Hardware in Loop 1/10 Scale Automobile

David Gordon | Micah Hilliard | Kathleen Bodden
Richard Allen| Chet Iwuagwu | Nicholas Muoio |

TEAM 503

Meet Team 503

Richard Allen

Design Engineer

Micah Hilliard

Structural Engineer

Nicholas Muoio

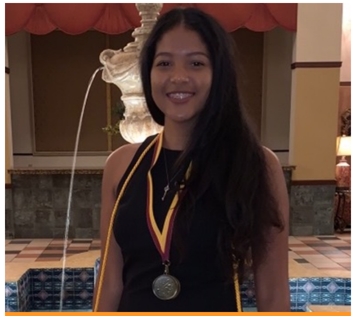
Controls Engineer

David Gordon

Hardware Engineer

Chet Iwuagwu

Software Engineer

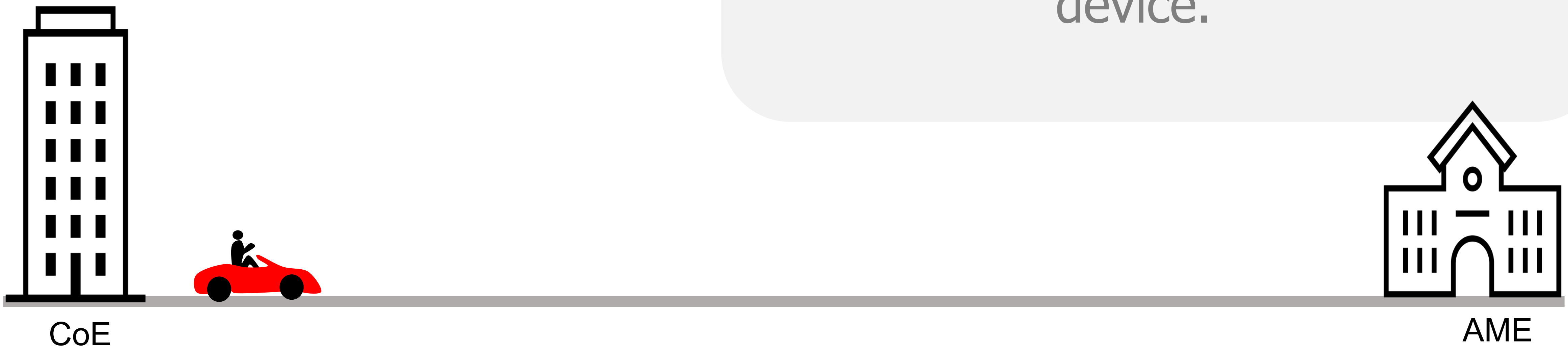


Kathleen Bodden

Research/Test Engineer

Project Objective

The objective of this project is to autonomously minimize inertial forces during propulsion and integrate with a concealed tracking device.



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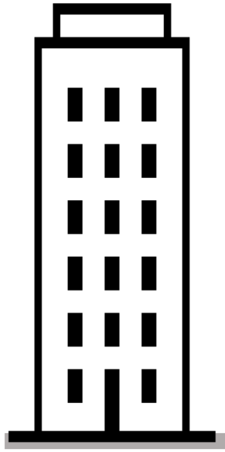
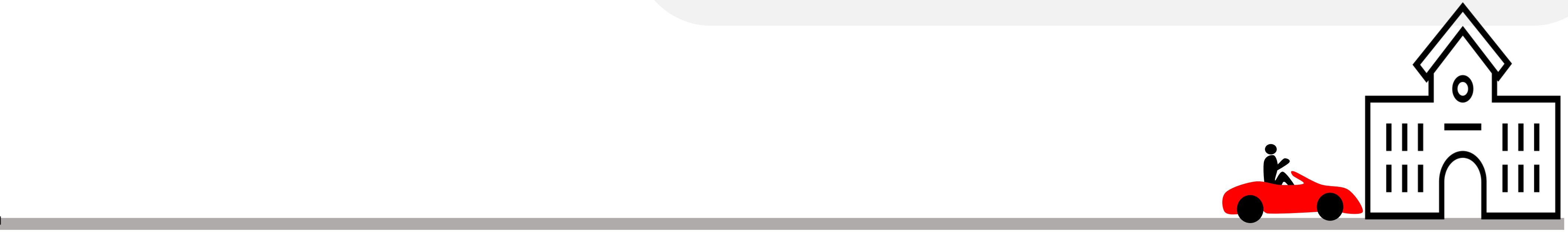




