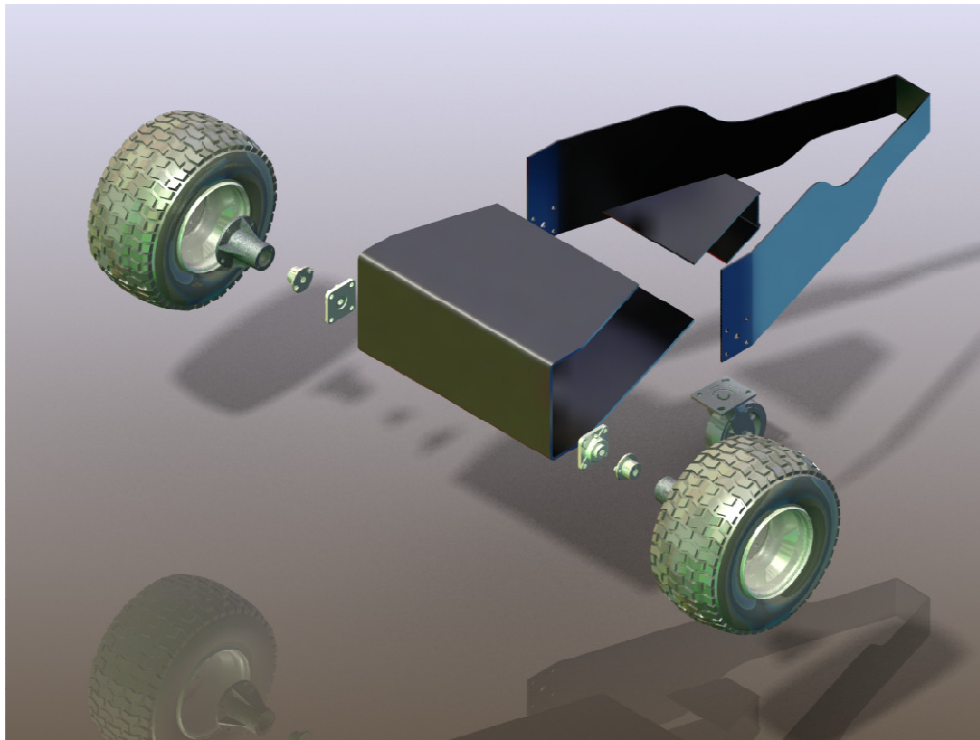




# R. Daneel Olivaw:

Kettering University Robotics Team



Lex Lombardi, Michael Gallant, Seth Borders, Lucas Bell, Jorge Horcasitas,  
Keenin Lake, Jessie Knerr, Amanda Azevedo, Raniel Ornelas

*We are grateful for the assistance of our Faculty Advisors, Professors Girma Tewalde and Jaerock Kwan  
and to our Lab Technicians Jerry Kozlowski and Ray Rust  
We also thank Jervis B Webb for their generous donations.*

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Required Faculty Advisor Statement

I certify that the engineering design of the new vehicle, R. Daneel Olivaw, described in this report, has been significant and equivalent to what might be awarded credit in a senior design course.

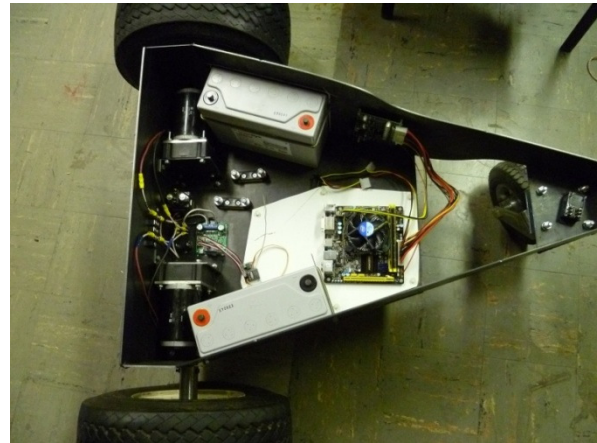
## I. Introduction

*This is Kettering University Robotics Club's first submission since 2006, and our team is excited to be a part of the IGVC competition of 2012! We enthusiastically present our newest design – R. Daneel Olivaw.*

*Our design philosophy focused on finding low cost and low man-hour solutions. We reused the 24V electric motors and the acrylic spacer from the 2005-2006 Bulldog I/II IGVC entry. Expenses saved through the reuse and repurposing of older materials allowed us to focus our budget on more critical components like sensors, controllers, circuits, and batteries. Generous donations by Jervis B Web included high quality batteries, a primary power contactor, an on/off switch, an e-stop button, and an indicator stack.*

*We relied on open source hardware and the maker movement knowledgebase to provide proven solutions to common problems. The result of our design is a remarkably agile, tremendously durable, and easily implemented ground vehicle.*

## II. Mechanical



R. Daneel is shaped like a triangular tub. Fabricated out of 10ga steel sheet, our design was assembled by novice welders. The shape of the tub allowed us to drill and mount components anywhere, providing rapid development.

