Multidisciplinary Senior Design
Project Readiness Package

Project Title:	RIT Hot Wheelz Test Bench
Project Number: (assigned by MSD)	P##xxx (P/ending year/project #, e.g. P15001 finishes in 2015 and is project number 001)
Primary Customer: (provide name, phone number, and email)	Martin Schooping mpsasp@rit.edu (585) 475-6759 Kathleen Lamkin-Kennard kaleme@rit.edu (585) 475-6775
Sponsor(s): (provide name, phone number, email, and amount of support)	Hot Wheelz Team Rachel Heise 484-624-1198 rsh9309@rit.edu
Preferred Start Term:	Fall 2017
Faculty Champion: (provide name and email)	Kathleen Lamkin-Kennard (kaleme@rit.edu)
Other Support:	Adam Tallman (atallman@ltu.edu), Maura Chmielowiec (maurac2187@gmail.com)
Project Guide: (assigned by MSD)	

Rachel Heise 6/27/2017

Prepared By Date

Received By Date

Items marked with a * are required, and items marked with a † are preferred if available, but we can work with the proposer on these.

Project Information

Hot Wheelz is a Formula SAE Hybrid team that will be creating a hybrid vehicle for the first time this year. One of the challenges that will arise is the integration of electrical systems with an internal combustion engine. In previous years, a test bench has been utilized to test the functionality of electrical components prior to placing them on the vehicle. This test bench has proven to be essential in ensuring electrical system integration. This older test bench was created in a previous project in the 2015-2016 school year called the Hot Wheelz Powertrain Testbench (P15280). In general, electrical troubleshooting and integration has proven to be difficult and take more time than mechanical troubleshooting. The use of a testbench allows the electrical team more time to perfect and verify their systems while the mechanical systems are being built on the car's frame.

This project will aim to create a robust system for testing the motor, engine, batteries, and circuitry via a new custom test bench. This will enable the team to test the functionality of and gather data from both individual components as well as large systems included in their powertrain designs. The overarching goal of this project is to create a specialized test bench that can be used for the next several years to test and verify electrical and engine designs. It will be adaptable to contain all feasible types of components the team might use. In the future, the team will not need to spend time creating mounts and fixtures just to test the systems out as the test bench will have adjustable mounts for all components. The team will also be able to reuse wire and connectors on the test bench so that resources are not wasted each year. This will allow the team as a whole to have more time actually testing, troubleshooting, and collecting data.

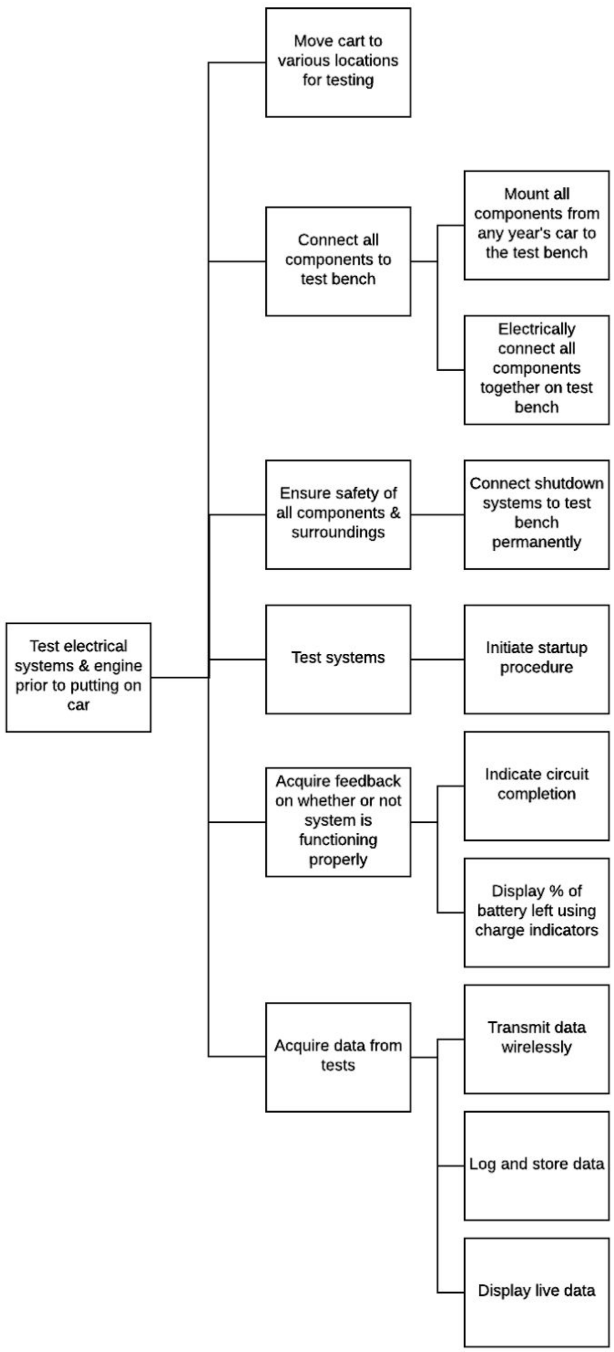
The original powertrain test bench has several shortcomings. There is currently a lot of difficulty in trying to mount various components, since components change year to year to adapt to the current vehicle design, and the test bench was not created with the ability to adjust to different mounting styles found on these components. Other difficulties and challenges include the lack of a permanent safety system, which has to be rebuilt every year for the current design, the lack of a cooling system for the powertrain components, the inability and lack of any data acquisition, the inefficient design of allocated space, and overall bulkiness of the cart which hinders easy transportation between team spaces in the Gleason building. For these reasons, a new testbench will be designed that overcomes these shortcomings.

