FLORIDA A&M UNIVERSITY-FLORIDA STATE UNIVERSITY

COLLEGE OF ENGINEERING

Formula 1/10 Autonomous Vehicle

Virtual Design Review 2

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FAMU-FSU College of Engineering

Team Members

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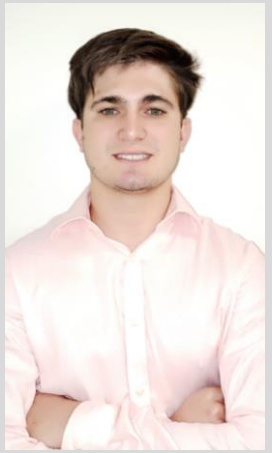


Michael Calisi
ELECTRICAL ENGINEER

Competition Background

- The Formula 1/10 competition gives students an opportunity to learn about perception, planning and control for autonomous vehicles [1].

Fig. 3: F/10 competition logo. [1]

- Autonomous vehicles work through the combination of sensors and software to make decisions and navigate.
- Robot Operating System (ROS) is commonly used to implement autonomous navigation.

Project Summary

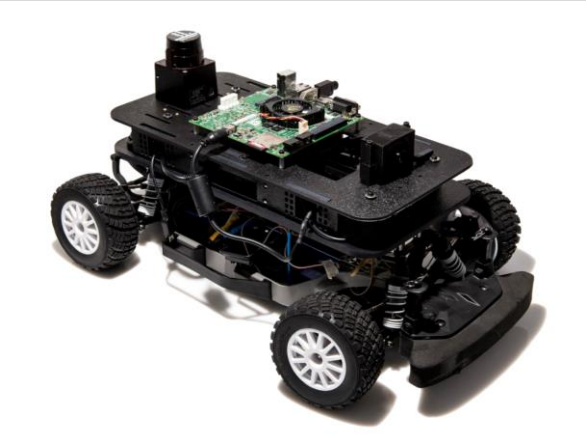


Fig. 1: An autonomous 1/10th scale vehicle. [1]

Fig. 2: A Winnebago capable of space travel. [2]

- Inspired by the Formula 1/10th Autonomous Racing Competition
- Design and build a vehicle that can analyze surroundings and navigate obstacles autonomously

Project Scope

- Project Description
  - Design and build an autonomous 1/10th scale race car (space winnebago).
- Key Goals
  - Navigate around obstacles autonomously.
  - Make decisions in real time.
  - Operate at a safe and controlled speed.
  - Ability to switch between autonomy and remote control.
- Market
  - Primary- The F1/10 competition
  - Secondary- RC car enthusiasts, the autonomous vehicle market, and cult movie enthusiasts.

