

# LVE Mass Production Cost Reduction Measures

## P11211, P11212, P11213

### Chassis

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#### Weight Reduction

The base plate and all uprights were replaced with the 12"x8"x4" steel box. The total number of screws was also reduced. This decreased the weight of the LVE from 8.1 lbs to 4.8 lbs. The LVE has the same overall dimensions allowing internal components to be mounted in the same position. The LVE has more internal room now that it is rectangular box, allowing internal components to be spaced out if desired. This change in shape may result in a less aesthetically pleasing design.

#### Motors

The reduction in weight allowed us to reduce the size of the motors and use motors with a plastic gearbox. Changing these components resulted in a cost reduction of \$448.75. The per unit price is down to \$125.46 for mass production for a total of \$1,254.60 for ten LVEs. This compares to the original value of \$170.33 and \$1703.35 for ten LVEs.

#### Additional Considerations

Some additional considerations of this design are that the MSA mounting will need to change. The MSA platform will need to be screwed into the top of the box, and nuts will need to be tack welded to the underside of the top of the box. This design will reduce machining time and assembly time. The overall structural integrity of the box will be sufficient. The following spreadsheet itemizes all of the changes. Also included are the torque calculations for the new motors.

### Controls

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#### RF Solution

The RF solution used was changed from the WOCCS system to a off the shelf solution found on spark fun. The savings is 64\$ per LVE and there is no functionality lost. The spark fun solution will also operate over uART.

#### UBS Cables

A number of USB cables and adapters were removed from the design as well due to the difficulty associated with using the USB connectors on the Ardiuno Nano and RF solutions. This presented a savings of 3.7\$ per LVE. Controls is not deleting the USB capability. Both the WOCCS and the Sparkfun solution both have USB ports and the Development board that we choose to continue with also has USB capability. What we are doing is removing it from the current design iteration due to the fact that in order to properly utilize the USB ports as a form of communication a

lot of work is required. Jared and Dan referred to this as a project in and of itself. The details behind the USB issue I believe has to do with both devices acting as slaves and neither one being designed to act as the master.

### **PCB Combination**

There is an increased cost in PCB due to a combination of the two PCB boards between the MSA and Controls team. The savings from this is shown in a reduction in MSA costs of 15\$ of PCB making the delta a savings of 10\$ per LVE. There are additional savings due to this change in the PCB redesign that are reflected in the MSA budget.

## **MSA**

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### **Gripper**

The gripper is the most expensive mechanical component in the MSA, in part because it is a purchased full assembly in the system. A significant cost reduction would include 3D printing all the gripper components. The model purchased is a good baseline for creating a functional gripper model that operates very simple. Some reductions in weight and reach could be made to further save weight and cost to the system. The cost then is only a small servo, which will save the MSA 18.17 per MSA and 181.71 off the total budget. This should not change the function of the gripper and should maintain the capabilities of the MSA.

By replacing the current gripper (robodyssey.com P/N GKWS) with a custom machined house in part could create a significant cost savings. The new design would include the purchase of an equivalent small servo to that in the current gripper assembly (sparkfun.com P/N ROB-09065) which has a 1.4 kg/cm output torque. Output torque from the gripper servo should well exceed the force required to grip the foam or wooden blocks used in demos by the previous gripper (about 0.6 lb force). Therefore the servo should have no significant reduction in performance.

At the onset of this project, information regarding the capabilities of the 3D printing in the Brinkman lab were generally unknown. After have a relatively simple and low importance part modeled using the prototype printer (I/O shroud) the structural stability of the plastic was very strong by inspection, certainly more than necessary for its application. This process can be used in the creation of a new prototype design if properly modeled and designed. Since it's outside our scope to redesign the parts currently, we won't perform such analysis. To design a gripper that can handle an input torque of 1.4 kg\*cm or a gripper force of 0.6 lb, but a design robust enough to withstand these forces should be simple to design. The material obtained for the shroud has shown outstanding resistance to the lower temperatures at the I/O board interface, and should have no issue handling the temperature seen at the small servo. Should the project be actually designed (assumed outside the scope of this document), thermal analysis could be performed to show whether further cooling need be provided, or a design with better exposure to ambient temperatures is required. The plastic from the gripper purchased or from the Brinkman lab prototype appear to have similar strengths, but would require testing to determine true robustness in design. However, the prototype should be plenty strong enough to hold the required force under normal operation. Either gripper material would likely break if dropped on the gripper with the weight of the MSA above it.

