FORMULA SAE
Engine Control Unit III
Project 09222

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Jordan Hibbits (EE)	Programming
Robert Joslyn (EE)	PCB Design
Giovanni Sorrentino (ME)	Case Design/Edge/NI DAQ
Bob Raymond (ISE)	Team Lead/NI DAQ
Andrew Rittase (EE)	Hardware

Todd Fernandez (TA)
George Slack (Guide)
Dr. Daniel Phillips (Guide)
Dr. Alan Nye (Advisor/Customer)

Project Description

- Develop A Functional Engine Control Unit to be used on the RIT SAE Formula Car Including Protective Case and Software Interface Design
- ECU Control Functions
  - Cam/Crank Input Sensors
  - Fan/Fuel Pump Relay Control
  - Intake Air and Coolant Temperature Sensor
  - Throttle Position Sensor (TPS)
  - Manifold Absolute Pressure Sensor (MAP)
  - Ignition Signal To CDI Box
  - Injector Driver Control
  - Oxygen Sensor

Customer Needs

Priority

Functionality

-Reliability
-Vibration/Heat Tolerance
-Cost of Manufacturing

-Performance

- Waterproof

Ergonomics

-Accessibility on Vehicle

- Portability

Esthetics

- Coordination with car design

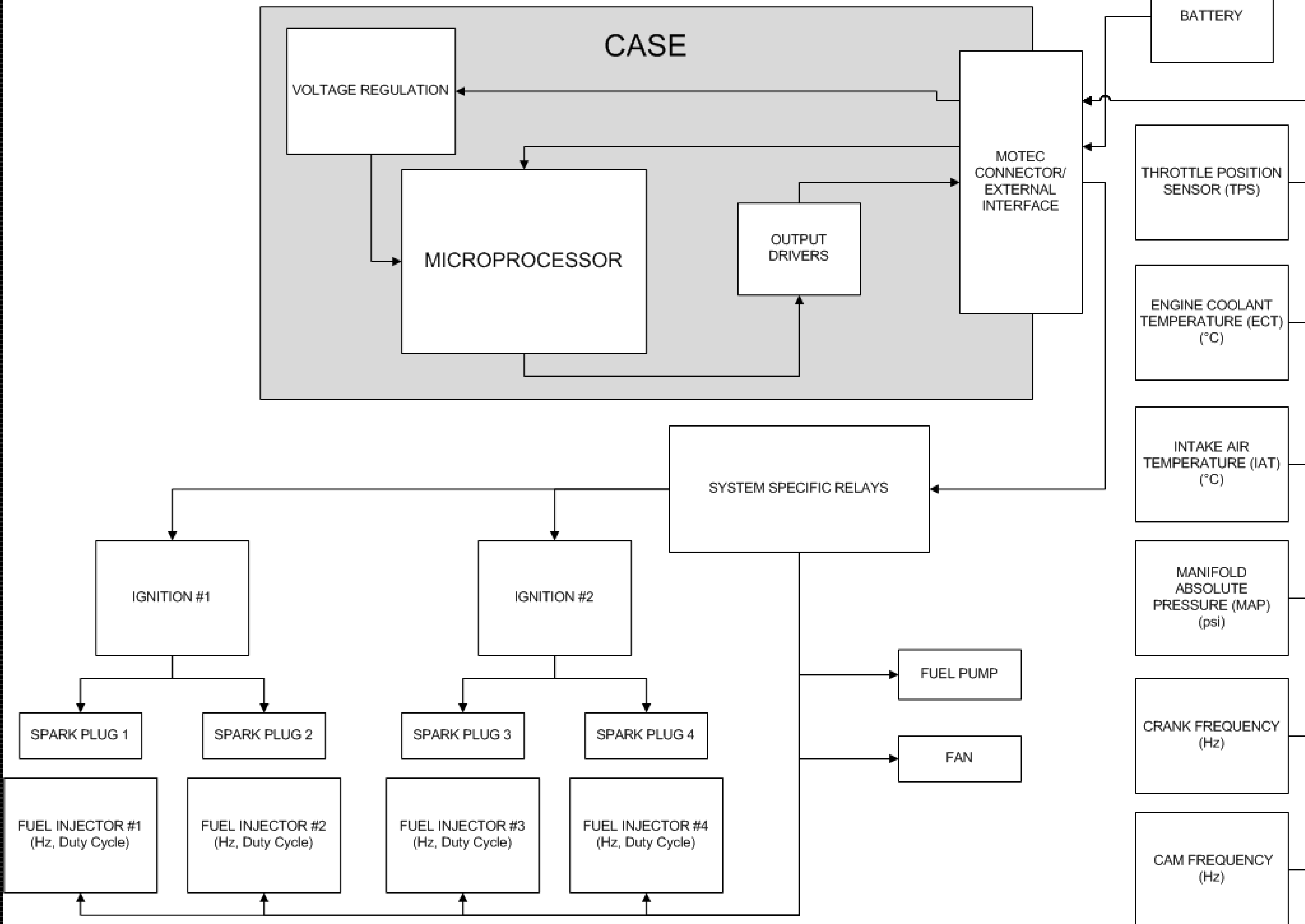
Customer Needs

- **Reliability testing** – to be completed through the NI DAQ testing plan to verify the system capabilities at extreme points and validation over long periods of time.
- **Heat Tolerance** – the unit itself is expected to generate only moderate amounts of heat. Specifically MOSFETs (which drive the fuel injectors), voltage regulation and the processor create the majority of this heat. Copper pads were placed under the MOSFETs and regulators to dissipate heat and Therm-a-gap gel inside the case will abduct heat away from the board.
- **Vibration Tolerance** – The Therm-a-gap gel which is being used to solve heat tolerance issues is a very thick porous material with vibration reducing capabilities. The gel filling the case will dampen the vibrations experienced by the car.
- **Cost of Manufacturing** – material cost for case being investigated. PCB boards cost is minimal at high production levels. Components cost $160, case $100, aim to stay below $300.

Customer Needs

- **Waterproof** – The case itself is welded. Silicone based sealant will be applied to all gaps and connections.