Project Scope

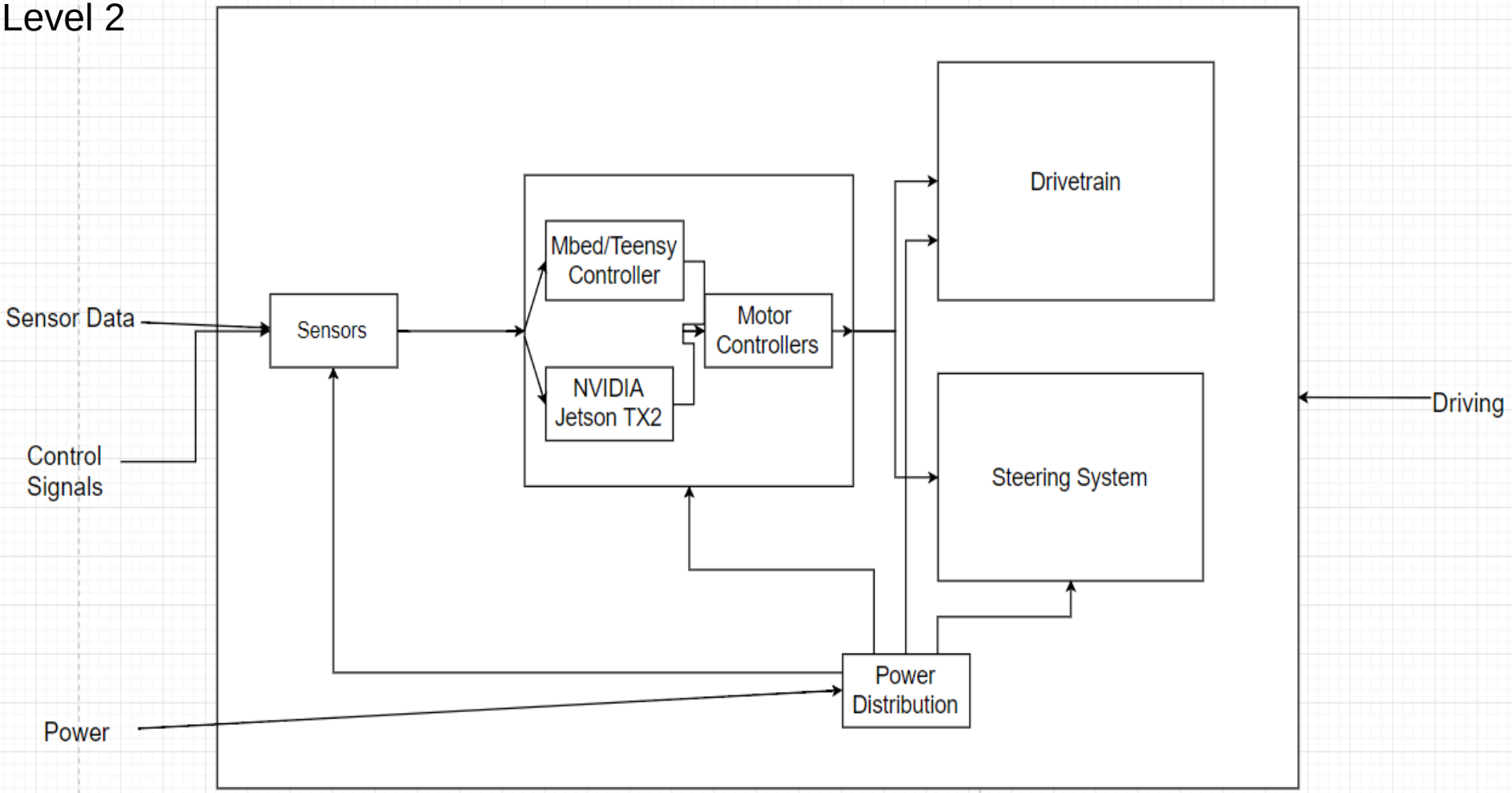
- Assumptions
  - Design will adhere to the rules and guidelines presented in the F 1/10 Autonomous Racing Competition Rule Book.
  - Physical prototype will be constructed by the end of the Spring 2019 semester.
  - Full access to ME and ECE labs and equipment to facilitate design and testing.
- Stakeholder
  - Sponsor: Dr. Hooker
  - Advisor: Dr. McConomy
  - F 1/10 Autonomous Racing Competition
  - FAMU-FSU College of Engineering

Customer Needs

Need Number	Customer Statement	Interpreted need
1	Vehicle should be capable of navigating from one room, down the hall, to another.	The vehicle needs to have the ability to propel itself forwards, backwards, steer left/right, and stop.
2	The vehicle needs to understand its environment and navigate the course autonomously.	The vehicle should have sensors and processors that interpret its surrounding environment and make decisions on where to go.
3	Needs to have the ability to switch between autonomous navigation and user control	The vehicle should include a feature which will override the autonomous navigation and allow a user to control the vehicle via remote.
4	All Decision making needs to be done on board the vehicle itself	All information must be processed on board of the vehicle
5	Needs to abide by the F1/10 Rules and Regulations	The vehicle's dimensions, electronics and features should all coincide with the competition rulebook.
6	Needs to have a killswitch feature.	The vehicle will have the ability to stop all operations on command.