Gripper parts may be made in the Brinkman lab at a cost of XXXX. (Awaiting new response from John Bonzo in Brinkman Lab) Note that the I/O shroud was never charged to me personally, and as far as I know, Brinkman Lab did not bill anyone in the Mechanical Engineering department for the shroud.

### **Mounting**

The mounting can have a reduction with a trade off in simplicity and robustness of the design. By changing the mounting from a cotter pin design to a screw on design, some parts can be removed. The loss is that the threading on the LVE is more likely to be cross threaded and ruin some attachment points. The savings will be about 4.00 per MSA.

### **Size**

Another savings that can be made is reducing the size and capabilities of the MSA. With a reduction of drive servo and link material we can remove 9.20 per MSA from the budget or 92.00 from the mass production budget. The tradeoff of this is a small range and sizing of the links would have to reduce. It would cut the size and spacing between pins about it half, which would be less impressive, but have a similar educational value.

### **Servo:**

A reduction in servo size or power is certainly highly unadvised, as it would severely limit the scope and size potential of the MSA. Clearly, the output torque of the drive motor of the MSA is directly linked to the range and capability of the MSA. However, putting a clear limitation on the range of solutions for any particular motor is extremely difficult given the 5 link geometries that are incorporated in the analysis. The range under which the system works should only be determined by the torque calculator provided. Savings could likely be made by reducing link thickness or width, gripper weight, and bolt or mounting weight, each of which are inputs to the calculator.

The current servo (sparkfun.com P/N ROB-09064) provides 6.5 kg\*cm output torque at stall. The small servo available from the same site (sparkfun.com P/N ROB-09065) provides just 1.4 kg\*cm of output torque. Note that this would require a reduction in all link dimension, component weights, and operating ranges. Without performing a redesign, as deemed outside the scope of this analysis, the entire change can likely be incorporated with decreasing the size of the MSA by about 50% of all dimensions, including the reach of the MSA (note: moment arms for some weights are compounded by other dimensions, and weight reductions are dependence on the redesign). This would not be highly recommended as it doesn't seem to relay a significant cost reduction.

The current reach of the MSA would be a window from 6" to 12" off the ground. The new window would be anticipated as being about 6" to 9" off the ground, barring actual figures of a redesign.

## Savings Summary

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	<b>Original Budget</b>	<b>Revised Budget</b>	<b>Savings</b>
<b>Chassis</b>	\$1,571.22	\$1,332.17	\$239.05
<b>Controls</b>	\$1,720.23	\$1,610.30	\$109.93
<b>MSA</b>	\$2,489.70	\$1,382.66	\$1,107.04
<b>Shipping</b>	\$289.06	\$216.26	\$72.80

