Umbilical Retraction Device

Griffin Brandt, Leah Blakney, Jonathan Armijo, William Shields

Capstone Spring 2022

Scope of Project

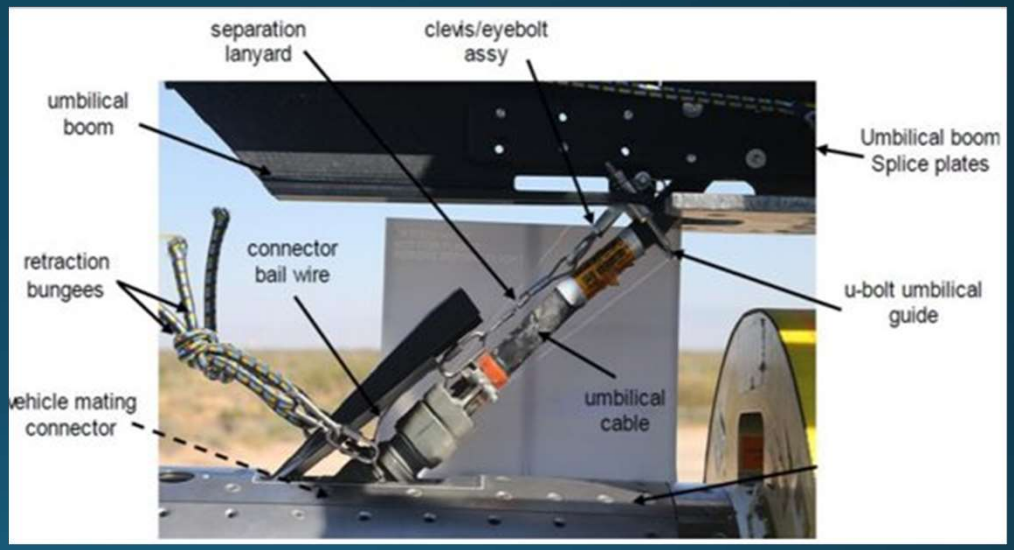
Project Background:

- Signals are sent off to rockets to the very second before it takes off by umbilical cables.
- If the cables are not removed once the rockets takes off, they will come into contact and damage the rocket.
- Current systems include one-time use bungee cables.

Project Goal:

- Design an umbilical retraction system to pull the umbilical away from the vehicle during launch.

Figure 1: Current Retraction Cable



Customer and Engineering Requirements

Table 1: CRs

Customer Requirements
CR1 - High Manufacturability
CR2 - High Reliability
CR3 - Easily Removable/Installed
CR4 - High Durability
CR5 - ESD Safe

Table 2: ERs

Engineering Requirements	Target
ER1 - Cost	<5000 ($)
ER2 - Side Force	<10 (lbs)
ER3 - Retraction Speed	6ft/s
ER4 - Temperature	-30 to 160 (F)
ER5 - Weight	1lb/1ft
ER6 - Adjustable	2 - 6 (ft)
ER7 - Success Rate	100 (%)

Decision Making

Table 3: Decision Matrix

		Vacuum Piston		Spring Piston	
Engineering Reqs.	Weight	Score	Weighted	Score	Weighted
Cost	12	4	0.48	3	0.36
Side Force	16	3	0.48	3	0.48
Retraction Speed	17	4	0.68	3	0.51
Temperature	11	5	0.55	4	0.44
Weight	14	3	0.42	3	0.42
Adjustability	10	4	0.4	2	0.2
Success Rate	20	3	0.6	4	0.8
Total	100	26	3.61	22	3.21

Figure 2: Vacuum Piston

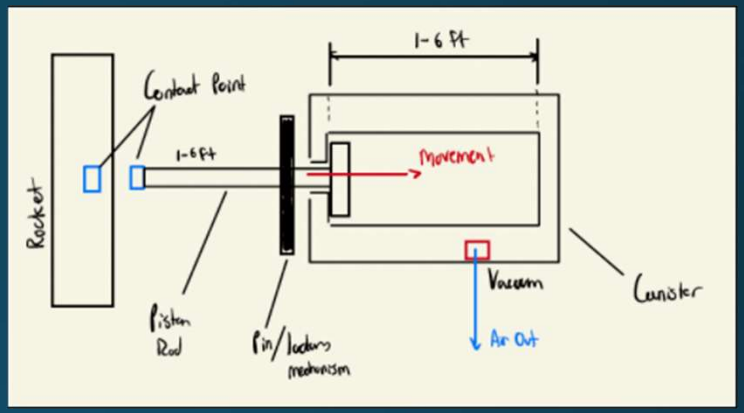
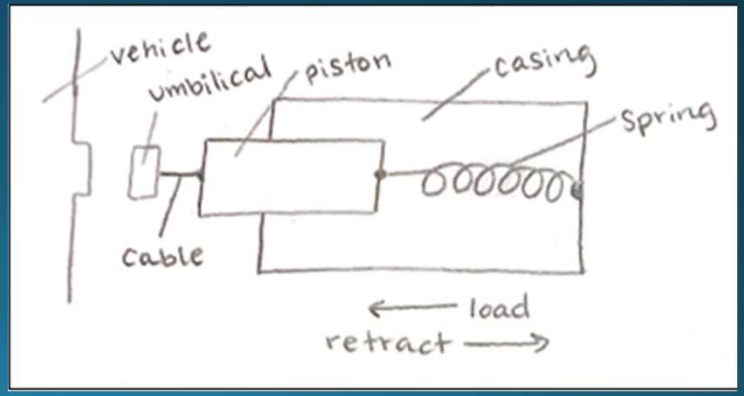