Functional Decomposition

Level 2



Targets

Target No.	Metric	Imp.	Units	Marginal value	Ideal value
1	Ability to navigate course	5	%	50%	80%
2	Autonomous Control Switch	5	Yes/No	Yes	Yes
3	Sensor detection distance	5	m	15.3m	17.3m
4	Run time	4	min	15min	20min
5	Cost	4	USD	3000	2000

Targets

Target No.	Metric	Imp.	Units	Marginal value	Ideal value
6	Battery capacity	4	mAh	5000	6000
7	Steering angle	3	degrees	25	30
8	Wheelbase	3	cm	35	26
9	Weight	3	lbs	8	5
10	Vehicle Dimensions				
	Length	3	cm	51	46
	Width	3	cm	29	23
	Height	3	cm	32	28

Targets

Target No.	Metric	Imp.	Units	Marginal value	Ideal value
11	Maximum acceleration	3	m/s^2	2.23	3.5
12	De-acceleration	3	m/s^2	5.36	6.71
13	Maximum velocity	2	mph	10	40
14	Track Width	2	cm	27	20
15	Wheel Dimensions				
	Weight	2	oz	1.5	1
	Diameter	2	cm	8	7.5
	Width	2	cm	3.5	2.8

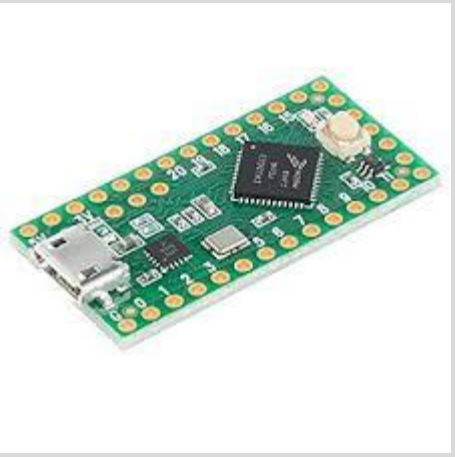
Concept Generation and Selection

- The rules and guidelines of the F1/10 Competition limit the deviance from recommended configuration
- Decision Matrices for each sub component were used to finalize selections

Concept Generation - Microprocessor

- Teensy 3.2
- Mbed FRDM-K64
- Raspberry pi 3
- TI MSP432

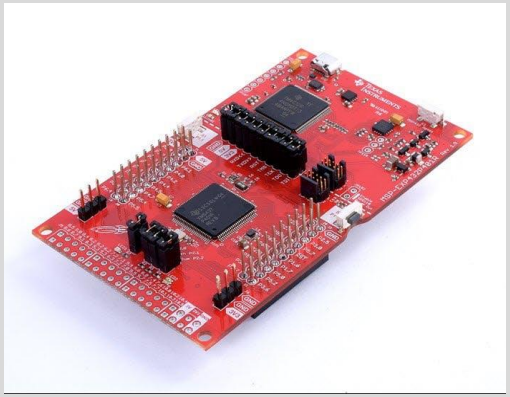
Teensy 3.2



Mbed FRDM-K64

Raspberry pi 3

Ti-MSP432



Concept Selection - Microprocessor

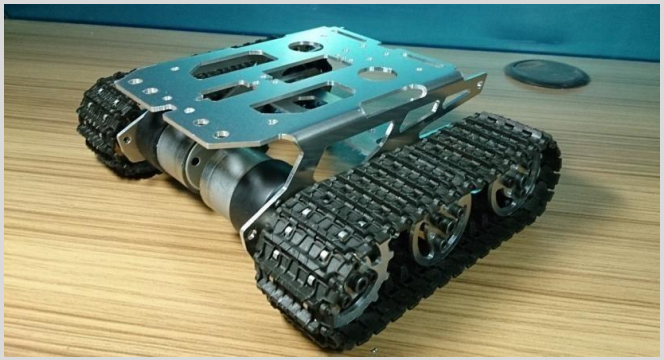
Microprocessor			
	Baseline	**Concept 1**	**Concept 2**
Criteria	Teensy 3.1	Teensy 3.2	Mbed FRDM-K64F
Power Usage	5V	S	+
RAM	64kB	S	+
Processing Power	72MHz	S	+
Ease of Assembly and Programming	Yes	S	S
	# of Plus	0	3
	# of Minus	0	0

Selection:

Mbed FRDM-K64

Concept Generation - Locomotion

- Wheels
- Tracks
- Omnidirectional wheel



Tracks

Wheels/Tires

Omnidirectional Wheels

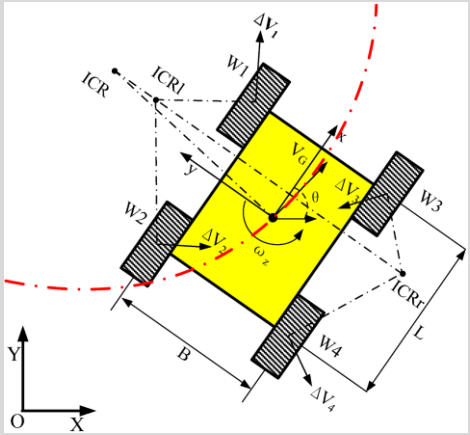
Concept: Selection - Locomotion

Tires			
	Baseline	**Concept 1**	**Concept 2**
Criteria	Traxxas BF Goodrich	Duratrax Bandito Buggy Tire	1/10 Tamiya F1 Tire
Tread	Deep	+	++
Cost	$18.95	+	-
Width	43 mm	+	+
	# of Plus	2	3
	# of Minus	0	1

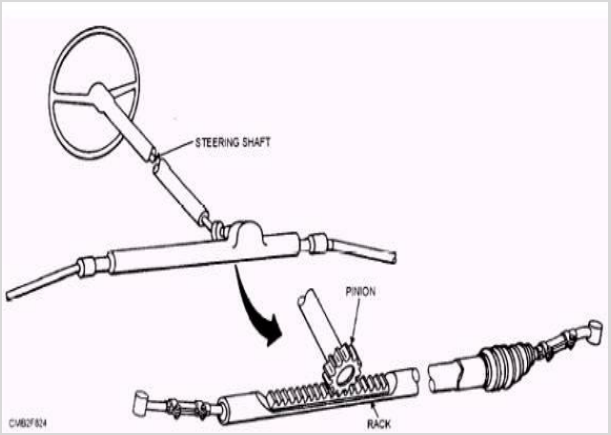
Selection: 1/10 Tamiya F1 Tire

Concept Generation - Steering

- Bell-Crank Linkage
- Rack and Pinion
- Linear Actuator
- Skid Steering

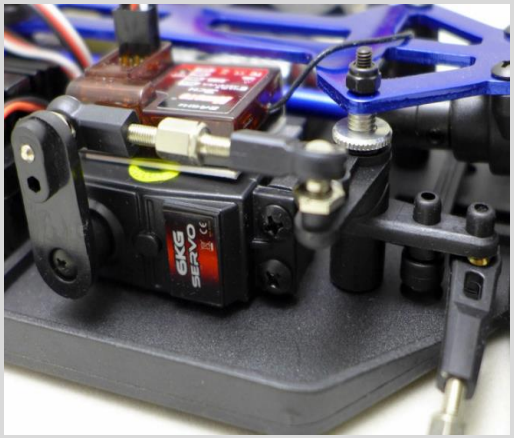


Skid Steering



Rack and Pinion

Linear Actuator



Bell-Crank Linkage

Concept Selection - Steering

Steering				
	Baseline	**Concept 1**	**Concept 2**	**Concept 3**
Criteria	Bell-Crank Linkage	Rack & Pinion	Skid Steering	Linear Acuator
Response Time	Fast	-	-	-
Complexity	Moderate	+	-	+
Turning at High Speed	Good	-	--	-
Turn Radius	Good	-	+	S
	# of Plus	1	1	1
	# of Minus	3	3	2

Selection:

Bell-Crank Linkage

Concept Generation - Sensors

- Stereoscopic Camera
- LIDAR
- IR Sensors
- Webcam
- Front/Back Camera Placement

Concept Selection - Camera

Camera				
	Baseline	**Concept 1**	**Concept 2**	**Concept 3**
Criteria	Zed	Pointgrey	Minoru	Logitech c920
Field of View	90x60x110	-	-	-
Power Consumption	5V	S	S	S
Depth Range	.5-20m	-	-	-
Frequency	100Hz	S	-	-
Price	$449	-	+	+
	# of Plus	0	1	1
	# of Minus	2	3	3