**Original LVE Mass Production Cost**

Item	Part Description	Supplier	Part Number	Quantity	Price Per Order	Units Per Order	# of MSA/LVE	Total Price
Chassis	154 to 1 Ratio Gear Motor	Pololu	1109	2	\$19.95	1	10	\$339.00
Chassis	7.2V 3000 mAh	All-Battery	11204-01	1	\$15.99	1	10	\$159.90
Chassis	Smooth Finish Polyethylene White (1/8"x12"x36")	McMaster-Carr	8752K311	1	\$12.85	1	10	\$128.50
Chassis	Connectors to Terminal Block	Digikey	A27449-ND	20	\$0.55	1	10	\$97.36
Chassis	RP-SMA to RP-SMA RF Cable	Digikey	CSA-RPSM-216-RSFB-ND	1	\$9.16	1	10	\$91.60
Chassis	Pololu Wheel 90x10mm Pair - Black	Pololu	1435	1	\$9.95	1	10	\$89.60
Chassis	Battery charger	All-Battery	1009	1	\$7.99	1	10	\$79.90
Chassis	Aluminum Panel (1/4"x12"x6")	McMaster-Carr	9246K45	1	\$72.95	1	1	\$72.95
Chassis	Casters	Home Depot	9392	2	\$5.96	1	10	\$59.60
Chassis	Motor mount	Pololu	1138	2	\$6.95	2	10	\$59.50
Chassis	1/4"-20 x1/2" Button Head Cap Screw	McMaster-Carr	92949A537	55	\$5.70	50	9	\$51.30
Chassis	Aluminum Spacers (2"x1/4"x0.115")	McMaster-Carr	92510A098	12	\$0.37	1	10	\$44.40
Chassis	Steel Bar 1/2"x1"x6"	McMaster-Carr	8910K212	1	\$34.89	1	1	\$34.89
Chassis	Female Tamiya Connector	All-Battery	80000-4	2	\$1.69	1	10	\$32.80
Chassis	Aluminum Project Enclosure	Radio Shack	270-238	1	\$2.99	1	10	\$29.90
Chassis	3 Position Switch	Digikey	EG4813-ND	1	\$3.32	1	10	\$27.50
Chassis	Steel Threaded Rod 4-40, 2ft	MSC	4352167	1	\$1.82	1	10	\$18.20
Chassis	Male Tamiya Connector	All-Battery	80001-4	1	\$1.69	1	10	\$16.40
Chassis	Velcro®strip	Home Depot	N/A	1	\$2.97	1	10	\$16.05
Chassis	25' - 18 AWG Power Black/Red Zip Cable	Radio Shack	278-567	1	\$7.99	1	2	\$15.98
Chassis	Terminal Block	Digikey	A98503-ND	3	\$0.59	1	10	\$15.97
Chassis	Aluminum Panel (1/4"x12"x8")	McMaster-Carr	8975K445	1	\$14.70	1	1	\$14.70
Chassis	Steel Square Rod (1/2"x1/2"x36")	McMaster-Carr	9143K176	3	\$13.91	1	1	\$13.91
Chassis	Fuse Holder	Mouser	576-03540601ZXGY	2	\$0.71	1	10	\$13.20
Chassis	Smooth Finish Polyethylene White (1/8"x12"x36")	McMaster-Carr	8752K311	1	\$12.85	1	1	\$12.85
Chassis	Steel Bar 1/2"x1"x12"	McMaster-Carr	8910K699	1	\$8.72	1	1	\$8.72
Chassis	Flat Socket Head Cap Screw 4-40 10 Pack	McMaster-Carr	90585A204	2	\$3.85	1	10	\$7.70
Chassis	Inserts for RF Power Connector	Digikey	WM3116CT-ND	2	\$0.35	1	10	\$4.10
Chassis	Power Connector to RF Board	Digikey	WM3700-ND	1	\$0.63	1	10	\$3.83
Chassis	12A Fuse for Main Power	Mouser	576-0311012.H	1	\$0.32	1	10	\$3.00
Chassis	Socket Cap Screws	McMaster-Carr	92949A239	1	\$2.33	1	1	\$2.33
Chassis	500mA Fuse for RF	Mouser	576-0312.500MXP	1	\$0.21	1	10	\$2.00
Chassis	Connectors to switch	Digikey	A100888CT-ND	3	\$0.07	1	10	\$1.96
Chassis	Nuts Zinc-Plated Steel 4-40 1/4" 3/32" 100	McMaster-Carr	90480A005	1	\$0.81	5	1	\$1.62
Control	PCB to motors	Digikey	ED2611-ND	1	\$0.41	1	10	\$3.73
Control	Resistors 47kohm	Mouser	CR0603-JW-473GLF	2	\$0.02	1	10	\$0.40
Control	Resistors 100kohm	Mouser	CR0603-JW-104GLF	4	\$0.02	1	10	\$0.80
Control	Capacitors 0.1uf	Mouser	C1608X7R1H104M	7	\$0.05	1	10	\$2.80
Control	Capacitors 0.01uf	Mouser	C1608X7R1H103M	3	\$0.03	1	10	\$0.90
Control	Fuses for Motor Output	Mouser	RUEF250S	2	\$0.42	1	10	\$7.00
Control	Arduino Nano dev Board	Robot Shop	RB-Gra-01	1	\$34.99	1	10	\$314.90
