

# **Multidisciplinary Senior Design: Detailed Design Review Agenda**

Land Vehicle for Education: P11211, P11212, P11213 – System Level Design

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## **Meeting Purpose:**

1. Review QFD and FMEA
2. Review LVE Test Plan
3. Discuss Bill of Materials and Overall Budget

## **Materials To Be Reviewed:**

1. Mission Profile
2. Updated Engineering Specifications
3. Quality Function Deployment (QFD)
4. Functional Failure Modes and Effects Analysis (FMEA)
5. Test Plan
6. Bill of Materials
7. Preliminary Budget Analysis
8. Interface Control Document
9. Project Schedule

**Meeting Date:** February 11, 2011

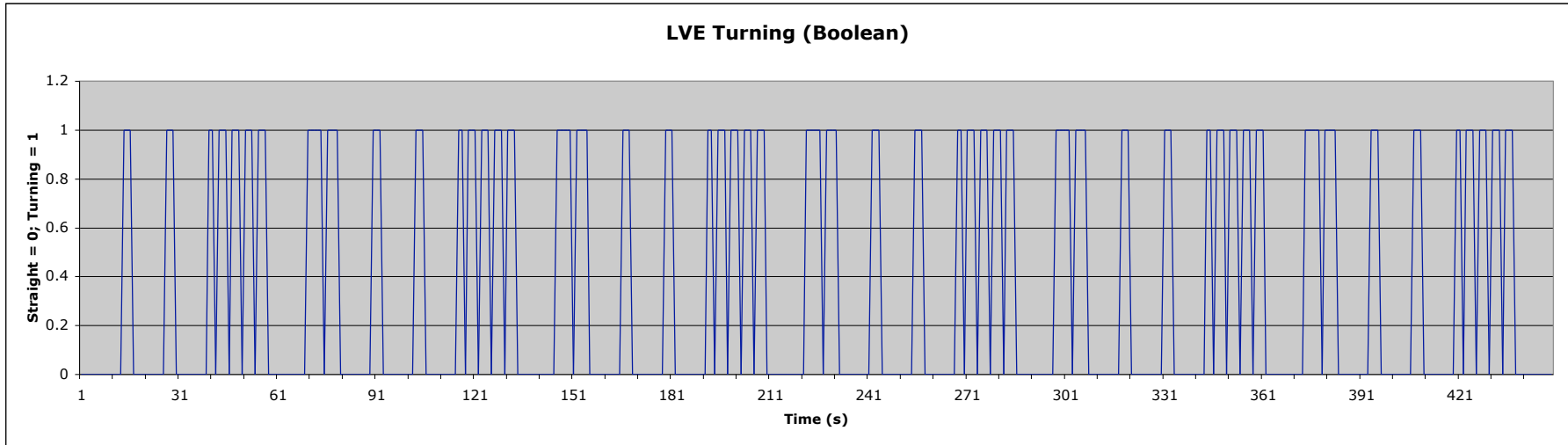
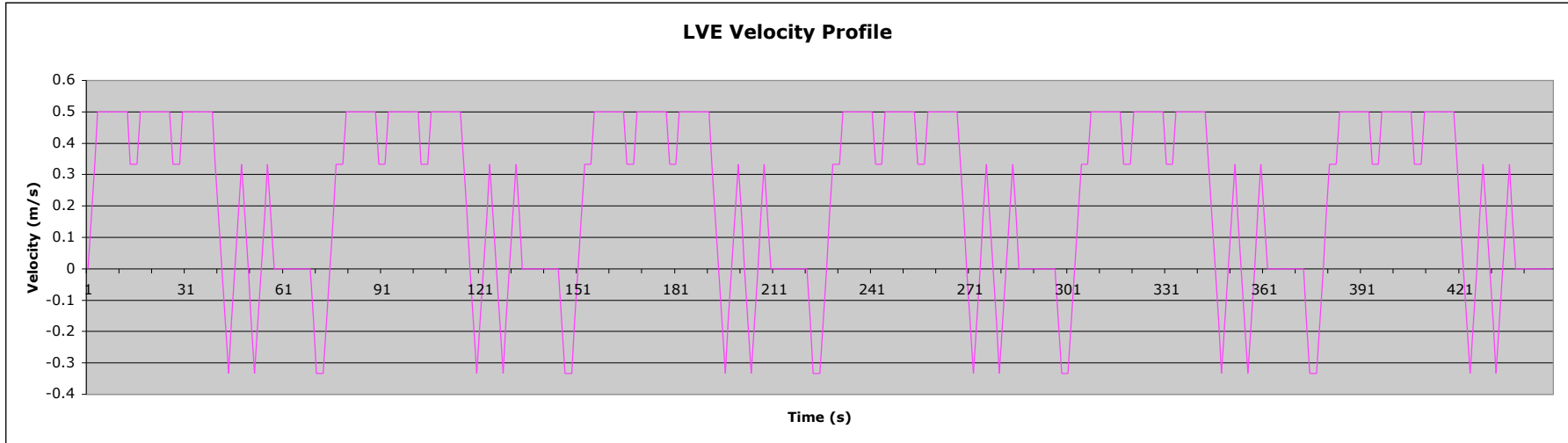
**Meeting Time:** 8:00-10:00 am