- **Performance** – Timing accuracy must be within +/- ½ degree and are requested to be +/- ¼ degree. For all other performance specifications see Design Specifications.
- **Documents Functional Concepts** – Request of user manual for the ECU system is a necessary deliverable by the end of senior design 2.
- **Accessibility** – The unit can be placed anywhere on the car that the connector cables allow it to reach. The formula team will be able to dictate their accessibility.
- **GUI** – The driver should be able to monitor all inputs and outputs through the GUI including a computation of ignition and injection accuracy.

P09222 ECU SYSTEM LEVEL DESIGN



Risk Analysis

Element	Issue	Possible Delay	Solutions	Critical Path
Programming	Optimizations affect the speed and accuracy of at which the ECU will operate. Timing toleraces must be met under these conditions. Calculations will determine if we meet these requirements.	Compiler lead time 3 days, funding issues will also cause delay	Purchase of full size complier ($1000 and week delay for delivery). This Also causes a budget issue for us and is not the reccommended soultion.	X
	Risk Level - Moderate	Delay Length - Long		
	Code Size - Code is currently at 11K using optimizations and is over the 16K limit without.	Compiler lead time 3 days, funding issues will also cause delay	Purchase of full size complier (as above.)	X
	Risk Level - Moderate	Delay Length - Long		
		MIN 0.5 Days, MAX 3 Days	Reduction of lookup tables library to minimize the size of the tables. This has limited capability in the amount that it can reduce the code size. It is inexpensive but requires man hours (estimated 5 hours.)	X
	Risk Level - Moderate	Delay Length - Short		
	Code De-bugging Time Forecasting Difficulties due to our teams' lack of experience with the code being used.	MIN 2 Days, MAX 1 Quarter	Contact Chris Fueurstein for assitance and explaination	X
	Risk Level - High	Delay Length - Long		
	Redesign of code if problems cannot be solved	MIN 1 Week, MAX 1 Quarter	Contact Chris Fueurstein for assitance and explaination	X
	Risk Level - High	Delay Length - Long		