Control	Motor Controller	Sparkfun	COM-09479	2	\$2.95	1	10	\$53.20
Control	Female Header Row	Sparkfun	PRT-00115	2	\$1.50	1	10	\$27.00
Control	Male Header Row	Sparkfun	PRT-00116	1	\$2.50	1	10	\$22.50
Control	Wire	Sparkfun	PRT-10367	1	\$1.50	1	10	\$13.50
Control	Battery to PCB	Sparkfun	PRT-08235	1	\$1.56	1	10	\$13.50
Control	WOCCS	WOCCS Prototype		1	\$63.00	1	20	\$1,260.00
MSA	MSA Main Board	BatchPCB	52056	1	\$15.00	1	10	\$150.00
MSA	MSA Chassis IO Board	BatchPCB	50564	1	\$5.00	1	10	\$50.00
MSA	90 deg Solid Angle 1.5" x 1.5" Aluminum (Servo Bracket, Pinned Mount, Servo Support, Effector Mount)	Home Depot	6957831 (MSC Smaller Part)	1	\$10.88	1	10	\$108.80
MSA	Press Fit Dowel Pin (Dowel Pin)	McMaster-Carr	98381A542	4	\$9.85	50	10	\$9.85
MSA-C	Hairpin Cotter Pin (Cotter Pin)	McMaster-Carr	98335A062	4	\$9.90	100	10	\$9.90
MSA	Washer Spacers (Washer Spacer)	McMaster-Carr	90295A456	3	\$3.92	50	10	\$3.92
MSA-C	Clevis Pins (Clevis Pin)	McMaster-Carr	98330A135	3	\$4.11	10	10	\$12.33
MSA	Plate Mounting Screws 1/4-20 x .75" Hex Head	ME Shop		10	\$0.00		10	\$0.00
MSA	Mounting Nuts 1/4-20 Plain (Plate Mount Nuts)	ME Shop		8	\$0.00		10	\$0.00
MSA	Servo Mounting Screws 4-40 x .5" Hex Head	ME Shop		8	\$0.00		10	\$0.00
MSA	Mounting Nuts 4-40 Plain (Servo Mount Nuts)	ME Shop		8	\$0.00		10	\$0.00
MSA	Board to Board / Mezzanine Connectors REC 1X12P VRT T/H	Mouser	6-535541-0	1	\$1.90	1	10	\$19.00
MSA	Break Away Headers - Straight	Mouser	69190-110HLF	5	\$0.35	1	10	\$17.50
MSA	Headers & Wire Housings 20P 4-WALL HEADER STRAIGHT 10U AU	Mouser	D2520-6002-AR	1	\$1.23	1	10	\$12.30
MSA	Cables (Cable Assemblies) 20P 6 SKT - SKT 28AWG STRANDED PVC	Mouser	1M-1010-020-3365-006.0-00-	1	\$3.84	1	10	\$38.40
MSA	Screw Terminals 3.5mm Pitch (2-Pin)	Sparkfun	PRT-08235	1	\$1.50	1	10	\$15.00
MSA	PTC Resettable Fuses 0.05A 30V 1210	Mouser	1210L005WR	1	\$0.23	1	10	\$2.30
MSA	PTC Resettable Fuses 24V 1.5A-HD 40A MAX	Mouser	1812L150/24MR	1	\$0.34	1	10	\$3.40
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 16volts 0.10uF X7R 20%	Mouser	C1608X7R1C104M	3	\$0.03	1	10	\$0.90
MSA	DC/DC Switching Converters 3A 28V In Step Down SWIFT DC/DC	Mouser	TPS54331D	1	\$0.00	1	10	\$0.00
MSA	Thick Film Resistors - SMD 0603 10KOHMS 5% 1/10WATT	Mouser	CR0603-JW-103ELF	1	\$0.02	1	10	\$0.20
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 150pF 50volts COG 5%	Mouser	C1608COG1H151J	1	\$0.03	1	10	\$0.30
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 50volts 220pF X7R 20%	Mouser	C1608X7R1H221M	1	\$0.03	1	10	\$0.30
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 50volts 0.015uF X7R 20%	Mouser	C1608X7R1H153M	1	\$0.04	1	10	\$0.40
MSA	Power Inductors 3.3uH 30%	Mouser	SRU1028-3R3Y	1	\$1.00	1	10	\$10.00
MSA	Schottky (Diodes & Rectifiers) SHOTTKY 25V 5A TR HIGH	Mouser	RSX501L-20TE25	1	\$0.71	1	10	\$7.10
MSA	Tantalum Capacitors - Solid SMD 68uF 10volts 10% C case	Mouser	593D686X9010C2TE3	1	\$2.11	1	10	\$21.10
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0805 X6S 16V 10uF	Mouser	GRM21BC81C106KA73L	1	\$0.58	1	10	\$5.80
MSA	Thick Film Resistors - SMD 1.87K 1% 1/10W	Mouser	CR0603-FX-1871ELF	1	\$0.05	1	30	\$1.50
MSA	Thick Film Resistors - SMD 20KOHM 1/10WATT 5%	Mouser	CR0603-JW-203GLF	1	\$0.02	1	30	\$0.60