**Meeting Location:** Bldg. 78, Rm.2220

## **LVE: Mission Profile**

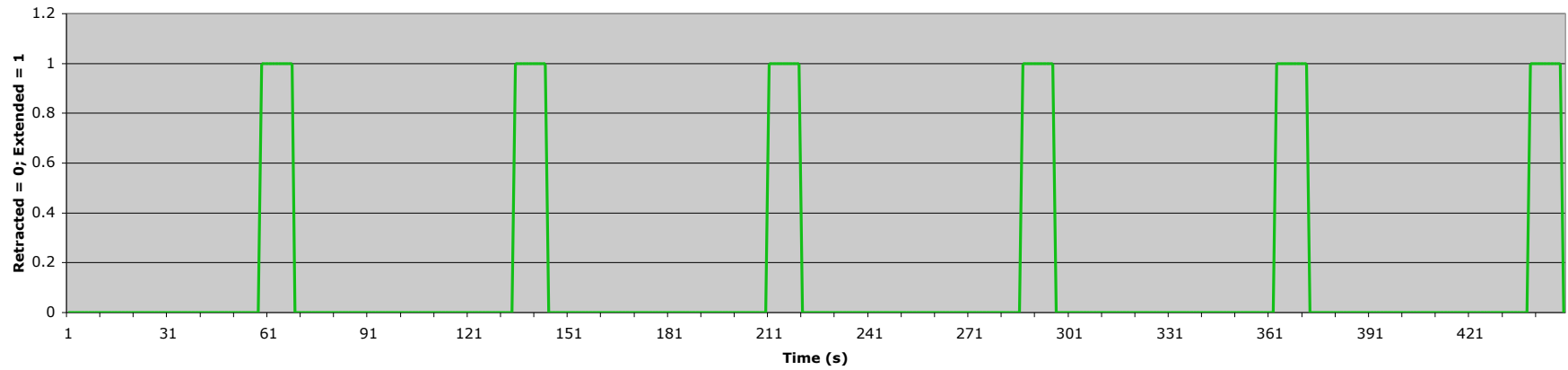
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1. LVE is removed from charging station fully charged
2. LVE travels straight for 25 ft on a carpeted floor (as is typical in Bldg. 9)
3. LVE makes 3 turn while traveling to the location of the Styrofoam blocks
4. LVE makes 2 turn while lining up the claw with the block
5. LVE grabs the Styrofoam block
6. LVE lifts the Styrofoam block
7. LVE makes 2 turns to end facing the opposite direction (90 degrees)
8. LVE travels straight for 25 ft on a carpeted floor while carrying the block
9. LVE makes 3 turns while traveling to the destination of the Styrofoam blocks
10. LVE makes 2 turns while lining the claw with the target destination
11. LVE lowers the Styrofoam block
12. LVE releases the Styrofoam block
13. LVE makes 2 turns to end up facing the opposite direction (90 degrees)
14. Steps 2-13 are repeated an additional 2 times, until 3 blocks have been moved
15. LVE is turned off and placed back in charging station

