2.810 Fall 2024

Steering Design Review

Alex Brush, Matthew Groll, Colin Kong,
Yong Ng, Alex Zhao

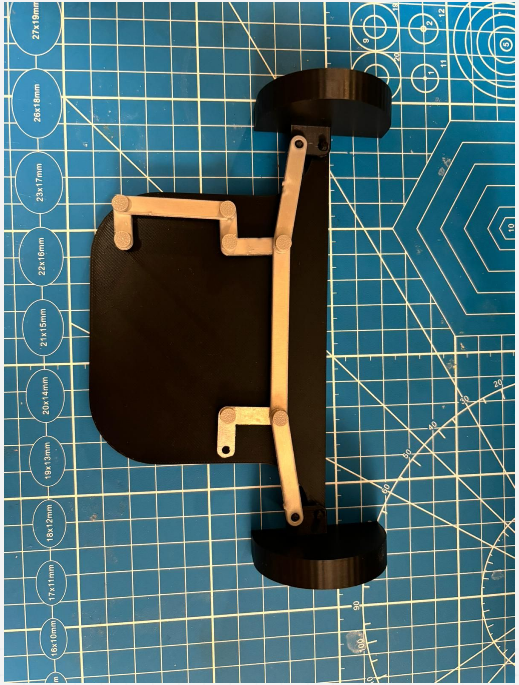
Steering Team Overview

- 1st round prototype

- Key dimensions frozen with chassis & suspension
    - Track Width
    - Wheelbase
    - Aspect Ratio

- Major design parameters selected
    - Parallel linkage
    - Ackermann steering (angles selected)

- High level interference check with suspension
    - Steering arms
    - Suspension arms
    - Uprights



Design Considerations

Aspect Ratio L/T

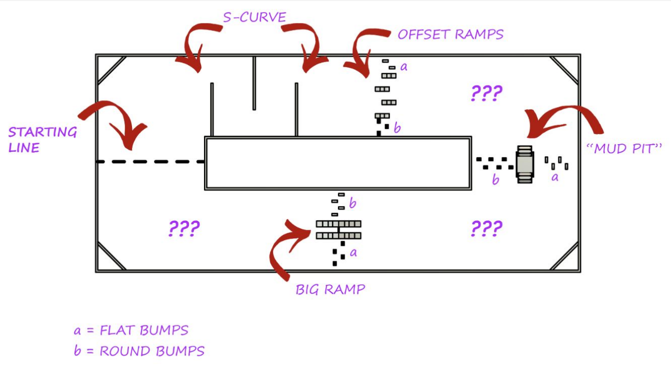
Low: Responsive. High: Stable

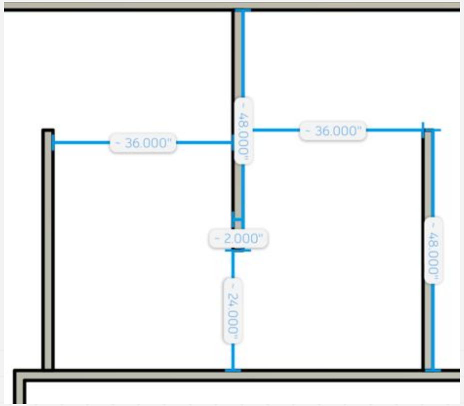
Ackermann steering geometry (low speed)

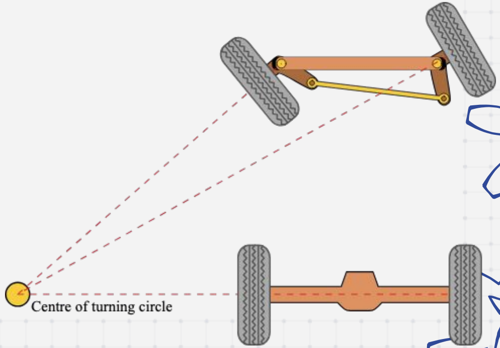
Inner δ = atan(L/(R+(T/2))

Outer δ = atan(L/(R-(T/2))

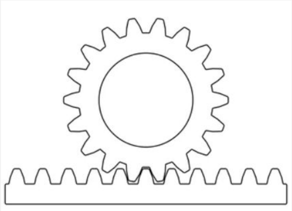
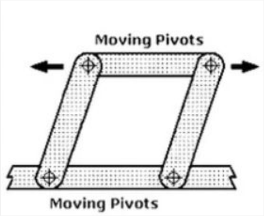
Wheelbase (L)	10 in.
Track Width (T)	6.5 in.
Turn radius (R)	12 in.
L/T Ratio	~1.5
Inner δ	49 deg
Outer δ	33 deg





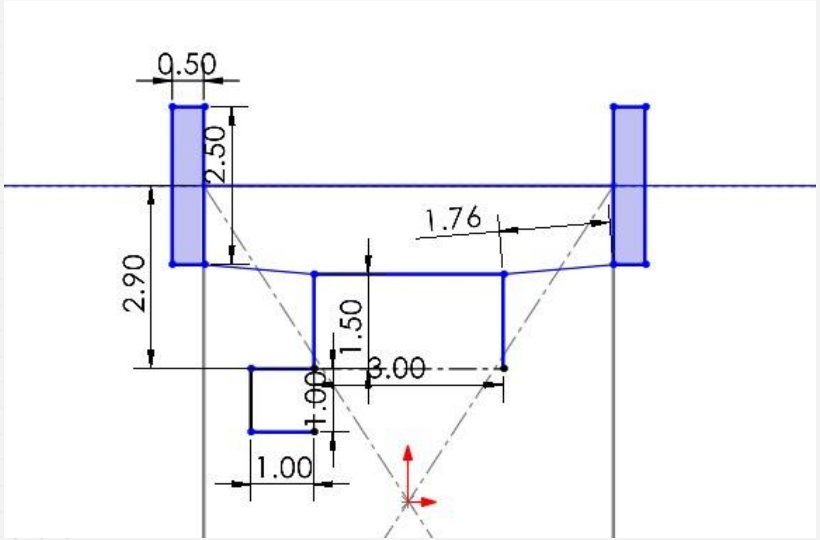


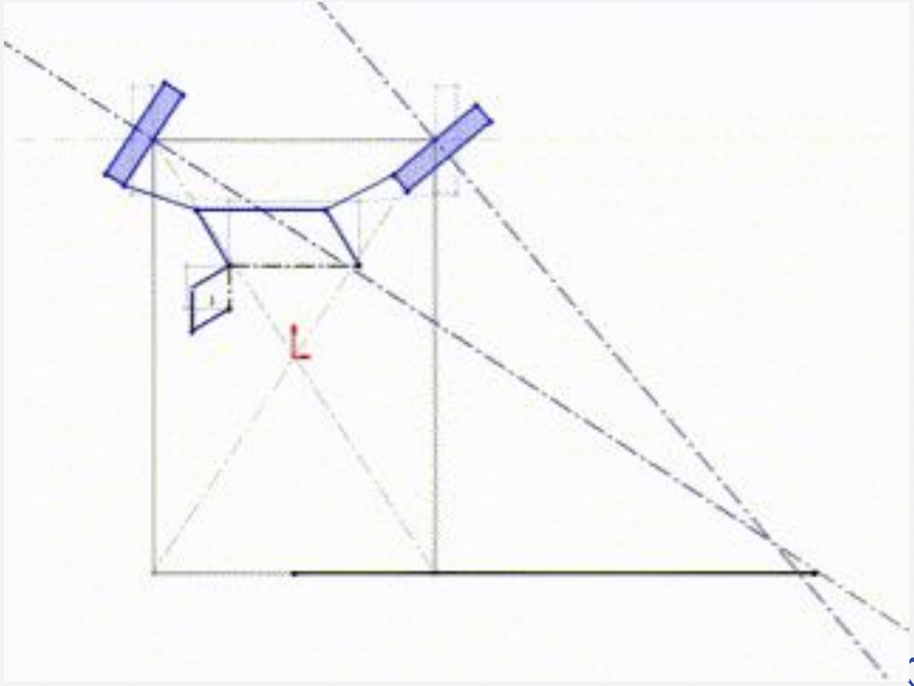
Mechanism Design Considerations

Geometry		Pros	Cons
Rack and Pinion		• Few parts • Small footprint • Ackermann steering	• Difficult to manufacture • Quality control
Parallel Linkage		• Easy to manufacture • Reliable • Ackermann steering	• Large footprint • Many parts

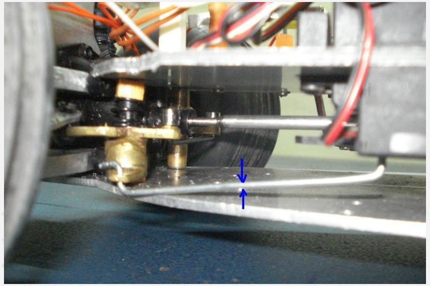
Design Model

Minimum Turning Radius: 12 in



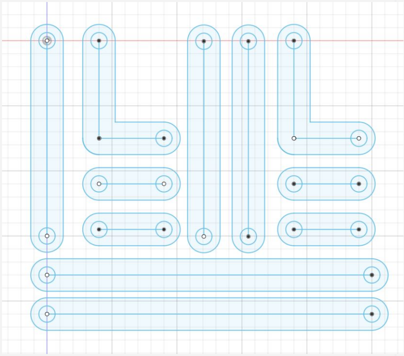


Attachment Design Considerations

Non-Rigid Attachment Method		Pros	Cons
Rod Ends		• High precision • Defined movement • Adjustable	• Complicated design • Large footprint
Metal Wire (can replace tie rod)		• Ease of design • Small footprint • High allowable tolerance	• Less consistent • Challenging SOP for assembly and re-assembly

DFM

- Material Selection: Aluminum
  - Good for steering linkage → High strength-to-weight ratio, ease of machining, accessibility, capable of batch processing
- Manufacturing Process: Waterjet Cutting
  - Precise, tight tolerances, no heating concern
  - Low setup and cycle time (~ 3-5 mins per set)
    → 5 hours production estimate for 50 cars
  - Automatic Process → Possible parallel processing
  - Low tooling cost, Minimal material waste, High flexibility
  - Good repeatability, tool availability in LMP shop



- Quality Control
  - Waterjet Precision: ±0.005" → Sufficient for RC car components
  - 20 ~ 30 sets can be produced in single run and with one aluminum bulk sheet
    - Minimal setup, low variances in parts produced
  - Manual caliper measurement incorporated into SOP to ensure consistency