MSA	Thick Film Resistors - SMD 348K ohm 1%	Mouser	CR0603-FX-3483ELF	1	\$0.05	1	30	\$1.50
MSA	TVS Diodes - Transient Voltage Suppressors 9V 400 Watts	Mouser	SMAJ9.0CA-7P	2	\$0.21	1	30	\$12.60
MSA	Thick Film Resistors - SMD 332OHM 1/10WATT 1%	Mouser	CR0603-FX-3320ELF	1	\$0.04	1	30	\$1.20
MSA	Standard LED - SMD Green Water Clr 40mcd 570nm	Mouser	598-8170-107F	1	\$0.10	1	30	\$3.00
MSA	Thick Film Resistors - SMD 76.8K ohm 1%	Mouser	CR0603-FX-7682ELF	1	\$0.05	1	30	\$1.50
MSA-C	6063 Aluminum .125" x .75" x 4' (Links)	MSC	89755K25	2	\$3.61	1	30	\$216.60
MSA	Acrylic Sheet (Mounting Plate)	MSC	63391486	1	\$9.83	1	30	\$294.90
MSA	Shroud for Chassis IO Board	Ponoko	N/A	1	\$1.25	1	10	\$12.50
MSA	Gripper and Servo Assembly (End Effector)	Robodyssey	GKWS	1	\$25.95	1	30	\$778.50
MSA	Arduino Pro Mini 328 - 5V/16MHz	Sparkfun	DEV-09218	1	\$18.95	1	10	\$189.50
MSA	Main Drive Servo (Drive Servo, Output Gear)	Sparkfun	ROB-09064	1	\$12.95	1	30	\$388.50
MSA	Servo Wire Extensions	Sparkfun	ROB-08738	1	\$2.95	1	30	\$88.50

<b>Chasis</b>	\$1,571.22	<b>Merchandise TOTAL</b>	\$5,781.15
<b>Controls</b>	\$1,720.23		
<b>MSA</b>	\$2,489.70	<b>Shipping</b>	\$289.06
		<b>FINAL TOTAL</b>	\$6,070.21