Our vehicle has 3-wheels, two of which are independent drive. The third wheel is a trailing caster wheel. Independent drive was the logical choice for our design criteria, especially because we already own a pair of wheelchair motors used in Kettering's 2005-2006 IGVC entrant, Bulldog I/II. These off-the-shelf geared motors are intended for use in wheelchairs with similar loads and speed requirements – high torque and low output speed.

Two wheel independent drive allowed us to integrate our forward, backward, and

turning motion controls into only two control values: left and right motors. This provides an excellent balance between simplicity of control, design time, and agility.

Low speed agility is a trait inherent to all 2-speed skid steer type vehicles as they can turn about the center of their drive axles. Our first challenge was to determine the ideal size and type of wheels and tires that would match the grassy competition surface and the maximum output shaft velocity of our motors. Through persistent scrounging, our team was able to locate two golf cart wheels and tires. A golf cart repair business had used wheels and tires with an outer diameter of 17.5". Our motor's maximum output shaft speed is 220rpm. This provided an ideal solution for a vehicle traveling over a grassy field at a limited speed of 10mph. Taking the maximum motor speed and the diameter of the outside of the tire, we can find the theoretical top speed of the vehicle.

$$\begin{aligned}
 C &= \pi D = 17.5\pi = 55in \\
 55in \times 220rpm &= 12100in/min \\
 12100in/min \div 12in/ft \div 5280ft/mi \\
 &\times 60min/hr = 11.5mph
 \end{aligned}$$

In this type of vehicle, a wide track further facilitates maneuverability by providing a long lever arm to rotate about the vertical axis. The track is 3ft wide, and a significant amount of weight is near or below the axles. The force required to rotate about the center point of the axles is minimal compared to a similarly designed and operated 4-wheel skid steer. Changes in heading are accurate, efficient, and even graceful.

The ideal location for the center of gravity is low and centered between the axles. The shape of the tub provides a low center of gravity designed for low-speed stability. The batteries and the drive motors are the heaviest components. Naturally, we decided to mount them symmetrically and as close to the drive wheels as was practical.

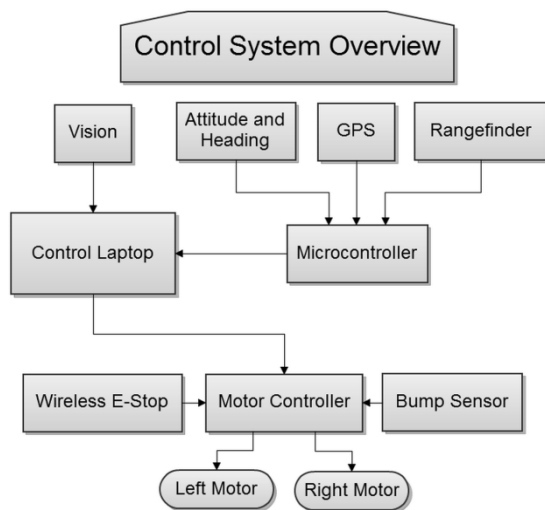
The trailing end of our vehicle is supported by a single caster wheel. A rectangular 4-wheel chassis with two caster wheels was also considered. Our primary concern was that two or more caster wheels may turn in opposite directions and bind at a potentially critical moment. Our team settled on a single, omnidirectional wheel.

The polygonal body shape was designed in Solidworks and cut by our team on a CNC plasma cutter. The open shape of the

tub provided us with a burly, drillable surface area. This allowed for rapid, flexible design and ease of assembly. Steel was selected for its availability, price, and ease of fabrication.

A tail stack is the final feature of our vehicle. It adds 1.5ft of height to the tail of the vehicle. It serves as an ideal location for the emergency stop button, indicator lights, and camera. The indicator stack is mounted at the top of the tail stack, displaying the vehicle's operating condition. Red indicates E-stop, yellow continuous indicates manual control, yellow flashing indicates automatic control, and green indicates power.