DFM

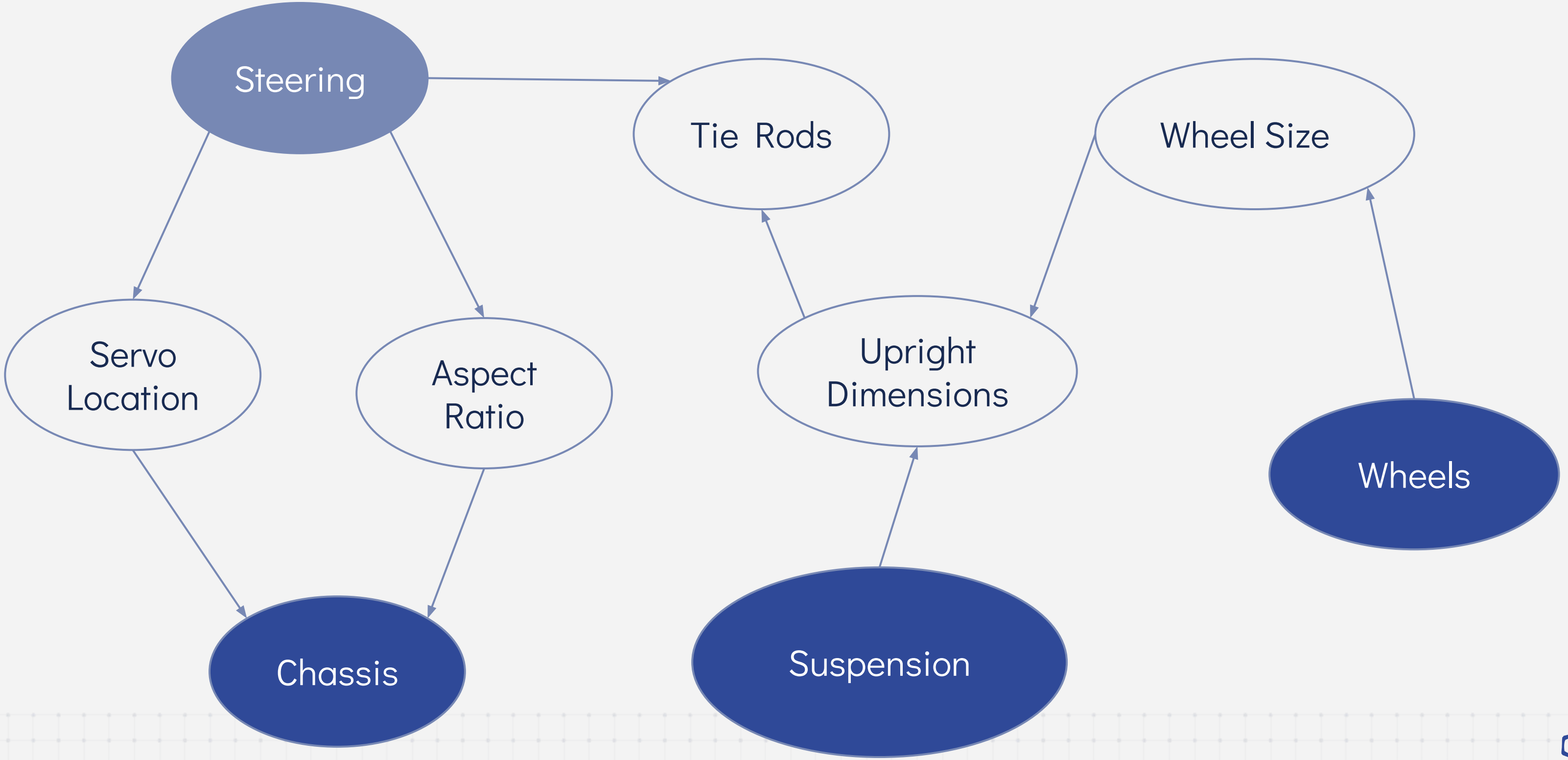
Tool & Process	Usage	Progress
3D printer	Rapid prototyping for function validation	N/A
Waterjet Cutter	Cutting 0.0625” Aluminum sheet into linkages	80%
CNC Mill	TBD, servo horn, improve linkage tolerance	N/A
Belt Sander, polishing	Deburr, smooth edges, finish	95%
Wire bending	Non-rigid attachment points to chassis, uprights	N/A
Caliper	Metrology, quality control	N/A
Screwdriver & Lubrication	Installation on the car assembly, ensure smooth transmission and rotation	100%

Procurement Plan

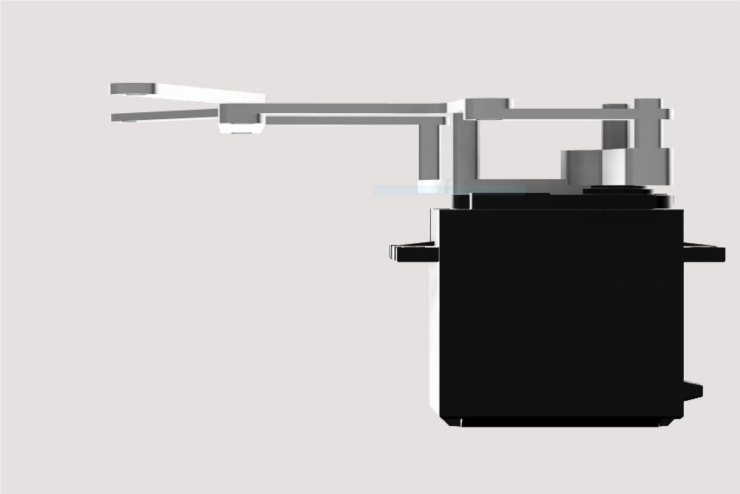
#	Product	Quantity	Description
1	Aluminum Sheet 0.0625”, 6061-T6	1 unit	Course-Provided Material
2	Servo Futaba s3003	50 units	Course-Provided Material
3	Steel wire ~ 2 inches	100 units	Course-Provided Material
4	Stainless Steel Shoulder Bolts 3/16 in	500 units	Planning
5	Lock Nuts 3/16 in	400 units	Planning