Revised LVE Mass Production Cost

Item	Part Description	Supplier	Part Number	Quantity	Price Per Order	Units Per Order	# of MSA/LVE	Total Price
Chassis	120 to 1 Plastic Gearmotor	Pololu	1119	2	\$5.25	1	10	\$105.00
Chassis	12"x8"x4" steel box	McMaster-Carr	75065K16	1	\$23.00	1	10	\$230.00
Chassis	Aluminum Spacers (1"x1/4"x0.115")	McMaster-Carr	92510A429	8	\$0.37	1	10	\$29.60
Chassis	1/4"-20 x1/2" Button Head Cap Screw	McMaster-Carr	92949A537	1	\$5.70	1	10	\$57.00
Chassis	Pololu Wheel 90x10mm Pair - Black	Pololu	1435	1	\$8.96	1	10	\$89.60
Chassis	Motor mount	Pololu	602	1	\$1.49	1	10	\$14.90
Chassis	7.2V 3000 mAh	All-Battery	11204-01	1	\$15.99	1	10	\$159.90
Chassis	Battery charger	All-Battery	1009	1	\$7.99	1	10	\$79.90
Chassis	Casters	Home Depot	9392	2	\$2.98	1	10	\$59.60
Chassis	Steel Threaded Rod 4-40, 2ft	MSC Direct	4352167	1	\$1.82	1	10	\$18.20
Chassis	25' - 18 AWG Power Black/Red Zip Cable	Radio Shack	278-567	1	\$7.99	1	10	\$79.90
Chassis	Fuse Holder	Mouser	576-03540601ZXGY	2	\$0.66	1	10	\$13.20
Chassis	12A Fuse for Main Power	Mouser	576-0311012.H	1	\$0.30	1	10	\$3.00
Chassis	Female Tamiya Connector - 18AWG	All-Battery	80000-4	2	\$1.64	1	10	\$32.80
Chassis	Male Tamiya Connector - 18AWG	All-Battery	80001-4	1	\$1.64	1	10	\$16.40
Chassis	Terminal Block	Digikey	A98503-ND	3	\$0.54	50	10	\$0.54
Chassis	3 Position Switch	Digikey	E64813-ND	1	\$2.75	1	10	\$27.50
Chassis	500mA Fuse for RF	Mouser	576-0312.500MXP	1	\$0.20	1	10	\$2.00
Chassis	Power Connector to RF Board	Digikey	WMF3700-ND	1	\$0.38	1	10	\$3.83
Chassis	Inserts for RF Power Connector	Digikey	WM3116CT-ND	2	\$0.21	1	10	\$4.10
Chassis	Connectors to Terminal Block	Digikey	A27449-ND	20	\$0.49	100	10	\$0.97
Chassis	Connectors to switch	Digikey	A100888CT-ND	3	\$0.07	100	10	\$0.07
Chassis	STICKY BACK 15 ft. x 3/4 in. VELCRO Tape	Home Depot	202261924	1	\$15.97	10	10	\$15.97
Chassis	RP-SMA to RP-SMA RF Cable	Digikey	CSA-RFSM-216-RSFB-ND	1	\$9.16	1	10	\$91.60
Chassis	Aluminum Project Enclosure	Radio Shack	270-238	1	\$2.99	1	10	\$29.90
Chassis	Nuts Zinc-Plated Steel 1/4"-20 7/17" 7/32" 100	McMaster-Carr	90473A029	1	\$2.33	1	10	\$23.30
Chassis	Nuts Zinc-Plated Steel 4-40 1/4" 3/32" 100	McMaster-Carr	90480A005	1	\$0.81	1	10	\$8.10
Chassis	Flat Socket Head Cap Screw 4-40 10 Pack	McMaster-Carr	90585A204	1	\$11.55	1	10	\$115.50
Chassis	Solarbotics GMW	Pololu	601	2	\$0.99	1	10	\$19.80
Control	Controller	Amazon		1	\$12.99	1	10	\$129.90