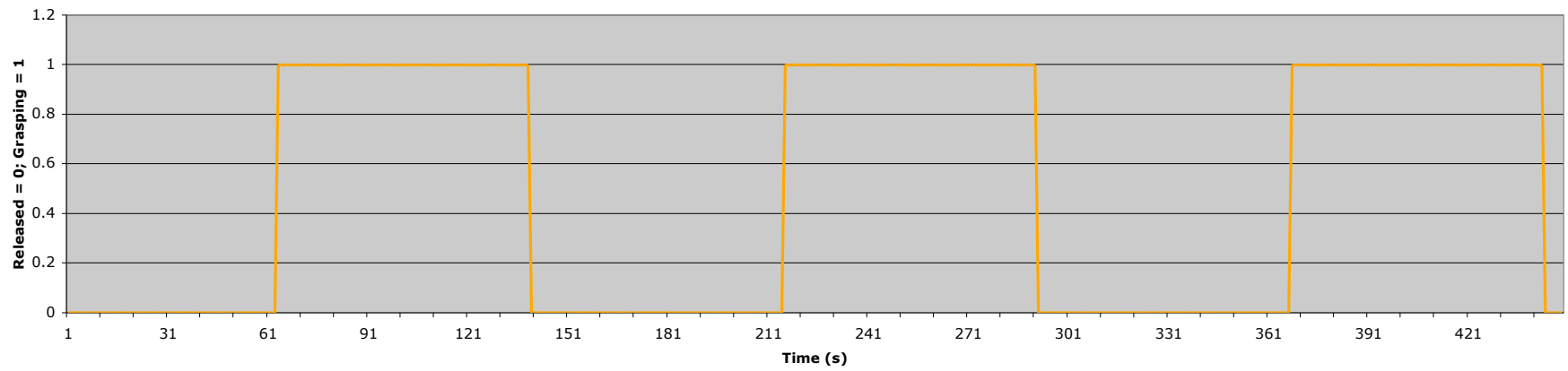


\* Ignore ramp up/down on boolean charts. Assume on/off only.

### Arm Extension (Boolean)



### Claw Grasp (Boolean)



\* Ignore ramp up/down on boolean charts. Assume on/off only.

# Engineering Specifications

SS #	System Specification	Metric	Value	Test
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## General 1.0

1.1	# of LVEs	Count	25-30	Analyze
1.2	Cost Per Mass Production LVE	\$	500	Analyze
1.3	Cost for initial prototype	\$	500	Analyze
1.4	Educational	Percentage of 5's	75%	Test
1.5	Required machinable parts	Count	>3	Demonstrate
1.6	Hand Tools Required by students	Count	<5	Demonstrate

## Chassis 2.0

2.1	Weight of Chassis	lbs	<5	Observe
2.2	Weight of Payload and MSA	lbs	<3	Observe
2.3	Speed of Fully Loaded LVE	mph	>2	Demonstrate
2.4	Turning Radius	in	<12	Demonstrate
2.5	Height Chassis	in	<8	Observe
2.6	Base Area of Chassis	in <sup>2</sup>	<144	Observe
2.7	Ability to travel up incline	Degrees	15	Demonstrate
2.8	Drop Height	ft	3	Analyze

## Power/Control 3.0

3.1	Battery Life At Full Load	Hours	>2	Demonstrate
3.2	Recharge Time for Full Battery	Hours	<4	Demonstrate

## Safety 4.0

4.1	Surface Temperature	Degrees F	<70	Observe
4.2	Number of Sharp Edges	Count	0	Demonstrate

## Production 5.0

5.1	Minimize Material Waste	lbs	<1	Observe
5.2	Lead time for OTS parts	Weeks	2	Observe
5.3	Time to construct LVE	Weeks	1	Demonstrate
5.4	Machined Parts Per LVE	Count	<20	Observe
5.5	Custom Order Components	Count	0	Observe

## Boolean 5.0

6.1	Incorporates EDG Concepts	Boolean	Y	Observe
6.2	Incorporates Materials Processing Concepts	Boolean	Y	Observe
6.3	Incorporates a design aspect	Boolean	Y	Observe
6.4	Enclosed Wiring	Boolean	Y	Observe
6.5	Complies with Regulations	Boolean	Y	Observe/Analyze
6.6	Uses standardized hardware	Boolean	Y	Observe