Cost Estimation ~$35.00 for each

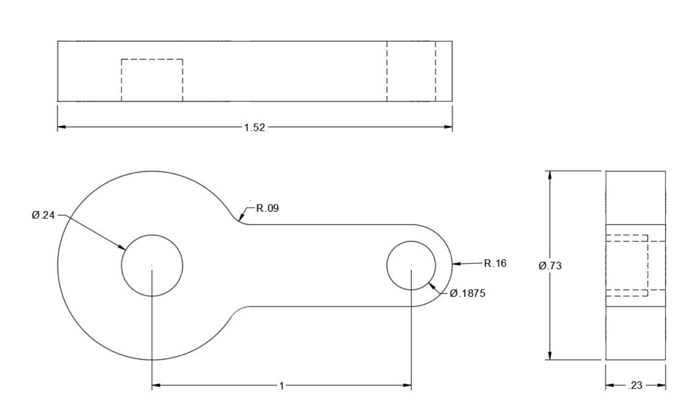
Critical Features/Mating Points

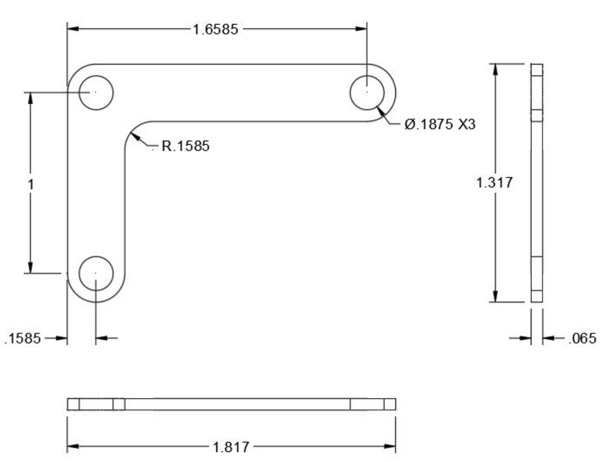


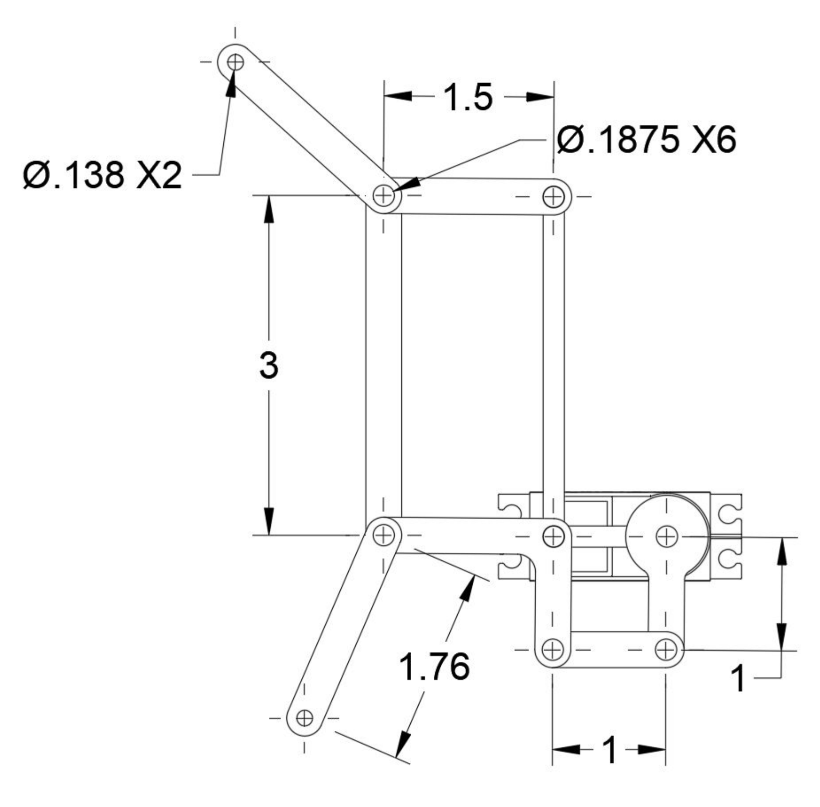
CAD Model



Drawings

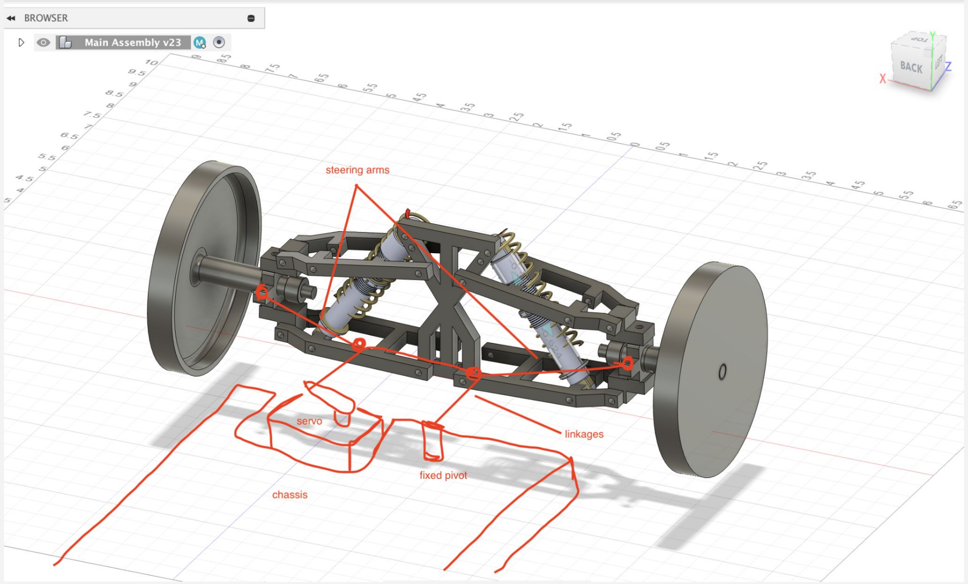

1.52
Ø.24
R.09
R.16
Ø.1875
Ø.73
1
.23

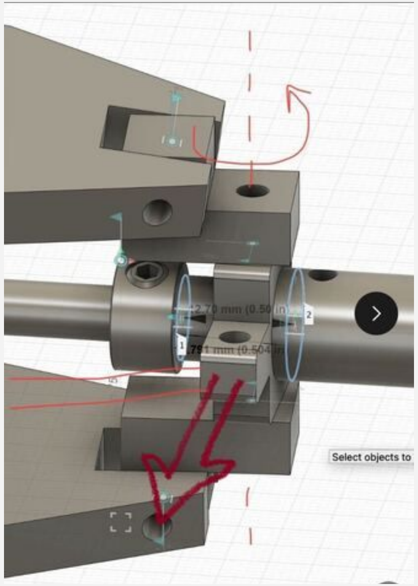

1.6585
Ø.1875 X3
R.1585
1
1.317
.1585
.065
1.817


1.5
Ø.1875 X6
Ø.138 X2
3
1.76
1
1

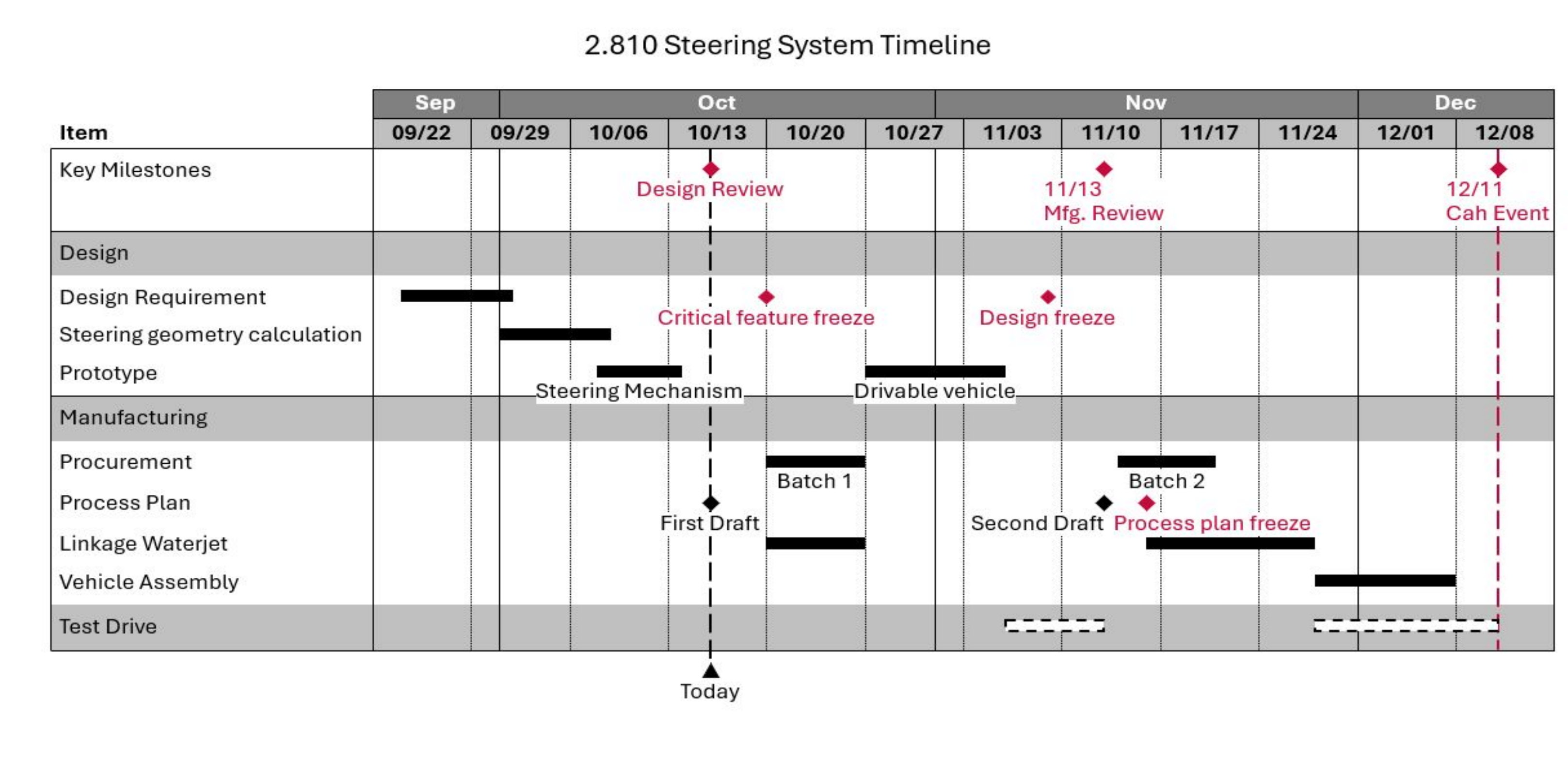
High Level Interference Checks

To-do: Align our CAD models, and physical V2 prototype to check fit





Strategic Plan



Future Work (Immediate)

Subgroup Compatibility:

- Chassis linkage + servo mounting
- Suspension/Wheels mounting and compatibility

Procure parts for functional prototype

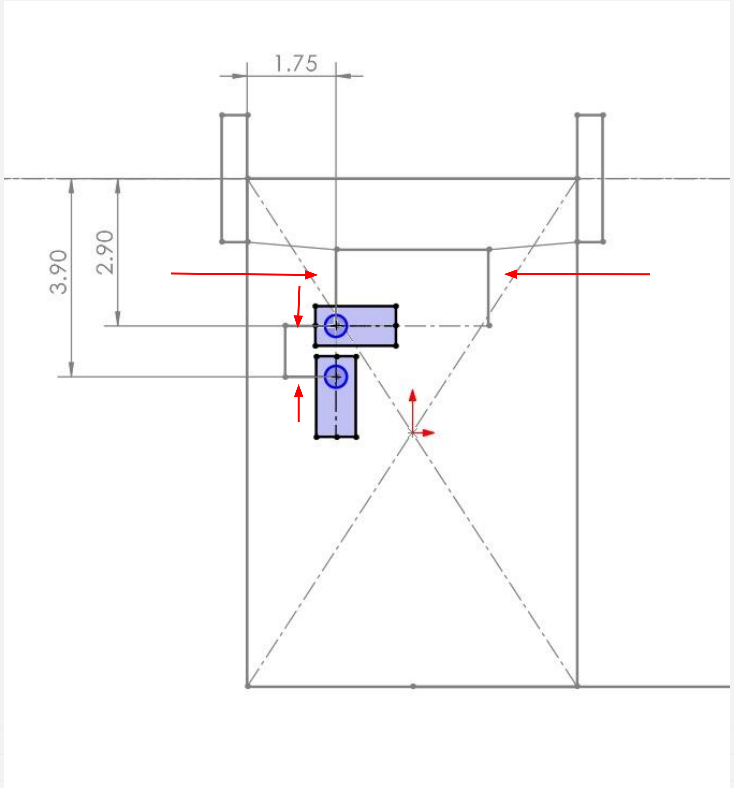
Finalized Prototype

- Create prototype with all final dimensions to interface with suspension + wheels + chassis for testing

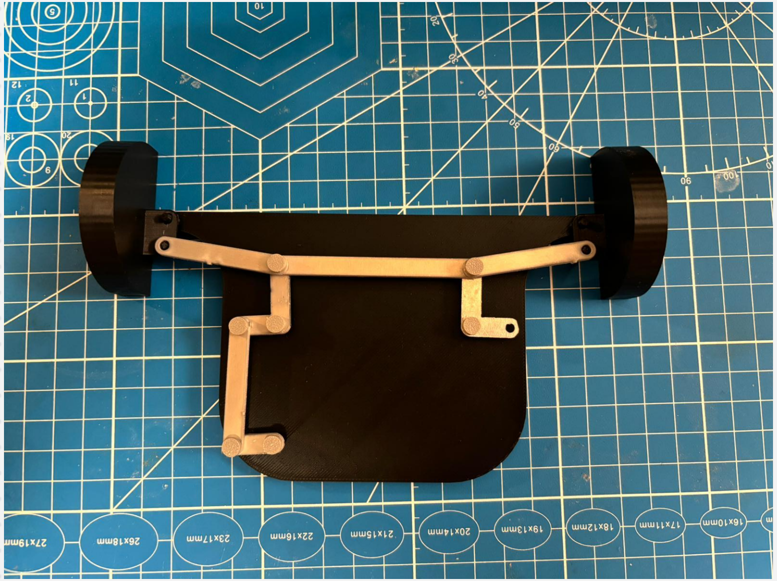
Thank you

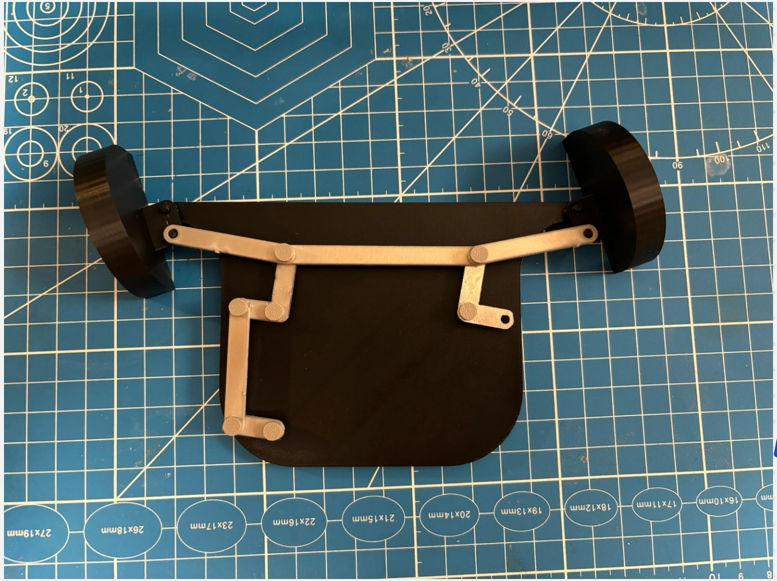
Any questions or feedback?