Control	2 X 4 PCB	Batch PCB	8975K445	1	\$20.00	1	10	\$200.00
Control	Diodes	Digikey	497-4548-1-ND	8	\$0.62	1	10	\$49.60
Control	PCB to motors	Digikey	ED2611-ND	1	\$0.41	1	10	\$4.10
Control	Resistors 47kohm	Mouser	CR0603-JW-473GLF	2	\$0.02	1	10	\$0.40
Control	Capacitors 0.1uf	Mouser	C1608X7R1H104M	7	\$0.05	1	10	\$3.50
Control	Capacitors 0.01uf	Mouser	C1608X7R1H103M	3	\$0.03	1	10	\$0.90
Control	Fuses for Motor Output	Mouser	RUEF2505	2	\$0.42	1	10	\$8.40
Control	Arduino Nano dev Board	Robot Shop	R8-Gra-01	1	\$34.99	1	10	\$349.90
Control	Motor Controller	Sparkfun	COM-09479	2	\$2.95	1	10	\$59.00
Control	Female Header Row	Sparkfun	PRT-00115	2	\$1.50	1	10	\$30.00
Control	Male Header Row	Sparkfun	PRT-00116	1	\$2.50	1	10	\$25.00
Control	Wire	Sparkfun	PRT-10367	1	\$1.50	1	10	\$15.00
Control	Battery to PCB	Sparkfun	PRT-08235	1	\$1.56	1	10	\$15.60
Control	Zigbee RF solution	Spark Fun		2	\$35.95	1	10	\$719.00
MSA	MSA Chassis IO Board	BatchPCB	50564	1	\$5.00	1	10	\$50.00
MSA	Shroud for Chassis IO Board	Ponoko	N/A	1	\$1.25	1	10	\$12.50
MSA	Break Away Headers - Straight	Mouser	69190-110HLF	5	\$0.35	1	10	\$17.50
MSA	Headers & Wire Housings 20P 4-WALL HEADER STRAIGHT 10U AU	Mouser	D2520-6002-AR	1	\$1.23	1	10	\$12.30
MSA	Cables (Cable Assemblies) 20P 6 SKT - SKT 28AWG STRANDED PVC	Mouser	1M-1010-020-3365-006-0-00-AB-00-0	1	\$3.15	1	10	\$31.50
MSA	Screw Terminals 3.5mm Pitch (2-Pin)	Mouser	1776275-2	1	\$0.28	1	10	\$2.80
MSA	PTC Resettable Fuses 0.05A 30V 1210	Mouser	1210L005WR	1	\$0.22	1	10	\$2.20
MSA	PTC Resettable Fuses 24V 1.5A-HD 40A MAX	Mouser	1812L150/24MR	1	\$0.32	1	10	\$3.20
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 16volts 0.10uF X7R 20%	Mouser	C1608X7R1C104M	3	\$0.03	1	10	\$0.90
MSA	DC/DC Switching Converters 3A 28V In Step Down SWIFT DC/DC Cnvrtr	Mouser	TP554331D	1	\$4.65	1	10	\$46.50
MSA	Thick Film Resistors - SMD 0603 10KOHMS 5% 1/10WATT	Mouser	CR0603-JW-103ELF	1	\$0.02	1	10	\$0.20
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 150pF 50volts C0G 5%	Mouser	C1608C0G1H151J	1	\$0.03	1	10	\$0.30
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 50volts 220pF X7R 20%	Mouser	C1608X7R1H221M	1	\$0.03	1	10	\$0.30
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 50volts 0.015uF X7R 20%	Mouser	C1608X7R1H153M	1	\$0.04	1	10	\$0.40
MSA	Power Inductors 3.3uH 30%	Mouser	SRU1028-3R3Y	1	\$1.00	1	10	\$10.00