* Preliminary Customer Requirements (CR):
What attributes does the customer seek in the final project? Each CR should map to one or more ER (see below).

Objective Statement: The Hot Wheelz Formula SAE team is in need of a robust and specialized powertrain test bench to accommodate interchangeable components of a Formula Hybrid car to use for several years.			
Group Name	**Objective Number**	**Objective Description**	**Relative Importance**
Optimization	1.1	A wireless telemetry system to easily view live system values	7 %
	1.2	Voltage and circuit completion indicators for ease of electrical troubleshooting	5 %
	1.3	Mount electrical components that stay constant from year to year in order to reduce team costs	7%
	1.4	Flexible mounting locations for a variety of components	11 %
	1.5	Ample storage space to house common breadboard components	2 %
Constraints	2.1	High portability to easily transport the cart to various locations	5 %
	2.2	The cart is sized appropriately to fit through relevant doors in Gleason	7 %
	2.3	A basic cooling system for major components to ensure maximum efficiency	1 %
	2.4	Emergency shutdown for both the tractive and low voltage circuits	10 %
	2.5	Easy interchangeability of accumulator, motor and IC engine components	9 %
Rules	3.1	The cart is grounded in accordance with the Formula Hybrid rules.	6 %
	3.2	The cart is isolated in accordance with the Formula Hybrid rules.	7 %
	3.3	The cart is fused in accordance with the Formula Hybrid rules.	5 %
	3.4	The emergency shutdown circuit is designed in accordance with the Formula Hybrid rules.	3 %
Data and Testing	4.1	Record and log specified data parameters in order to analyze the efficiency of the powertrain design	3%
	4.2	Alert to any component failures and safety faults to diagnose design issues	8%
	4.3	Record temperature data for the accumulator, motor, and IC engine components	4%

† Functional Decomposition (will not be given to the students, but will be provided to the team's guide for reference):

What functionality will be delivered in order to satisfy the customer requirements? This may be in the form of a list of functions, a function tree or a FAST diagram.



* Preliminary Engineering Requirements (ER):

Include both metrics and specifications. Each ER should map to one or more CRs (see above).
Metrics: what quantities will be measured in order to verify success?
Specifications: what is the target value of the metric that the team should design to?