Selection:

Zed Stereoscopic Camera

Concept Selection - LIDAR

LIDAR			
	Baseline	**Concept 1**	**Concept 2**
Criteria	Kokuyo UST-10LX	Sweep 360 LIDAR Sensor	RPLIDAR A2M8 360
Cost	$1,600	++	++
Accuracy	40mm	-	-
Range	10m	+	+
Scanning Frequency	40 Hz	-	-
Power	24V DC	+	+
	# of Plus	4	4
	# of Minus	2	2

Selection:

RPLIDAR A2M8 360

Concept Generation - Battery

- LiPO
- Alkaline
- NiMH
- Li-ion

NiMH Battery

Li-ion Battery

LiPO Battery

Concept Selection - Battery

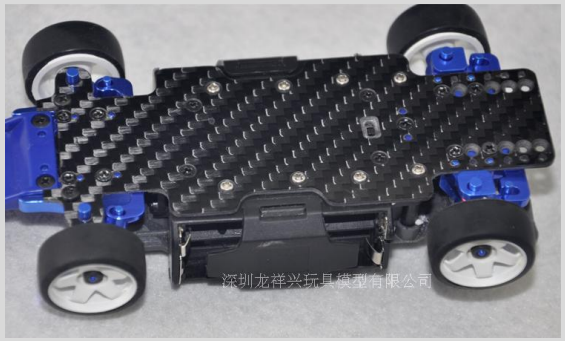
Battery			
	Baseline	**Concept 1**	**Concept 2**
Criteria	LiPo Venom	3s LiPo Gens Ace	Traxxas 7.4
Capacity	5400mAh	-	+
Energy	250Wh/kg	S	+
Weight	0.354kg	-	-
Charge Time	30 min	S	+
Max Current	65A at 35C	-	S
Cost	$40.99	+	+
	# of Plus	1	3
	# of Minus	3	1

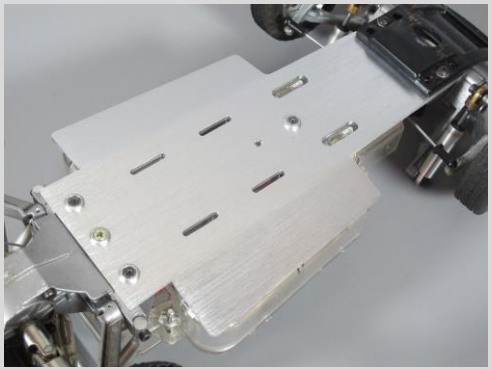
Selection:

LiPo Venom

Concept Generation - Chassis

- Traxxas Rally 1/10 Race Car
- 3D Printed ABS Plastic
- 3D Printed Carbon Fiber
- Aluminum Frame water-jetted





Concept Selection - Chassis

Chassis				
	Baseline	**Concept 1**	**Concept 2**	**Concept 3**
Criteria	Traxxas Rally 1/10 Race Car	3D Printed ABS Plastic	3D Printed Carbon Fiber	Aluminum Frame- Water Jet
Cost	$169.99	++	--	-
Durability	Very	-	+	+
Flexibility	Very	-	+	-
Ease of Manufacturing	Already made	+	--	-
Shock Resistance	Good	-	+	-
Weight	1.13g/cm^3	-	+	-
	# of Plus	3	4	1
	# of Minus	4	4	5

Selection:

Traxxas Rally 1/10 Race Car

Concept Generation- Motor

- Titan 12-turn 550 motor
- Traxxas Velineon 3500 1/10 brushless
- Castle Creations 1/10 1406 1Y
- Stirling Engine

Left: Titan 12T, Middle: Velineon, Right: Castle Creations

Stirling engine

Concept Selection - Motor

Motor				
	Baseline	**Concept 1**	**Concept 2**	**Concept 3**
Criteria	Titan 12-turn 550 motor	Traxxas Velineon 3500 1/10 brushless	Castle Creations 1/10 1406 1Y	Stirling Engine
Cost	$22.45	-($74.99)	- ($84.95)	- ($57.00)
Power Usage	8.4V	- (11.1V)	- (11.1V)	+ (5V)
Weight	0.2kg	- (0.274kg)	S (0.2kg)	- (0.5kg)
kV	3000 RPM/V	+ (3500)	+ (4600)	- (120)
Max RPM	25000	+ (50000)	+ (100000)	-- (600)
	# of Plus	2	2	1
	# of Minus	3	2	5

