Systems Level Design Review
P11303: Roue Training Wheel

Meeting Date: October 8, 2010
Meeting Location: Room 09-2030
Meeting time: 11:00am – 12:30 pm

Bryce Mankowski – EE
Matt Rothberg – EE
Jared Burdick - EE
Brian Dominiak - ME

Meeting Purpose

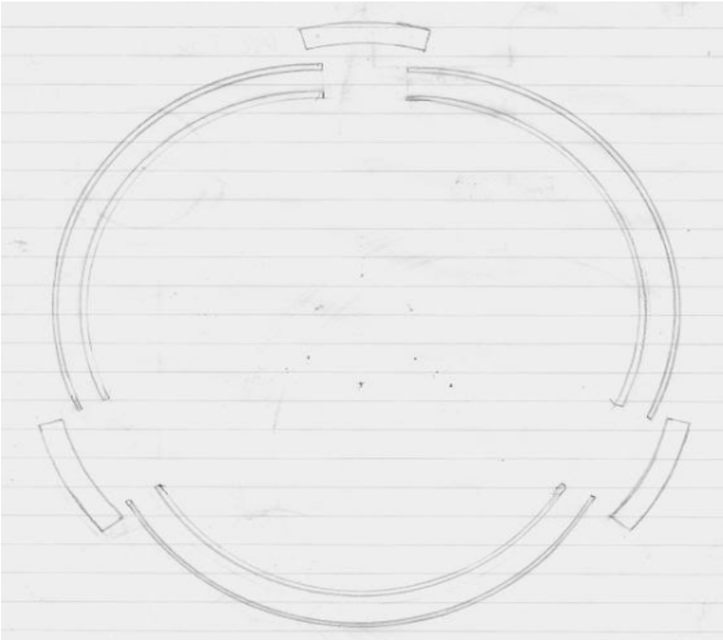
1. Overview of the project
2. Confirm Engineering Specifications
   & Customer Needs
3. Review Design Concepts
4. Propose a design approach and confirm its
   functionality
5. Cross-disciplinary review: generate further ideas

Materials to be Reviewed

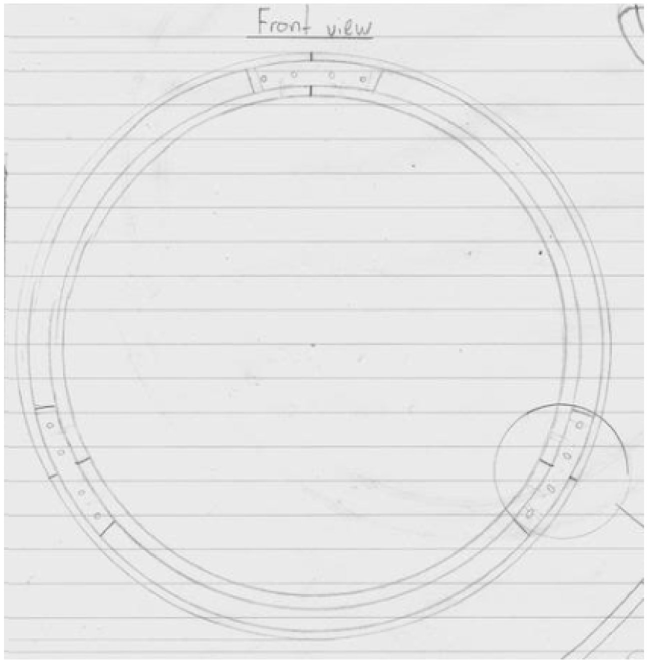
1. Project Description
2. Work Breakdown Structure
3. Customer Needs
4. Engineering Specifications
5. Current System Design Schematic
6. Concept Selection – RF Antenna
7. Concept Selection – Wireless Technology
8. Concept Selection – Inertial Sensor
9. Concept Selection – Microprocessor
10. Concept Selection – Power Source
11. Project Plan
12. Risk Assessment

Project Background:

- A Roue Wheel is wheel that is approximately five to six feet in diameter and is used most commonly in circus acts. It is made up of three parts of hollow aluminum that are joined together by three parts of solid aluminum



Three sections of aluminum pipe with solid aluminum



Roue Wheel joined together

Project Description:

Problem Statement:

- Create device implemented into Roue Training Wheel that would allow for relative inertial tracking sent to a computer in real time to provide instantaneous feedback to person training.