Figure 3: Spring Piston



Decision Making

Table 4: Decision Matrix (Continued)

		Dog Leash		Two Arms	
Engineering Reqs.	Weight	Score	Weighted	Score	Weighted
Cost	12	4	0.48	3	0.36
Side Force	16	4	0.64	4	0.64
Retraction Speed	17	3	0.51	3	0.51
Temperature	11	2	0.22	4	0.44
Weight	14	2	0.28	2	0.28
Adjustability	10	4	0.4	4	0.4
Success Rate	20	5	1	3	0.6
Total	100	24	3.53	23	3.23

Figure 4: Dog Leash Sketch

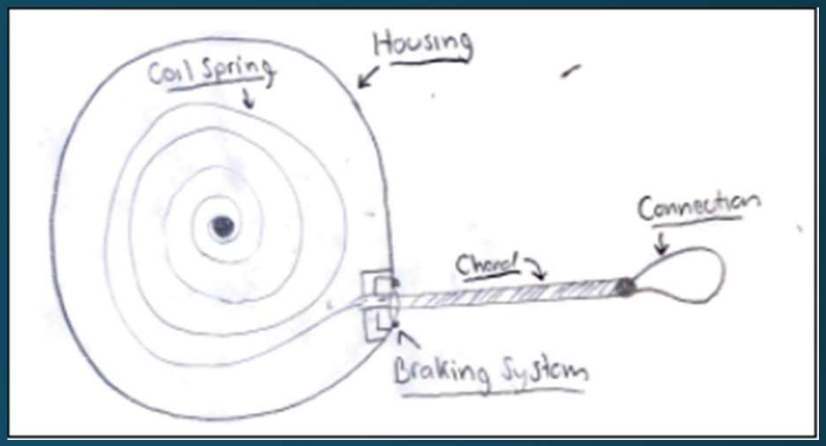
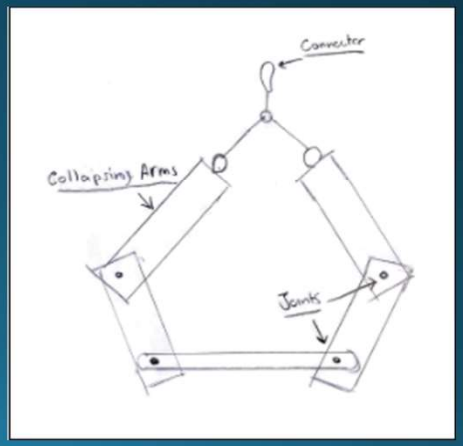


Figure 5: Two Arms Sketch



Decision Making

Table 5: Pugh Chart

	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
Criteria	Vac. Piston	Spring Piston	Slingshot	Dog Leash	Two Arms	Bunjee
High Durability	+	+	S	+	+	D
High Manufacturability	-	-	S	-	-	
Easily Installed	+	+	S	+	S	A
Success Rate (100%)	-	-	S	S	+	
Cost ($)	+	+	+	+	+	T
Retraction Speed (6ft/1s)	S	S	S	-	-	
Weight (1lb/1ft)	-	-	S	-	-	U
Side Force (<10lbs)	+	+	+	+	S	
Size	-	-	S	-	-	M
Sum +	4	4	2	4	3	
Sum -	4	4	0	4	3	
Sum S	1	1	7	1	2	

- Failure Modes and Effects Analysis
- Significant dependence on input signal from microcontroller
- Motor selection was crucial (maintaining efficiency and power)
- Multiple moving parts (maintain proper guidelines and through analysis)

Device Design

- Concept generation ended with the design of a winch.
- Will use a geared motor to turn a wheel that will pull in a retracting cable connected to the umbilical
- Actuation system is from a switch that is triggered when the umbilical is pulled away.
- Side plates welded to bottom base.
- All other components screwed and bolted together.