Selection:

Castle Creations 1/10 1406 1Y

All Concept Selections

Component	Preferred Choice
Motor	Castle Creations 1/10 1406 1Y
Tires	1/10 Tamiya F1 Tire
Microprocessor	Mbed FRDM-K64F
Battery	LiPo Venom
Chassis	Traxxas Rally Chassis
Body	Winnebago
Camera	Zed Stereoscopic Camera
Lidar	RPLIDAR A2M8 360
External Controller	Xbox Controller
Motor Controller	Sidewinder 4
Steering System	Bell-crank Linkage

Bill of Materials

Part #	Category					
	Main Components	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
1	Traxxas 1/10th Car platform with RC	1	$299.95	$299.95	15.00%	11.95%
2	Vintage 1970's Tonka Winnebego	1	$40.00	$40.00	2.00%	1.59%
3	ZED Mounting Bracket	1	$0.00	$0.00	0.00%	0.00%
4	LIDAR Mounting Bracket	1	$0.00	$0.00	0.00%	0.00%
5	IMU Mounting Bracket	1	$0.00	$0.00	0.00%	0.00%
6	Jetson Mounting Bracket	1	$0.00	$0.00	0.00%	0.00%
7	Teensy Microprocessor Mounting Bracket	1	$0.00	$0.00	0.00%	0.00%
		Subtotals	$339.95	$339.95	17.00%	13.55%

	Sensors	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
8	SparkFun 9DoF Razor IMU M0	1	$49.95	$49.95	2.50%	1.99%
9	LIDAR- RPLIDAR A2M8 360	1	$319.00	$319.95	16.00%	12.71%
10	*GIFT* ZED Camera	1	$449.00	$0.00	0.00%	17.89%
		Subtotals	$817.95	$369.90	18.50%	32.59%

Bill of Materials

	Power	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
11	*GIFT* Li-Po battery 5000mAh, 3 cell 11.1V #2872	1	$74.99	$0.00	0.00%	2.99%
12	*GIFT* Li-Po battery Charger #2970	1	$49.99	$0.00	0.00%	1.99%
13	Traxxas 2976 AC to DC Converter	1	$25.79	$25.79	1.29%	1.03%
14	4 AA batteries	1	$7.18	$7.18	0.36%	0.29%
		Subtotals	$157.95	$32.97	1.65%	6.29%

	Processing	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
15	*GIFT* Nvidia Jetson TX2	1	$468.00	$0.00	0.00%	18.65%
16	Orbitty Carrier board for TX2	1	$173.00	$173.00	8.65%	6.89%
17	Teensy 3.2	1	$24.43	$24.43	1.22%	0.97%
		Subtotals	$665.43	$197.43	9.87%	26.51%

Bill of Materials

	Miscelaneous Electronics	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
18	USB wifi dongle	1	$8.99	$8.99	0.45%	0.36%
19	USB Hub	1	$29.95	$29.95	1.50%	1.19%
20	FTDI	1	$15.00	$15.00	0.75%	0.60%
21	Micro USB Cable	1	$4.99	$4.99	0.25%	0.20%
22	Ethernet cable (optional)	1	$2.99	$2.99	0.15%	0.12%
23	POE cable (optional)	1	$3.99	$1.00	0.05%	0.16%
24	Traxxas Lipo to JST balance cable extender	1	$14.99	$14.99	0.75%	0.60%
25	USB to Ethernet adapter (for lidar with ethernet conn)	1	$9.49	$9.49	0.47%	0.38%
26	Servo cable	1	$3.00	$3.00	0.15%	0.12%
27	SD Cards (optional)	2	$49.90	$49.90	2.50%	1.99%
28	*GIFT* Xbox One Controller	1	$43.67	$0.00	0.00%	1.74%
		Subtotals	$186.96	$140.30	7.02%	7.45%