Stakeholders

Central Intelligence Agency

Shayne McConomy
FAMU-FSU College of Engineering

Camilo Ordoñez
FAMU-FSU College of Engineering

FAMU-FSU College of Engineering

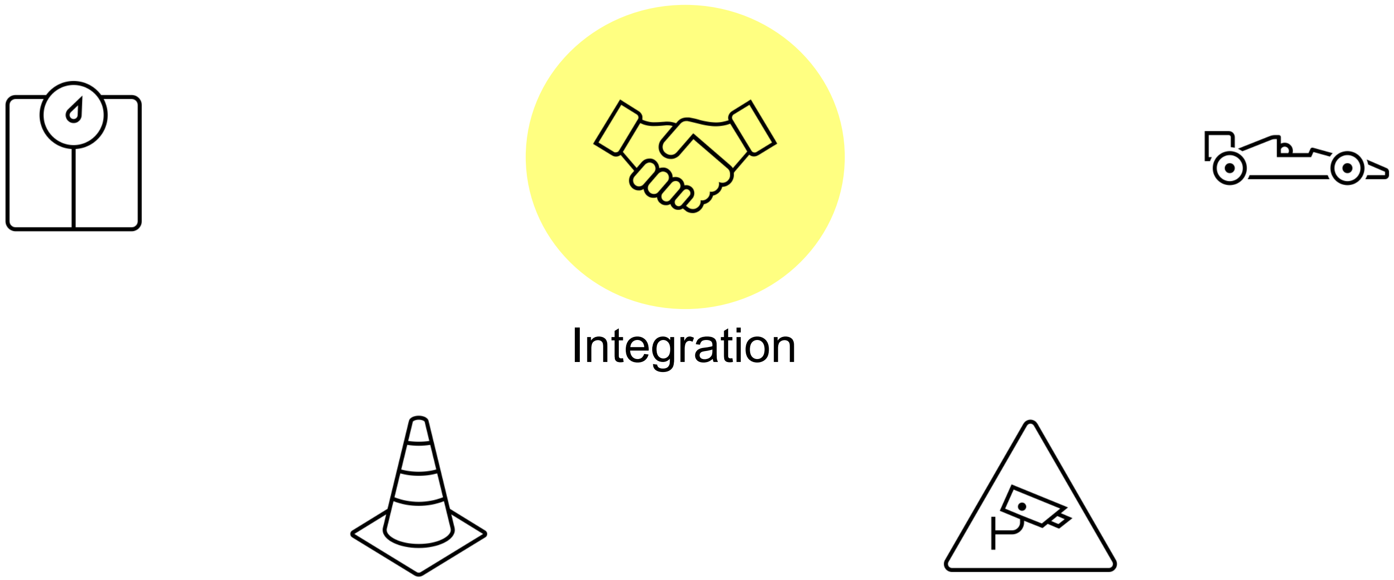
Key Goals

- Integrated with Team 504
- Autonomous
- Maintain velocity
- Minimize inertial losses

Customer Needs

Lightweight

Customer Needs



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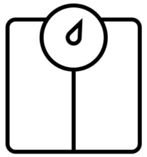
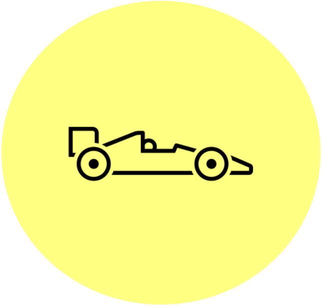
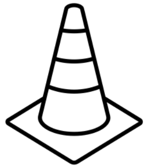
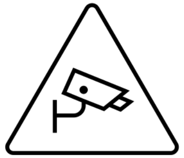




Maintain Velocity





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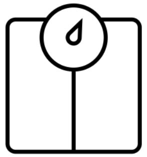
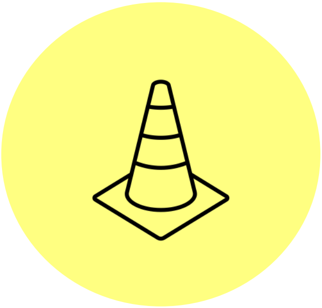
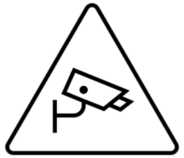