PCB Board	Error in PCB Design	1 week + time to notice +cost	Error in design of ordered PCB board is a monetary and time issue. There is a balance between money and lead time that would have to be decided on in this situation. Our original plan is to purchase with one week lead time. Purchase during winter and	
	Risk Level - High	Delay Length - Long		
	Destruction of PCB all PCB boards Printed	1 week + time to notice +cost	Purchase of multiple boards will reduce the risk of this occuring. The incremental cost of the boards is low enough to reason for purchase of extra boards.	X
	Risk Level - Low	Delay Length - Long		
Lab Testing	Destruction of Board		PCB Board leadtime based on our budget will be one week. As a result we will be ordering extra boards with the initial order since the set up cost is high and the incremental cost for additional boards is relatively small. Populating additional boards will prevent this issue.	
	Risk Level - Moderate	Delay Length - Short		
	Evidence to prove theorectical calculations wrong		Problem diagnosis required and repairs made to PCB design and re-order.	X
	Risk Level - Moderate	Delay Length - Long		
	Destruction of Case	5 days	Diagnosis would be required at this point and evaluation of the current design. Lead time for materials to rebuild is	
	Risk Level - Low	Delay Length - Moderate		

Field Testing	Insufficient testing	Customer satisfaction	Though testing can be reduced in the case that other tasks take longer to complete, this will most definitley result in the product not being used. This result would not qaulify as a success for our team.	X	
	Risk Level - Moderate	Delay Length - Incompletion			
	Destruction of Board	1/2 week	See Above.	X	
	Risk Level - Low	Delay Length - Long			
	Destruction of Case	1 week	See Above	X	
	Risk Level - Low	Delay Length - Moderate			
O2 Sensor Development/Verification	Measurements of Oxygen Sensor Inputs/Outputs while under operating conditions	1 week	Further investigation would be needed into determining the input/output waveforms between the Oxygen sensor on the engine and the ECU circuitry.	X	
	Risk Level - Moderate	Delay Length - Long			
Case	Case waterproofing not sufficient	3 days	Re-apply water sealant and possibility of damage to board. Additional boards being populated.	X	
	Risk Level - Moderate	Delay Length - Short			
	Overheating of internal components	1 day to 2 weeks	Revise thermal analysis and increase amount of thermal interface material or alternative solutions to dissapate heat.	X	
	Risk Level - Moderate	Delay Length - Long			

State of the Design

- **Microelectronics Hardware Development**
  - Initial Design Complete
  - Optimization in Progress
- **Oxygen Sensor Design**
  - Under Investigation
  - Oxygen Sensor Measurements Required for Design Verification
- **PCB Layout Design**
  - Preliminary Design Complete
  - More Efficient Re-Design Under Consideration

State of the Design

- **Software Design**
  - Overview Analysis
- **NI-DAQ**
  - Functional
  - Awaiting Interface with TI Board to Assess Further Debugging
- **Case Design**
  - Preliminary Design Complete
  - Key Issues Addressed
  - Further Analysis required

Budget

Manufacturing Budget

Hardware Components	$ 162.00
Case Material	$ 118.00
PCB Board (Heavily based on quantity)	$ 57.00

Course Budget

Hardware Components	$ 162.00
Case Material	$ 118.00
PCB Boards	$ 285.00
Testing Equipment	$ 47.00

