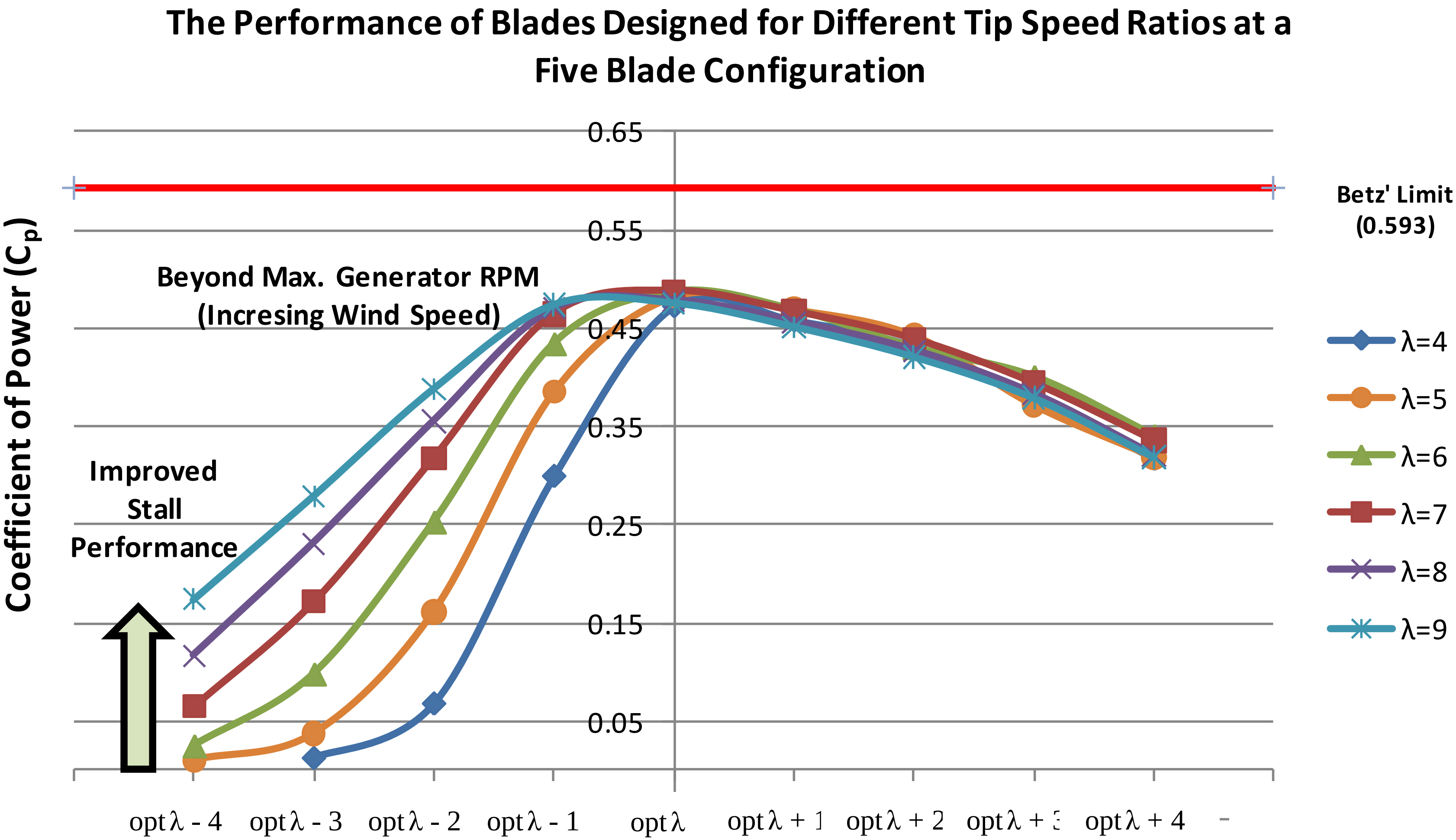
The 2011 Vehicle

- Based upon 2010 architecture:
  - Retains existing frame
  - Retains electric drive-train
- Design improvements:
  - New turbine blades designed through undergraduate research project
  - Variable pitch hub system developed through undergraduate design project
  - Electrical control system redesign