Obstacles



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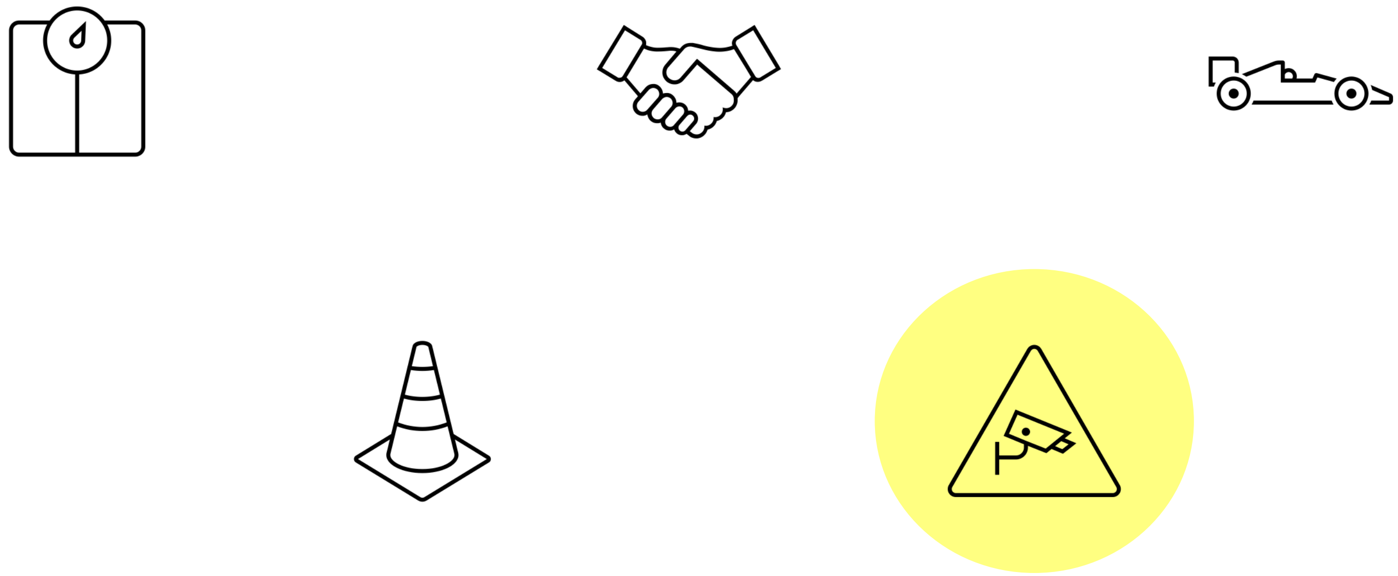
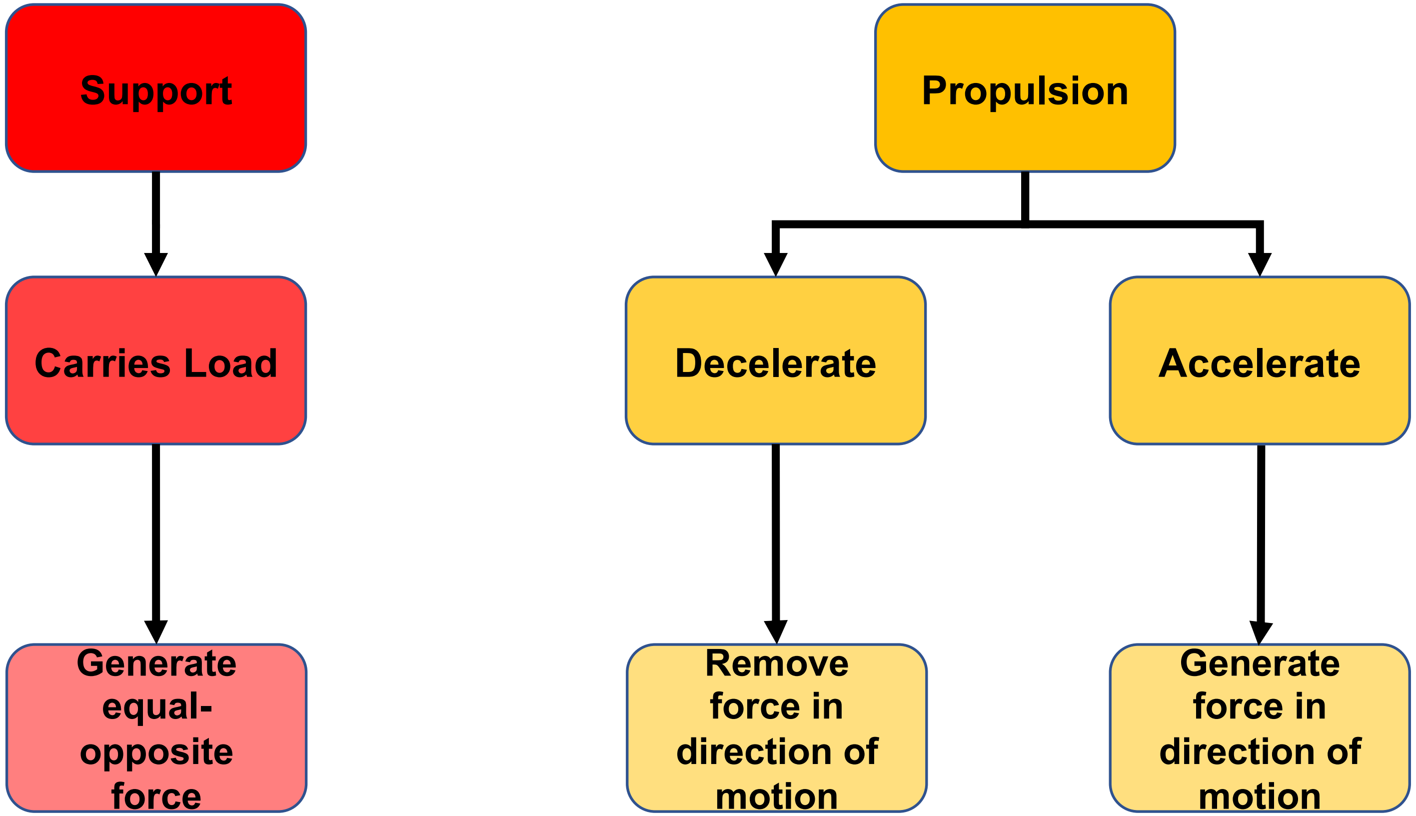


Camera Placement

Functional Decomposition

Hierarchy Flow Chart



Functional Decomposition

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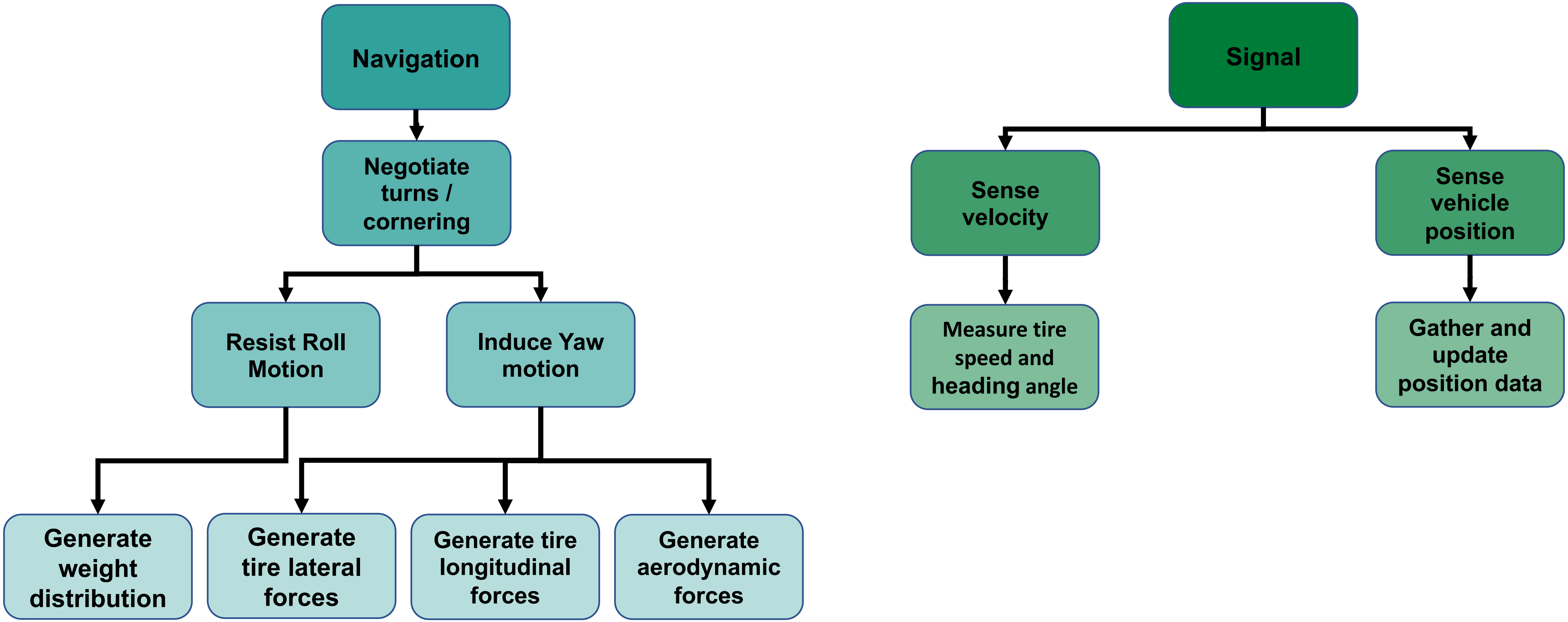