Appendix: Servo Locations



Appendix: Prototype





Appendix: Design Extensions

Scrub radius

- Correlated with steering effort

Kingpin angle/steering axis inclination

- Self-centered steering
- Straight-line performance

Caster

- Similar effects as SAI. Keep positive

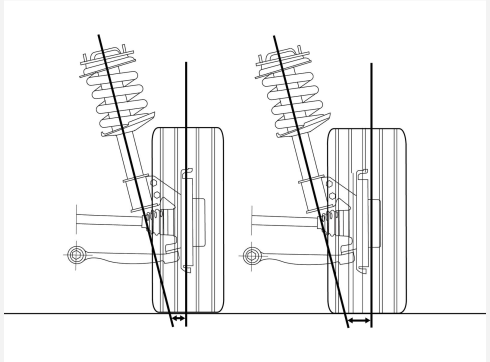
Camber

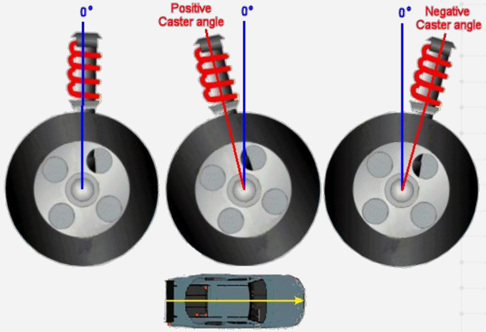
- Impacts mainly high speed corners

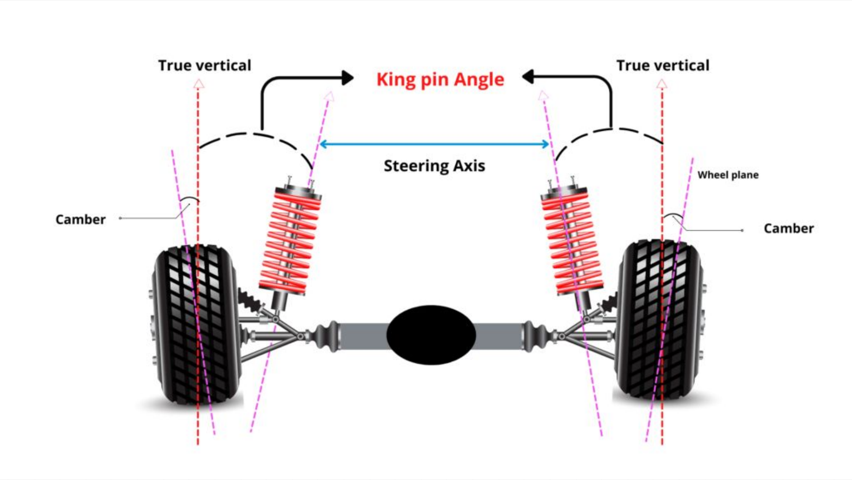
(Assumed near vertical OK)

Toe

- In: stability. Out: responsiveness.







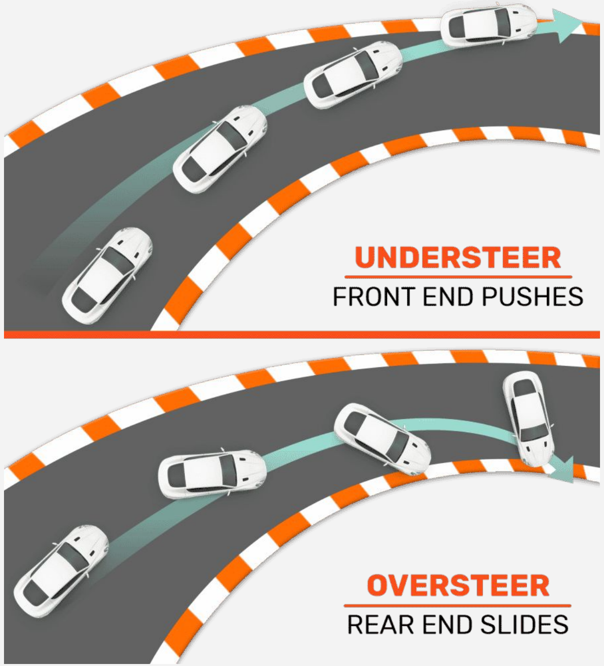
Appendix: Design Extensions

Oversteer/Understeer

To-do:
Determine weight distribution
Finalize suspension geometry
Tire material
Practical Tests

Reduce Oversteer
Decrease Ackermann, Toe-in, Decrease Steering Sensitivity

Reduce Understeer
Increase Ackermann, Toe-out, Increase Steering Sensitivity



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Steering Manufacturing Review

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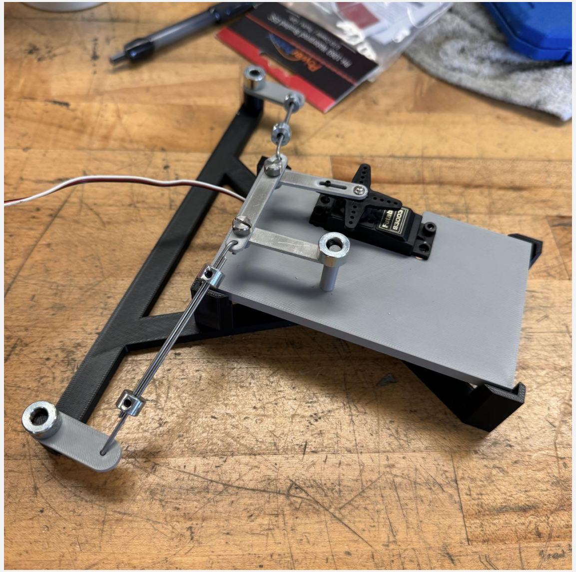
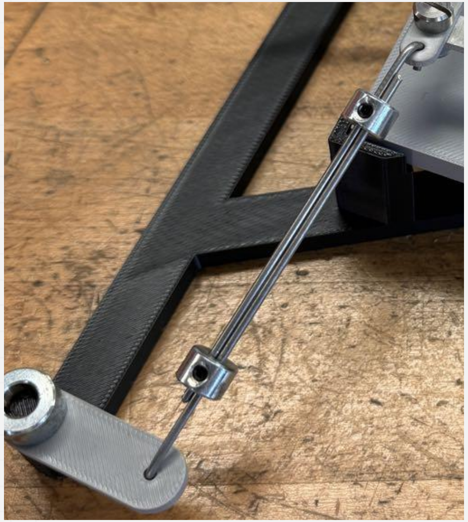
Steering Team Overview

- Key elements of the prototype worked well
- Confirmed vertical compliance and adjustability for installation
- Small batch production done and timed
    - (Manufacture timed, assembly estimated)
- Wire bending challenging and arbitrary. Overall process and setup times were high
    - Jigs built to optimize and standardize
- Hard to gauge performance without testing. Hoping to see turning ability on a test car, if time allows



Working prototype

Design Changes/Considerations



Adjustable wire links
Mock uprights pivoting

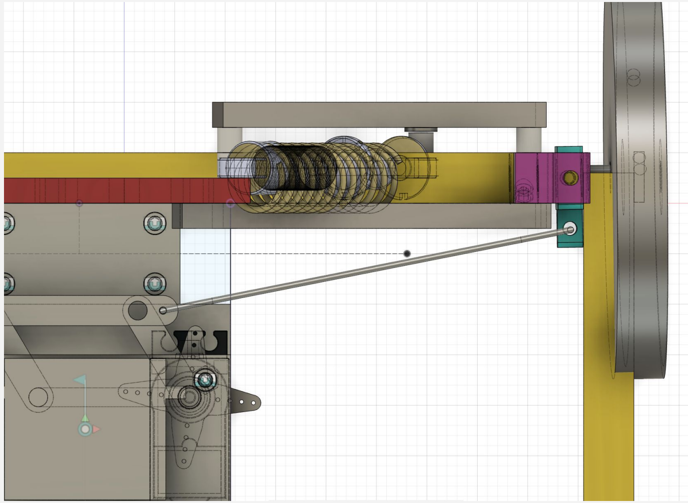
Servo horn mounting
Servo to chassis mounting

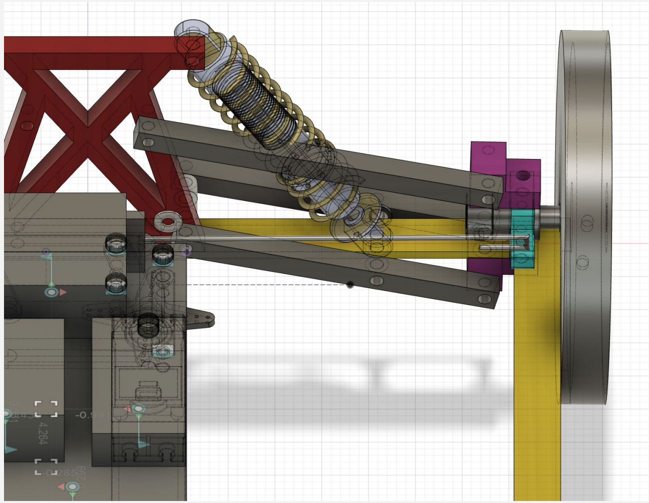
Fixed pivot
-> standoff

Design Changes/Considerations

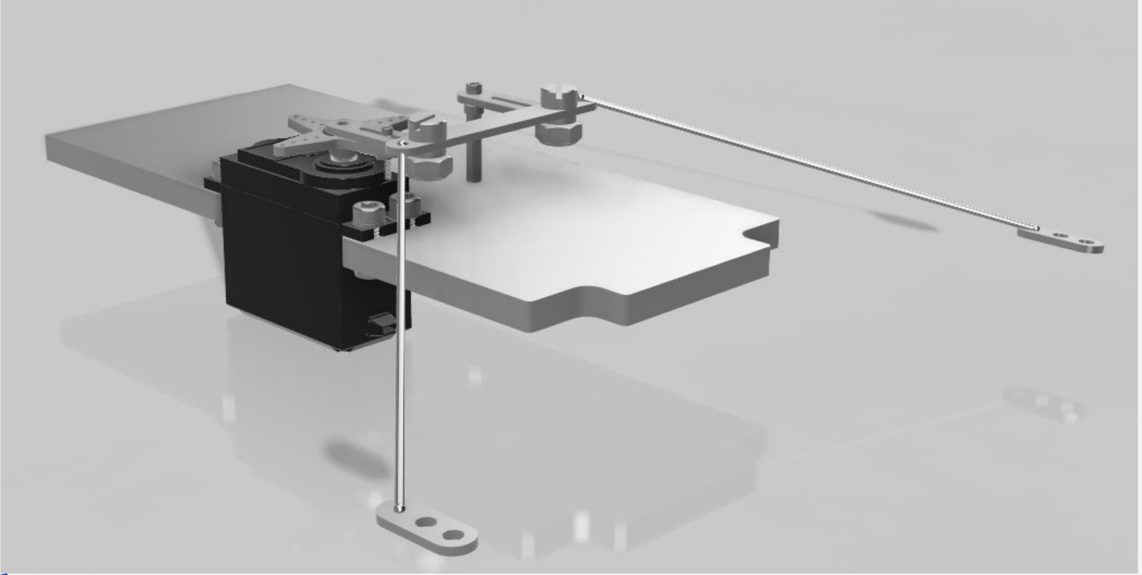
Geometry change: Wheelbase x Track Width of 10” x 6.5” -> 10” x 10”

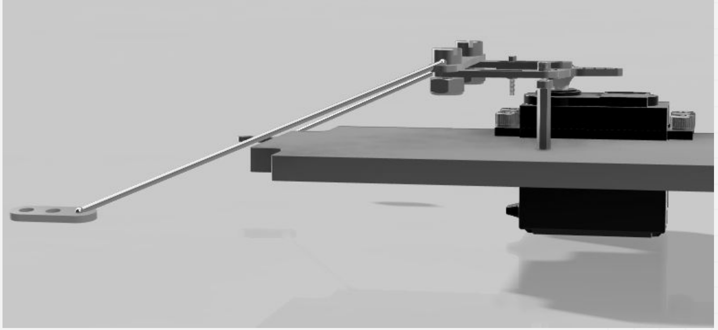
Links modified and shifted, but no fundamental design changes on account of geometry