## Functional FMEA

Function or Requirement	Potential Failure Modes	Potential Causes of Failure	Occurrence	End Effect on Product, User, Other Systems	Severity	Detection Method/ Current Controls	Detection	RPN	Actions Recommended to Reduce RPN	Action Item #
Transports Vehicle	Does not move	Motors do not produce enough power	1	LVE will not be able to complete the assigned task and will fail to provide educational value to the students	3	ICD	2	6	Power Calculation / ICD meetings	1
		Does not read signal from controls	1		3	ICD	1	3	Open communication between chassis and controls teams / ICD meetings	2
		Not enough traction from wheels	2		2	Chassis Team	1	4	Traction Calculation	3
		Vehicle overheats	3		3	Chassis Team	1	9	Account for chassis cooling	4
		Improper voltage output from controls	2		3	ICD/Controls	2	12	Voltage Calculation / ICD meetings	5
		Improperly programmed	3		1	Controls Team	2	6	Test the program periodically	6
		Wires do not connect	1		2	ICD	2	4	ICD meetings	7
		WOCCS doesn't function as intended	3		3	None	1	9	Communicate with WOCCS team	8
	Moves too fast	Too much power going to the motors	2	LVE will not be able to complete the assigned task and will fail to provide educational value to the students	2	ICD/Controls	1	4	Power Calculation / ICD meetings	9
	Moves too slow	Not enough power going to the motors	2		2	ICD/Controls	1	4	Power Calculation / ICD meetings	10
	Does not move in intended direction	Motor speeds are not calibrated	3		3	Controls/Chassis	1	9	Incorporate user control	11
		Motos are not aligned	1		3	Chassis Team	1	3	Placement measurements	12
		Signals are crossed	2		1	Controls Team	1	2	Detailed electrical drawings	13
		Wheels will not skid on floor surface	2		2	Chassis Team	1	4	Traction Calculation / Account for use in field house	14
Supports MSA	Cannot support MSA load	Structure is too weak	2	LVE will not be able to complete the assigned task and will fail to provide educational value to the students	3	ICD	1	6	Load Calculation / ICD meetings	15
		Structure is unbalanced	2		2	ICD/Chassis	1	4	Account for location and weight of load from MSA / ICD meetings	16
		Connectors do not match	1		1	ICD	1	1	ICD Meetings	17
	Does not provide power to the MSA	Battery is undersized	1		3	ICD	2	6	Battery Calculation / ICD meetings	18
		Connectors do not match	1		1	ICD	1	1	ICD Meetings	19

Educates Students	Does not educate students	Does not incorporate design aspect	1	Students will not benefit from this exercise	3	MSA Team	1	3	Provide components to be drawn by students using CAD	20
		Does not require hands on machining	1		3	MSA Team	1	3	Provide components to be machined by students	21
		Tasks are too simple	2		2	MSA Team	3	12	Account for multiple students working on each LVE over the course of several weeks	22
Carries Object	Cannot grasp object	Not enough grip strength in claw	2	MSA will not be able to complete the task	2	MSA Team	1	4	Account for the maximum possible load	23
		Claw is too small	1		2	MSA Team	1	2	Define object to be carried and design to maximum tolerances	24
	Cannot support object	Motors cannot power supporting the arm	2		2	ICD/MSA Team	2	8	Load Calculations / account for weight of arm as well as payload	25
		Not enough power going to the motors	2		2	MSA Team	1	4	Power Calculation / ICD meetings	26
		Mechanical structure of arm is too weak	2		2	MSA Team	1	4	Load Calculations / account for the maximum possible load	27



## Preliminary Detailed Testing Plan

SS #	System Specification	Verification Strategy (TOAD)	Pass/Fail Criteria	Data
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### General 1.0

1.1	# of LVEs	Analyze	20 mass produced LVEs	
1.2	Cost of Mass Produced LVEs	Analyze	\$5,000 deployment cost	
1.3	Cost for initial prototype	Analyze	Costs at most \$500 to produce	
1.4	Educational	Test	75% approval from student survey	
1.5	Student machined parts	Demonstrate	At least 3 parts to be machined by students	
1.6	Hand Tools Required by students	Demonstrate	At most 5 hand tools required for construction	