Figure 6: CAD Drawing (Exploded View)

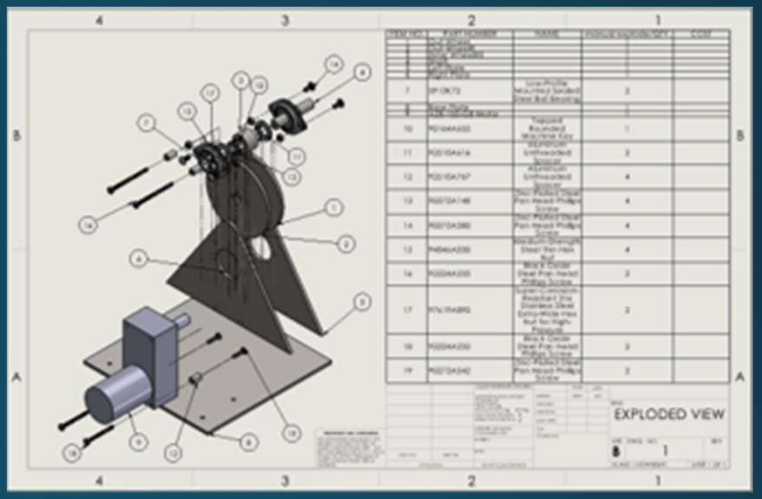
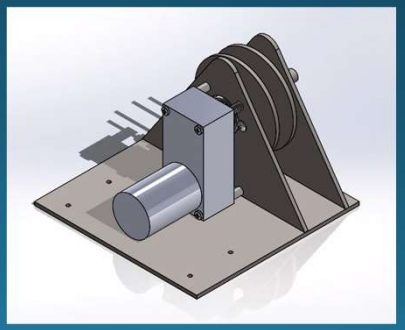


Figure 7: CAD Assembly



Manufacturing

- Multiple parts cut out on a laser cutter by the company Send-Cut-Send.
- Insider shaft pieces manufactured in house at the NAU machine shop.
- Welding was performed by managers of the NAU machine shop.

Table 6: Manufacturing Plan

Part / Assembly	Part #	Quantity	Price	Total Price	Status	Supplier	Manufacture	Start/OrderDate	Finish/ReceiveDate
Left Disk Cut andTapped	NA	1	$40.98	$40.98		SendCutSend	SendCutSend	5-Feb	14-Feb
Right Disk Cut andTapped	NA	1	$41.05	$41.05		SendCutSend	SendCutSend	5-Feb	14-Feb
Left Side Plate Cut andTapped	NA	1	$40.55	$40.55		SendCutSend	SendCutSend	5-Feb	14-Feb
Right Side Plate Cut andTapped	NA	1	$41.66	$41.66		SendCutSend	SendCutSend	5-Feb	14-Feb
Base Plate	NA	1	$123.97	$123.97		SendCutSend	SendCutSend	5-Feb	14-Feb
Welding, R/L Plate to Base	N/A	1	N/A	N/A		N/A	Machine Shop	25-Feb	25-Feb
Inside Wheel	N/A	1	N/A	N/A		Home Depot	Jonathan/Machine Shop	25-Feb	4-Mar
Shaft	N/A	1	N/A	N/A		Home Depot	Jonathan/Machine Shop	25-Feb	4-Mar
Electrical Layout	N/A	1	N/A	N/A		N/A	Jonathan	4-Mar	11-Mar
Machine Assembly	N/A	1	N/A	N/A		N/A	Griffin/ MachineShop	7-Mar	30-Mar
Electrical Assembly	N/A	1	N/A	N/A		N/A	Jonathan/Machine Shop	7-Mar	29-Mar
Full Assembly	N/A	1	N/A	N/A		N/A	Team	14-Mar	30-Mar

Manufacturing/Final Working Assembly

- Figure [8] is of the electrical circuit which includes an activator switch (bottom right, a 40 Amp fuse (left), power supply (top), and motor controller (bottom)
- Figure [9] shows the machined assembly which includes all manufactured pieces along with the motor.
- Wood used on base to support structure.