Eng. Req	Customer Obj. #	Engineering Metric	Marginal Value	Ideal Value	Source
S1.a	1.1	Distance from system for successful retrieval of data	> 0 ft	> 10 ft	-
S1.b	1.1, 4.1	Interval at which data is logged and stored	<= 5 sec.	<= 1 sec.	-
S2.a	1.2	Indicators spaced at minimum distance intervals in tractive and low voltage systems	< 2ft	< 1ft	-
S2.b	4.2	Number of Fault indicators that can be activated	>2	10	-
S3	1.3, 2.4	Number of shutdown buttons (master switches, BRBs)	>3	6	Formula Hybrid Rules
S4	1.3, 1.4	Number of components that can be mounted	20	25	-
S5	1.5	Volume of dedicated storage space for breadboard components	>0.3 ft^3	0.5 ft^3	-
S6	2.5	Time to interchange different accumulators, motors, and IC engines	<15 min	5 min	-
S7.a	2.1	Minimum force required to move cart	100 lbf	<100 lbf	-
S7.b	2.1, 2.2	Width of cart	<3.5 ft	<3 ft	Width of smallest relevant door
S8.a	2.3	Number of heat dissipating devices per critical component	>= 1	2	-
S8.b	2.3, 4.3	Motor temp	-40C - 80C	50C	Data Sheet
S8.c	2.3, 4.3	Controller temp	-40C - 50C	25C	Data Sheet
S8.d	2.3, 4.3	Accumulator temp	-20C - 55C	30C	Data Sheet
S8.e	2.3, 4.3	BMS temp	-40C - 80C	25C	Data Sheet
S8.f	2.3, 4.3	Engine temp	-40C - 80C	50C	Data Sheet
S9.a	3.1	Resistance to low voltage system ground (measured at accessible metal parts)	< 300 mΩ	0 – 150 mΩ	Formula Hybrid Rules

S9.b	3.2	Physical separation of tractive and low voltage components	>2cm	>3cm	Formula Hybrid Rules
S9.c	3.2	Electrical insulation thickness (if not physically separated by creepage distance)	>0.25mm	5mm	Formula Hybrid Rules
S9.d	3.4	Order of shutdown (see figure 38 from Formula Hybrid Rules below)	Figure 38	-	Formula Hybrid Rules
S9.e	3.3	Each wire gauge has specified minimum fuse value (see table 23 from Formula Hybrid rules below)	Table 23	-	Formula Hybrid Rules, Component Manuals