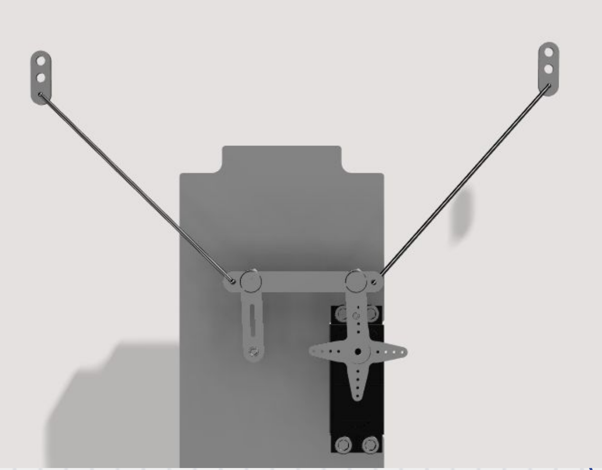




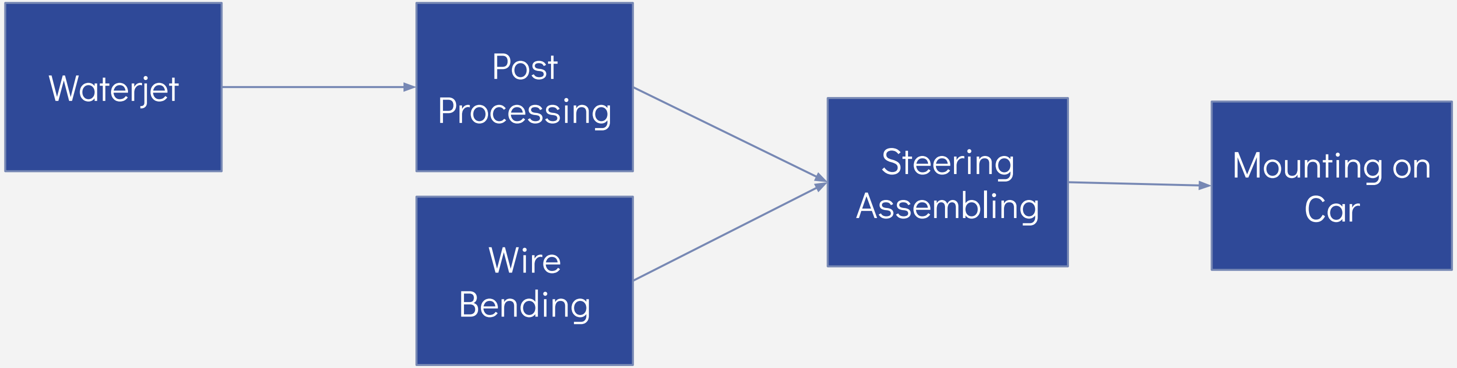
CAD Renderings







Manufacturing System



Process	Setup Time [min]	Operation Time [min]	Total Process Time [min]
Waterjet	7.58	4.00	11.58
Post Processing	0.67	2.40	3.07
Wire Bending	2.83	4.73	7.56
Steering Assembling	0	1.43	1.43
Mounting on Car	0	3.70	3.70
Overall	**11.08**	**16.26**	**27.34**

High Level Process Plan

Process Plan	Group: Steering	Part Name: Steering system	Version: 1
Revision Date: 11/12/2024		Group Members in Attendance: Alex B, Alex Z, Colin, Matthew, Yong	
Approval Date:			
Application of previous lessons learned:			

#	**Process**	**Setup Time (minutes)**	**Process Time (minutes)**	**Notes**	**Total time 40 cars (minutes)**	**Total time for 1 million cars (minutes)**
1	Waterjet Linkages	7.58	4.00	Cut 5 Linkages for each unit	167.58	4,000,007.58
2	Post Process Linkages	0.67	1.60	Sand edges and Ream Holes	64.67	1,600,000.67
3	Wire Bending	2.83	4.73	Ream collars, Cut wire and Bend wire	192.17	4,733,336.17
4	Assemble Steering Subsystem	0.00	1.43	Attach linkages, wire and servo	57.33	1,433,333.33
5	Mount to Car	0.00	3.70	Attach to chassis and suspension	148.00	3,700,000.00

	40 cars	1 million cars
Total time (hours)	**10.50**	**257,777.96**
Lab time (hours)	**8.02**	**196,777.93**

Low Level Process Plan: Wire Bending

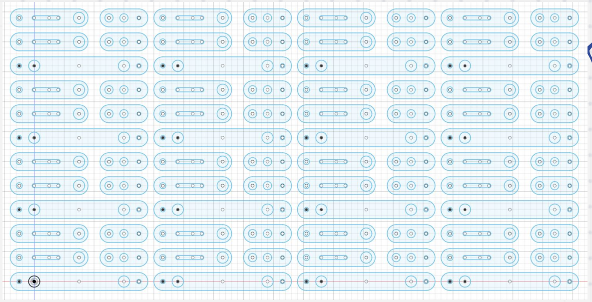
Process Plan	Group: Steering	Part Name: Wire Bending	Version: 1
Revision Date: 11/5/2024		Group Members in Attendance: Alex B, Alex Z	
Approval Date:			
Application of previous lessons learned:			

Setup Time	170	seconds
Process Time	284	seconds

Setup time = 0

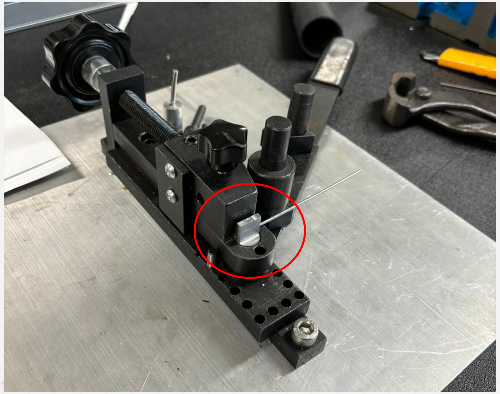
#	Task	Machine	Tool	Materials	Time (s)	Repetition	Time for 1 Car	Evaluation/Measurement	Reaction Plan	Notes
1	Assemble drilling/reaming soft jaws on vice		Vice 3/16" allen key	Soft Jaw	150	0	0			
2	Unscrew set screw in wire collar		1/16" allen key	Shaft collar	10	4	40			
3	Clamp shaft collar		Vice	Shaft collar	3	4	12			Shaft collar does not fit in circular part of soft jaw
4	Setup the hand drill	Hand drill	0.1285" No.30 Reamer	Shaft collar	20	0	0			
5	Ream the center of the shaft collar	Hand drill	0.1285" No.30 Reamer	Shaft collar	2	4	8	Confirm two wires fit in step 9	Scrap shaft collar and use a new one	
6	Unclamp shaft collar from soft jaws		Vice	Shaft collar	1	4	4			
7	Cut wire to 3.5" using mount jig as measuring device		Wire cutter Wire mount jig	Wire	10	4	40	confirm at step 9 if wire fits in mount jig	If >+- 0.25" scrap wire and cut a new piece	
8	Bend 0.5" end of wire to 180* in bender		Wire bender	Wire	15	4	60	Visual - check wire is bent	Bend further if not bent enough	
9	Attach wires together at 4.15" length using jig		1/16" allen key Wire mount jig	Wire Shaft collar	60	2	120	Check if wire and collars fit together and in jig	If parts do not fit refer to reaction plan above	

Design for manufacturing



- Material Selection: Aluminum
- Manufacturing Process: Waterjet Cutting, Wire Bending
- DFM Practices:
  - Uniform thickness and 2D profile links
    - Batch Production, Easy to waterjet, Minimize #uniqure parts
  - Prototyping: Wire works much better than linkages [Flexibility & Tool Availability]
    - 2 bended wires + 2 shaft collars per set
  - Jigs / Fixtures ready for production

Wire Assembly Jig

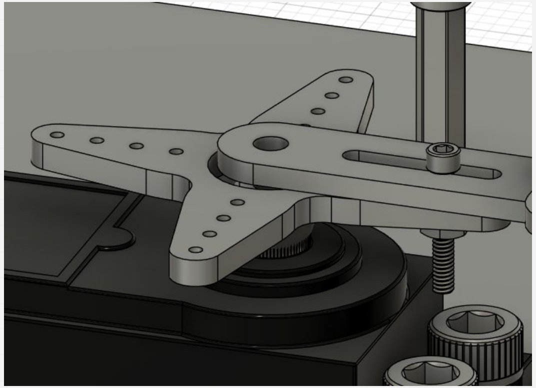


Wire Bend Tool

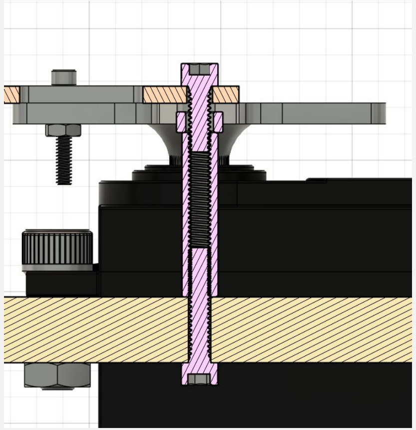
Reaming Jaws

Design for manufacturing

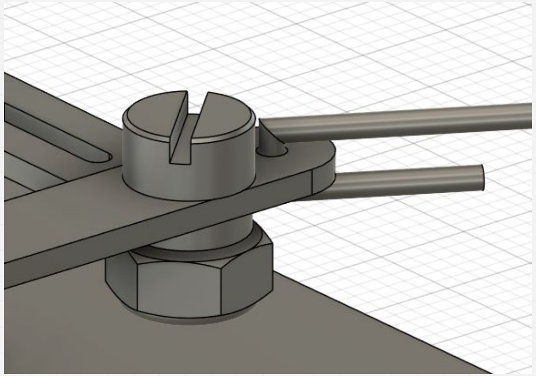
- Joints:



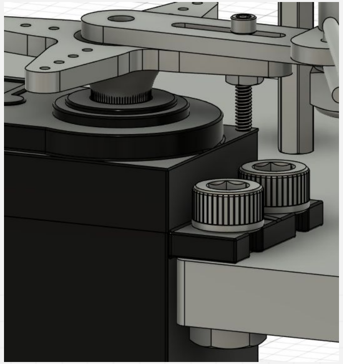
Servo Horn Joint:
0-80 ⅜ " Screw X 1
0-80 Nut X 1
Servo Screw: (come together with the servo)



Steering Pivot Joints:
2-56 ¼ " Screw X 1
2-56 7/16"Screw X 1
2mm Spacer X 1
2-56, ⅝" Hex Standoff



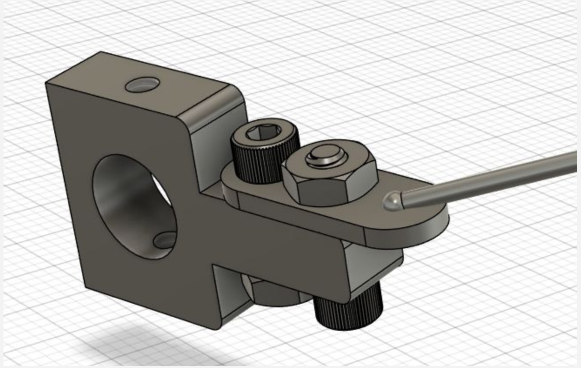
Steering Link Joints:
8-32 ⅛" Shoulder Screw X 2
8-32 LockNut X 2