Targets & Metrics

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- Carries Load
- Resisting Roll Motion
- Inducing Yaw Rate
- Top Speed

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- Carries Load
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Targets & Metrics

Carries Load → Resisting Roll Motion → Inducing Yaw Rate → **Top Speed**

Concept Generation

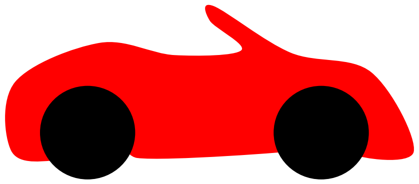
Morphological Chart

	IDEA 1	IDEA 2	IDEA 3
STEERING	Ackermann	Differential	Omnidirectional
SOFTWARE	ROS 1	ROS 2	-
PATHING	Model Predictive Control + PID	Sample Based Model Predictive Optimization	Genta
BRAKING	Resistive	Regenerative	Reverse

Morphological Chart

Brainstorming

Biomimicry



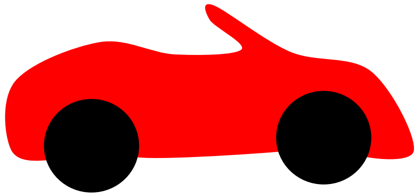
Concept Generation

1. Sensors attached to balloon/kite that floats above the car
2. Reinforcement learning for object avoidance
3. Lengthen wheelbase to increase efficiency (a to CG length)