Bill of Materials

	Mechanical	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
29	Traxxas 3769 Spring Preload Spacers	2	$10.44	$10.44	0.52%	0.42%
30	Allen Key Set	1	$8.99	$8.99	0.45%	0.36%
31	8 mm plastic spacers /standoffs	4	$2.21	$2.21	0.11%	0.09%
32	3mm ABS	1	$6.38	$6.38	0.32%	0.25%
33	6mm ABS	1	$9.74	$9.74	0.49%	0.39%
34	6mm Hex M/F Standoff 14mm	8	$33.60	$33.60	1.68%	1.34%
35	6mm Hex F/F Standoff 19mm	6	$16.74	$16.74	0.84%	0.67%
36	6mm Hex F/F Standoff 45 mm	4	$11.20	$11.20	0.56%	0.45%
37	6mm Hex F/F Standoff 35 mm	4	$10.12	$10.12	0.51%	0.40%
38	M3 screws x 10 mm	26	$7.01	$7.01	0.35%	0.28%
39	Miscelleneous Nuts, Bolts, Hardware	N/A	$50.00	$50.00	2.50%	1.99%
		Subtotals	$166.43	$166.43	8.32%	6.63%

	Power Board	Quantity	Cost	Amount Paid	% of Budget	% of Total Cost
40	Miscelleneous Power Board Components	N/A	$100.00	$100.00	5.00%	3.98%
		Subtotals	$100.00	$100.00	5.00%	3.98%

Bill of Materials

	Total Cost	Total Spent		Total % Purchased:	11.90%
Comb. Subtotal:	$2,334.67	$1,346.98		Total Budget:	$2,000.00
Sales Tax:	$175.10	$101.02		% of Budget Used:	72.40%
TOTAL:	$2,509.77	$1,448.00		Budget Remaining:	$552.00

The Next Steps

- Risk Assessment - Safety concerns with this project?
- Purchasing parts and assembling vehicle
- Collecting Data
  - Zed Stereoscopic camera readings of hallway dimensions.
- ROS tutorials
- Develop governing dynamic equations for controls
- Begin CAD work on mounting brackets
- Begin coding motor drivers

References

[1]A New 12 Volt Linear Actuator Steering System Is Coming To a Nucanoe Near You https://www.nucanoe.com/nucanoe-forums/topic/a-new-12-volt-linear-actuator-steering-system-is-coming-to-a-nucanoe-near-you/

[2]BangBang Motor, https://www.amazon.com/BangBang-Stirling-Engine-Model-Generator/dp/B072Q9LTB

[3]Bell Crank https://en.wikipedia.org/wiki/Bellcrank

[4]Bumblebee2 0.3 Mp Color Firewire 1394a 2.5mm (sony Icx424) https://www.ptgrey.com/bumblebee2-stereo-vison-03-mp-color-firewire-1394a-25mm-sony-icx424-camera

[5]Duratrax Bandito 1/10 Buggy Tire Front 4wd C2 (2) https://www.towerhobbies.com/cgi-bin/wti0001p?&I=DTXC3972&P=FR&gclid=CjwKCAjwyOreBRAYEiwAR2mSkuuzPXKOg62gHsfxZOgdJiUr0p8DJV51_nysHKZdpmTI-QUxGZbXGRoCli4QAvD_BwE

[5]Focbox Speed Controller https://www.enertionboards.com/FOCBOX-speed-controller.htm

[6]Frdm-k64f https://os.mbed.com/platforms/FRDM-K64F/

[7]Gens Ace 5000mah 7.4v 50c 2s1p Hardcase Lipo Battery 24# with New Packing https://www.gensace.de/gens-ace-5000mah-7-4v-50c-2s1p-hardcase-lipo-battery-24-with-new-packing.html#

[8]How Car Steering Works Karim Nice - https://auto.howstuffworks.com/steering2.htm

[9]John D.-Tim Bryant-Randy Grimmer-Ethan Stones-Michael Cook-Jason -Jill -Jason williams - https://www.rcplanet.com/traxxas-titan-550-motor-12t-tra3785/