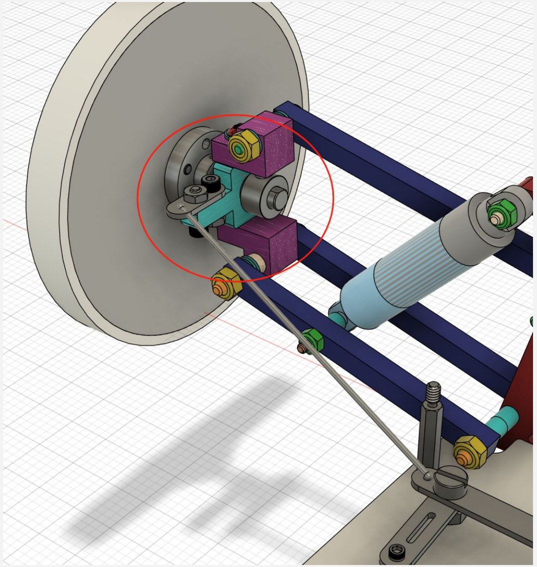
Servo Mount Joints:
8-32 7/16 " Screw X 4
8-32 1/4"Nut X 4

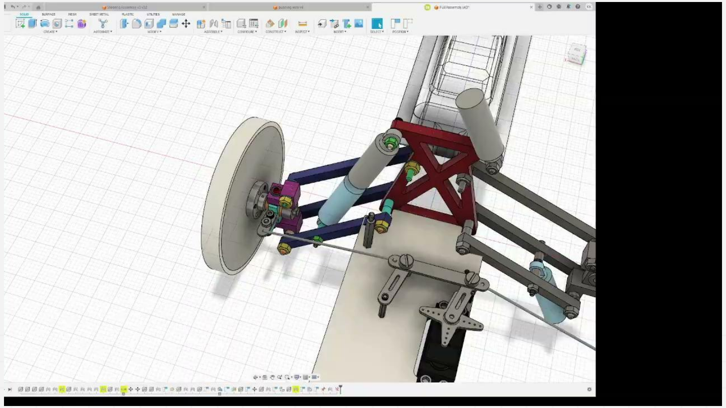
Design for manufacturing

- Joints:



Upright /Knuckle joints
5-40 7/16 ” Screw X 4
5-40 ¼ ”Narrow Nuts X 4





Bill of Materials (BOM)

				Administrative								Pu				
Component	Part Name	Part Number	Photo	Current Quantity	Quantity per Car	Purchase Status	Delivery Status	Unit Price	40 Car Price	Number Bought	Purchased Price					
Servo	Futaba S3003 Servo	S3003		40	1	N/A	N/A	$6.00	$239.90	0	$0.00	Am				
Aluminum Sheet	6061 Aluminum Sheet 0.063" Thickness	89015K52		1	1	N/A	N/A	$0.19	$7.73	0	$0.00	Mcl				
Steel Wire	2mm Low-Carbon Steel Rod	8920K12		200	2	N/A	N/A	$1.81	$144.80	0	$0.00	Mcl				
Shoulder Bolt	Slotted 18-8 Stainless Steel Precision Shoulder Screw 3/16" Shoulder Diameter, 1/8" Shoulder Length, 8-32 Thread	91829A201		10	2	Ordered	Delivered	$1.63	$130.40	10	$16.30	McMaster-Carr	N/A	91829A201	connection	https://www.mcmaster.com/91829A201/
Lock Nut	Low-Strength Steel Thin Nylon-Insert Locknut Zinc-Plated, 8-32 Thread Size	90633A009		100	2	Ordered	Delivered	$0.03	$2.58	100	$3.23	McMaster-Carr	N/A	90633A009	Linkage connection	https://www.mcmaster.com/90633A009/
Shaft Collar	Set Screw Shaft Collar for 1/8" Diameter, Zinc-Plated 1215 Carbon Steel	6432K17		10	4	Not Ordered	N/A	$1.84	$294.40	0	$0.00	McMaster-Carr	N/A	6432K17	Wire connection	https://www.mcmaster.com/6432K17/
0-80 3/8" Screw	Black-Oxide Alloy Steel Socket Head Screw 0-80 Thread Size, 3/8" Long	91864A003		10	1	Not Ordered	N/A	$0.26	$10.55	0	$0.00	McMaster-Carr	N/A	91864A003	Screw attached link to servo	https://www.mcmaster.com/91864A003/
0-80 Nuts	18-8 Stainless Steel Narrow Hex Nut 0-80 Thread Size	90730A001		10	1	Not Ordered	N/A	$0.11	$4.27	0	$0.00	McMaster-Carr	N/A	90730A001	servo link nut	https://www.mcmaster.com/90730A001/
8-32 7/16" Screw	Super-Corrosion-Resistant 316 Stainless Steel Socket Head Screw 8-32 Thread Size, 7/16" Long	92185A193		10	4	Not Ordered	N/A	$0.23	$37.06	0	$0.00	McMaster-Carr	N/A	92185A193	Servo mount to chassis	https://www.mcmaster.com/92185A193/
8-32 1/4" Nut	Steel Narrow Hex Nuts	90760A009		10	4	Not Ordered	N/A	$0.04	$5.97	0	$0.00	McMaster-Carr	N/A	90760A009	Servo mount nut	https://www.mcmaster.com/90760A009/
2-56 5/8" Female Female Standoff	Female Threaded Hex Standoff 18-8 Stainless Steel, 1/8" Hex, 5/8" Long, 2-56 Thread	91115A955		0	1	Not Ordered	N/A	$2.71	$108.40	0	$0.00	McMaster-Carr	N/A	91115A955	chassis standoffs	https://www.mcmaster.com/91115A955/
2-56 1/4" Screw	Black-Oxide Alloy Steel Socket Head Screw 2-56 Thread Size, 1/4" Long	91251A077		0	2	Not Ordered	N/A	$0.09	$7.26	0	$0.00	McMaster-Carr	N/A	91251A077	chassis standoff bolts	https://www.mcmaster.com/91251A077/
2mm spacer	Aluminum Unthreaded Spacer 4.500 mm OD, 2 mm Long, for M2.5 Screw Size	94669A211		0	1	Not Ordered	N/A	$0.40	$16.00	0	$0.00	McMaster-Carr	N/A	94669A211	chassis spacers	https://www.mcmaster.com/94669A211/
2-56 7/16" Screw	Black-Oxide Alloy Steel Socket Head Screw 2-56 Thread Size, 7/16" Long	91251A060		0	1	Not Ordered	N/A	$0.56	$22.50	0	$0.00	McMaster-Carr	N/A	91251A060	chassis standoff bolts	https://www.mcmaster.com/91251A060/
5-40, 7/16" Screw	18-8 Stainless Steel Socket Head Screw 5-40 Thread Size, 7/16" Long	92196A127		0	4	Not Ordered	N/A	$0.08	$13.44	0	$0.00	McMaster-Carr	N/A	92196A127	upright connection	https://www.mcmaster.com/92196A127/
5-40, 1/4" Nuts	Steel Narrow Hex Nuts Zinc-Plated, 5-40 Thread Size, 1/4" Wide	90760A130		0	4	Not Ordered	N/A	$0.04	$6.14	0	$0.00	McMaster-Carr	N/A	90760A130	upright connection	https://www.mcmaster.com/90760A130/

Money Spent	Predicted Total Cost
$19.53	$658.97

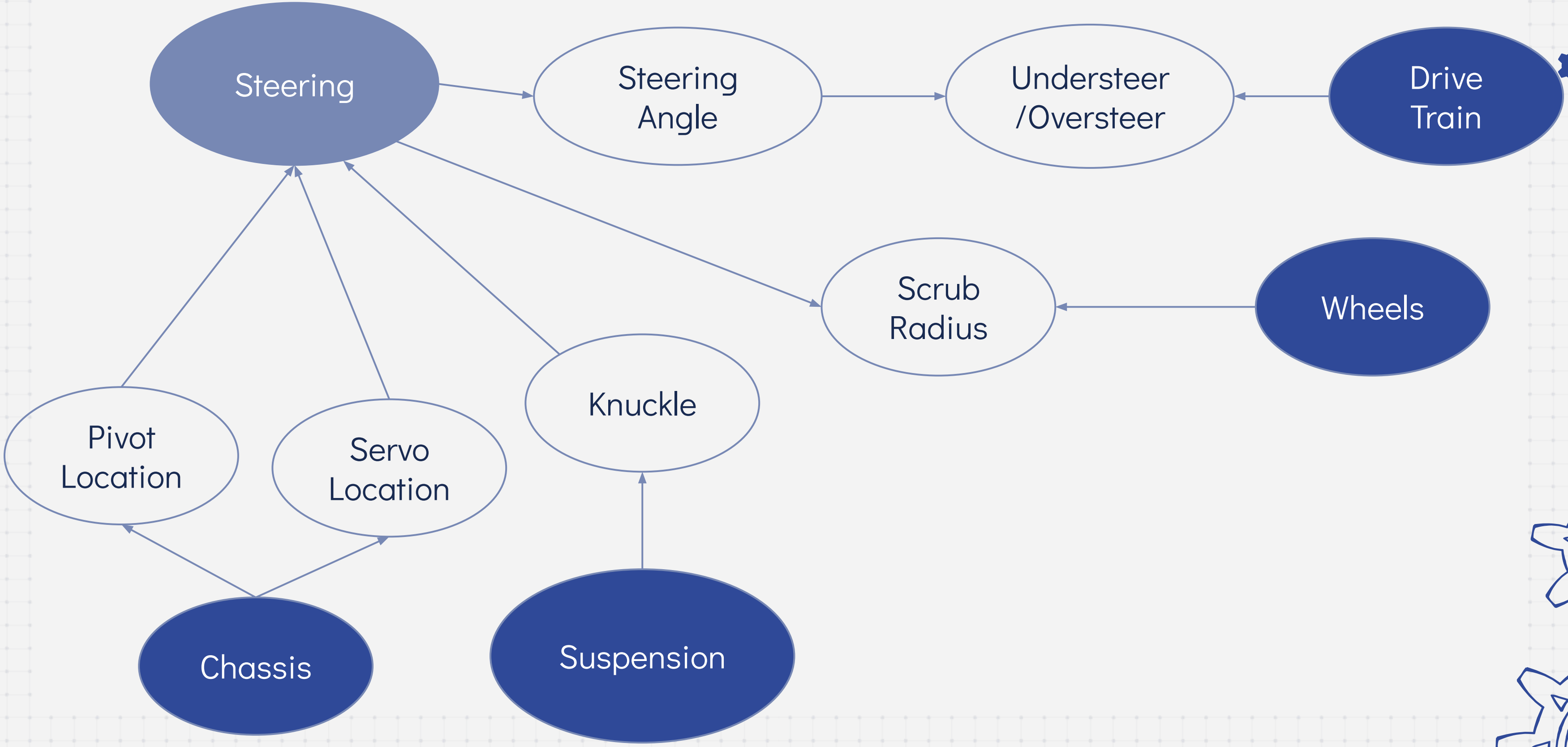
Cost and time Analysis

Cost of a sub-assembly for current steering small scale batch production for 40 units	
Cost per unit[1]	$26.29
Total Cost for 40 cars	$1,051.40
Total Production Time	10.50 hours