### III. Electrical



Our low cost/low hours is echoed throughout the design of the electrical

system. Prebuilt components and wires with standardized connectors were our first choice throughout the entire build. Except for the motors, every individual electrical component can be removed and reinstalled without the need to first remove another nearby component or access panel. A sample layout of R. Daneel Olivaw is on p.11 of this report.

Our electrical system consists entirely of commodity hardware. For example, our mainboard is the Foxconn H67S. It is abundant, inexpensive, powerful, and small. We use two low cost Arduino controllers that reformat our sensor data and provide a USB uplink. The motor controller is the small but powerful Roboteq 50V SDC2150. All of our components use standard interfaces for easy integration.

An off/on/start selector controls power to the entire system. The start position is connected to the mainboard and boots the PC.

Both wireless and manual emergency stop functionality is included. The manual deactivation control is activated by a large red button on the tail stack. Both the manual input and the wireless input activate the primary power contactor and the E-stop relay. Each of these relays is capable of

independently stopping the robot. The E-stop relay directly shunts the motors to brake the vehicle as quickly as possible. The red light in the indicator stack illuminates when the fail-safe is activated, clearly broadcasting its emergency stop condition.

Our motor controller was selected for its convenient USB programming and control capabilities. It also supports auto fallback to manual control in case of a loss of autonomous control. At any point the operator can override autonomous control.

An Arduino based sensor package streams real-time data to the CPU from our inertial measurement unit, GPS, and ultrasonic sensors. The Arduinos convert sensor signals into a stream of characters and write that information to a USB COM port. Arduinos are cheap and easy to use, with a wide variety of freely available code online.

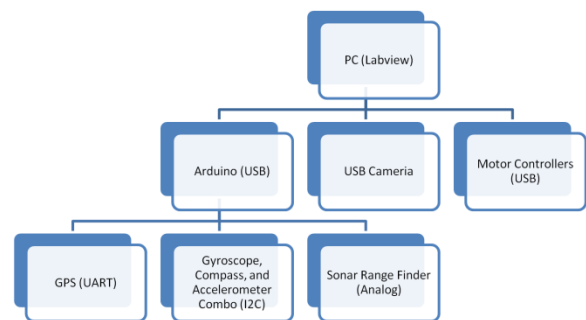
Getting the Arduino to read our inertial measurement unit (IMU) was achieved quickly due to available open source code. Our 3.3V Arduino controls the IMU and the GPS, and our 5 volt Arduino controls the ultrasonic sensor. By isolating the ultrasonic sensors we were able to double our sampling rate. The IMU is an integrated

accelerometer, gyroscope, and magnetoscope. Our GPS sensor uses a standard serial interface to pass data directly through the Arduino straight to our CPU. Our camera is the only sensor that does not send data through the Arduino, as it connects directly to the mainboard through USB.

#### IV. Software

There are two parts to our software design. These are the programs running on the two Arduino minis and LabView VI. Labview VI receives and processes the data sent to it from the Arduinos and the USB camera.

LabView will take the data from the GPS, Accelerometer, ultrasonic sensors, and camera to find three sets of information. These are location and motion information, obstacle location, and object color identification.



Labview cross-references data from the gyroscope, the accelerometer, the compass and the GPS to find the current location, the distance to the next GPS waypoint, the angle to the waypoint, and the current velocity. After the data is collected by the Arduino it is parsed and sent through a moving average and low pass filter to remove noise. The data is then converted mathematically to velocity and angle from North. Current GPS coordinates and waypoint GPS coordinates are used to find the distance and angle to the next waypoint.

Using the parsed information from the Arduino, Labview calculates the distance to the object detected by the sensor. This is averaged with previous values to reduce noise.

The robot's vision system is the Microsoft LifeCam Studio. It is used for the lane detection and color matching that assists the robot's navigational ability. The lane detection feature allows us to recognize and follow lines. Color matching will primarily be used to distinguish between red (right) and green (left) flags for navigation during the final portion of the course. Labview and NI's Vision Development

Module will be used to program the camera and our detection algorithms.

R. Daneel uses a combination of video filters, edge detection, color matching, and color analysis modules to help distinguish the white lanes from the rest of the course. Image processing filters out anything that is not a white lane for the algorithm to use. On screen pixel measurements between the two lanes are used to determine the best route for the vehicle to travel.

Our programming currently has no ability to map points on a global map. We plan on designing and implementing this feature next year. The local map is provided by our camera, with other sensors filling in data where possible.