### Chassis 2.0

2.1	Weight of Chassis	Observe	Weighs at most 5lbs	
2.2	Weight of Payload and MSA	Observe	Weighs at most 3 lbs	
2.3	Speed of Fully Loaded LVE	Demonstrate		
2.4	Turning Radius	Demonstrate	Less than 12 inches	
2.5	Height Chassis	Observe	Less than 8 inches	
2.6	Base Area of Chassis	Observe	Less than 144 square inches	
2.7	Ability to travel up incline	Demonstrate	Can travel up a 15 degree incline	
2.8	Drop Height	Analyze	Can be dropped from a maximum of 3 feet and still function as intended	

### Power 3.0

3.1	Battery Life At Full Load	Demonstrate	Battery can power fully loaded LVE for a minimum of 90 minutes	
3.2	Recharge Time for Full Battery	Demonstrate	Battery can be fully recharged in less than 4 hours	

### Safety 4.0

4.1	Surface Temperature	Observe	Surface temperature never exceeds 130 degrees F	
4.2	Sharpness of Edges	Demonstrate	No edges tear through more than 3 sheets of tissue paper	

### Production 5.0

5.1	Minimize Material Waste	Observe	All material scraps weigh less than 1 lb	
5.2	Lead time for OTS parts	Observe	All parts can be acquired within 2 weeks	
5.3	Time to construct LVE	Demonstrate	Mass produced LVEs can be constructed in less than 40 man hours	
5.4	Machined Parts Per LVE	Observe	Each LVE contains no more than 20 custom machined parts	
5.5	Custom Order Components	Observe	The LVE contains no custom ordered parts	

### Boolean 5.0

6.1	Incorporates EDG Concepts	Observe	Each LVE requires parts to be drawn using a CAD program	
6.2	Incorporates Materials Processing Concepts	Observe	Each LVE requires parts to be machined	
6.3	Incorporates a design aspect	Observe	Each LVE requires parts to be designed by students	
6.4	Enclosed Wiring	Observe	There is no exposed wiring in the chassis	
6.5	Complies with Regulations	Observe/Analyze	LVE must comply with all RIT regulations	
6.6	Uses standardized hardware	Observe	No specialized tools are required for student assembly	