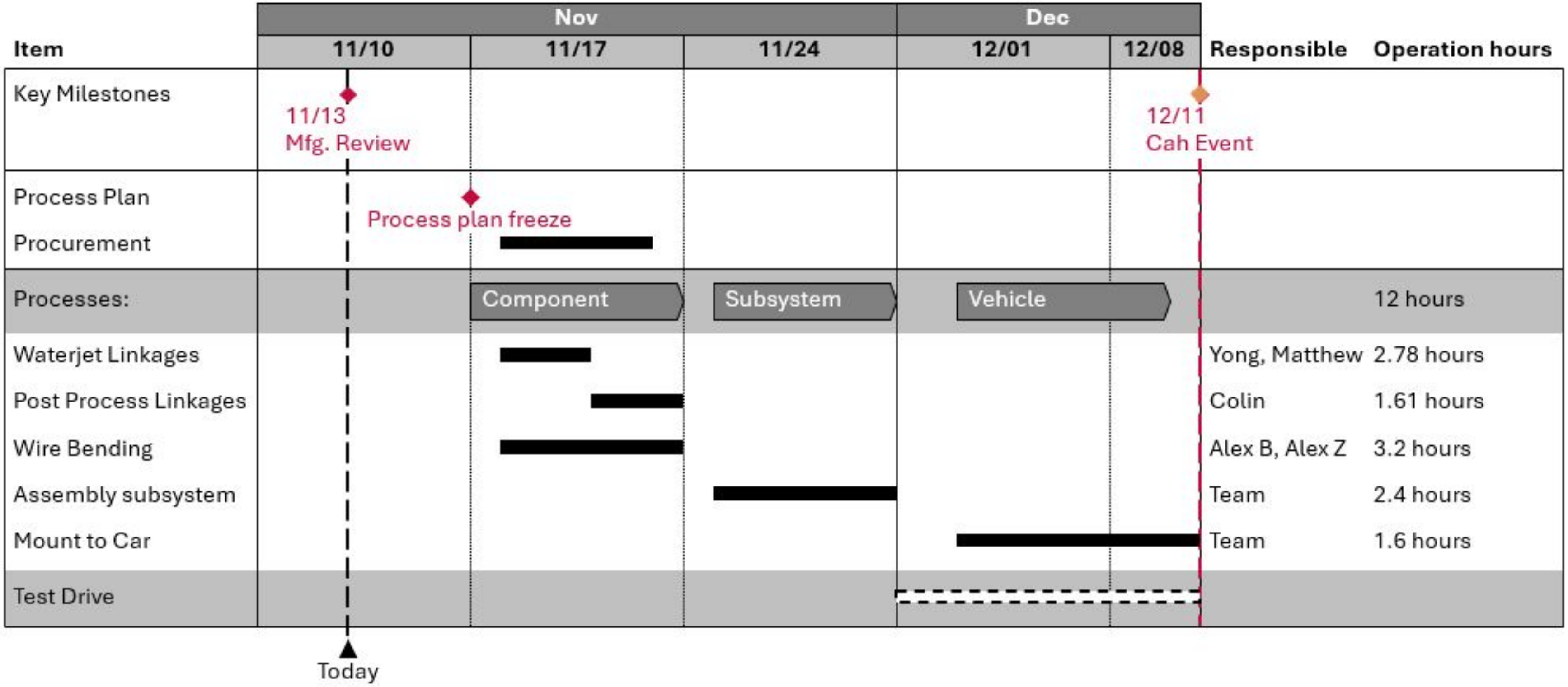
Cost of a sub-assembly for projected full scale industrial production for an order of 1,000,000 units (Total Production time for 1,000,000 units = 257,777.96 hours)			
	Average Rate	**Cost to produce 1,000,000 units**	**Percentage of Total Cost**
Material Cost	$26.29/unit	$26,290,000	94%
Labor Cost	$2.99/hour [2]	$770,756.10	2.7%
Waterjet Operation Cost	$25/hour [3]	$902,777,78	3.2%
	Total Cost	**$27,963,534**	**100%**

[1] The cost per unit includes parts provided by the course. Actual cost per unit paying with budget is $16.47.
[2] This is the estimation of manufacturing labour cost per hour in Vietnam in 2022. From https://www.statista.com/statistics/744071/manufacturing-labor-costs-per-hour-china-vietnam-mexico/#:~:text=Premium%20statistics-,Manufacturing%20labor%20costs%20per%20hour,%2C%20Vietnam%2C%20Mexico%202016%2D2020&text=In%202018%2C%20manufacturing%20labor%20costs,2.73%20U.S.%20dollars%20in%20Vietnam.
[3] The Waterjet Operation Cost is $25-30/hour to operate for consumables and maintenance parts. From official website of the machine, https://www.omax.com/en/us/learn/what-to-consider-before-buying?srsltid=AfmBOoqF1FRcrT_YVVvL6JXGfAYWwIWYTsbui4KmJAhHkhm_rsUMBO61

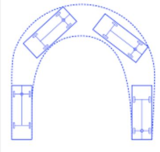
Mating Points and Critical Features



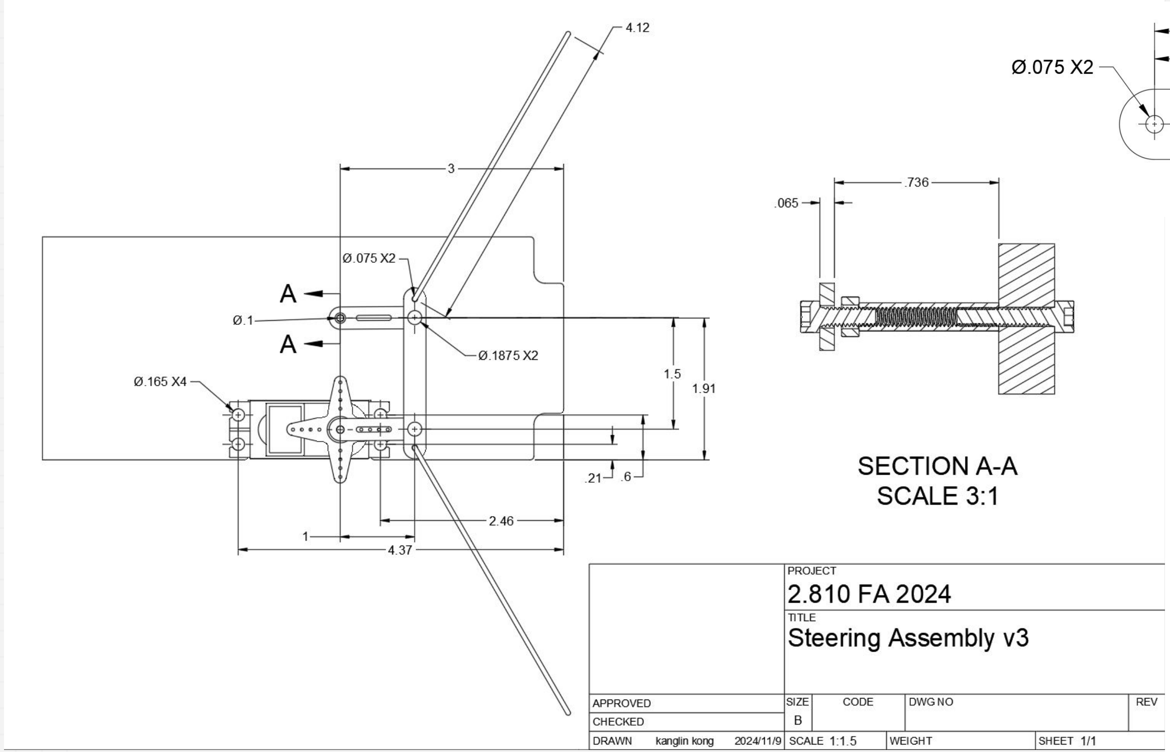
Strategic Plan

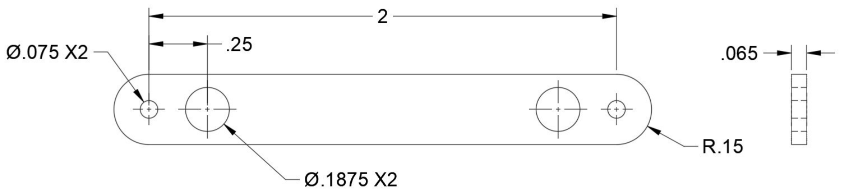


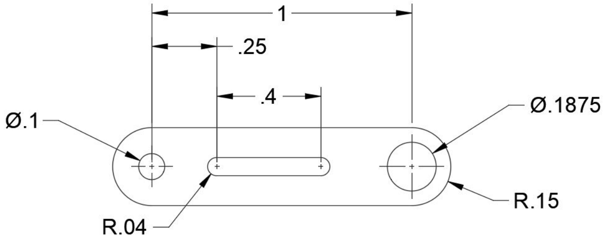
Descoping

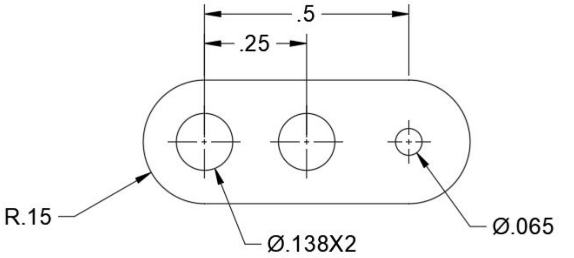
Original Proposal	Potential Risk	Solution
Pre-assemble all steering assemblies 	Tolerance issues	Will manually tune wire links with shaft collars
Steering linkages dimension designed for 12” turn radius 	Understeer or oversteer causes collisions	Prepared a separate linkage design with higher turn radius
Servo connected through a series of long linkages 	Servo not strong enough to turn the wheel	Prepared a separate set of linkage design with better leverage

Dimensioned Drawings









Thank you

Any questions or feedback?