Labview also tracks the GPS waypoints to map where the robot needs to arrive. The two vehicle states that control movement through the course are the *approach waypoint* state and the *obstacle avoidance* state. In the *approach waypoint* state, the vehicle uses the GPS, compass, and camera to determine the distance and direction to the next waypoint. The camera will provide information about the location of white lines, colored flags, and obstacles. When the ultrasonic sensors find an

obstacle, *obstacle avoidance* mode is activated. At this point, the vehicle will use its sensors to maneuver around the object, reorient itself towards the GPS waypoint, and return to the *approach waypoint* state.

During the *obstacle avoidance* state, Labview monitors the obstacle color for the red/green combination if those colors are present. If these colors are not present, Labview uses the border to determine which path around the obstacle is superior. Naturally, when a GPS point is met, R. Daneel moves on to the following waypoint.

## V. Our Team

The Kettering University Robotics club consists of small group of self-motivated students who have accomplished a lot in a short period of time.

Lex Lombardi is our club's president and lead mechanical and electrical engineer. He designed, fabricated, and assembled the majority of the vehicle. Lex's contributions to our team are extensive. He has not only designed and fabricated most of the vehicle, but he has designed circuitry, programmed the Arduinos, and taught several of our members how to weld.

Michael Gallant is our club's treasurer, editor, and assistant mechanical engineer. He assisted Lex with purchasing and delivering materials and the fabrication and assembly of the vehicle. He also wrote and edited most of this design report.

Keenin Lake is our electronics assistant. He produced and helped design circuitry and helped assemble the electronic components of the vehicle.

Seth Borders is our club's vice president. He attends student government meetings and promotional events on our behalf, provides food for our meetings, and assists with administrative duties.

Jessie Knerr is our secretary. She keeps us all impeccably organized by taking meticulous notes at meetings. She posts these notes in a shared club folder so that we can all stay organized and focused.

Our programming team lead is Lucas Bell. Along with Lucas, Jorge Horcasitas, Raniel Ornelas, and Amanda Azevedo work together to develop our software strategy, program our sensor package, and develop our mapping technique.

In the timeline on p. 9, please take note of the unique CO-OP class schedule of Kettering University. Kettering has two sections of students and four 10-week long

semesters each year. Kettering students spend 6 months of every year working a CO-OP job. From January through March our team was out of class, working at our jobs. Our development time is unusually short, and we have had to work with dedication to accomplish our goals

