The Ski Haus Tow Rope

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Problem Statement

- **Rail Jam Competition:** a terrain park competition for skier and snowboarders where they must complete as many tricks as possible on the given features in a set amount of time
- To do this, competitors must hike the competition area after each attempt for the entirety of their heat
- Hiking in ski and snowboard boots with your gear takes a lot of effort especially in a timed scenario
- This causes a lot of fatigue and has led to people getting seriously injured from exhaustion

Project Description

Design a motorized rope system that can transport skiers and snowboarders up a slope

The device must be portable for competitions at different locations

Allowing for people to ride up instead of hike reduces fatigue and potential injury

Sponsored by Ski Haus

What is a Tow Rope?

- A tow rope is a common subset of chair lifts that transports riders up the slopes while they are still on the ground
- They are usually industrial, permanent installations similar to chair lifts
- Commonly used in terrain parks or where chair lifts are not as practical
- There are two common types: Surface lifts (T-bar) and the parallel rope tow

Parallel Rope Tow

Surface Lift

Customer and Engineering Requirements

Customer Requirements

- Quickly Transports riders
- Safe for all riders
- Minimum towability of 5 people
- Portable (easy set up/take down)
- Covers the ground of a typical rail jam competition
- Durable for all weather conditions

Engineering Requirements

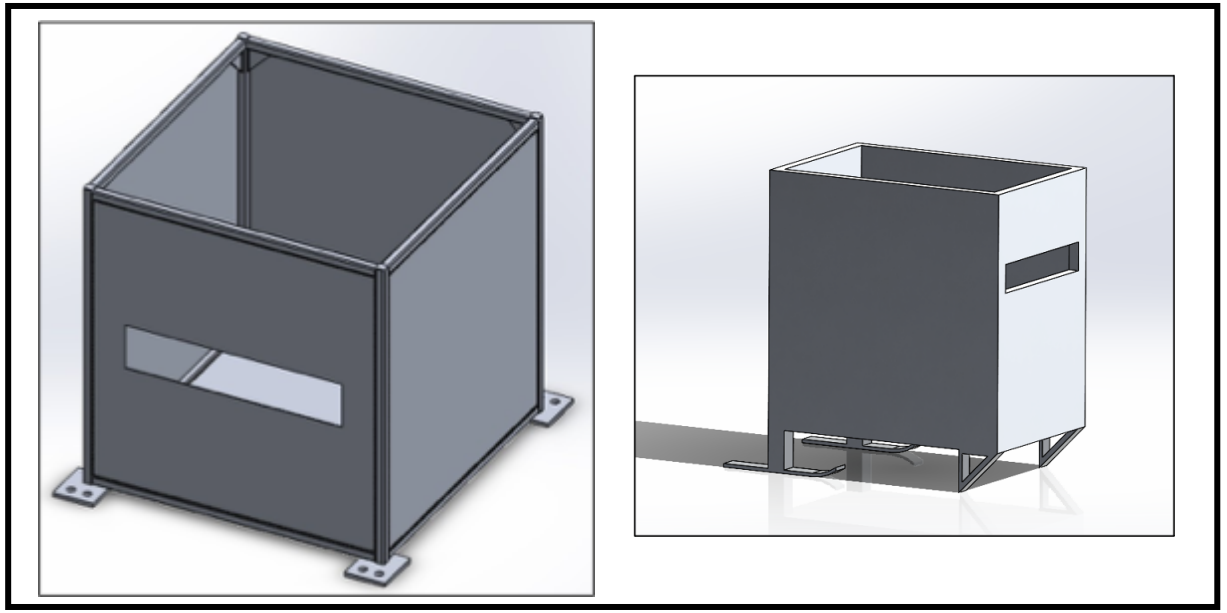
- Motor capable of towing 60 people/hour
- Safety features: quick stop, adjustable speeds, and encased mechanical parts
- Motor no less than 10 HP
- Portability: less than 300lbs, wheels and handles
- Towable distance of 200ft – 300ft
- Anti rust and temperature tolerant material