Objectives / Scope:

- Create a device that would not impede the rider in any way
- Ensure the data is accurate and will provide proper feedback
- Allow device to run for an entire work day
- Ensure that the device is capable of undergoing the forces and stresses that the rider delivers to the wheel
- Device has wireless transmission to a computer for processing

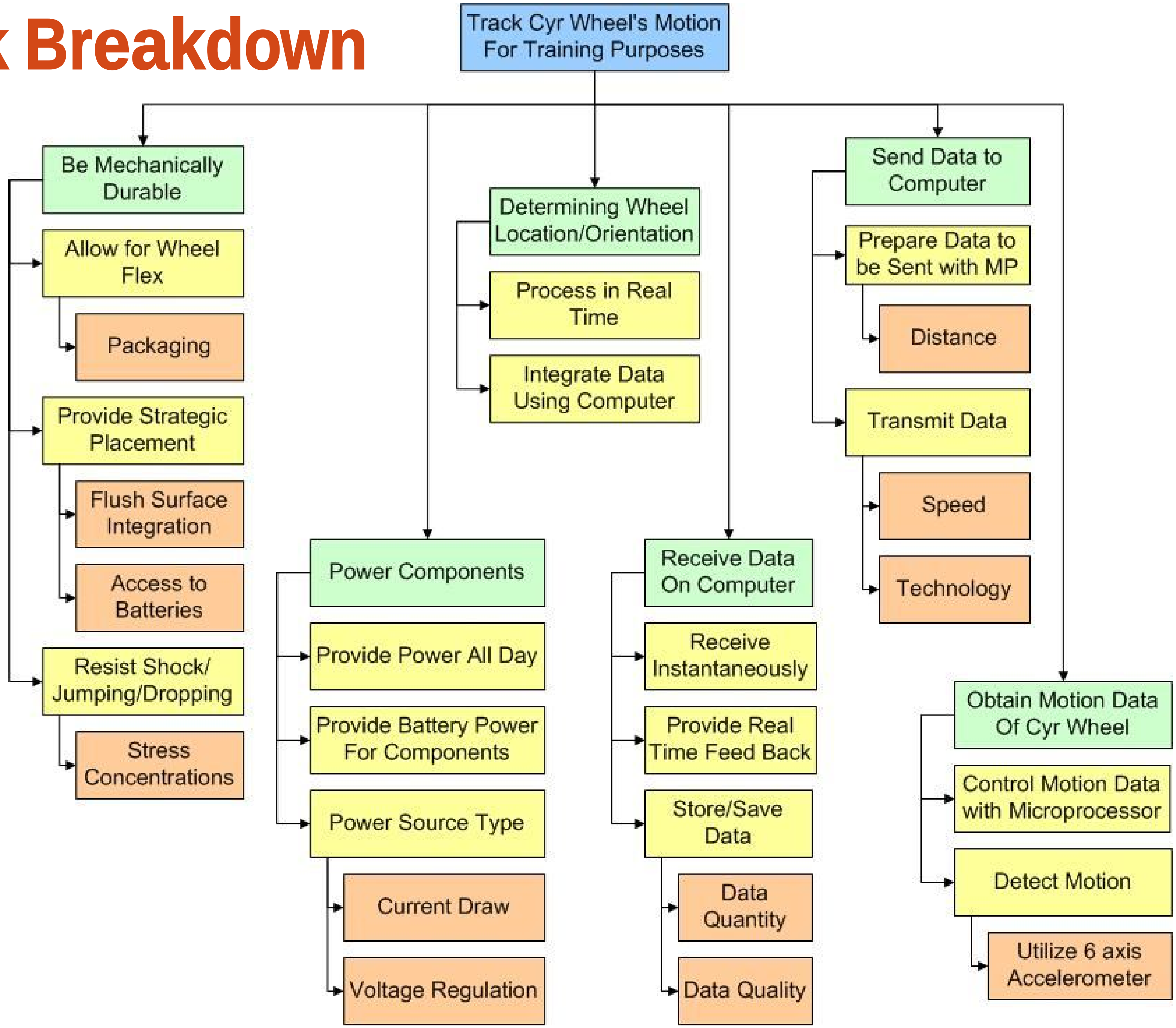
Deliverables:

- Meet customer needs
- Mechanical design
- Electrical Schematics
- Progressive functioning prototypes

Expected Benefits Project Benefits:

- The benefits of this project would serve as a training device giving a person riding the wheel instant feedback of the forces, general position, and position compared to previous position, etc. The information extracted could also be used to sync with lights in a show to provide choreography with the person on the wheel.

Work Breakdown



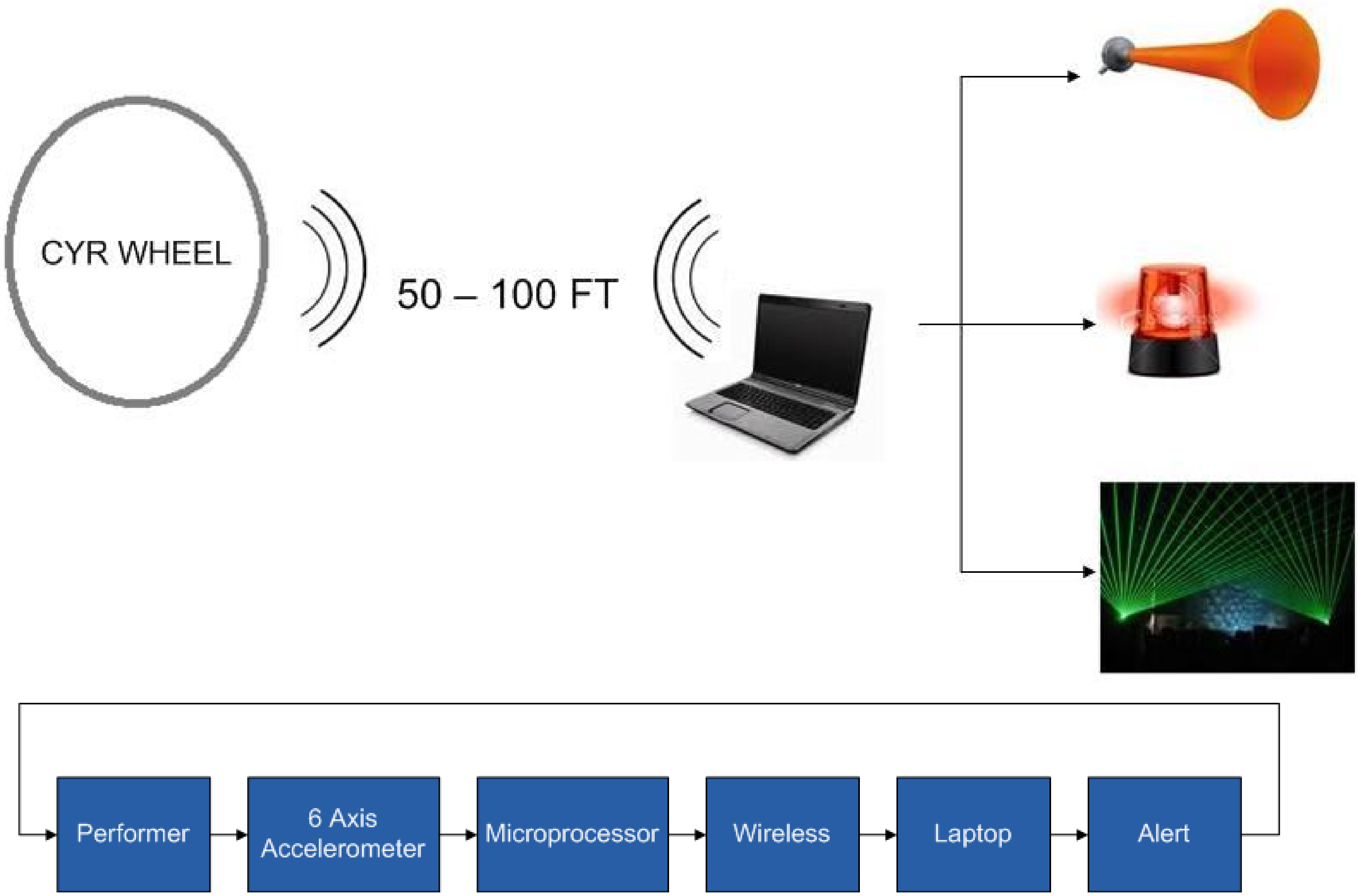
Customer Needs

Customer Need #	Importance	Description	Comments/Status	Customer Request
		Mechanical		
ME1	High	A device which fits in the roué wheel	Packaging	Product needs to be robust.
ME2	Low	Device can be easily installed	Packaging	Device doesn't interfere with function of wheel
ME3	Low	Device is user friendly	Implementation	Device is aesthetically pleasing.
ME4	High	The rider feels as if he's riding the wheel with no device internally (balance of wheel)	Implementation	Device must be user friendly.
ME5	Low	Device has easy battery access removal/charging	Packaging	
ME6	Med	The rider feels as if he's riding the wheel with no device externally(aesthetically)	Implementation	
ME7	Low	Device operates normally after many uses	Durability	
ME8	High	Device operates normally if wheel is dropped	Durability	
ME9	High	Sensor fits in roué wheel	Sensor	
ME10	High	Heat Distribution	Packaging	
		RF		
RF1	High	Device has good transmission (eg. cell phones don't interupt)	Implementation	Device must transmit over long distances inertial data to computer.
RF2	High	Device sends data wirelessly to computer	Implementation	
		Power		
PW1	Med	Device can be used for an entire practice session	Power	Device must operate at least all day long.
PW2	Med	Device has low power consumption	Power	
PW3	Med	Low voltage drain	Power	
PW4	Med	Low current drain	Power	
		General Electrical		
GE1	Med	Can be easily debugged	Implementation	Device accurately tracks wheel's motion.
GE2	High	Device tracks 6 axes of motion	Implementation	Device operates in real-time without lag.
GE3	High	Sensor is accurate	Sensor	
GE4	High	Sensor operates if there is a shock	Sensor	
GE5	Med	Sensor's implementation is simple (clock)	Sensor	
GE6	Med	Data Transferred from sensor is fast	Sensor	
		Other		
OT1	Med	Device is reasonably priced	Cost	Budget max $1500