Morphological Chart

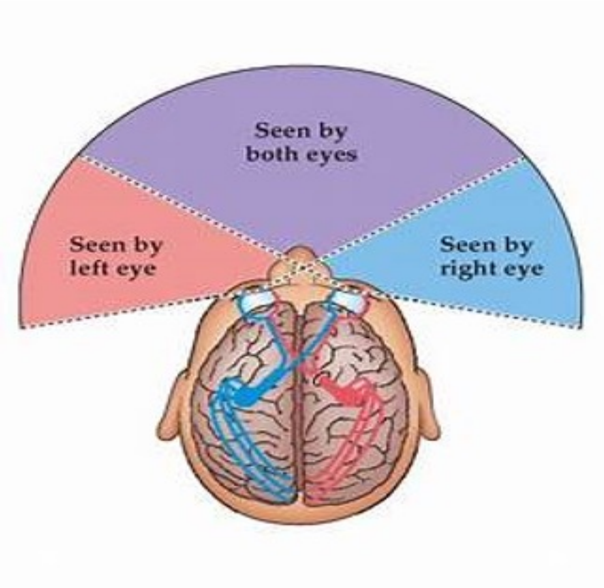
Brainstorming

Biomimicry

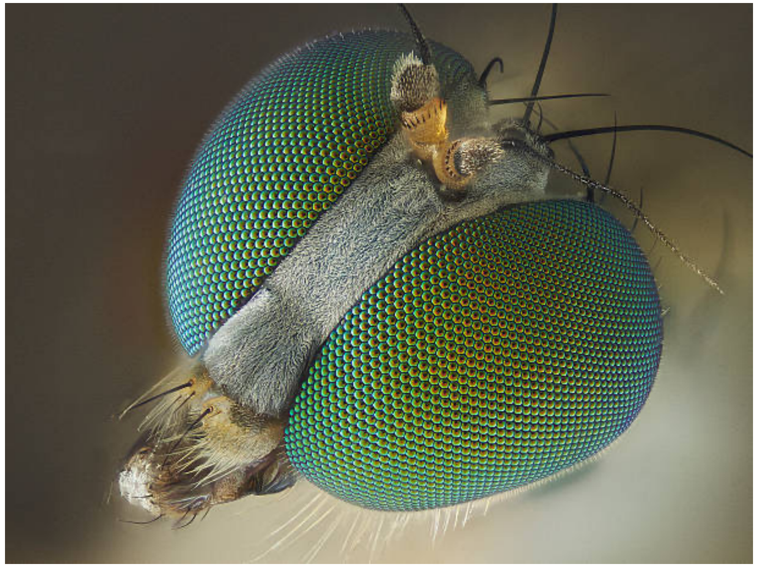


Concept Generation

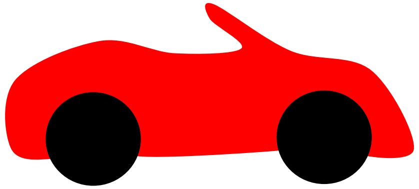
Morphological Chart



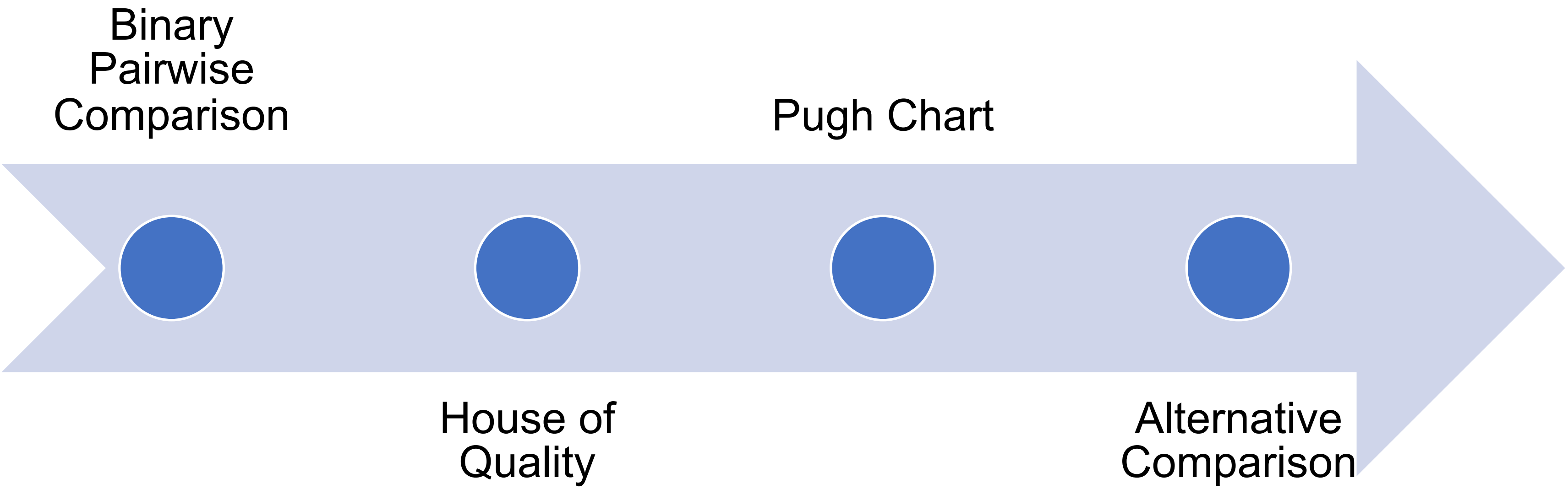
Brainstorming



Biomimicry



Concept Selection



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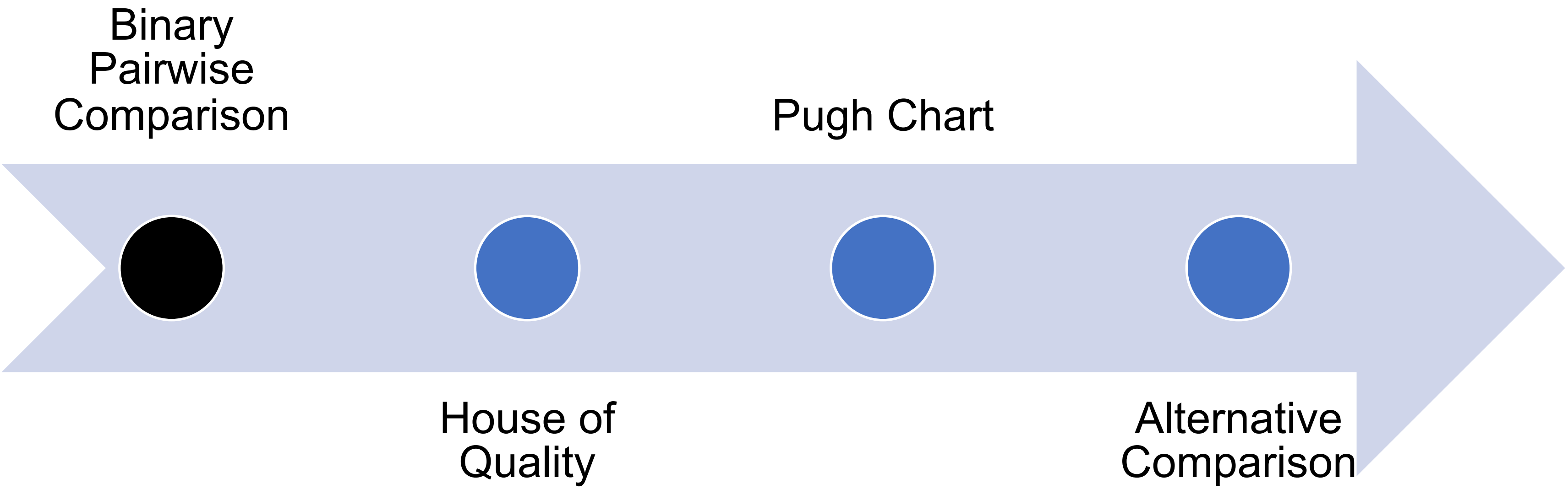