Budget

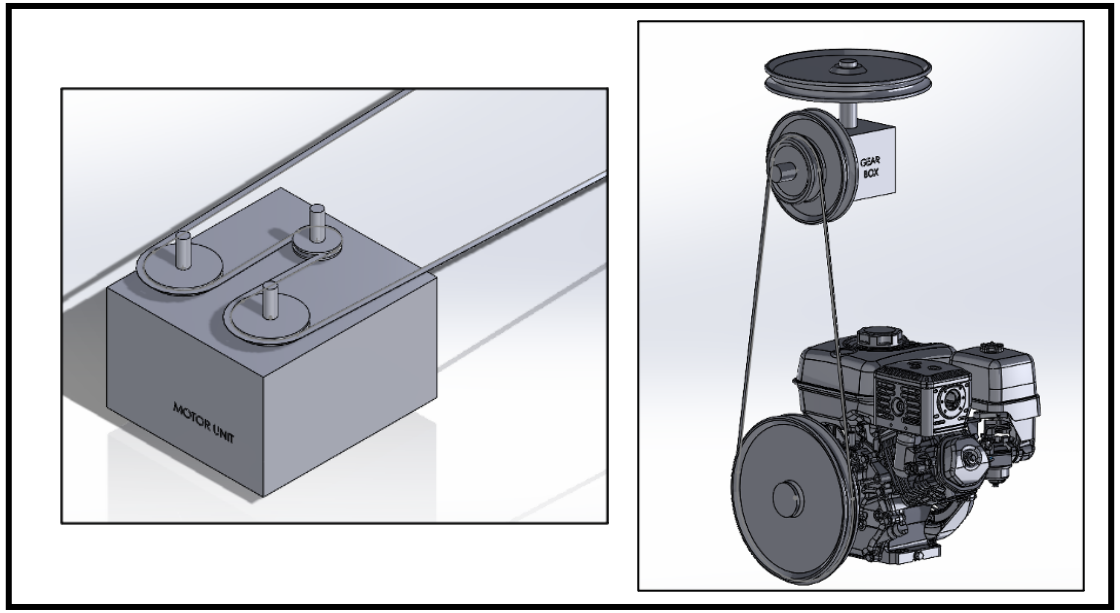
Activity	Date	Deposit/Withdrawls	Available budget
Recieved $200 from Treedogs Media Movie Fundraiser	11/25/2021	$200	$200.00
Bought prototype materials	12/7/2021	$14.18	$185.82
Bought engine out of pocket	12/16/2021	$413.79	-$227.97
Paid Teak for hoodie fundraiser art out of pocket	12/18/2021	$200	-$427.97
Recieved $1800 from Ski haus hoodie fundraiser	1/20/2022	$1,800	$1,800.00
Purchased Gearbox and sheaves	1/21/2022	$290.00	$1,510.00
Purchased Rope	1/22/2022	$460.00	$1,050.00
Purchased aluminum square tubing	1/22/2022	$250	$800.00
Purchased (5) 6 inch pulleys and (17) shaft clamps	2/3/2022	$224.70	$574.30
Purchased (6) sheave bearings	2/3/2022	$29.17	$545.13
Purchased (2) shaft couples	2/3/2022	$26.49	$518.64
Purchased (3) 2.45 inch pulleys	2/3/2022	$102.62	$416.03
Purchased 7ft steel shafts	2/12/2022	$78.28	$337.75
To Date Gofundme status fundraising for $1000	2/17/2022	$962.27	$1,300.02
Purchased (4) acrylic sheets	2/18/2022	$169.63	$1,130.39
Purchased (3) 2.45" pulleys	2/19/2022	$54.60	$1,075.79
Purchased (4) kevlar v belts	2/19/2022	$23.92	$1,051.87
Purchased (2) wheels	2/19/2022	$18.54	$1,033.33
purchased keystock	3/23/2022	$2.66	$1,030.67
3 more v belts	3/23/2022	$17.92	$1,012.75
zoro axel clamps	3/23/2022	$13.50	$999.25
Mayorga steel	3/24/2022	$94.44	$904.81
More flange Bearings	3/26/2022	$28.22	$876.59
Home depot hex nuts	3/26/2022	$20	$856.59
Hitch pins	3/27/2022	$34.81	$821.78
Wyatt Lunch	3/28/2022	$20	$801.78
napa Sleeve retainer	3/28/2022	$10.80	$790.98
home depot Hex nuts	3/28/2022	$3	$787.98
2nd hex nuts home depot	3/28/2022	$3	$784.98
mounting hardware	3/28/2022	$45.86	$739.12
harbor freight towbar	3/28/2022	$87.33	$651.79
napa gear oil	3/28/2022	$11.16	$640.63
napa belt	3/28/2022	$12.60	$628.03
harbor freight rust reformer, splice tools, anchor D-rings	4/2/2022	$45.53	$582.50
Online centrifugal clutch	4/2/2022	$100.73	$481.77
back plexiglass	4/2/2022	$58.38	$423.39
Home depot hex bolts/nuts	4/6/2022	$7.32	$416.07
Home depot hinges, anchors, latches, traction	4/6/2022	$72.87	$343.20
Weld labor Jared	4/6/2022	$10	$333.20
Harbor Freight returns	4/9/2022	$20	$353.20
Welding labor meyorgas	4/9/2022	$190 (covered by shop)	$353.20
UV Inhibiting Tint	4/9/2022	$55.89	$297.31
splicing tools	4/10/2022	$63.83	$233.48
Replacement belt	4/10/2022	$12.60	$220.88
Anchor Stakes	4/11/2022	$37.80	$183.08
Rope carriers	4/11/2022	$44.98	$138.10
Total Made		$2,962	
Total Spent		$3,251.15	