## Preliminary LVE Budget Estimate

### Chassis

Item	Description	Supplier	Part Number	Quantity	Cost @ 1	Total Cost @ 1	Cost @ 5	Total Cost @ 5	Cost @ 10	Total Cost @ 10	Unit	LVE/MSA
Aluminum Panel (1/4"x12"x8")	Bottom Panel	McMaster-Carr	8975K445	1	\$14.70	\$14.70		\$73.50		\$147.00	each	LVE
1/4"-20 x1/2" Button Head Cap Screw	Attach Sides, Base & Moter Mounts	McMaster-Carr	92949A537	1	\$5.70	\$5.70		\$5.70		\$5.70	50 pack	LVE
154 to 1 Ratio Gear Motor	Drive Motor	Pololu	1109	2	\$19.95	\$39.90	\$16.95	\$169.50	\$14.95	\$299.00	each	LVE
MICRO 22'S ON ROAD Dagu Wild Thumper Wheel 120x60mm and 4mm Shaft Adapter - Metallic Red	Wheels/Tires/Hubs	Pololu	1558	2	\$11.95	\$23.90	\$10.76	\$107.60	\$10.76	\$215.20	each	LVE
Motor mount		Pololu	1138	1	\$6.95	\$6.95	\$6.95	\$20.85	\$5.95	\$29.75	2 pack	LVE
7.2V 5000 mAh	Battery	All-Battery	11228	1	\$39.99	\$39.99		\$199.95		\$399.90	each	LVE
Battery charger		All-Battery	1005	1	\$22.95	\$22.95		\$114.75		\$229.50	each	LVE
Wire and Connectors, est.	Wire+Connectors			1	\$30.00	\$30.00		\$150.00		\$300.00		LVE
Casters	Caster Wheels	Home Depot	9392	2	\$2.98	\$5.96	\$2.98	\$29.80	\$2.98	\$59.60	each	LVE
Steel Square Rod (1/2"x1/2"x12")	Uprights	McMaster-Carr	9143K171	3	\$3.48	\$10.44		\$52.20		\$104.40	each	LVE
Plastic Panels, Fiberglass (1/8"x12"x36")	Side panels	McMaster-Carr	3345K51	1	\$14.18	\$14.18		\$70.90		\$141.80	each	LVE
Aluminum Spacers (2"x1/4"x0.115")	Spacers for lifting PC boards	McMaster-Carr	92510A098	6	\$1.49	\$8.94	\$1.49	\$44.70	\$1.49	\$89.40	each	LVE
1/4"-20 x5" Socket Head Cap Screw	To hold lifted PC boards in place	McMaster-Carr	90128A572	1	\$7.20	\$7.20		\$7.20		\$14.40	5 pack	LVE
Steel Bar 1/2"x1"x12"	attachement	McMaster-Carr	8910K699	1	\$8.72	\$8.72		\$43.60		\$87.20	each	LVE
SMA to SMA RF Cable	Cable to attach Antenna to RF Board	Digikey	931-1103-ND	1	\$3.04	\$3.04	\$3.04	\$15.20	\$3.04	\$30.40	each	LVE
Serial Line Connectors		Digikey	A34956-ND	2	\$0.83	\$1.66		\$8.30		\$16.60		LVE
18 AWG Power Black/Red Zip Cable	Power Cabling	Parts-Express	100-050	10	\$0.31	\$3.10		\$15.50		\$31.00	per foot	LVE
Fuse Holder	Power	Digikey	F1500-ND	2	\$1.15	\$2.30	\$1.06	\$10.59	\$1.06	\$21.18	each	LVE
Fuse Holder	Fuse Holder for Motors	Digikey	F3130-ND	1	\$2.24	\$2.24	\$2.24	\$11.20	\$2.06	\$20.64		LVE
4A Fuses for MSA	Fuses for MSA (5 Items Min)	Digikey	F2511-ND	5	\$0.35	\$1.74	\$0.35	\$8.85	\$0.35	\$17.40	each	LVE
12A Fuse for Main Power		Digikey	283-2608-ND	1	\$0.93	\$0.93	\$0.93	\$4.65	\$0.86	\$8.58	each	LVE
Female Tamiya Connector	Batteries to Chassis 18 AWG Wire	All-Battery	80000-4	2	\$1.69	\$3.38		\$16.90		\$33.80	each	LVE
Male Tamiya Connector	Charger to Chassis 18 AWG Wire	All-Battery	80001-4	1	\$1.69	\$1.69		\$8.45		\$16.90	each	LVE
Terminal Block	Battery/charger/chassis	Digikey	A98503-ND	1	\$0.59	\$0.59		\$2.95		\$5.90	each	LVE
3 Position Switch	Power Switch for MSA	Digikey	EG4813-ND	1	\$2.71	\$2.71		\$13.55		\$27.10	each	LVE
<b>Total</b>						\$262.91		\$1,206.39		\$2,352.35		

### Controls

Item	Description	Supplier	Part Number	Quantity	Cost @ 1	Total Cost @ 1	Cost @ 5	Total Cost @ 5	Cost @ 10	Total Cost @ 10	Unit	LVE/MSA
Motor Controller	2 H bridges			1	\$50.00	\$50.00		\$250.00		\$500.00		LVE
Arduino Nano	and extra pins			1	\$50.00	\$50.00		\$250.00		\$500.00		LVE
<b>Total</b>						\$100.00		\$500.00		\$1,000.00		