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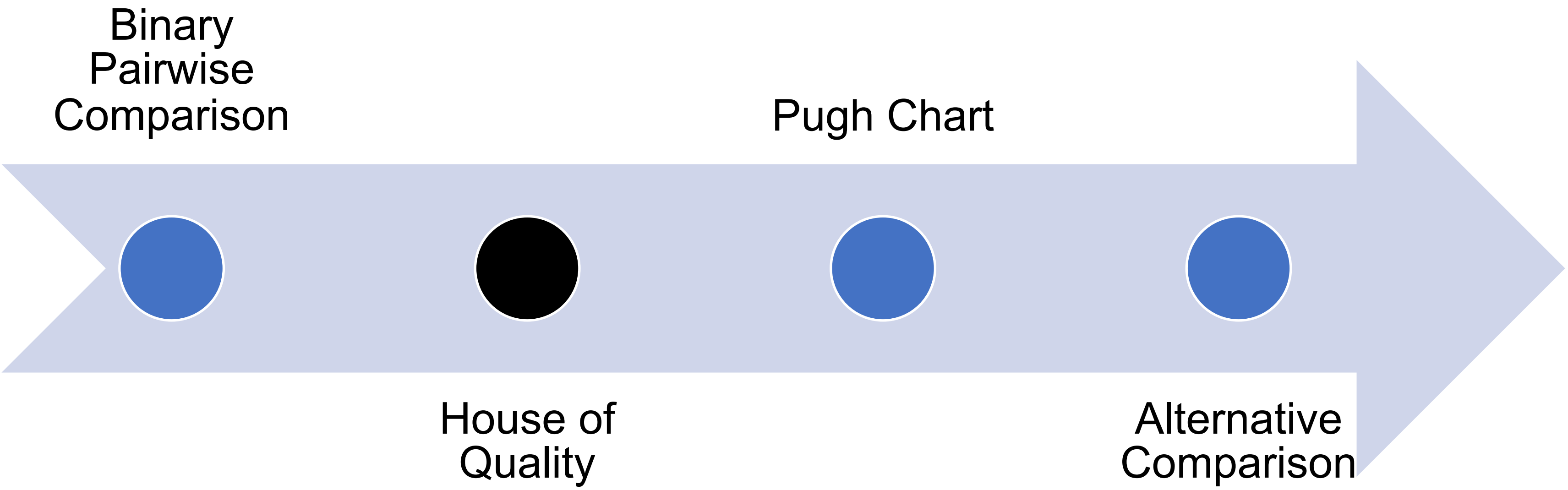
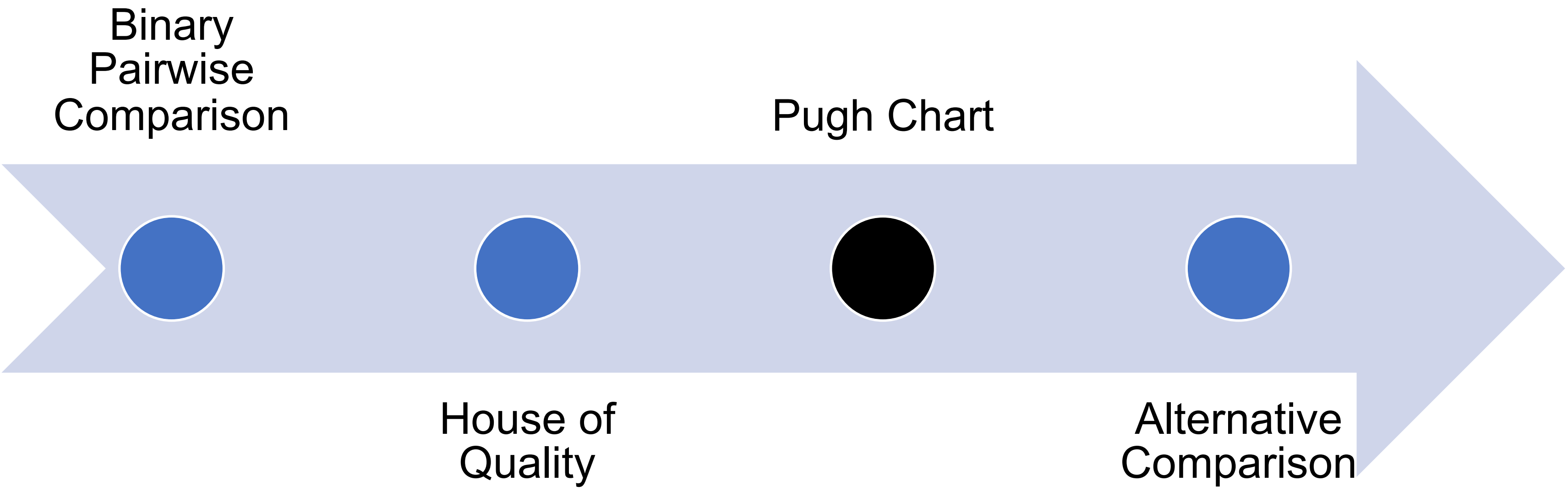


House of Quality

		Engineering Characteristics												
Improvement Direction		↑	↑	↓	↓	↓	↑	↑	↓	↑			↑	↓
Units		s	m	kg	cm	PPR	Hz	rad/s	rad/s	m/s	J	Iterations	m/s	m
Customer Requirements	**Importance Weight Factor**	**Generates Force**	**Removes Force**	**Carries Payload**	**Fits Payload**	**Measure tire speed**	**Gather & Update position data**	**Resist roll motion**	**Induce yaw rate**	**Top speed**	**Battery size**	**Simulation runs**	**Maintained velocity**	**Turning radius**
1) Optimized Pathing	3	3	3			3	9		3	3	9	9	3	9
2) Point A to B in 5 minutes	2	9	3	3		9	9		3	9	9	3	3	3
3) Autonomously Controlled	4	3	3			9	3	3	9	3	1	9	9	3
4) Reduce inertial losses	7	9	9	3	3	9	3		3	9	9	9	9	9
5) Carries Payload	1	9	9	9	9			3	1		3		9	1
6) Handles Road Grade	0	3	3	1			3	3				3	9	1
7) Simulated Environment	8	3	3			9	3		9	3		9	9	3
8) Maintaining optimal velocity	5	9	9	3		9	9	1	3	9	9	9	9	9
9) Fully Integrated with Team 504s Project	6	3	3	0	0	0	9	0	3	0	3	3	9	3
Raw Score	**2213**	198	186	51	30	243	201	20	178	171	178	267	294	196
Relative Weight %		8.947	8.405	2.305	1.356	10.981	9.083	0.904	8.043	7.727	8.043	12.065	13.285	8.857
Rank Order		5	7	10	11	3	4	12	8	9	8	2	1	6