- Project was team initiated and funded
- Fundraised $1800 from sweatshirt sales
- Made $1000 from GoFundMe
- TBD from Collective Raffle
- $200 from Treedogs Media Movie Fundraiser
- $289.15 out of pocket from the team

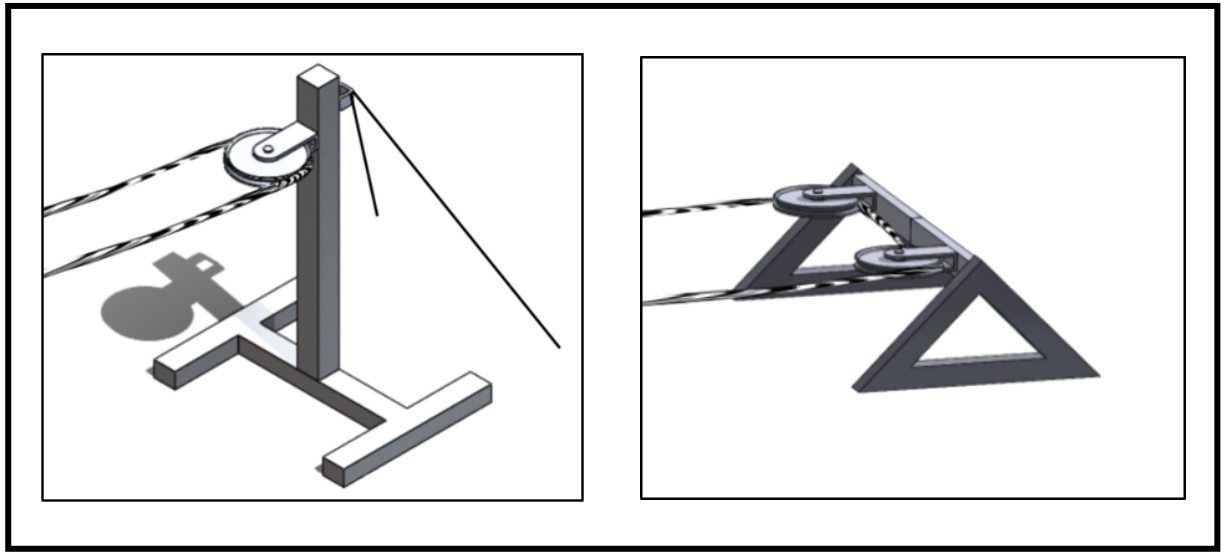
- **Total: $3251.15 spent**



Frame



Drive Unit

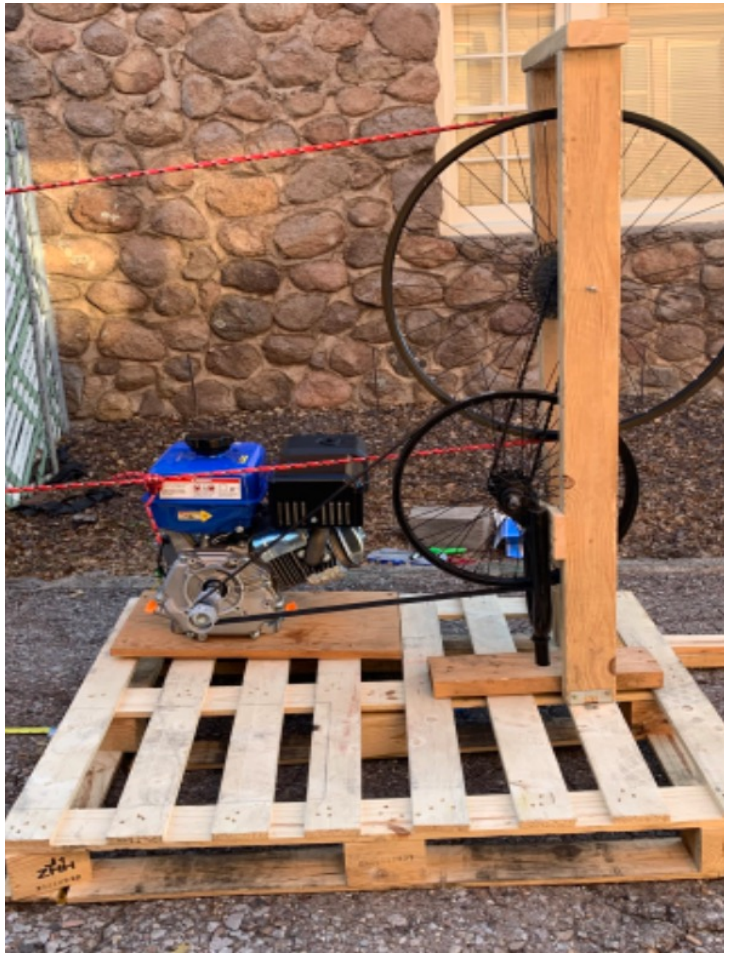


Top Pulley

Concept Generation

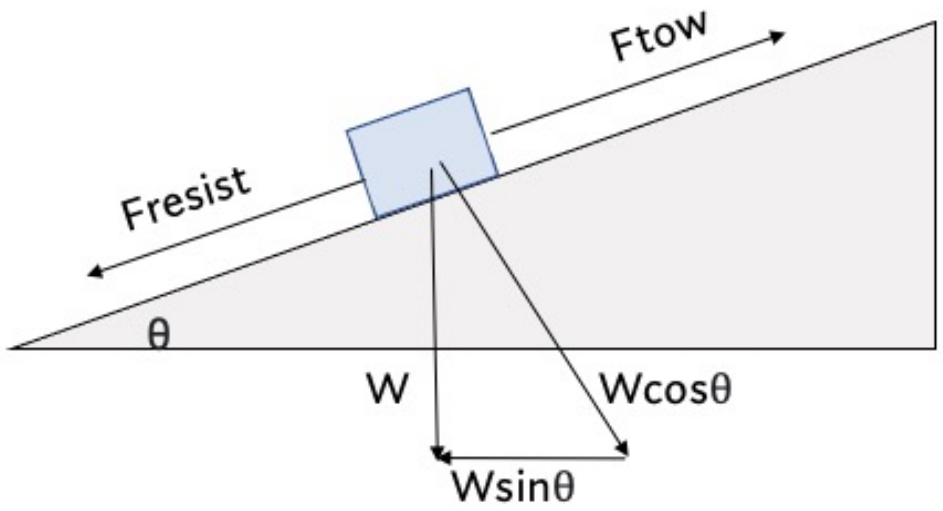
- The frames were not very mobile and didn’t incorporate mounting points
- The drive units were unable to gear down the engine properly
- The top pulleys needed to be combined for height and width as well as stability for the weight it will endure

Prototype



- Geared down with large wheel ratio
- Vertical rope with large bull wheel on the receiving end
- No gearbox

Design Analysis



Schematic used for dynamic analysis

Yes, our motor of 16HP will be more than capable of towing 10 people at a constant velocity of 1.5 m/s. A 10:1 gear box will be necessary to increase torque and decrease speed.