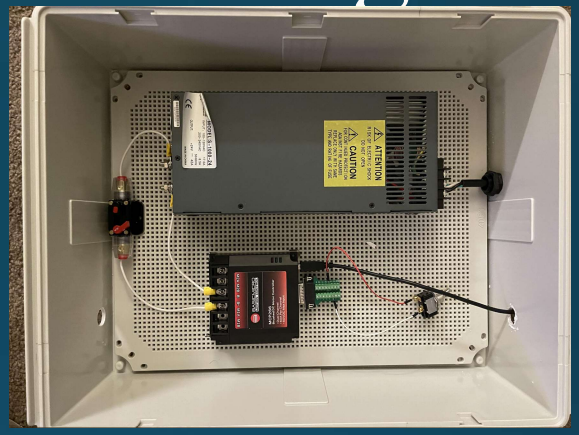


Figure 8: Electrical Circuit

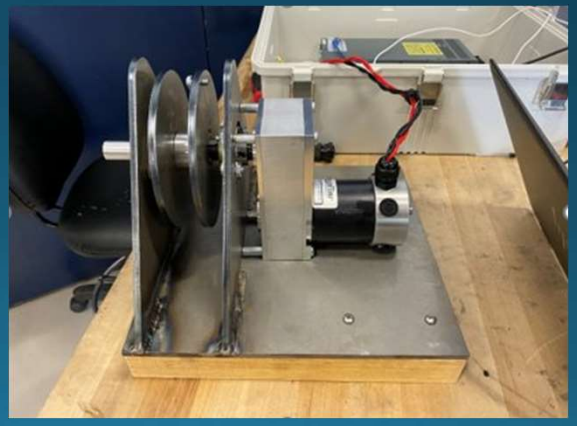


Figure 9: Hardware Assembly

Budget

- The total purchasing is $1890.30
- The budget from our client Northrop Grumman was $5000
- Current balance of $3109.70

Table 7: Purchasing Plan

Part / Assembly	Part #	Quanti	Price	Total Pric	Statu	Supplier	Manufacture	Start/Order Dat	Finish/ Receive Dat
Cord	KIT110-2	1	$ 64.00	$ 64.00		Wes Spur	Wes Spur	12-Nov	10-Jan
Motor	A128-150-G8	1	$ 529.00	$ 529.00		AmpFlow	AmpFlow	17-Nov	3-Feb
Motor Controller	MCP266	1	$ 269.00	$ 269.00		AmpFlow	AmpFlow	17-Nov	3-Feb
Power Supply	S-1000-24	1	$ 199.00	$ 199.00		AmpFlow	AmpFlow	17-Nov	3-Feb
Speed Adjuster	MCP DM Controller	1	$ 20.00	$ 20.00		AmpFlow	AmpFlow	17-Nov	3-Feb
Bearing 1"	5913K74	2	$ 12.77	$ 25.54		McMaster-Carr	N/A	1-Feb	10-Feb
Bearing 3/4"	5913K73	2	$ 11.90	$ 23.80		McMaster-Carr	N/A	1-Feb	10-Feb
Machine key	90164A655	2	$ 7.22	$ 14.44		McMaster-Carr	N/A	3-Feb	10-Feb
Left Disk Cut and Tapped	NA	1	$ 40.98	$ 40.98		SendCutSend	SendCutSend	5-Feb	14-Feb
Right Disk Cut and Tapped	NA	1	$ 41.05	$ 41.05		SendCutSend	SendCutSend	5-Feb	14-Feb
Left Side Plate Cut and Tapped	NA	1	$ 40.55	$ 40.55		SendCutSend	SendCutSend	5-Feb	14-Feb
Right Side Plate Cut and Tapped	NA	1	$ 41.66	$ 41.66		SendCutSend	SendCutSend	5-Feb	14-Feb
Base Plate	NA	1	$ 123.97	$ 123.97		SendCutSend	SendCutSend	5-Feb	14-Feb
Tool Replacement Cord 14/3	342-576	1	$ 14.47	$ 14.47		Home Depot	CerroWire	7-Feb	7-Feb
Southwire Cord 1.66/ Ft	12/3 300 Volt	3	$ 1.66	$ 4.98		Home Depot	Gardner Bender	7-Feb	7-Feb
16-14 AWG Ring Terminals 15 pack	15-104	1	$ 2.95	$ 2.95		Home Depot	Gardner Bender	7-Feb	7-Feb
12-10 AWG Ring Terminals 15 pack	15-107	1	$ 3.61	$ 3.61		Home Depot	Gardner Bender	7-Feb	7-Feb
22-18 AWG Spade Terminal 6 Pack	15-111	1	$ 2.40	$ 2.40		Home Depot	Gardner Bender	7-Feb	7-Feb
D-Sub Serial Adapters	DB15 RS232	1	$ 12.99	$ 12.99		Amazon	Jienk	21-Feb	1-Mar
Enclosure	0791778468009	1	$ 161.99	$ 161.99		Amazon	YUEQING QILI ELECTRICAL	21-Feb	1-Mar
Toggle Switch	69196O8793716	1	$ 7.19	$ 7.19		Amazon	HiLetgo	21-Feb	1-Mar
Power Socket w Switch Fuse	B082ZFRV1B	1	$ 8.99	$ 8.99		Amazon	MXRS	21-Feb	1-Mar
External Cooling Fan	B009OWVUJ0	1	$ 18.99	$ 18.99		Amazon	AC Infinity	21-Feb	1-Mar
Cable Gland Pack	0752771026917	1	$ 16.49	$ 16.49		Amazon	Cable Gland	21-Feb	1-Mar
40A Inline Circuit Breaker	B07KF2PV6V	1	$ 16.99	$ 16.99		Amazon	Ý-SOLAR	21-Feb	1-Mar
Wire Connector Kit	B01LCG52C6	1	$ 13.99	$ 13.99		Amazon	ÈL-SKY	21-Feb	1-Mar
Hot Rolled Plate Gusset	B00YWBSR94	1	$ 12.99	$ 32.37		Amazon	IMS	21-Feb	1-Mar
Gusset with Hole	B009Q73QMM	1	$ 12.25	$ 12.25		Amazon	Allstar Performance	21-Feb	1-Mar
Lathe Stock	B01F80WG1W	1	$ 29.99	$ 29.99		Amazon	Stoner Metals	21-Feb	1-Mar
Chassis Mount for Connectors Sets	HS-4	1	$ 11.99	$ 11.99		Powerwerx	Powerwerx	21-Feb	1-Mar
Aluminum Material	NA	1	$ 27.93	$ 27.93		Home Depot	Home Depot	26-Feb	26-Feb
Scrap Wood & Bolt, Nut, and Screw K	NA	1	$26.14	$ 26.14		HomeCo	HomeCo	3-Mar	3-Mar
Side Plate and Disk	NA	1	$30.62	$ 30.62		SendCutSend	SendCutSend	7-Mar	28-Mar