Concept Selection



Pugh Chart

86. Completely even weight distribution

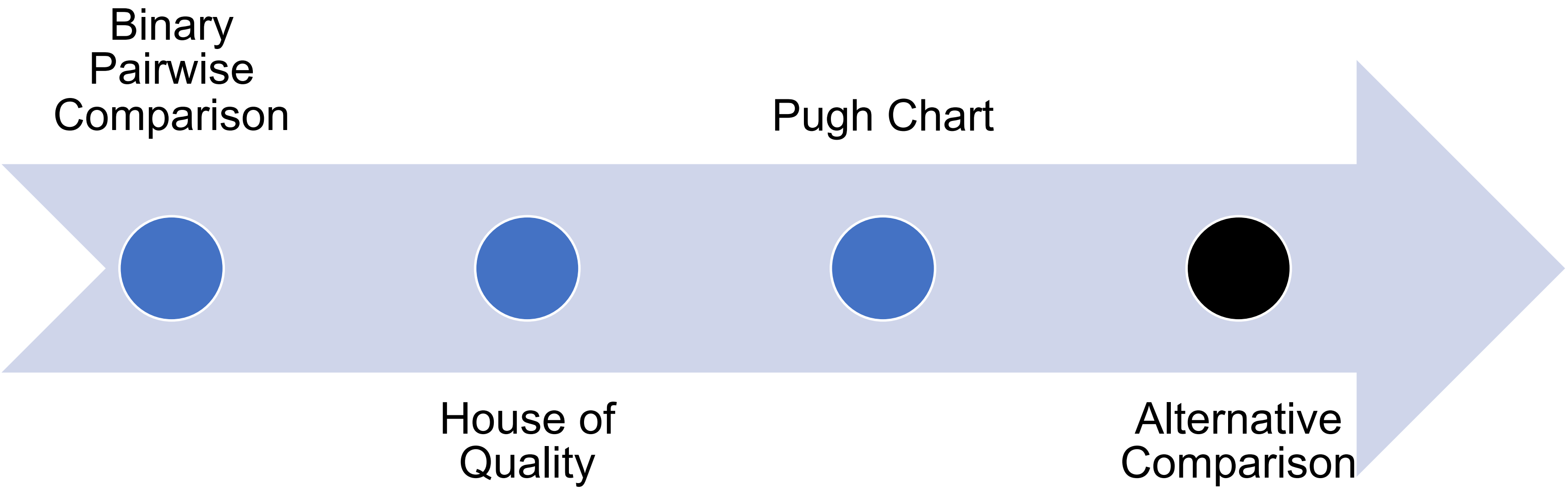
28. Ackermann-ROS2-MBPC + PID-Resistive

29. Ackermann-ROS2-MBPC + PID-Regenerative

47. Omnidirectional -ROS2-MBPC + PID-Regenerative

		Concepts		
Selection Criteria	86	28	29	47
Generates Force	Datum	S	+	+
Removes Force		S	+	+
Carries Payload		S	S	S
Fits Payload		S	S	S
Measure Tire Speed		S	S	-
Gather and Update Position Data		S	S	-
Resist Roll Motion		S	S	S
Induce Yaw Rate		+	+	-
Top Speed		S	-	-
Battery Size		S	+	+
Simulations		+	+	+
Maintain Velocity		+	+	-
Turning Radius		S	S	-
	# of Plus(+)	3	6	4
	# of Minus(-)	0	0	6

Concept Selection



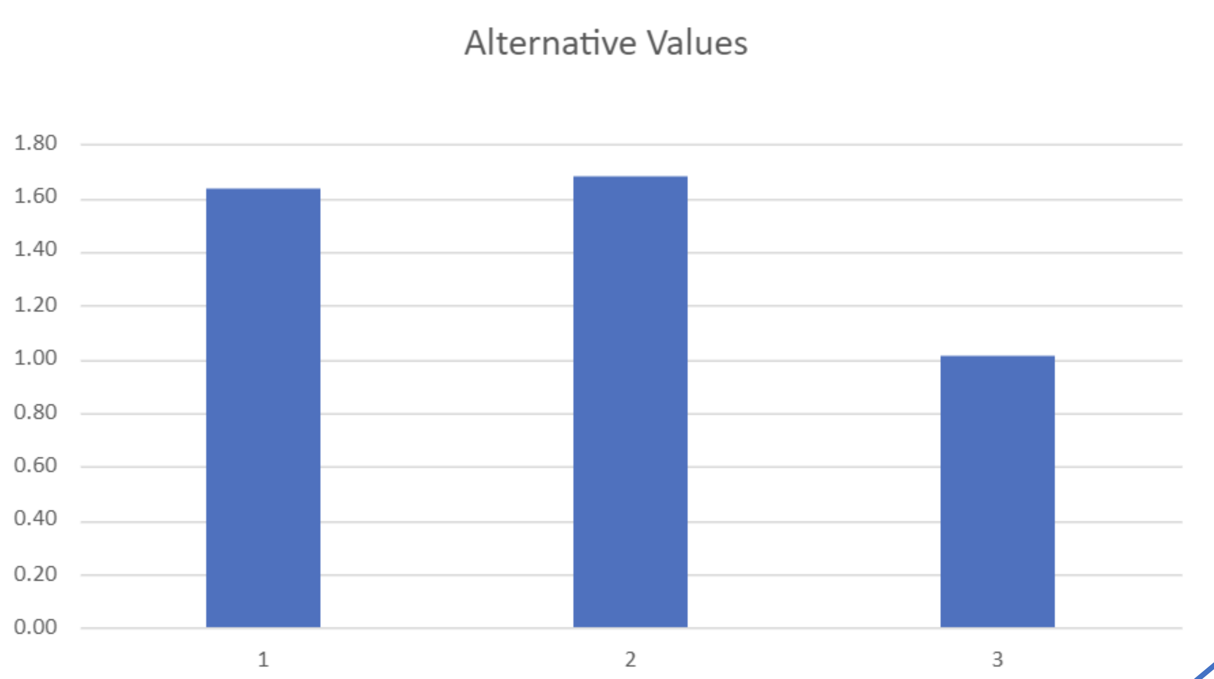
Alternative Comparisons

	Maintained Velocity			
Concepts	# 28	# 29	# 47	Avg
# 28	1	1	5	2.33
# 29	1	1	5	2.33
# 47	0.2	0.2	1	0.47
Total	2.20	2.20	11	