Component	Qty	Description	Price (each)	Price (total)
1N4148WTDICT	2	DIODE SWITCH 100V 150MW SOD-523	$0.43	$0.86
300-8538-1	1	CRYSTAL 7.3728 MHZ SMT 18PF	$0.75	$0.75
0467.500NR	9	FUSE .500A FST 0603	$1.02	$9.18
0467001.NR	2	FUSE 1A 32V FST 0603	$1.02	$2.04
1008AF-112XKL	5	CHIP INDUCTOR 1.1 µH	$1.21	$6.05
AD8397ARZ	2	IC OP AMP R-R HI OUTPUT 8-SOIC	$5.51	$11.02
AD8604AR	5	IC OPAMP QUAD R-R I/O 14-SOIC	$2.34	$11.70
BAT760DICT	1	DIODE SCHOTTKY 30V 1A SOD-323	$0.72	$0.72
T494D107K010AT	5	CAPACITOR TANT 100UF 10V 10% SMD	$2.60	$13.00
C0603C104K5RACTU	34	CAP CERAMIC .100UF 50V X7R 0603	$0.06	$2.18
C0603C103J5RACTU	18	CAP CERAMIC 10000PF 50V X7R 0603	$0.03	$0.59
CC0603CRNP09BN5R0	1	CAP CERAMIC 5.0PF 50V NP0 0603	$0.07	$0.07
C0603C180J5GACTU	1	CAP CERAMIC 18PF 50V NP0 0603	$0.06	$0.06
C0603C471K5RACTU	1	CAP CERAMIC 470PF 50V X7R 0603	$0.07	$0.07
GRM31MR71A225KA01L	2	CAP CER 2.2UF 10V 10% X7R 1206	$0.27	$0.54
LMK316B7106KL-T	1	CAP CER 10UF 10V X7R 1206	$0.40	$0.40
81-GRM32R71A226KE20L	1	CAP CERAMIC 22uF 10% 10V X7R 1210	$2.62	$2.62
FDS8884TR	4	MOSFET N-CH 30V 8.5A 8-SOIC	$0.48	$1.92
LM1949N	4	IC CONTROLLER INJESTOR DRV 8-DIP	$4.35	$17.40
LT1933ES6	2	IC REG SW 600MA HS STDN TSOT23-6	$4.48	$8.96
MBRM140T3G	2	DIODE SCHOTTKY 40V 1A POWERMITE	$0.33	$0.65
MSS6122-273MLB	1	Inductor, Surface Mount, Shielded, 27uH	$0.88	$0.88
MSS6122-393MLB	1	Inductor, Surface Mount, Shielded, 39uH	$0.88	$0.88
CRCW06030000Z0EA	62	RES 0.0 OHM 1/10W 5% 0603 SMD	$0.07	$4.59
CRCW06031K50FKEA	4	RES 1.5K OHM 1/10W 1% 0603 SMD	$0.08	$0.32
CRCW06032R00FNEA	4	RES 2.00 OHM 1/10W 1% 0603 SMD	$0.08	$0.32
CRCW06033K00FKEA	4	RES 3.00K OHM 1/10W 1% 0603 SMD	$0.08	$0.32
CRCW06033K90FKEA	9	RES 3.9K OHM 1/10W 1% 0603 SMD	$0.08	$0.73
CRCW06034K99FKEA	4	RES 4.99K OHM 1/10W 1% 0603 SMD	$0.08	$0.32
CRCW06036K80FKEA	9	RES 6.8K OHM 1/10W 1% 0603 SMD	$0.08	$0.73
CRCW06037K50FKEA	4	RES 7.50K OHM 1/10W 1% 0603 SMD	$0.08	$0.32