Testing

Video 1: Motor Startup Test

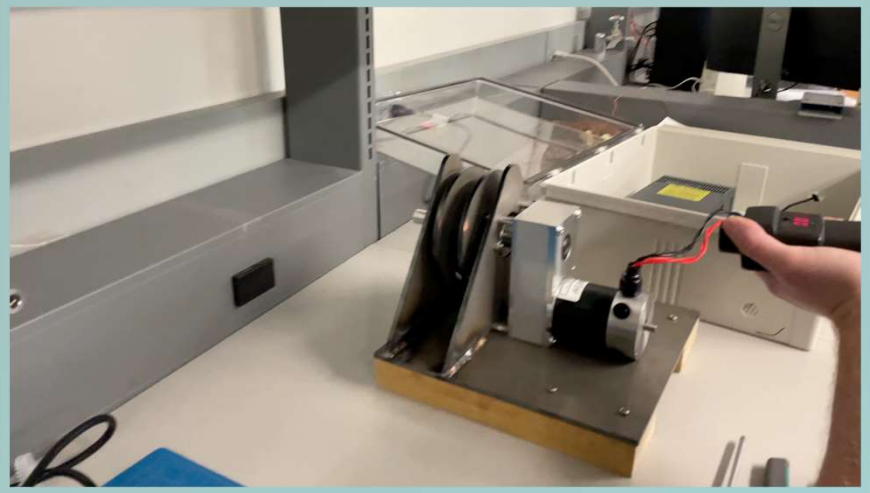


Table 8: Testing Overview

Test	Relevant Requirement	Procedure Summary	What was Learned
Motor Startup	CR2	Motor, MCP and power supply all connected and ran. Emergency stop intiated at different speeds.	All components working correctly. Gearbox was capable of handling braking load.
Cable Test	CR2, CR4, ER4, ER6	Flame applied to cable. Different weight were hung from cable.	Chosen cable could withstand loads and conditions that our device would experience.
Rotation Speed	ER2, ER3, ER5, ER6, ER7	Device was ran at different duty cycles and speed was measured with a tachometer.	Were able to obtain speeds for different duty cycles which were used for calibrating our motor controller.
Retraction Speed	ER2, ER3, ER5, ER6, ER7	Device tested with different loads that mocked pulling an umbilical cable.	Helped determine if our device would meet our customer requirements for retraction speed.
Side Force	ER2	Our cable was attached to a force gauge and the initial force from the weight of the chord and carabiner were recorded.	Showed that we were well under the customer requirement for initial side force.
Environmental Testing	CR2, CR4, ER2, ER3, ER4, ER5, ER6, ER7	Device tested at extreme temperatures to simulate launch conditions.	Showed that our device could withstand launch conditions.