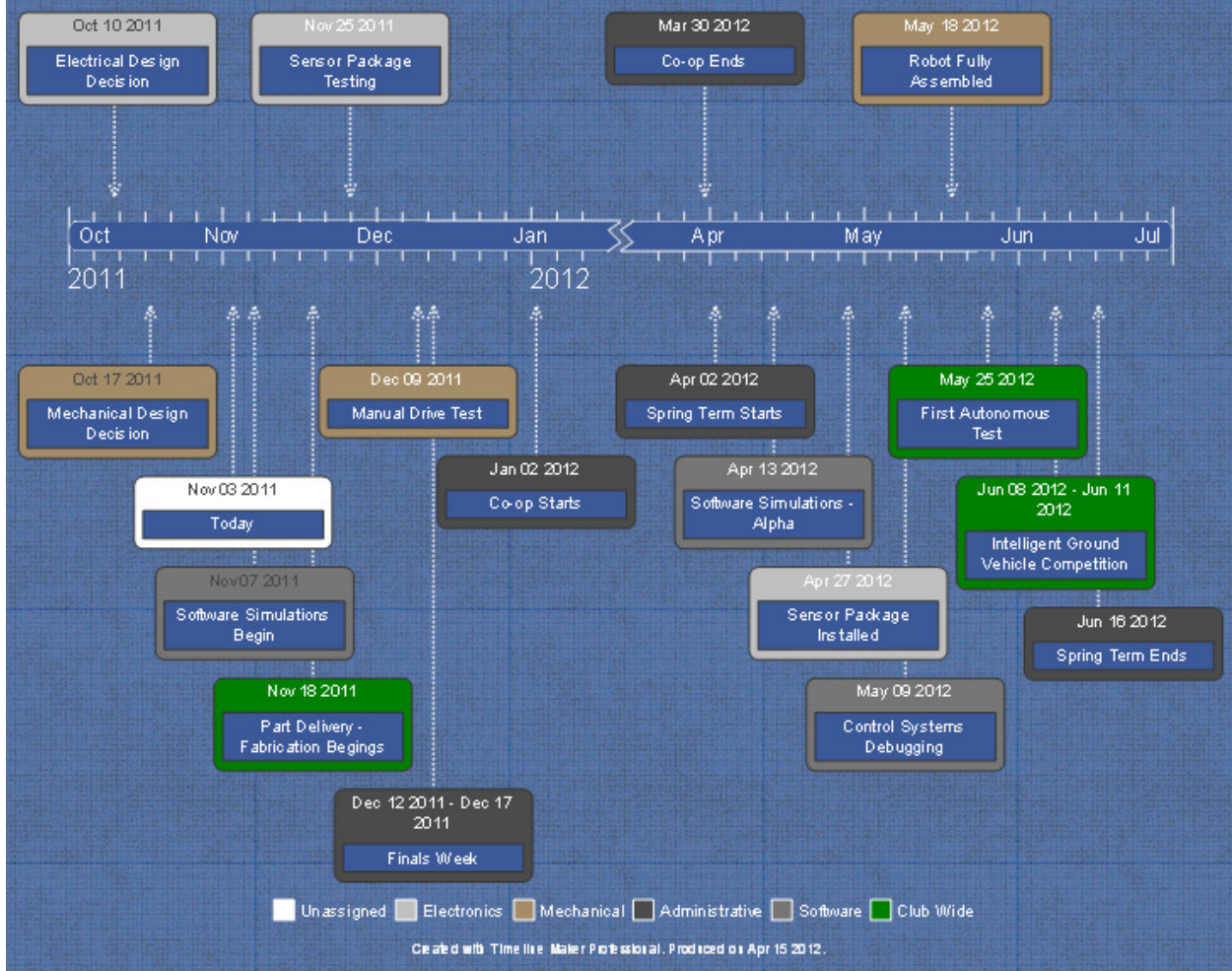
In the budget on p.10, it is clear that the motor controller is the single most expensive item. The expense was worthwhile because it saved the most time in the design of our controls. We are actively soliciting donations, and we expect our barebones budget to increase next year.

We estimate that our team spent a total of 1480 hours working on R. Daneel. The following chart, timeline, and bill of materials show how our team spent our time and our money. We are all very much looking forward to attending the competition. We hope you will enjoy R. Daneel Olivaw as much as we do!

<b>Category</b>	<b>Time</b> (in hours)	<b>Team Members</b>
Design	400	Lex Lombardi
Design Report	30	Michael Gallant Lex Lombardi
Fabrication and Assembly	400	Lex Lombardi Michael Gallant Keenin Lake
Administration	300	Lex Lombardi Seth Borders Michael Gallant Jessie Knerr
Programming	350	Lucas Bell Jorge Horcasitas Raniel Ornelas Amanda Azevedo