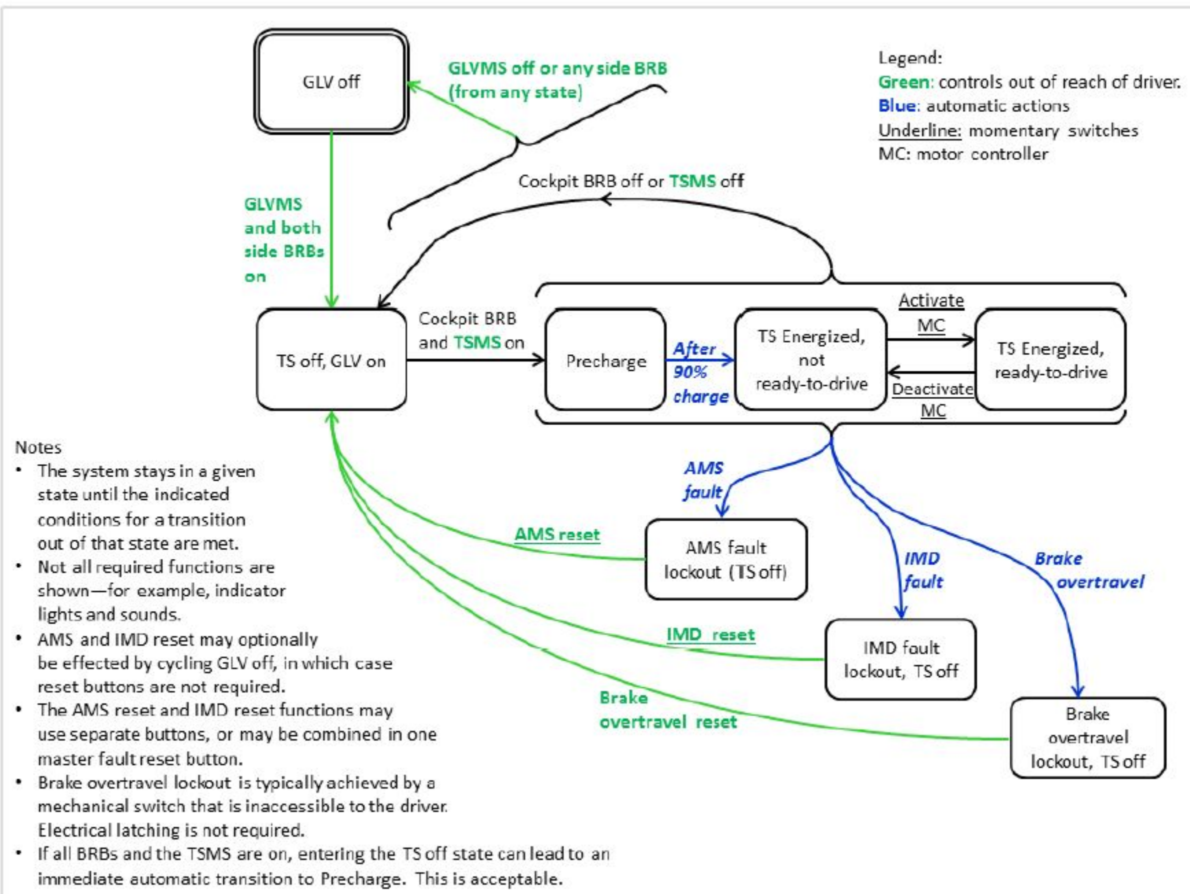


Figure 38 - Example Shutdown State Diagram

Wire Gauge Copper AWG	Conductor Area mm^2	Max. Continuous Fuse Rating (A)
24	0.20	5
22	0.33	7
20	0.52	10
18	0.82	14
16	1.31	20
14	2.08	28
12	3.31	40
10	5.26	55
8	8.37	80
6	13.3	105
4	21.2	140
3	26.7	165
2	33.6	190
1	42.4	220
0	53.5	260
2/0	67.4	300
3/0	85.0	350
4/0	107	405
250 MCM	127	455
300 MCM	152	505
350 MCM	177	570
400 MCM	203	615
500 MCM	253	700

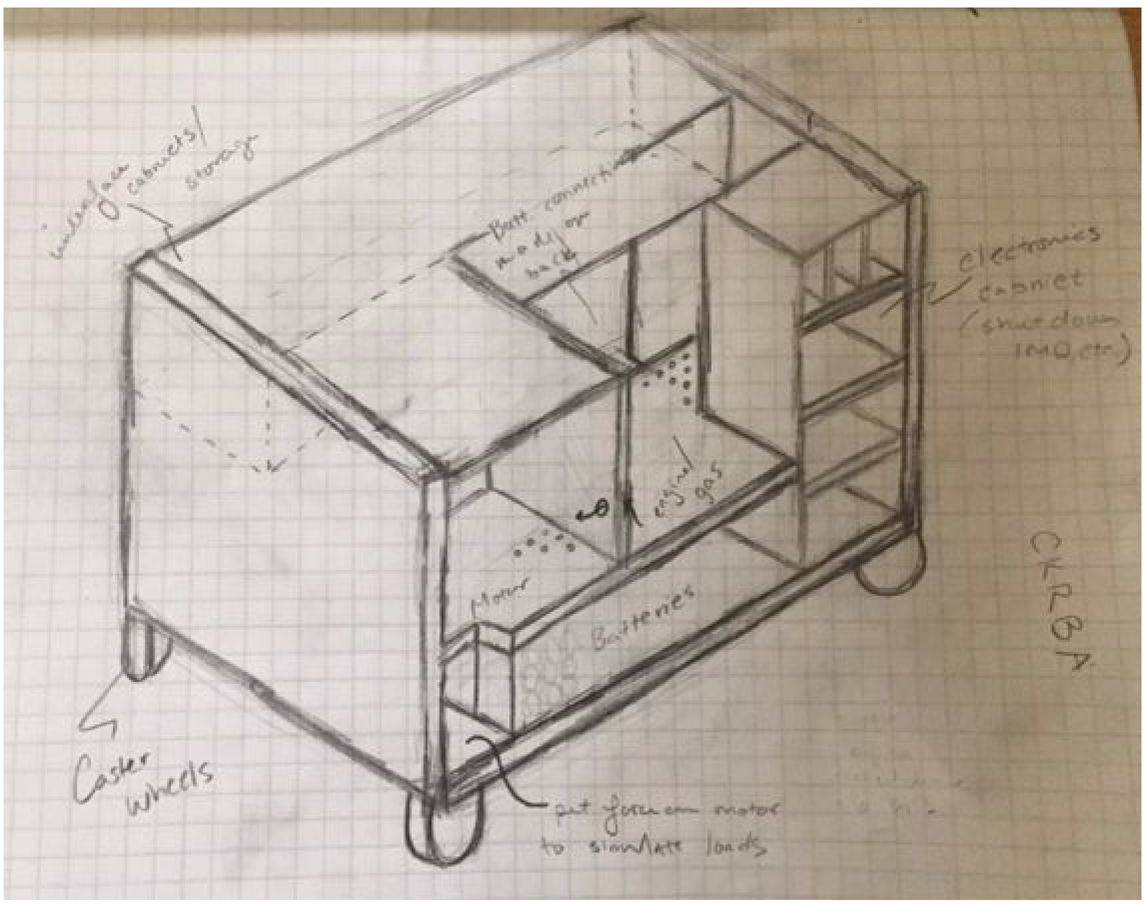
Standard Metric Wire Size mm^2	Max. Continuous Fuse Rating (A)
0.50	10
0.75	12.5
1.0	15
1.5	20
2.5	30
4.0	40
6.0	60
10	90
16	130
25	150
35	200
50	250
70	300
95	375
120	425
150	500
185	550
240	650
300	800