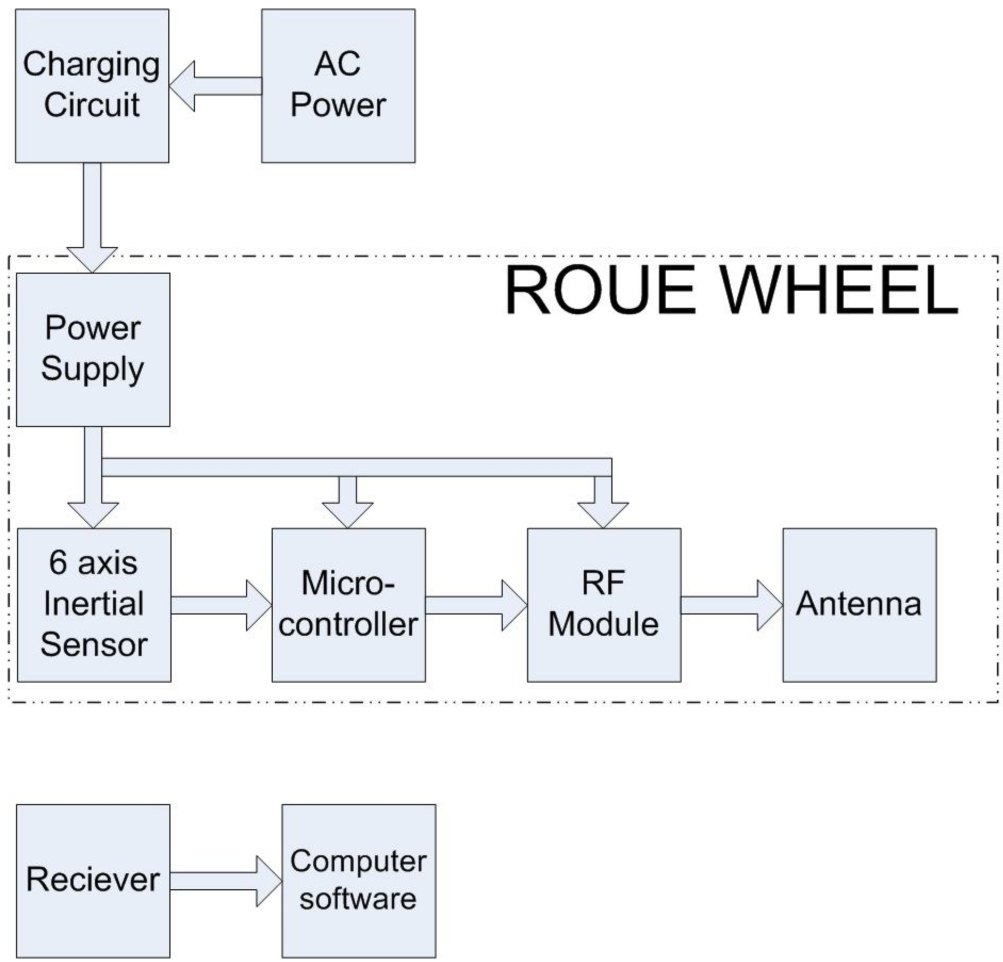
Engineering Specs

Engr. Spec. #	Importance	Source	Specification (Description)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
ES1	High	ME1	Overall Package Dimensions x	mm	20	10	Brian
ES2	Low	ME1	Overall Package Dimensions y	mm	20	10	Brian
ES3	Low	ME1	Overall Package Dimensions z	mm	100	70	Brian
ES4	Low	ME2	Clearance Between Removable Parts	mm	2	1	Brian
ES5	High	ME4	Weight of Device	g	1000	300	Brian
ES6	Low	ME5	Device Removal Time	mins	5	3	Brian
ES7	Med	ME6	COG Shifts Less Than	cm	10	5	Brian
ES8	Low	ME7	Life span of Device	years	1	5	Brian
ES9	High	ME8	Drop Test	meter	2	5	Brian
ES10	Med	ME8	Sensor Robustness	G	2	8	Brian
ES11	High	ME9	Sensor Dimensions	mm	15	7	Brian
ES12	High	ME10	Temperature Does Not Go Over	deg. C	100	80	Brian
ES13	High	RF1	Antenna Power Output	dBm	20	0	Matt
ES14	High	RF2	Data Transmission Range	m	25	50	Matt
ES15	Med	PW1	Battery Life per session	Hours	8	12	Bryce
ES16	Med	PW2	Low Power Consumption	Watts	2.5	1.5	Bryce
ES17	Med	PW3	Voltage Drain	V	5	2.5	Bryce
ES18	Med	PW4	Current Drain	mA	500	200	Bryce
ES19	Med	GE1, ME3	Number of Buttons	#	3	0	Brian/Bryce
ES20	High	GE2	Number of axes Tracked	#	3	6	Jared
ES21	High	GE3	Sensor Accuracy	%	+/-5	+/-3	Jared
ES22	High	GE4	Shock	G	1,000	10,000	Jared
ES23	Med	GE5	Clock Implementation on chip time generation	%	+/-5	+/-2	Bryce
ES24	Med	GE5	Clock Implementation sync with accelerometer	Hz	1M	8M	Bryce
ES25	Med	GE6	Processor Speed	KHz	200	8000	Bryce
ES26	Med	OT1	Overall Price	$	1500	300	All