# KURT Timeline (Fall 2011-Spring 2012)



## Bill Of Materials - IGVC 2012

#	Description	Supplier	Ea	Qty	Total
<b>Purchased Parts</b>					
1	Camera	<a href="http://newegg.com">newegg.com</a>	\$80.00	1	\$80.00
2	Ultrasonic rangefinder	<a href="http://maxbotix.com">maxbotix.com</a>	\$56.00	2	\$112.00
3	Logic Level Converter	<a href="http://sparkfun.com">sparkfun.com</a>	\$1.95	2	\$3.90
4	Bump Sensors	<a href="http://digiquey.com">digiquey.com</a>	\$15.21	2	\$30.42
5	IUM 9DoF Stick (Accel, Mag, Gyro)	<a href="http://sparkfun.com">sparkfun</a>	\$99.95	1	\$99.95
6	GPS	<a href="http://sparkfun.com">sparkfun</a>	\$74.95	1	\$74.95
7	GPS Antenna	<a href="http://sparkfun.com">sparkfun.com</a>	\$12.95	1	\$12.95
8	10ga 4x8 Sheet Steel	SLH Metal	\$190.90	1	\$190.90
9	Golf Cart Tires		\$41.20	1	\$41.20
10	Motor Controller	<a href="http://robotiq.com">robotiq.com</a>	\$225.00	1	\$225.00
11	e-stop button	<a href="http://digiquey.com">digiquey.com</a>	\$38.69	1	\$38.69
12	Arduino Pro Mini 328 - 5V/16MHz	<a href="http://sparkfun.com">sparkfun.com</a>	\$18.95	2	\$37.90
13	Xbee - Arduino adapter	<a href="http://parallax.com">parallax.com</a>	\$27.99	2	\$55.98
14	Wireless E-Stop Contactor	<a href="http://digiquey.com">digiquey.com</a>	\$102.84	1	\$102.84
15	USB Mini-B Cable - 6 Foot	<a href="http://sparkfun.com">sparkfun.com</a>	\$3.95	2	\$7.90
16	FTDI Basic Breakout - 5V	<a href="http://sparkfun.com">sparkfun.com</a>	\$14.95	2	\$29.90
17	Motor Shunt E-Stop Relay	<a href="http://digiquey.com">digiquey.com</a>	\$14.90	2	\$29.80
18	Spring Terminals, 6 position	<a href="http://www.sparkfun.com">www.sparkfun.com</a>	\$1.50	4	\$6.00
19	PicoSwitch	<a href="http://dimensionengineering.com">dimensionengineering.com</a>	\$19.99	1	\$19.99
20	Regen Diode D116	<a href="http://digiquey.com">digiquey.com</a>	\$1.59	1	\$1.59
21	Jumper Wire -0.1", 2 pin, 12"	<a href="http://www.sparkfun.com">www.sparkfun.com</a>	\$1.95	1	\$1.95
22	USB A to Mini B 6" (Mobo to MotorController)	<a href="http://newegg.com">newegg.com</a>	\$6.99	1	\$6.99
23	USB 3.3vFTDI	<a href="http://www.sparkfun.com">www.sparkfun.com</a>	\$17.95	1	\$17.95
24	ATX Extender	<a href="http://www.mini-box.com">www.mini-box.com</a>	\$5.95	1	\$5.95
25	USB 5pin to 5pin header cable	<a href="http://www.mini-box.com">www.mini-box.com</a>	\$1.50	1	\$1.50
26	1x M4-ATX, 250w Car Computer Power Supply	<a href="http://mini-box.com">mini-box.com</a>	\$89.50	1	\$89.50
27	1x Foxconn H67S Motherboard	<a href="http://newegg.com">newegg.com</a>	\$59.99	1	\$59.99
28	1x Intel Pentium G620 Sandy Bridge 2.6GHz	<a href="http://newegg.com">newegg.com</a>	\$69.99	1	\$69.99
29	2x Crucial 4GB DDR3 RAM	<a href="http://newegg.com">newegg.com</a>	\$16.99	2	\$33.98
30	Locktite and nylon hardware assortment	Home Depot	\$12.05	1	\$12.05
31	Mineature Hardware and Spacers	Home Depot	\$10.26	1	\$10.26
32	Arduino Pro Mini 328 - 3.3V/8MHz	SparkFun	\$18.95	2	\$37.90
33	Break Away Female Headers	SparkFun	\$1.50	2	\$3.00
34	Heat Sink Compound	SparkFun	\$1.95	2	\$3.90
35	SparkFun Stickers	SparkFun	\$0.30	5	\$1.50
36	FEM. QK. Disconnect ..250 12/10	Electronic Parts Specialists	\$12.38	1	\$12.38
37	Eurocard 3 Hole ISL. 3.9 X 6.3	Electronic Parts Specialists	\$7.00	1	\$7.00
<b>Total</b>					<b>\$1,577.65</b>

<b>Webb Donated Parts</b>		Visi #	Qty	Ea	Total
12V TPPL Battery		C1106133	2	\$255.15	\$510.30
SB-50		C1085760	2	\$2.69	\$5.38
M6x20mm Screw		C1022189	4		
M6 Lock Washer		C1093233	4		
#6AWG Welding Wire (per ft)			2		
			2		
Primary Power Contactor		C1079511	1	\$53.29	\$53.29
#6AWG 3/8" Ring Terminal		C1000554	4		
BUSSMANN 50Amp ANN Fuse (SUB with 60/70/80 or 100 AMP Ver)		C1064729	2	\$15.91	\$31.82
BUSSMANN Fuse Block		C1022954	2	\$16.74	\$33.48
Off On Start Switch		C1095561	1	\$21.97	\$21.97
Red/Green/Amber 24V Indicator Stack (any in stock)		C1074014	1	\$48.56	\$48.56
Battery Charger (24V, 15/20A)		C1097215	1	\$186.90	\$186.90
E-Stop Pushbutton		C1098166	1	\$32.28	\$32.28
<b>Total</b>					<b>\$923.98</b>
<b>Grand Total</b>					<b>\$2,501.63</b>