Blade Design



Blade Design

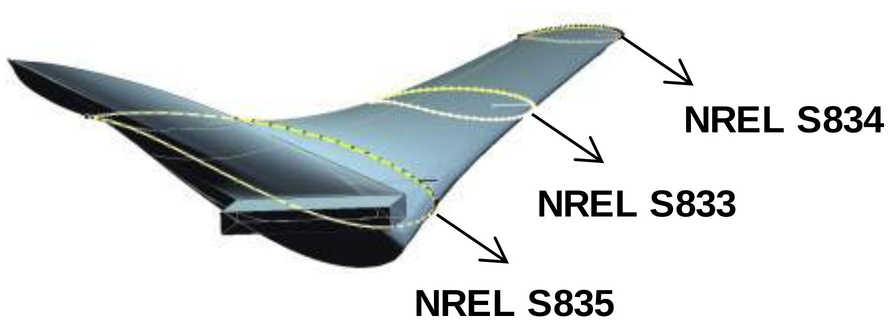


Blade Design

Final Design Features

Rotor Configuration	Two Equal Sized Wind Turbines
Generator	Variable RPM
Swept Area (m^2)	$2m^2$ each
Rotor Diameter (m)	1.596
Optimum Tip Speed Ratio	7
No. of Blades	5
Overall Blade Twist (deg.)	27.4 (nonlinear)

WINDENERGY EVENTS

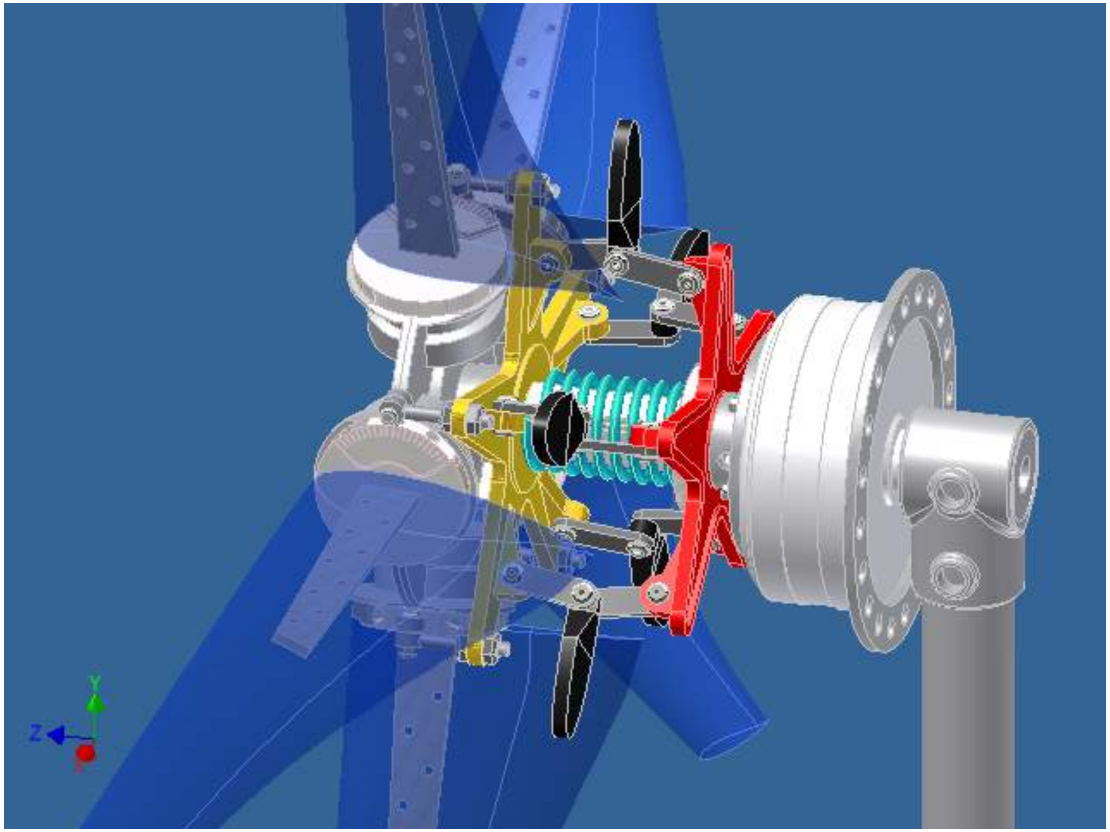


Blade Manufacture

- ProLab blade mould manufactured using CNC miller
- Glass-fibre skins with foam core
- Steel root fitting for hub attachment