System Overview



Concept System Design Schematic



Antenna Placement Concept Selection

		1			2			3			4			5		
		Whole Wheel			Groove in Aluminum			Longitudinal Groove in PVC			Circumferential Groove in PVC			Inside Aluminum		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Omni-Directionality	3	4		12	1	Aluminum is ground plane	3	3		9	4		12	3		9
Mechanical Robustness	2	4		8	3		6	4		8	3		6	4		8
ME Simplicity	2	4		8	3		6	3		6	3		6	2		4
Amount of Loss	3	4		12	1		3	4		12	4		12	1	Wheel acts as Faraday Cage	3
EE Simplicity	5	1	Impedance Matching	5	3		15	3		15	3		15	2		10
Total			45			33			50			51			34	

Wireless Technology Concept Selection

		1			2			3			4			5		
		ZigBee			Bluetooth			Wifi			Eye-Fi			Infared		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Data Rate	1	2	250kbps	2	2	1Mbps	2	2	up to 150 Mbps	2	2	up to 150 Mbps	2	2	2.4kbps-1Gbps	2
Range	4	3	76m	12	3	up to 100 m	12	1	70m	4	1	70m	4	0	short range	0
Size	1	4	30mm x 15mm	4	3	40mm x 15mm	3	2	40mm x 25mm	2	2	32mm x 24mm	2			0
~ Cost	2	4	50	8	3	60	6	2	70	4	4	44	8			0
Frequency	2	2	900Mhz, 2.4Ghz	4	1	2.4 GHz	2	1	2.4 GHz	2	1	2.4 GHz	2	1	Varies	2
Low Power	3	4		12	1		3	2		6	2		6	3		9
Omni-Directionality	4	4		16	4		16	4		16	4		16	1		4
Total			30			25			14			18			4	

Zigbee Concept Selection

		1			2			3			4		
		Digi Xbee Module XB24-Z7CIT-004			Microchip MRF24J40MA module			Freescale MC13213 IC			TI CC2530Fxx IC		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Ratin g	Notes	Wtd
Size	1	1	33mm x 25mm	1	1	30mm x 18mm	1	2	9mm x 9mm	2	2	6m x 6mm	2
Supply Voltage	1	2	2.8v-3.4v	2	2	2.4-3.6v	2	2	1.8-3.7V	2	1	3.9v	1
Current Draw at Tx	5	2	45mA	10	3	25mA	15	3	20mA	15	2	40mA	10
On Board Microcontroller	1	1	no	1	1	no	1	2	Yes	2	2	Yes	2
Price	3	2	$17	6	3	$8.99	9	4	$2.49	12	3	$6.29	9
Module or IC?	3	3	Module	9	3	Module	9	1	IC	3	1	IC	3
RF Power	1	3	0 dBm	3	3	0dBm	3	3	0 dBm	3	1	4.5 dBm	1
Total			32			40			39			28	

Motion Tracking Technology Concept Selection

		1			2			3		
		Inertial Sensors			Camera/Image Sensors			Ultrasonic Sensors		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Accuracy	9	4		36	4		36	2		18
Cost	9	4	<$75	36	1	<$200	9	4	<$75	36
Durability	3	4		12	3		9	4		12
Portability	9	4		36	3		27	3		27
Ease of Use	3	4		12	2		6	3		9
Feasability	3	5	Practical	15	3	Moderate	9	4	Practical	12
Total			147			96			114	