	Simulation Runs			
Concepts	# 28	# 29	# 47	Avg
# 28	1	1	1	1
# 29	1	1	1	1
# 47	1	1	1	1
Total	3	3	3	

	Measure Tire Speed			
Concepts	# 28	# 29	# 47	Avg
# 28	1	1	7	3
# 29	1	1	7	3
# 47	0.14	0.14	1	0.43
Total	2.14	2.14	15	

Alternative Comparisons



Concept	Alternative Value
# 28	1.64
# 29	1.68
# 47	1.02

29. Ackermann-ROS2-MBPC + PID-Regenerative

Future Work

- Simulations (MATLAB, Gazebo, ROS, Adams)
- Estimate Budget Expenses
- VDR3 Poster Board
- Prepare for in-person sponsor meeting

TEAM 503

Hardware in Loop 1/10 Scale Automobile

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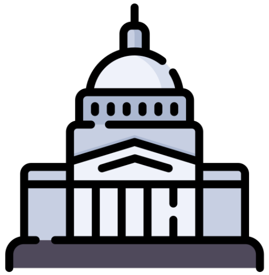
Markets

Primary

- Private and public government agencies
- CIA, FBI, etc.



Secondary

- Original Equipment Manufacturers (OEMs)
- Spyware enthusiasts
- Private search teams

Customer Needs

Question/Prompt	Customer Statement	Interpreted Need
What is the estimated weight of the design?	Must be able to carry a payload without impacting maneuverability.	Focus primarily on a lightweight design to compensate for the extra weight that will be added.
Is the design based on the F1tenth competition requirements?	Yes, but improve on the design to gear towards the CIA requirements.	Follow F1tenth specifications but optimize being able to keep up with a tracked target.
What is the estimated cost of the design?	F1tenth bill of materials approximates $3500.	Work adjacent with team 504 to combine budgets and determine which team is financially capable of buying what items.
What is the general design of the obstacles?	min: 12x12x30cm max: 35x32x30cm LiDAR perceivable material	Design the obstacle out of cardboard to be detectable by LiDAR, starting at one of the size extremes.

Question/Prompt	Customer Statement	Interpreted Need
Are the obstacles static or dynamic?	Both	Design for static obstacles first, then make the design more complex.
Define failure to avoid an obstacle?	The goal is to keep up with a target being tracked so, ideally, the design should not crash.	LiDAR specifications: detection range = 10 m scanning frequency = 40 Hz angular resolution = 0.25°
What speed is the vehicle operating at?	The average speed on a track is 35mph while the vehicle can go upwards of 70mph. Cornering and maneuverability affect speed.	Determine an optimal speed that does not sacrifice maneuverability. An even weight distribution can achieve an infinite critical velocity; however, acceleration will compromise weight distribution.

Functional Decomposition

Cross Reference Table

	Propulsion	Support	Signal	Navigation	Total
Generate force in direction of motion	X				1
Remove force in direction of motion	X				1
Generate Equal & Opposite Force		X			1
Generate Weight Distribution	X	X		X	3
Generate tire lateral forces				X	1
Generate tire longitudinal forces				X	1
Generate aerodynamic forces	X			X	2
Measure light Reflection from object			X	X	2
Measure tire speed and heading angle data			X		1
Measure and update position data			X		1
Total	4	2	3	5	

F1Tenth Requirements

Restricted Class allows only cars that meet the following constraints:

1. The vehicle is constructed according to the official bill of materials. The teams are allowed to use components of similar or lower specifications.
2. Each vehicle will be inspected as a part of qualification whether it meets the criteria. In case the criteria are not met, the vehicle is moved to the Open Class.
3. **F1TENTH Competition is a battle of algorithms. Any hardware that should turn the odds in your favor is not allowed**.
4. *Chassis*: Any chassis listed as *1:10 scale* car is allowed. Preferably **1:10 Traxxas** (e.g., TRA74054, TRA6804R, TRA68086), but generally, any chassis with similar dimensions is allowed. Both 4WD and 2WD are permitted.
5. *Main Computation Unit*: **Nvidia Jetson Xavier NX**, Equivalents to the Nvidia Jetson NX (e.g. Nvidia Jetson TX2, Nvidia Jetson Nano), or anything of equal or lower GPU and CPU specification is allowed. Examples of possible computation units could be: Raspberry Pi, Arduino, Beaglebone.
6. *LiDAR*: **Hokuyo UST-10LX**, its equivalent, or anything of lower specifications is allowed. The main observed characteristics are: detection range (10 m), scanning frequency (40 Hz), and angular resolution (0.25°).
7. *Camera*: Both *monocamera* (e.g. Logitech C270, Logitech C920, Raspberry Pi Camera Module V2, Arducam) and *stereokameras* (e.g. Intel Realsense, ZED) are allowed.
8. *Engine*: Only brushless DC motors are allowed. The **Velineon 3500 kV**, its equivalent, or anything of lower specifications regarding power and torque are allowed.
9. *Other sensors*: Other sensors (IMUs, encoders, custom electronic speed controllers) are not restricted. Indoor GPS sensors (e.g. Marvelmind) are not allowed. In addition, in the spirit of the competition, components with significant internal computation power are prohibited.

Nicholas