### MSA (Controls)

Item	Description	Supplier	Part Number	Quantity	Cost @ 1	Total Cost @ 1	Cost @ 5	Total Cost @ 5	Cost @ 10	Total Cost @ 10	Unit	LVE/MSA
Arduino Pro Mini 328 - 5V/16MHz	uC Daughtercard	Sparkfun	DEV-09218	1	\$18.95	\$18.95		\$94.75	\$17.06	\$170.60		LVE
MSA Main Board	MSA Control Board	BatchPCB	52056	1	\$15.00	\$15.00		\$75.00	\$15.00	\$150.00		LVE
MSA Chassis IO Board	MSA Chassis IO Board	BatchPCB	50564	1	\$5.00	\$5.00		\$25.00	\$5.00	\$50.00		LVE
Shroud for Chassis IO Board	Shroud for IO	Ponoko	N/A	1	\$1.25	\$1.25		\$6.25	\$1.25	\$12.50		LVE
Break Away Headers - Straight	Headers for Main Board and IO	Mouser	69190-110HLF	5	\$0.35	\$1.75		\$8.75	\$0.35	\$17.50		LVE
STRAIGHT 10U AU	Header for IO Bus	Mouser	D2520-6002-AR	2	\$1.23	\$2.46		\$12.30	\$1.23	\$24.60		LVE
Cables (Cable Assemblies) 20P 6 SKT - SKT 28AWG STRANDED PVC	Connection Between Main Board And Chassis	Mouser	1M-1010-020-3365-006.0-00-AB-00-0	1	\$3.84	\$3.84		\$19.20	\$3.15	\$31.50		LVE
Screw Terminals 3.5mm Pitch (2-Pin)	Terminal for Batt Wires	Mouser	1776275-2	1	\$0.28	\$0.28		\$1.40	\$0.28	\$2.80		LVE
PTC Resettable Fuses 60volt 40amp Hold .05 Trip .1	PTC Fuse for uC	Mouser	MF-R005-0	1	\$0.30	\$0.30		\$1.50	\$0.30	\$3.00		LVE
PTC Resettable Fuses Radial Lead 1.9A 33V 40A Imax	PTC Fuse for Servos	Mouser	RTEF190-2	1	\$0.53	\$0.53		\$2.65	\$0.48	\$4.80		LVE
Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 16volts 0.10uF X7R 20%	Decoupling Caps	Mouser	C1608X7R1C104M	2	\$0.03	\$0.06		\$0.30	\$0.03	\$0.60		LVE
SWIFT DC/DC Cnvrtr	Switch Power Supply	Mouser	TPS54331D	1	\$4.65	\$4.65		\$23.25	\$4.65	\$46.50		LVE
<b>Total</b>						\$54.07		\$270.35		\$514.40		