Results

Table 10: Specification

Customer Requirement	CR Met? (Yes or No)	Client Acceptable (Yes or No)
CR1 - High Manufacturability	Yes	TBD
CR2 - High Reliability	More testing needed	TBD
CR3 - Easily Removable/Installed	More testing needed	TBD
CR4 - High Durability	More testing needed	TBD
CR5 - ESD Safe	Yes	TBD

Engineering Requirement	Target	Tolerance	Measure/Calculated Value	ER Met? (Yes or No)	Client Acceptable (Yes or No)
ER1 - Cost	<5000 ($)	TBD	1860 ($)	Yes	TBD
ER2 - Side Force	<10 (lbs)	TBD	TBD	TBD	TBD
ER3 - Retraction Speed	6ft/s	TBD	700 RPM Max	More Testing Needed	TBD
ER4 - Temperature	-30 to 160 (F)	TBD	TBD	TBD	TBD
ER5 - Weight	1lb/ft	TBD	TBD	TBD	TBD
ER6 - Adjustible	2 - 6 (ft)	TBD	Yes	TBD	TBD
ER7 - Success Rate	100 (%)	100%	So Far	So Far	TBD

Future Work

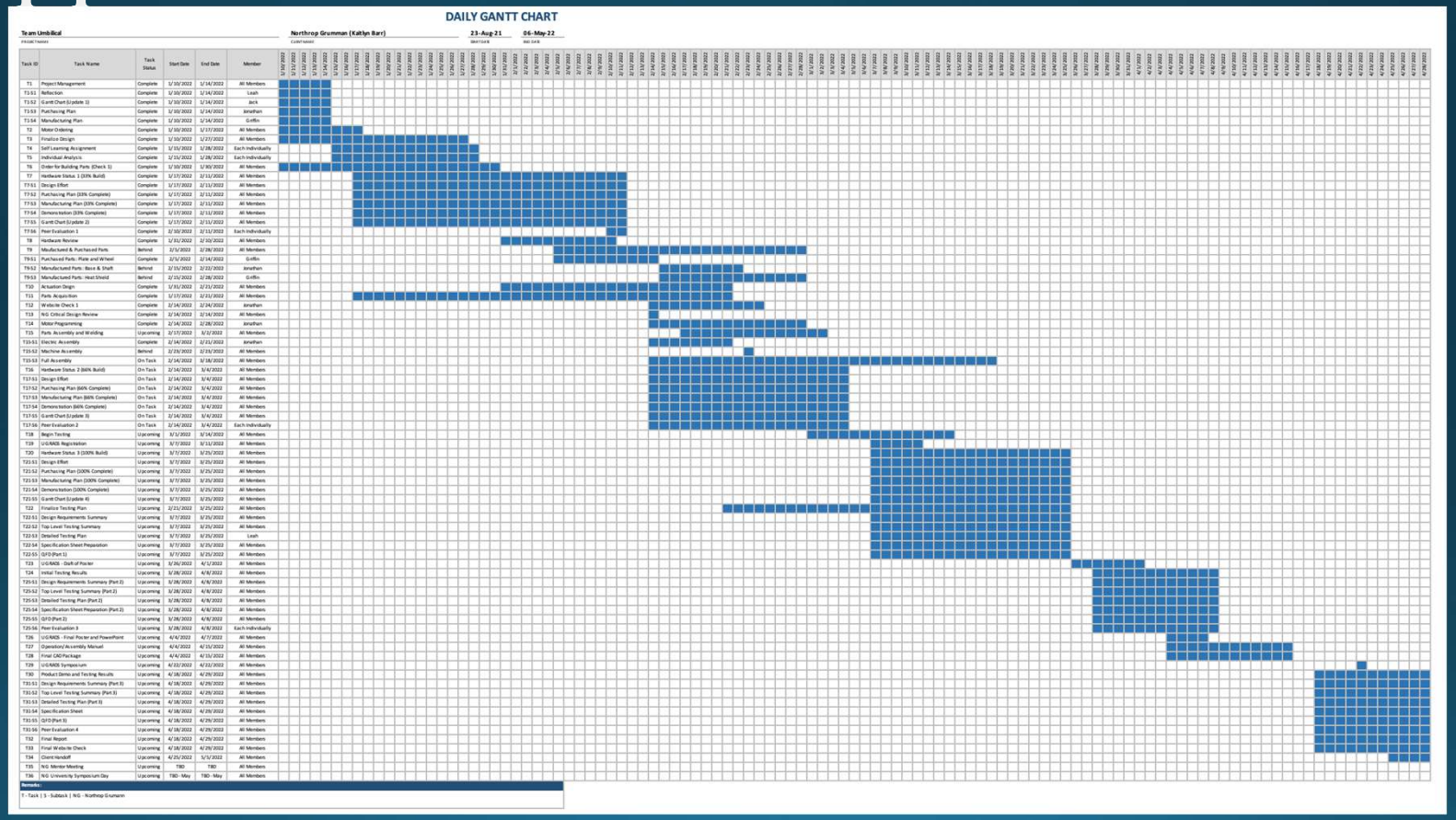
- Heat shield to be added to the device.
- Testing with different weighted wheels to decrease moment of inertia.
- Fatigue testing on parts.
- Testing in real scenarios, at tilted angles, and different cord sizes.