[10]Laser Scanner, https://www.robotshop.com/en/sweep-v1-360-laser-scanner.html

[11]Lidar Scanner https://www.roscomponents.com/en/lidar-laser-scanner/155-rplidar-a2m8.html

[12]Logitech - C920 Pro Webcam - Black https://www.bestbuy.com/site/logitech-c920-pro-webcam-black/4612476.p?skuId=4612476&ref=212&loc=1&ds_rl=1266837&gclid=CjwKCAjwyOreBRAYEiwAR2mSkhAxTXYgzZwBJnzVVM23aQBjztfeMdsO3fPjfg7uouaRt0SL_-zHxRoCdBUQAvD_BwE&gclsrc=aw.ds

[13]Minoru3d https://www.minoru3d.com/

[14]Motor Control http://www.castlecreations.com/en/sidewinder-4-1/sidewinder-4-sensorless-esc-basher-edition-w-1406-4600-sensor-ready-motor-010-0164-01

[15]Motor, Velineon 3500, Brushless (assembled with 12-gauge Wire and Gold-plated Bullet Connectors) Admin - https://traxxas.com/products/parts/motors/velineon3500motor

References

[16]PS4 Controller Link https://www.amazon.com/DualShock-Wireless-Controller-PlayStation-Black-4/dp/B01LWVX2RG/ref=sr_1_4?s=videogames&ie=UTF8&qid=1541114387&sr=1-4&keywords=ps4+controller

[17]Robot Check https://www.amazon.com/Traxxas-7600mAh-7-4V-2-Cell-Battery/dp/B00S1R0VEY

[18]Sensored Motor, http://www.castlecreations.com/en/1406-4600kv-sensored-motor-060-0056-00

[19]Skid Steering https://groups.csail.mit.edu/drl/courses/cs54-2001s/skidsteer.html

[20]Tamiya Rubber Rear Tire F104 (2) https://www.towerhobbies.com/cgi-bin/wti0001p?&I=TAMC2543&P=FR&gclid=CjwKCAjwyOreBRAYEiwAR2mSkpTZmlJ-Ibc966pDKBVhDNm6KO7m6aLsz8betGylwHIfJ3EADGrriRoCZ1EQAvD_BwE

[21]Teensy 3.2 & 3.1 - New Features https://www.pjrc.com/teensy/teensy31.htm

[22]The Camera That Senses Space and Motion,https://www.stereolabs.com/zed/

[23]The Real Cost Of Cheap 3d Printer Filament John Schneider - https://www.3dfuel.com/blogs/infographic/the-real-cost-of-3d-printer-filament

[24]Thread https://forums.traxxas.com/showthread.php?8970725-Type-of-plastic-used-Name-of-factory-made-in-School-Project

[25]Traxxas Prographix Body For Rally 10th, "7411x" https://www.rchobbyexplosion.com/Traxxas_ProGraphix_Body_for_10th_Rally_VXL_p/tra7411x.htm?

[26]Traxxas Rally 4x4 1/10 Lcg Upgraded Rally Car Roller Rolling Chassis (read) https://www.ebay.com/i/273231006265?chn=ps

[27]Traxxas Tires Bf Goodrich Mud-terrain Slash 4x4 Tra6871 https://www.rcplanet.com/traxxas-tires-bf-goodrich-mud-terrain-slash-4x4-tra6871/?gclid=CjwKCAjwyOreBRAYEiwAR2mSkqGscyEt2R6J0WKLVee773E61Lf6s8XuicUpdci3d8rAzp17oivpChoCH4kQAvD_BwE

[29]Xbox Controller https://www.amazon.com/Xbox-Wireless-Controller-Black-one/dp/B01LPZM7VI/ref=sr_1_3?ie=UTF8&qid=1541114365&sr=8-3&keywords=xbox+one+controller

[30]Xl-5 Electronic Speed Control, Waterproof (land Version, Low-voltage Detection, Fwd/rev/brake) Admin - https://traxxas.com/products/parts/escs/3018Rxl5waterprooflvdhttps://traxxas.com/products/parts/escs/3018Rxl5waterprooflvd

Questions?