		4			5			6		
		Camera / Retroreflective			Infrared			Magnetic		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Accuracy	9	4		36	1		9	4		36
Cost	9	1	<$200	9	4	<$50	36	3	<$125	27
Durability	3	3		9	4		12	3		9
Portability	9	2		18	4		36	3		27
Ease of Use	3	2		6	4		12	4		12
Feasability	3	1	Difficult	3	5	Practical	15	4	Practical	12
Total			81			120			123	

Inertial Sensor Concept Selection

		1			2			3			4			5		
		Invensense (Gyro)			ST (Gyro)			Parallax (Gyro)			ST (Accel)			Kionix (Accel)		
	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Supply Voltage (V)	3	4	2.1 to 3.6	12	4	2.4 to 3.6	12	3	3.4 to 6.5	9	4	2.16 to 3.6	12	4	1.8 to 3.6	12
Current Draw (mA)	3	4	6.1	12	4	6.1	12	4	5.25	12	4	0.8	12	5	0.8	15
Size (mm^3)	9	4.5	4x4x0.9	41	4.5	4x4x1.1	41	3	19.2x17.6x12	27	4.5	4x4x1.1	41	5	3x3x0.9	45
Processing	1	4	Yes	4	1	No	1	1	No	1	1	No	1	1	No	1
Price ($)	9	4	10 to 20	36	4	10 to 20	36	3	30 to 50	27	4	5 to 15	36	4	10 to 20	36
Eval Board	3	4	Yes	12	1	No	3	1	No	3	1	No	3	4	Yes	12
Force (G)	9	0	0	0	0	0	0	0	0	0	4	2g to 8g	36	4	2g to 8g	36
Gyro Range (°/s)	9	5	250 to 2000	45	5	250/500/2000	45	2	300	18	0	0	0	0	0	0
Interface	1	3	I2C	3	4	I2C/SPI	4	3	SPI	3	4	I2C/SPI	4	4	I2C/SPI	4
Total			164.5			153.5			100			144.5			161	

Microprocessor Concept Selection

		1			2			3			4		
		Microchip PIC			TI MSP 430			Freescale			Zilog eZ80		
	Weight	Rating		Wtd	Rating		Wtd	Rating		Wtd	Rating		Wtd
Uart	2	2	Yes as attachment	4	3	Yes	6	1	No	2	1	No	2
Processor Speed	3	1	1-16MHz	3	2	4-25MHz	6	3	1-50MHz	9	2	20Mhz	6
Low Power Consumption	7	3	Yes	21	2	Yes	14	3	Yes	21	1	no	7
Sleep ability	5	3	Yes	15	3	Yes	15	3	Yes	15	1	no	5
Cost	3	2	$2-10	6	2	$2-10	6	3	$1-5	9	1	$10.00	3
Size	5	2	<1 cm	10	2	<1cm	10	2	<1cm	10	2	<1cm	10
Many I/O ports	2	2	10 to 48	4	2	10 to 80	4	3	0 to 95	6	2	8 to 44	4
Step through Debugging	9	3	Some	27	3	Yes	27	3	Yes	27	1	No	9
Development board	7	3	Yes	21	3	Yes	21	3	Yes	21	3	Yes	21
Zigbee Included	8	2	With Dev Board	16	3	Yes	24	3	Yes	24	1	No	8
Easy Programming	8	2	C-compiler	16	2	C-compiler	16			0	2	C-compiler	16
Separate Programmer	5	3	Yes	15	1	No	5	2	Yes	10	1	No	5
Total			158			154			154			96	