Variable Pitch Mechanism

- Variable pitch hub mechanism developed through undergraduate design project

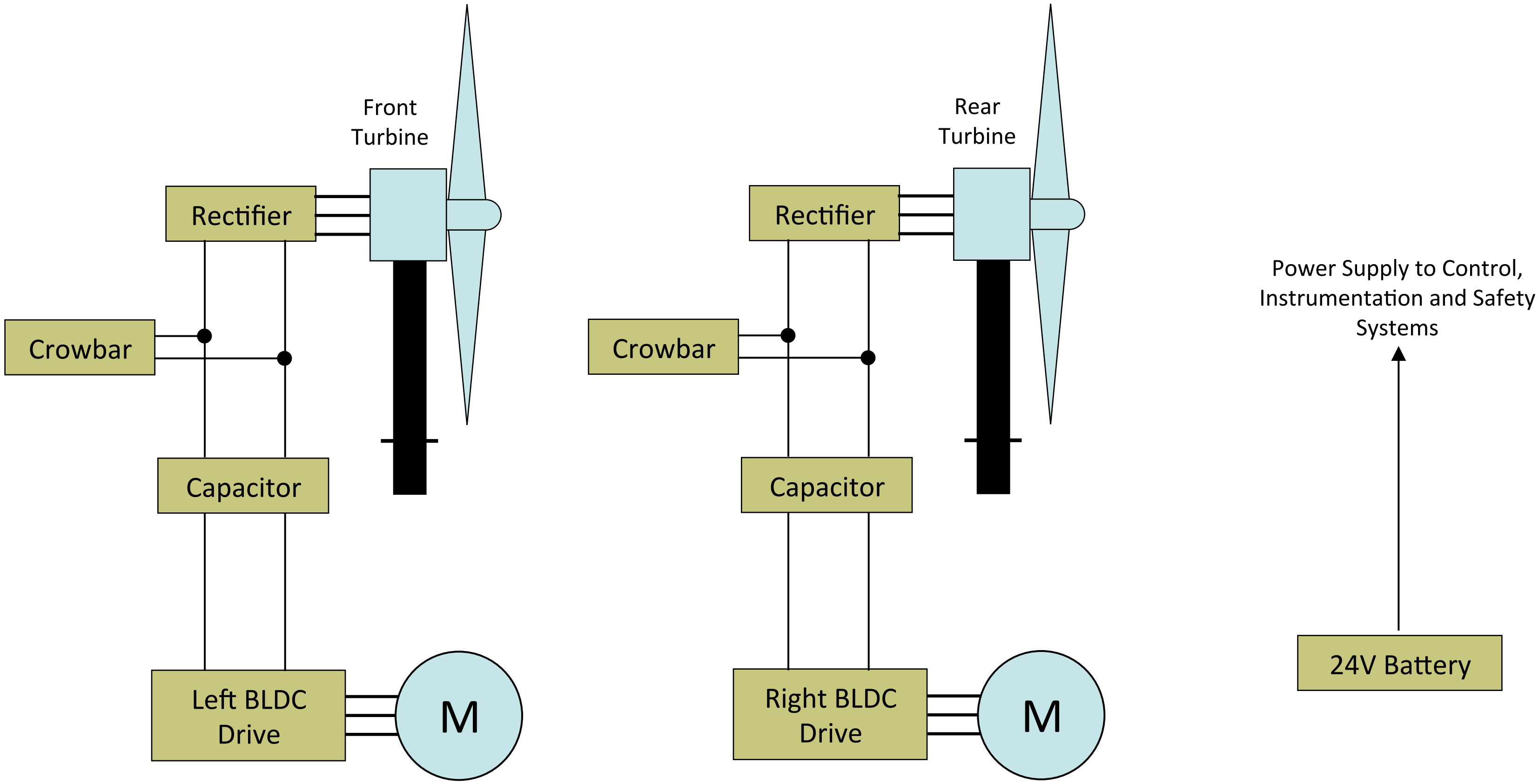


Variable Pitch Mechanism

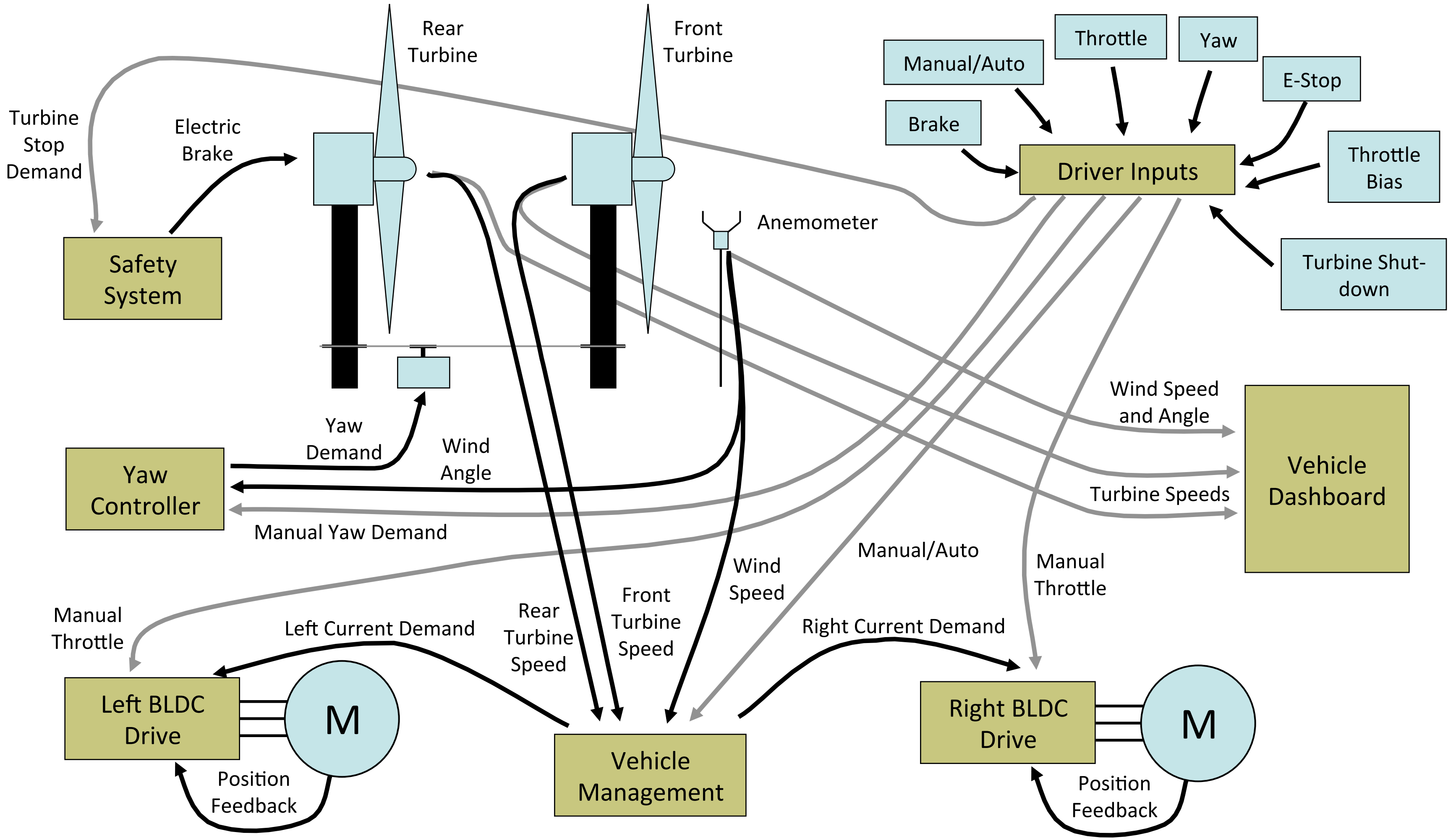
- Only partial manufacture of variable pitch mechanism possible in time available
- Angle of blades is fully adjustable but must be fixed at start of race
- Future work will implement an automatic pitch system for active control during race