Questions?

Appendix - QFD

1	Cost														
2	Side Force		3												
3	Retraction Speed		3	9											
4	Temperature		1	0	1					Legend					
5	Weight		9	9	3	0				A	W.L. Gore for Lockheed Martin				
6	Umbilical Length		0	9	9	0	9			B	Northrop Grumman Umbilical				
7	Success Rate		9	3	9	9	1	3		C	NASA Retraction Arm				
			Technical Req.							Customer Option Survery					
	Customer Needs	Customer Weights	Cost	Side Force	Retraction Speed	Temperature	Weight	Length	Success Rate (%)	1. Poor	2	3. Average	4	5. Good	
1	High Manufacturability	3	3	0	0	0	3	1	3		A		C	B	
2	High Reliabilty	5	3	9	9	3	3	1	9		C		B	A	
3	Easily Installed/Removed	4	1	0	0	0	9	3	3	A	C		A	B	
4	High Durability	4	9	9	9	9	3	9	9	B				AC	
5	ESD Safe	3	1	1	3	3	0	0	1					ABC	
	Tech Req.Units		Dollars($)	Pounds (lbs)	Speed (ft/s)	Fahrenheit (F)	Force (lb/ft)	Feet (ft)	Success Rate (%)						
	Tech Req. Targets		5000	<10	6ft / 1s	-30F to 160F	1lb / 1ft	2ft to 6ft	100						
	Absolute Tech. Importence		67	84	90	60	72	56	105						
	Relative Tech Importance		5	3	2	6	4	7	1						