Table 23 – Wire Current Capacity (single conductor in air)

* Constraints:
List any external factors that limit the selection of alternatives, e.g., allowable footprint, budget, required use of legacy hardware/software.

- Allowable footprint (take up limited space on the senior design floor)
- Be able to use cart over several years for varying electrical designs
- Accommodate different engines, motors, and batteries

† Potential Concepts: (will not be given to the students, but will be provided to the team's guide for reference):
Generate a shortlist of potential solutions, along with the disciplines that may be required to realize each. This helps to ensure that projects are feasible.



[*] **Project Deliverables:**
Minimum requirements:
- All design documents (e.g., concepts, analysis, detailed drawings/schematics, BOM, test results)
- working prototype
- technical paper
- poster
- All teams finishing during the spring term are expected to participate in Imagine RIT

Additional required deliverables:
- Final Cart
- Commonly created electrical systems (Shut down, IMD, etc.)

† Budget Information:
Include total budget, any major cost items anticipated, and any special purchasing requirements from the sponsor(s).

Approximate Total Budget: $3500

- Materials - to build the cart
  - Cart materials - $1000
  - Wheels - $150
  - Steel/aluminum for mounts - $300
  - Fasteners - $50
  - Fuel lines - $100
  - Fuel pump - $150
- Sensors - to evaluate system performance
  - Current - $50 per (~3)
  - Temperature - $20 base (~10)
  - Voltage - $20 per (~5)
  - RPM/Speed - $30 per (~3)
- Wireless System - for data transmission
  - Raspberry Pi + accessories - $100
  - Wireless Transmitter - $200
  - CAN bus adapter - $200
  - Misc. - $100
- Electrical cables and connectors - for cart usability
  - Anderson connectors - $10 per (~20)
  - High voltage wire - $100
  - Misc. breadboard components - $50

* Intellectual Property:

At this time we do not believe we will have any issues with intellectual property.

Project Resources

† Required Resources (besides student staffing):
Describe the resources necessary for successful project completion. When the resource is secured, the responsible person should initial and date to acknowledge that they have agreed to provide this support. We assume that all teams with ME/ISE students will have access to the ME Machine Shop and all teams with EE students will have access to the EE Senior Design Lab, so it is not necessary to list these. Limit this list to specialized expertise, space, equipment, and materials.

Faculty list individuals and their area of expertise (people who can provide specialized knowledge unique to your project, e.g., faculty you will need to consult for more than a basic technical question during office hours)	**Initial/ date**
Marty Schooping (Electrical, Mechanical theory and design), Kathleen Lamkin-Kennard (Systems design and integration)	
Environment (e.g., a specific lab with specialized equipment/facilities, space for very large or oily/greasy projects, space for projects that generate airborne debris or hazardous gases, specific electrical requirements such as 3-phase power)	**Initial/ date**
Access to the Hot Wheelz room, secure space for exposed high voltage equipment	
Equipment (specific computing, test, measurement, or construction equipment that the team will need to borrow, e.g., CMM, SEM,)	**Initial/ date**
Hot Wheelz-owned equipment (soldering irons, crimpers, Anderson crimpers, high voltage tools, etc.) Previous year's motor, batteries, etc. for testing of test bench	
Materials (materials that will be consumed during the course of the project, e.g., test samples from customer, specialized raw material for construction, chemicals that must be purchased and stored)	**Initial/ date**
Other	**Initial/ date**

† Anticipated Staffing By Discipline:
Indicate the requested staffing for each discipline, along with a brief explanation of the associated activities. "Other" includes students from any department on campus besides those explicitly listed. For example, we have done projects with students from Industrial Design, Business, Software Engineering, Civil Engineering Technology, and Information Technology. **If you have recruited students to work on this project (including student-initiated projects), include their names here.**