Power Source Concept Selection

		1			2			3			4		
		Alkaline			Lithium Metal			NiMH			Lithium Ion		
	Weight	Rating		Wtd	Rating		Wtd	Rating		Wtd	Rating		Wtd
Voltage	1	2	1.5	2	2	1.5	2	1	1.2	1	4	3.7	4
Rechargeable	2	1	No	2	1	No	2	4	Yes	8	4	Yes	8
Current draw	3	1	250mA	3	2	2A	6	4	5A	12	3	4A	9
Initial Cost	3	4	$3	12	3	$6	9	2	$50	6	1	$100	3
Operating cost (daily)	7	1	$3	7	1	$4	7	4	$0.25	28	4	$0.25	28
Ease of Use	9	1	Daily replacement of batteries	9	1	1-2 Day replacement	9	4	Plug Charger in	36	4	Plug Charger in	36
ME Simplicity	5	1	Involved	5	1	Involved	5	2	Hold drilled, size constraints	10	4	Charge hole to be drilled	20
EE Simplicity	9	4	Simple	36	4	Simple	36	2	Requires Charge Circuit	18	1	Requires Charge Circuit	9
# of batteries required	4	3	3	12	3	3	12	1	6	4	4	2	16
Self Discharge Rate	6	4	low	24	4	minimal	24	1	20% immediately, 30%/month after	6	3	5%/Month	18
Cycle Durability	7	1	1	7	1	1	7	3	500-1000	21	3	400-1200	21
Total Watt Hours	2	3	3.75*3 = 11.25	6	4	4.5*3 = 13.5	8	4	6*2.4 = 14.4	8	3	2*5.5 = 11	6
Total			125			127			158			178	

Key Milestones

- Select Concept Design
- Obtain Development Boards
- Connect Development Boards Together
- Integrate With Microcontroller on Development Board
- Test Prototype Functionality
- Design PCB layout and Build
- Build Prototype in Sample
- Build Final Design Into Cyr Wheel
- Test Phase: Compare to Engineering Spec

Risk Assessment

ID	RISK ITEM	CAUSE	EFFECT	LIKELIHOOD	SEVERITY	IMPORTANCE	ACTION TO MINIMIZE RISK	OWNER
1	Structural Failure	Simulation failed to account for worst case.	Project failure	2	3	6	Simulate with factor safety	Brian
2	Slow Shipments	Poor planning	Miss Deadlines	3	2	6	Plan Ahead	Bryce/ Brian
3	Wheel manufactured slow	Customer slow	Miss Deadlines	1	2	2	Give plenty of time to manufacture	Bryce
4	Parts out of stock	Poor supplier	Miss Deadlines	2	1	2	Check other distributors and look early	All
5	Circuit elements don't fit inside wheel	Poor Planning	Re-engineer circuitry	1	2	2	Ensure clearance in all directions when designing PCB	Bryce/ Jared
6	Team member falls behind	Poor work ethic or too much work assigned	Miss Deadlines	3	2	6	Assign specific deliverables, stress importance of peer review	Bryce
7	Batteries explode inside wheel	Poor EE design	Catastrophic Failure	1	3	3	Test charge circuit before placing in wheel.	Bryce/ Jared
8	Electronics fail to function properly	Poor EE design/not enough testing	Miss Deadlines	2	2	4	Debug and test thoroughly prior to wheel insertion	Electrical
9	No suitable wireless implemtation found	Not enough research/No technology	Project Failure	1	3	3	Thoroughly research wireless options	Matt
10	Antenna fails to transmit the required distance	Antenna poorly designed	Miss Deadlines	2	2	4	Redesign antenna	Matt
11	Inertial sensor fails to operate as expected	Under-informed team member or sensor fails	Miss Deadlines	1	2	2	Debug and test rigorously or purchase new part.	Jared
12	Turn around time exceeds expectation	Contracted company slow	Miss Deadlines	1	2	2	Plan to send out work early	Bryce/ Matt
13	Budget exceeds expectations	Poor budgeting	Run out of money	1	1	1	Work out costs beforehand, request more funds	All
14	Electronic parts break	Poor ME	Re-design ME	1	2	2	Plan for more shock than expected	Brian
15	Heat dissipation method unsuitable	Poor ME design	Product lifetime limited	1	2	2	Design method to sink heat	Brian
16	Electronics draw too much current (battery life)	Poor code design or not enough research	Wheel needs to be recharged often	2	2	4	Oversize batteries/ re-code for powersaving/ change components	Electrical