Control System Upgrades

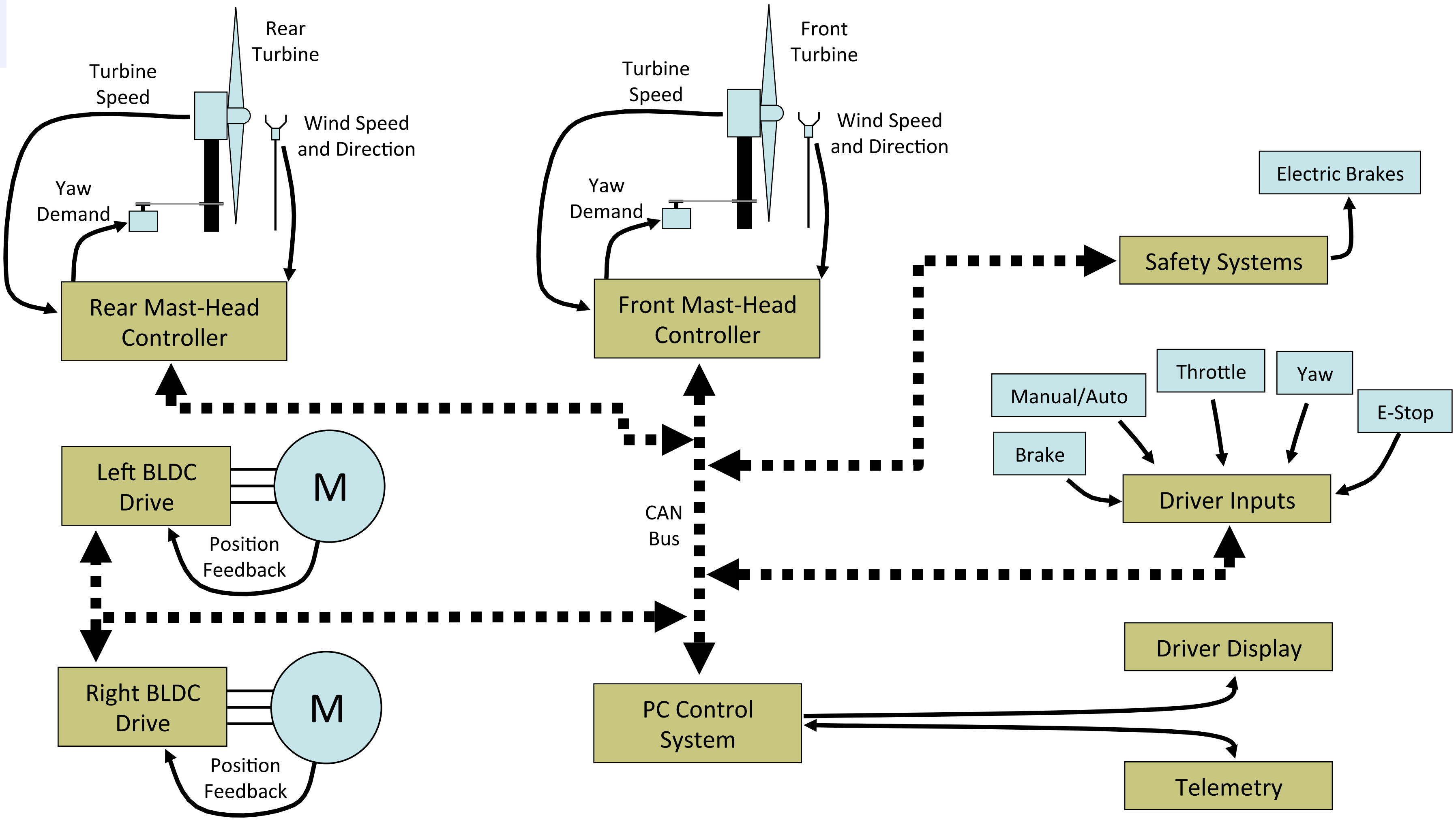
Power Flow Overview



2010 Control System



Vehicle Control System for 2011



On-Going Work and Future Projects

On-Going Work and Future Projects

- On-going and future projects for after 2011 race:
  - Completion of active pitch mechanism
  - Further improvements to electric control system
  - Composite Shrouds to improve aerodynamic efficiency of turbines (initial development has been started)
  - Aerodynamic vehicle shell and potential development of composite chassis for reduced weight

On-Going Work: Shroud Development

- Aerodynamic and flat duct profiles investigated by team of Engineering Design students
- Testing completed at various wind speeds
- Effects of yaw, inaccurate yaw and turbine pressure drop investigated
- Initial manufacturing work started with support from Aviation Enterprises Ltd

Acknowledgements

The team would like to express their immense thanks to the following partners who have made their entry into the Aeolus Race possible

University of BRISTOL

Aviation Enterprises Ltd

GL

GL Garrad Hassan

BOEING®

THE BRISTOL PORT COMPANY

Aeolus Power WIND ENERGY Right Turbine, Right Place