Dept.	# Req.	Expected Activities

BME	0	n/a
CE	1	Implement a live wireless data transmission system with logging functionality, and a clean user interface to view data and easily adjust CAN definition profiles. Interface various sensors with microcontrollers and program the boards to process both sensor and CAN bus data. Design circuits for the sensors and assist with designing other electrical systems. (Cindy Gomez)
EE	1	Design an interface of cables and connectors that would best fit the electrical circuits used by the Hot Wheelz team. Ensure all cabling and fusing is done appropriately and in accordance with Formula Hybrid rules. Create overall circuit hardware design for any sensor interfaces, cooling, and power interfaces. Ensure signal integrity of transmission lines. (Kendra Brock)
ISE	1	Manage the project timeline and budget through the process. Manage sourcing, purchasing, and communications with mentors and advisors. (Rachel Heise)
ME	2	Manufacture and assemble adjustable cart mechanical features. Find locations and mounting techniques for all electrical features. Determine thermal characteristics and optimize opportunities for adjustment on all parts of cart. (Rebecca Michalski, Alaysia Gilbert)
Other	0	

* Skills Checklist:
Indicate the skills or knowledge that will be needed by students working on this project. Please use the following scale of importance:
1 = must have
2 = helpful, but not essential
3 = either a very small part of the project, or relates to a “bonus” feature
blank = not applicable to this project

Computer Engineering

	CE Core Knowledge		CE Elective Knowledge
	Digital design (including HDL and FPGA)	1	Networking & network protocols
1	Software for microcontrollers (including Linux and Windows)	1	Wireless networks
2	Device programming (Assembly, C)		Robotics (guidance, navigation, vision, machine learning, control)
1	Programming: Python, Java, C++	2	Concurrent and embedded software
2	Basic analog design	1	Embedded and real-time systems
	Scientific computing (including C and Matlab)		Digital image processing
3	Signal processing		Computer vision
2	Interfacing transducers and actuators to microcontrollers	3	Network security

			Other (specify)

Electrical Engineering

	EE Core Knowledge		EE Elective Knowledge
1	Circuit Design (AC/DC converters, regulators, amplifies, analog filter design, FPGA logic design, sensor bias/support circuitry)		Digital filter design and implementation
2	Power systems: selection, analysis, power budget		Digital signal processing
	System analysis: frequency analysis (Fourier, Laplace), stability, PID controllers, modulation schemes, VCO's & mixers, ADC selection	2	Microcontroller selection/application
1	Circuit build, test, debug (scope, DMM, function generator	3	Wireless: communication protocol, component selection
	Board layout		Antenna selection (simple design)
	Matlab	1	Communication system front end design
	PSpice	3	Algorithm design/simulation
2	Programming: C, Assembly		Embedded software design/implementation
	Electromagnetics: shielding, interference		Other (specify)

Industrial & Systems Engineering

	ISE Core Knowledge		ISE Elective Knowledge
	Statistical analysis of data: regression		Design of Experiment
3	Materials science	2	Systems design – product/process design
1	Materials processing, machining lab		Data analysis, data mining
	Facilities planning: layout, mat'l handling		Manufacturing engineering
	Production systems design: cycle time, throughput, assembly line design, manufacturing process design	2	DFx: manufacturing, assembly, environment, sustainability
	Ergonomics: interface of people and equipment (procedures, training, maintenance)		Rapid prototyping
	Math modeling: OR (linear programming, simulation)		Safety engineering
1	Project management		Other (specify)
1	Engineering economy: Return on Investment		
	Quality tools: SPC		
	Production control: scheduling		
	Shop floor IE: methods, time studies		
3	Computer tools: Excel, Access, AutoCAD		
	Programming (C++)		

Mechanical Engineering

	ME Core Knowledge		ME Elective Knowledge
1	3D CAD		Finite element analysis
	Matlab programming	2	Heat transfer
1	Basic machining		Modeling of electromechanical & fluid systems
2	2D stress analysis	2	Fatigue and static failure criteria
2	2D static/dynamic analysis		Machine elements
	Thermodynamics		Aerodynamics

	Fluid dynamics (CV)			Computational fluid dynamics
3	LabView			Biomaterials
	Statistics		1	Vibrations
2	Materials selection		2	IC Engines
			1	GD&T
				Linear Controls
				Composites
			3	Robotics
				Other (specify)