MSA	Schottky (Diodes & Rectifiers) SHOTTKY 25V 5A TR HIGH EFFICIENCY	Mouser	RSX501L-20TE25	1	\$0.71	1	10	\$7.10
MSA	Tantalum Capacitors - Solid SMD 68uF 10volts 10% C case	Mouser	5930686X9010C2TE3	1	\$0.39	1	10	\$3.90
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0805 X6S 16V 10uF	Mouser	GRM21BC1C106KA73L	1	\$0.58	1	10	\$5.80
MSA	Thick Film Resistors - SMD 1.87K 1% 1/10W	Mouser	CR0603-FX-1871ELF	1	\$0.05	1	10	\$0.50
MSA	Thick Film Resistors - SMD 20KOHM 1/10WATT 5%	Mouser	CR0603-JW-203GLF	1	\$0.02	1	10	\$0.20
MSA	Thick Film Resistors - SMD 348K ohm 1%	Mouser	CR0603-FX-3483ELF	1	\$0.05	1	10	\$0.50
MSA	TVS Diodes - Transient Voltage Suppressors 9V 400 Watts	Mouser	SMAJ9.0CA-7P	2	\$0.21	1	10	\$4.20
MSA	Thick Film Resistors - SMD 3320OHM 1/10WATT 1%	Mouser	CR0603-FX-3320ELF	1	\$0.04	1	10	\$0.40
MSA	Standard LED - SMD Green Water Clr 40mcd 570nm	Mouser	598-8170-107F	1	\$0.10	1	10	\$1.00
MSA	Multilayer Ceramic Capacitors (MLCC) - SMD/SMT 0603 50volts 0.01uF X7R 20%	Mouser	C1608X7R1H103M	2	\$0.03	1	10	\$0.60
MSA	Thick Film Resistors - SMD 76.8K ohm 1%	Mouser	CR0603-FX-7682ELF	1	\$0.05	1	10	\$0.50
MSA	Acrylic Sheet (Mounting Plate)	MSC	63391486	1	\$9.83	1	10	\$98.30
MSA	Press Fit Dowel Pin (Dowel Pin)	MMC	98381A542	4	\$14.16	50	10	\$14.16
MSA	90 deg Solid Angle 1.25" x 1.25" Aluminum (Servo Bracket, Pinned Mount, Servo Support, Effector Mount)	Home Depot	6957831 (MSC Smaller Part)	1	\$10.88	1	30	\$326.40
MSA	Plate Mounting Screws 1/4-20 x .75" Hex Head	MMC	91251A540	10	\$13.04	100	30	\$39.12
MSA	Mounting Nuts 1/4-20 Plain (Plate Mount Nuts)	MMC	90480A029	8	\$3.15	100	30	\$9.45
MSA	Servo Mounting Screws 4-40 x .5" Hex Head	MMC	91251A110	8	\$7.85	100	30	\$23.55
MSA	Mounting Nuts 4-40 Plain (Servo Mount Nuts)	MMC	90480A005	8	\$0.81	100	30	\$2.43
MSA	Main Drive Servo (Drive Servo, Output Gear)	Sparkfun.com	ROB-09065	1	\$8.53	1	30	\$255.90
MSA	Servo Wire Extensions	Sparkfun.com	ROB-08738	1	\$2.66	1	30	\$79.80
MSA	Washer Spacers (Washer Spacer)	MMC	90295A456	3	\$3.92	50	30	\$7.84
MSA	Gripper and Servo Assembly (End Effector)	Robodyssey.com	GKWS	1	\$25.95	1	10	\$259.50
MSA	6063 Aluminum .125" x .75" x 4" (Links)	MSC	32004871	1	\$28.68	1	10	\$286.80
MSA	Clevis Pins (Clevis Pin)	MMC	98330A135	3	\$4.11	10	30	\$12.33
MSA	Hairpin Cotter Pin (Cotter Pin)	MMC	98335A062	3	\$9.90	100	30	\$9.90

Chasis	\$1,332.17	Merchandise TOTAL	\$4,325.13
Controls	\$1,610.30		
MSA	\$1,382.66	Shipping	\$216.26
		FINAL TOTAL	\$4,541.39