MSA

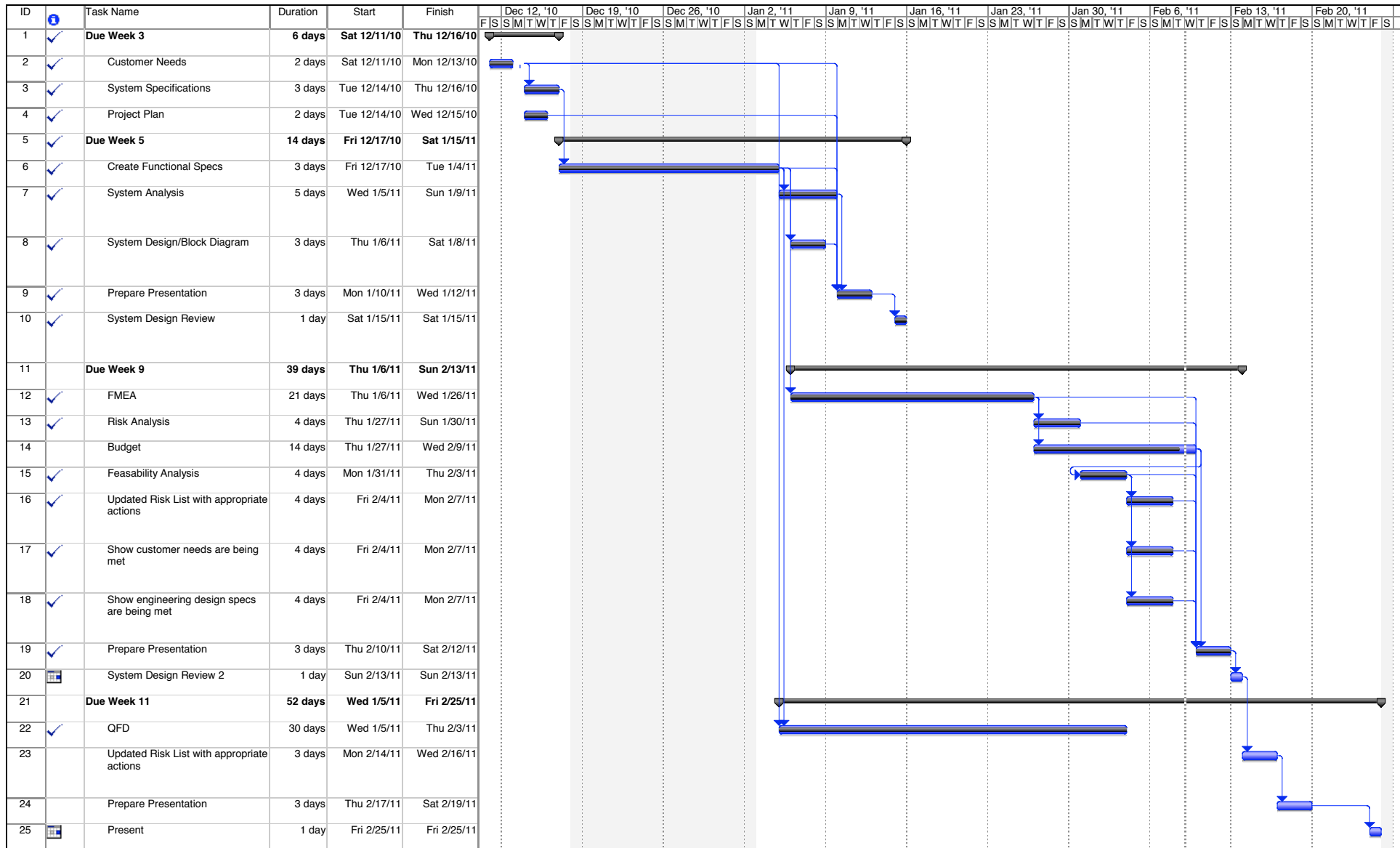
Plate	Acrylic Sheet	<a href="http://www1.msdir ect.com">http://www1.msdir ect.com</a>	P/N 63391692		\$9.83	\$9.83					each	MSA
Mounting Standoffs	Unthreaded Plastic Standoff	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 92825A135		\$8.88	\$8.88					100	MSA
Mounting Bolts	Socket Cap Screw, Hex Head	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 91253A548		\$7.70	\$7.70					25	MSA
Material	Aluminum Stock	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 8975K741		\$10.18	\$10.18					each	MSA
Material	Aluminum Stock	<a href="http://www1.msdir ect.com">http://www1.msdir ect.com</a>	P/N 32000788		\$13.14	\$13.14					each	MSA
Mounting Bolts	Socket Cap Screw, Hex Head	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 91251A113		\$9.55	\$9.55					100	MSA
Mounting Nuts						\$0.00						MSA
Material	6061 Aluminum, Rectangular Bar	<a href="http://www1.msdir ect.com">http://www1.msdir ect.com</a>	P/N 32012254		\$17.23	\$17.23					each	MSA
Material	6061 Aluminum, Rectangular Bar	<a href="http://www1.msdir ect.com">http://www1.msdir ect.com</a>	P/N 05207360		\$13.07	\$13.07					each	MSA
Material	6061 Aluminum, Rectangular Bar	<a href="http://www1.msdir ect.com">http://www1.msdir ect.com</a>	P/N 32000739		\$5.97	\$5.97					each	MSA
Bearings	Double Shielded Ball Bearing	<a href="http://www.walmart .com">http://www.walmart .com</a>	P/N AW06015, Walmart 000934757		\$10.86	\$10.86					8	MSA
Mounting Bolt	Socket Cap Screw, Hex Head	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 91251A552		\$6.57	\$6.57					25	MSA
Nuts	Standard Plain Hex Nut	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 95505A601		\$2.15	\$2.15					100	MSA
Mounting Standoffs	Unthreaded Plastic Standoff	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 92825A135		\$8.88	\$8.88					100	MSA
Clevis Pins	Adjustable Length Clevis Pin	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>	P/N 98330A145		\$4.11	\$4.11					10	MSA
Cotter Pin	Hairpin Cotter Pin	<a href="http://www.mcmast er.com">http://www.mcmast er.com</a>			\$10.00	\$10.00					100	MSA
Complete Arm Assembly	Assembly with servo mount				\$30.00	\$30.00					each	MSA

**Total** \$168.12 \$0.00 \$0.00

Final

**Total** **Total Cost @ 1** **Total Cost @ 5** **Total Cost @ 10**  
 \$585.10





Project: MSDGnatt Date: Wed 2/9/11	Task		Progress		Summary		External Tasks		Deadline	
	Split		Milestone		Project Summary		External Milestone			