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Source: https://stock.adobe.com/search?k=drift+car

Appendix: Waterjet Low Level Process Plan

Google Excel Link:
https://docs.google.com/spreadsheets/d/1ZWi6__vBNrzrHZUbRx1LYUOh8SjxtHooqiUCdQ6L9Ak/edit?usp=sharing

Process Plan	Group: Steering	Part Name: Water jet	Version: 1	
Revision Date: 11/12/2024		Group Members in Attendance: Yong, Matthew		
Approval Date:				
Application of previous lessons learned:				

Setup Time	455	seconds
Process Time	240	seconds

Step #	Task	Machine	Tool	Materials	Time (s)	Repetition	Time for 1 Car	Evaluation/Measurement	Reaction Plan	Notes
1	Turn on water jet pressure	Water jet			5	0	0	Visual		
2	Place Aluminum sheet in machine			Aluminum Sheet	15	0	0	Calipers (~0.063" height)		
3	Place Bricks on the sheet			Bricks	15	0	0	Visual (Confirm plate is stable)		
4	Load File in OMAX Layout				10	0	0	Visual (confirm file units set to inches)		
5	Clean Up Drawing				5	0	0	Visual		
6	Select Quality 3				5	0	0	Visual (All lines should turn pink)		
7	Create Lead in/Lead out Path				5	0	0	Visual		
8	Create tabs for each linkage				25	0	0	Visual (Tabs on curve sides of the linkages)		
9	Check Cutting Path				5	0	0	Visual (Verify path is on the outside of the linkage and inside the holes)		
10	Open in OMAX Make				5	0	0	Visual (Confirm material and thickness)		
11	Fill garnet			Garnet	180	0	0	Cylinder of gardnet (~13 inches)		filename: "for manufacturing"
12	Home X,Y, Z axis of the machine		0.06 gage		180	0	0	Visual (Axes homed accurately)		
13	Set "Path Start" Location				30	1	30	Visual		
14	Increase water level				5	1	5	Visual (Half of the bricks)		
15	Cut profile				130	1	130	Visual (fully cut with tabs)	Hit e-stop and restart	
16	Remove bricks and aluminum sheet			Aluminum Sheet Bricks	15	1	15			
17	Snap tabs to remove linkages from sheet			Aluminum Sheet	60	1	60	Visual (Parts cut as design)	Redo waterjet for linkage	

Appendix: Linkage Process Low Level Process Plan

Google Excel Link:

https://docs.google.com/spreadsheets/d/1ZWi6__vBNrzrHZUbRx1LYUOh8SjxtHooqiUCdQ6L9Ak/edit?usp=sharing

Process Plan	Group: Steering	Part Name: Linkage Process	Version: 1
Revision Date: 11/5/2024		Group Members in Attendance: Colin	
Approval Date:			
Application of previous lessons learned:			

Setup Time	40	seconds
Process Time	96	seconds

Setup time = 0

#	Task	Machine	Tool	Materials	Time (s)	Repetition	Time for 1 Car	Evaluation/Measurement	Reaction Plan	Notes
1	Grind tabs off of linkages	Belt sander		Linkages	10	5	50	Visual (smooth edge)	Redo waterjet for linkage	
2	Setup drill	Hand drill	0.191" drill bit	Linkages	20	0	0			
3	Clamp linkage in soft jaws		Vice	Linkages	3	5	15			linkage hole should either stick out of soft jaw or be aligned over circular section
4	Drill large linkage holes	Hand drill	0.191" drill bit	Linkages	2	4	8	Fits shoulder bolt	Redo waterjet for linkage	
5	Setup drill		0.073" drill bit	Linkages	20	0	0			
6	Clamp linkage in soft jaws		Vice	Linkages	3	5	15			linkage hole should either stick out of soft jaw or be aligned over circular section
7	Drill small linkage holes	Hand drill	0.073" drill bit	Linkages	2	4	8	Fits wire	Redo waterjet for linkage	

Appendix: Steering Subsystem Low Level Process Plan

Google Excel Link:

https://docs.google.com/spreadsheets/d/1ZWi6__vBNrzrHZUbRx1LYUOh8SjxtHoogiUCdQ6L9Ak/edit?usp=sharing

Process Plan	Group: Steering	Part Name: Steering Subsystem	Version: 1
Revision Date: 11/5/2024		Group Members in Attendance: Alex B, Alex Z, Colin, Matthew, Yong	
Approval Date:			
Application of previous lessons learned:			

Setup Time	0	seconds
Process Time	86	seconds

Setup time = 0

#	Task	Machine	Tool	Materials	Time (s)	Repetition	Time for 1 Car	Evaluation/Measurement	Reaction Plan	Notes
1	Attach servo horn to servo		Phillips head screwdriver	Servo Servo horn Servo screw	14	1	14	Fully engaged bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	Materials provided with servo
2	Bolt servo linkage to servo horn		0.028" Allen key Needlenose pliers	0-80 3/8" Bolt 0-80 18-8 Nut Servo Linkage	20	1	20	Fully engaged nut/bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	
3	Attach mid-linkage to servo linkage		Flathead screwdriver Wrench	18-8 Shoulder Bolt 8-32 Lock Nut Mid Linkage	20	1	20	Fully engaged nut/bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	
4	Attach fixed pivot linkage to mid-linkage		Flathead screwdriver Wrench	18-8 Shoulder Bolt 8-32 Lock Nut Mid Linkage Pivot Linkage	20	1	20	Fully engaged nut/bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	The pivot linkage is identical to the servo linkage
5	Attach wire to mid-linkage			Wire Assembly Mid Linkage	3	2	6	Confirm wire can rotate in the small linkage hole	Too tight fit = send back to linkage process. Too loose fit = scrap	
6	Attach wire to upright linkage			Wire Assembly Upright Linkage	3	2	6	Confirm wire can rotate in the small linkage hole	Too tight fit = send back to linkage process. Too loose fit = scrap	

Appendix: Mount to Car Low Level Process Plan

Google Excel Link:
https://docs.google.com/spreadsheets/d/1ZWi6__vBNrzrHZUbRx1LYUOh8SjxtHooqiUCdQ6L9Ak/edit?usp=sharing

Process Plan

Group: Steering

Part Name: Full Car

Version: 1

Revision Date: 11/5/2024

Approval Date:

Group Members in Attendance: Alex B, Alex Z, Colin, Matthew, Yong

Application of previous lessons learned:

Setup Time	0	seconds
Process Time	222	seconds

#	Task	Machine	Tool	Materials	Time (s)	Repetition	Time for 1 Car	Evaluation/Measurement	Reaction Plan	Notes
1	Bolt servo onto chassis		5/64" Allen key Wrench	8-32 7/16" Bolt 8-32 Nut Steering Assembly Chassis	28	1	28	Fully engaged nut/bolt	Make clearance holes larger if needed	
2	Install fixed pivot linkage onto pivot with spacer below linkage		5/64" Allen key Wrench	18-8 5/8" Standoff 2-56 1/4" Bolts 2mm Spacer Steering Assembly	38	1	38	Fully engaged bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	
3	Install upright linkage to suspension		1/16" Allen key Wrench	5-40 7/16" Bolt 5-40 1/4" Nut Steering Assembly Chassis + Suspension	18	2	36	Fully engaged nut/bolt	Too tight fit = send back to linkage process. Too loose fit = scrap	
4	Adjust wire as needed		1/16" Allen key	Steering Assembly Chassis + Suspension	60	2	120	Confirm wire fully locked in position. Cannot remove from shaking wire in all directions	Unscrew shaft collar, straighten wheel, tighten shaft collar	

Appendix: Design Extensions

Scrub radius

- Correlated with steering effort

Kingpin angle/steering axis inclination

- Self-centered steering
- Straight-line performance

Caster

- Similar effects as SAI. Keep positive

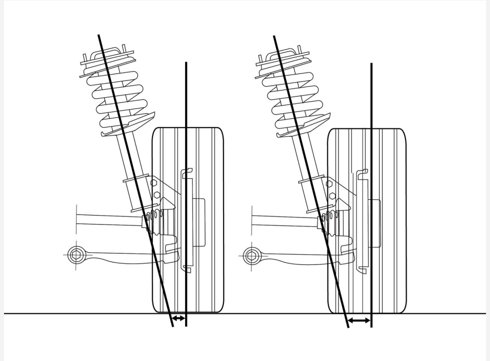
Camber

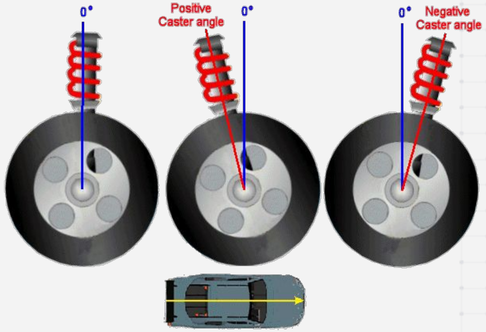
- Impacts mainly high speed corners

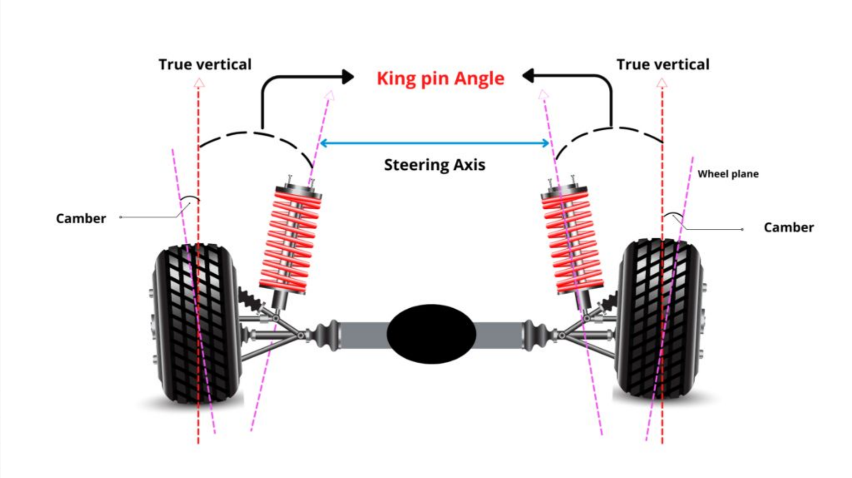
(Assumed near vertical OK)

Toe

- In: stability. Out: responsiveness.







Appendix: Design Extensions

Oversteer/Understeer

To-do:

Determine weight distribution

Finalize suspension geometry

Tire material

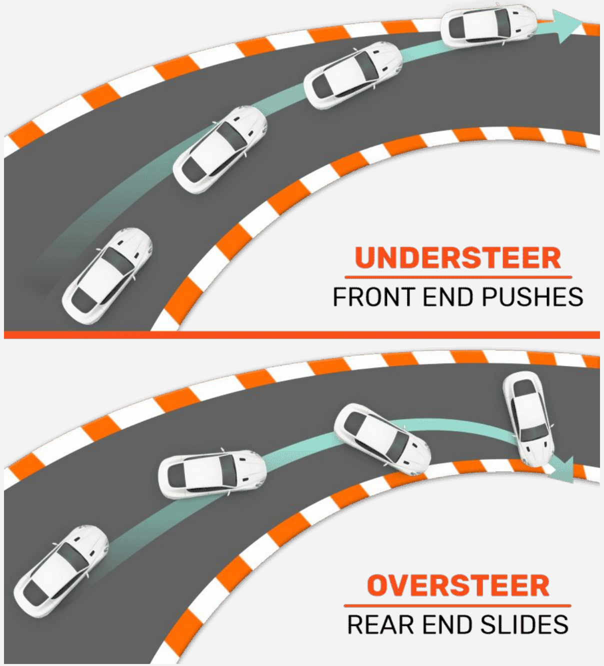
Practical Tests

Reduce Oversteer

Decrease Ackermann, Toe-in, Decrease Steering Sensitivity

Reduce Understeer

Increase Ackermann, Toe-out, Increase Steering Sensitivity



sub-assembly team overview - Matthew
design considerations - Matthew
process plan - Alex B
design for manufacturing - Colin
Bill of Materials (BOM) - Alex B
Present an analysis of your manufacturing processes as a system - Alex B
cycle time and process times - Yong (waterjet) Alex B (wire bend, assembly)
cost per unit, cost and time analysis - Yong
critical features and mating points - Yong present, Matthew slides
Gantt Chart and strategic plan - Alex Z
descoping strategies - Alex Z
dimensioned drawings - Colin
CAD renderings - Colin