CRCW060310K0FKEA	54	RES 10.0K OHM 1/10W 1% 0603 SMD	$0.08	$4.37
CRCW060315K0FKEA	7	RES 15.0K OHM 1/10W 1% 0603 SMD	$0.08	$0.57
CRCW060330K1FKEA	2	RES 30.1K OHM 1/10W 1% 0603 SMD	$0.08	$0.16
CRCW060333K0FKEA	6	RES 33.0K OHM 1/10W 1% 0603 SMD	$0.08	$0.49
CRCW060347K0FKEA	2	RES 47.0K OHM 1/10W 1% 0603 SMD	$0.08	$0.16
CRCW060339K0FKEA	1	RES 39.0K OHM 1/10W 1% 0603 SMD	$0.08	$0.08
CRCW060354K9FKEA	1	RES 54.9K OHM 1/10W 1% 0603 SMD	$0.08	$0.08
CRCW0603499RFKEA	4	RES 499 OHM 1/10W 1% 0603 SMD	$0.08	$0.32
RL7520WS-R10-F	4	RES .10 OHM 2W 1% 0830 SMD	$1.93	$7.73
ERJ-1TYJ392U	4	RES 3.9K OHM 1W 5% 2512 SMD	$0.40	$1.58
SN74AHCT125	3	IC QUAD BUS BUF GATE 3ST 14TSSOP	$0.47	$1.41
TC4468COE	1	IC MOSFET DVR QUAD AND 16SOIC	$2.48	$2.48
TMP36FSZ	1	IC SENSOR TEMP 2.7/5.5 8SOIC	$1.65	$1.65
TMS470R1B512PGET	1	IC RISC MICRO 16/32BIT 144-LQFP	$14.74	$14.74
SMBJ5360B-TP	12	DIODE ZENER 5W 25V SMB	$1.00	$12.00
S1GB-13	8	RECTIFIER GPP SMD 400V 1A SMB	$0.53	$4.24
TPS70302PWP	1	IC ADJ1.22-5.5V LDO 24-HTSSOP	$5.29	$5.29
CRCW060318K0FKEA	1	RES 18.0K OHM 1/10W 1% 0603 SMD	$0.08	$0.08
CRCW060351K1FKEA	1	RES 51.1K OHM 1/10W 1% 0603 SMD	$0.08	$0.08
TAJB226K010R	1	CAP TANTALUM 22UF 10V 10% SMD	$0.55	$0.55
TPSB476K010R0250	1	CAP TANT LOWESR 47UF 10V 10% SMD	$1.13	$1.13
C0603C224J5RACTU	2	CAP CERAMIC .22UF 50V X7R 0603	$0.04	$0.09
S1GBDITR-ND	6	RECTIFIER GPP SMD 400V 1A SMB	$0.08	$0.48
FDS6673AZ	2	MOSFET P-CH 30V 14.5A 8SOIC	$1.01	$2.02
Aluminum Sheet Stock 2024-T3	1	12 X 12 X .04"	$20.40	$20.40
Aluminum Rod Stock	1	3/32" diameter	$2.09	$2.09
Therm-A-Gap A580 (best for vibration dampening)	1	custom	-	-
Silicon based waterproofing sealant (Permatex)	1	3 oz	$6.00	$6.00
Vibra-tite	1	30 cc	$18.00	$18.00
#4 Screws-SS100 degree	8	TBD	$2.00	$2.00
Antivibration Washers	4	-	-	-
			Total:	**$210.49**

Programming/
GUI
Jordan Hibbits
¼

Build Simulation Models – √ A

Prototype Problem Components – √ A

Microprocessor Spec. √
Andrew Ritt e

Sensors ¾
Dereck Bojanowski

PCB Layout/Build √
Robert Joslyn

Dynamics/Casing
-Vibration
-Thermal ding
-Waterproof
-Case size
Giovanni Sorrentino
½

Lab Testing
and Debugging
All Members

Statistical Analysis
-Benchmarking vs.
Current system
Bob Raymond (PM)

Field Testing
All Members/
Customer

Operations Manual

Functional Product

Fall
3
4
5
6
7
8
9
10
11

Spring
1
2
3
4
5
6
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11

Senior Design – Spring (but mostly winter)

Programming
Timing analysis
Jordan Hibbits

O_2 Functionality
Jordan Hibbits

PCB Layout
Optimization
Robert Joslyn

PCB Order
Robert Joslyn

PCB Population
Dereck, Andrew

PCB Board Testing
Dereck, Andrew, Rob

PCB Re-Order (Buffer)
Robert Joslyn

O_2 Sensors Circuitry
And testing
Dereck Bojanowski

Case Revisions
Giovanni Sorrentino

Thermal Modeling
Using actual PCB
Giovanni Sorrentino

Case Build
Giovanni Sorrentino

Winter
1
2
3
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10
11

Lab Testing
All Members

Field Testing
All Members/
Customer

Statistical Analysis
Benchmarking vs.
Current system
Bob Raymond (PM)

Project
Documentation
-Manual for Users
- Records for 4th Gen.

Spring
1
2
3
4
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10
11

Functional Product