Appendix – Gantt Chart



DAILY GANTT CHART

Team Umbilical — Project Name

Northrop Grumman (Kathyn Barr) — Customer

23-Aug-21 — Start Date

06-May-22 — End Date

Task ID	Task Name	Task Status	Start Date	End Date	Member
T1	Project Management	Complete	1/10/2022	1/14/2022	All Members
T1-S1	Reflection	Complete	1/10/2022	1/14/2022	Leah
T1-S2	Gantt Chart (Update 1)	Complete	1/10/2022	1/14/2022	Jack
T1-S3	Purchasing Plan	Complete	1/10/2022	1/14/2022	Jonathan
T1-S4	Manufacturing Plan	Complete	1/10/2022	1/14/2022	Griffin
T2	Motor Ordering	Complete	1/10/2022	1/17/2022	All Members
T3	Finalize Design	Complete	1/10/2022	1/27/2022	All Members
T4	Self Learning Assignment	Complete	1/15/2022	1/28/2022	Each Individually
T5	Individual Analysis	Complete	1/15/2022	1/28/2022	Each Individually
T6	Order for Building Parts (Check 1)	Complete	1/10/2022	1/10/2022	All Members
T7	Hardware Status 1 (33% Build)	Complete	1/17/2022	2/11/2022	All Members
T7-S1	Design Effort	Complete	1/17/2022	2/11/2022	All Members
T7-S2	Purchasing Plan (33% Complete)	Complete	1/17/2022	2/11/2022	All Members
T7-S3	Manufacturing Plan (33% Complete)	Complete	1/17/2022	2/11/2022	All Members
T7-S4	Demonstration (33% Complete)	Complete	1/17/2022	2/11/2022	All Members
T7-S5	Gantt Chart (Update 2)	Complete	1/17/2022	2/11/2022	All Members
T7-S6	Peer Evaluation 1	Complete	2/10/2022	2/11/2022	Each Individually
T8	Hardware Review	Complete	1/31/2022	2/10/2022	All Members
T9	Manufactured & Purchased Parts	Behind	2/1/2022	2/28/2022	All Members
T9-S1	Purchased Parts - Plate and Wheel	Complete	2/1/2022	2/14/2022	Griffin
T9-S2	Manufactured Parts - Base & Shaft	Behind	2/15/2022	2/22/2022	Jonathan
T9-S3	Manufactured Parts - Heat Shield	Behind	2/15/2022	2/28/2022	Griffin
T10	Actuation Origin	Complete	1/31/2022	2/21/2022	All Members
T11	Parts Acquisition	Complete	1/17/2022	2/11/2022	All Members
T12	Website Check 1	Complete	2/14/2022	2/24/2022	Jonathan
T13	NG Critical Design Review	Complete	2/14/2022	2/14/2022	All Members
T14	Motor Programming	Complete	2/14/2022	2/28/2022	Jonathan
T15	Parts Assembly and Welding	Upcoming	2/17/2022	3/2/2022	All Members
T15-S1	Electric Assembly	Complete	2/14/2022	2/21/2022	Jonathan
T15-S2	Machine Assembly	Behind	2/23/2022	2/23/2022	All Members
T15-S3	Full Assembly	On Task	2/14/2022	3/18/2022	All Members
T16	Hardware Status 2 (66% Build)	On Task	2/14/2022	3/4/2022	All Members
T17-S1	Design Effort	On Task	2/14/2022	3/4/2022	All Members
T17-S2	Purchasing Plan (66% Complete)	On Task	2/14/2022	3/4/2022	All Members
T17-S3	Manufacturing Plan (66% Complete)	On Task	2/14/2022	3/4/2022	All Members
T17-S4	Demonstration (66% Complete)	On Task	2/14/2022	3/4/2022	All Members
T17-S5	Gantt Chart (Update 3)	On Task	2/14/2022	3/4/2022	All Members
T17-S6	Peer Evaluation 2	On Task	2/14/2022	3/4/2022	Each Individually
T18	Begin Testing	Upcoming	3/3/2022	3/14/2022	All Members
T19	UG/MAS Registration	Upcoming	3/7/2022	3/11/2022	All Members
T20	Hardware Status 3 (100% Build)	Upcoming	3/7/2022	3/25/2022	All Members
T21-S1	Design Effort	Upcoming	3/7/2022	3/25/2022	All Members
T21-S2	Purchasing Plan (100% Complete)	Upcoming	3/7/2022	3/25/2022	All Members
T21-S3	Manufacturing Plan (100% Complete)	Upcoming	3/7/2022	3/25/2022	All Members
T21-S4	Demonstration (100% Complete)	Upcoming	3/7/2022	3/25/2022	All Members
T21-S5	Gantt Chart (Update 4)	Upcoming	3/7/2022	3/25/2022	All Members
T22	Finalize Testing Plan	Upcoming	2/21/2022	3/25/2022	All Members
T22-S1	Design Requirements Summary	Upcoming	3/7/2022	3/25/2022	All Members
T22-S2	Top Level Testing Summary	Upcoming	3/7/2022	3/25/2022	All Members
T22-S3	Detailed Testing Plan	Upcoming	3/7/2022	3/25/2022	Leah
T22-S4	Specification Sheet Preparation	Upcoming	3/7/2022	3/25/2022	All Members
T22-S5	QFD (Part 1)	Upcoming	3/7/2022	3/25/2022	All Members
T23	UG/MAS - Draft of Poster	Upcoming	3/28/2022	4/1/2022	All Members
T24	Initial Testing Results	Upcoming	3/28/2022	4/8/2022	All Members
T25-S1	Design Requirements Summary (Part 2)	Upcoming	3/28/2022	4/8/2022	All Members
T25-S2	Top Level Testing Summary (Part 2)	Upcoming	3/28/2022	4/8/2022	All Members
T25-S3	Detailed Testing Plan (Part 2)	Upcoming	3/28/2022	4/8/2022	All Members
T25-S4	Specification Sheet Preparation (Part 2)	Upcoming	3/28/2022	4/8/2022	All Members
T25-S5	QFD (Part 2)	Upcoming	3/28/2022	4/8/2022	All Members
T25-S6	Peer Evaluation 3	Upcoming	3/28/2022	4/8/2022	Each Individually
T26	UG/MAS - Final Poster and PowerPoint	Upcoming	4/4/2022	4/7/2022	All Members
T27	Operation/Assembly Manual	Upcoming	4/4/2022	4/15/2022	All Members
T28	Final CAD Package	Upcoming	4/4/2022	4/15/2022	All Members
T29	UG/MAS Symposium	Upcoming	4/22/2022	4/22/2022	All Members
T30	Product Demo and Testing Results	Upcoming	4/18/2022	4/29/2022	All Members
T31-S1	Design Requirements Summary (Part 3)	Upcoming	4/18/2022	4/29/2022	All Members
T31-S2	Top Level Testing Summary (Part 3)	Upcoming	4/18/2022	4/29/2022	All Members
T31-S3	Detailed Testing Plan (Part 3)	Upcoming	4/18/2022	4/29/2022	All Members
T31-S4	Specification Sheet	Upcoming	4/18/2022	4/29/2022	All Members
T31-S5	QFD (Part 3)	Upcoming	4/18/2022	4/29/2022	All Members
T31-S6	Peer Evaluation 4	Upcoming	4/18/2022	4/29/2022	All Members
T32	Final Report	Upcoming	4/18/2022	4/29/2022	All Members
T33	Final Website Check	Upcoming	4/18/2022	4/29/2022	All Members
T34	Client Handoff	Upcoming	4/25/2022	5/3/2022	All Members
T35	NG Mentor Meeting	Upcoming	TBD	TBD	All Members
T36	NG University Symposium Day	Upcoming	TBD - May	TBD - May	All Members

Remarks:

T - Task | S - Subtask | NG - Northrop Grumann

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