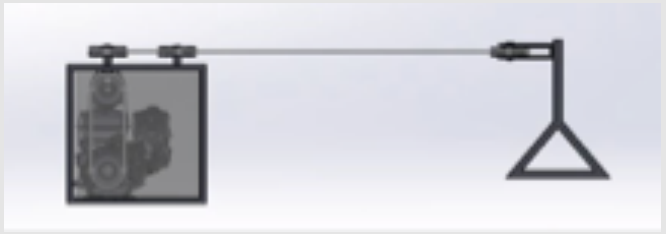
Calculations

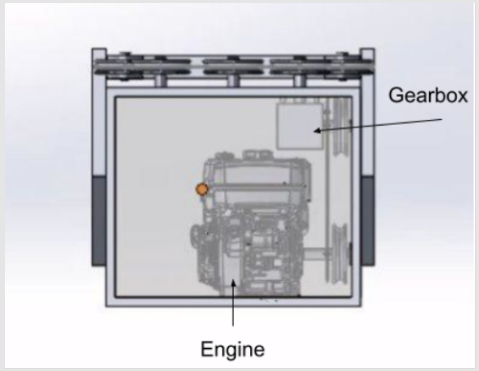
N = mgcosθ = 8554.73N
Ftow = Uk*N+mgsinθ = **3308.5N**
Fresist = **855.47N**
Ftow>>Fresist
T = F*r = **252.12 Nm**
Velocity of 1.5 m/s
Speed = Velocity/Circumference = 187.98 RPM
Power = T*Speed = **6.7 HP needed**

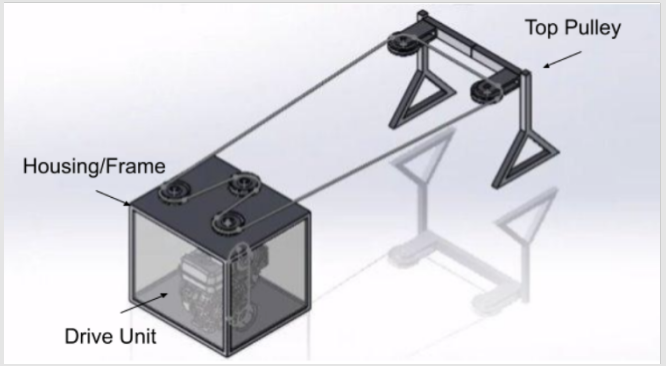
Assumptions (worst conditions)

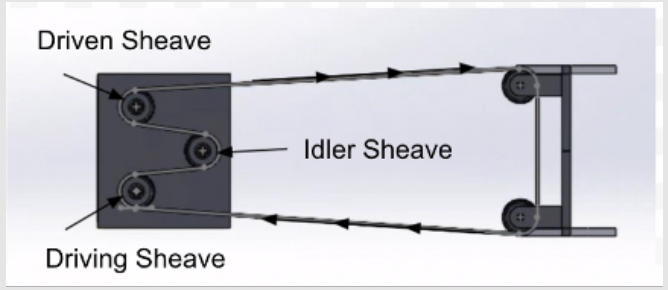
- 10 people at 200lbs
- Θ = 16 degrees
- Kinetic friction = 0.1
- Velocity of 1.5 m/s
- 16 HP motor with max torque of 28.5 Nm and max speed of 3600 rpm
- Sheave wheel of a 6-inch diameter (0.1524m)

First Iteration Design









- The top pulley is very similar to our final design
- Drive unit have the same set up for horizontal sheaves
- Gearing ratio in this iteration is not compliant with our motor
- Plexi glass frame was used in final design

Design Analysis

Drive Shaft ø2.45 " pulley to Shaft 1 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{3600\ RPM}{2.5510} = 1411.2\ RPM$$

Shaft 1 ø6.25 " pulley velocity = Shaft 1 ø2.45 " pulley velocity

Shaft 1 ø2.45 " pulley to Shaft 2 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{1411.2\ RPM}{2.5510} = 553.19\ RPM$$

Shaft 2 ø6.25 " pulley velocity = Shaft 2 ø2.45 " pulley velocity

Shaft 2 ø2.45 " pulley to Shaft 3 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{553.19\ RPM}{2.5510} = 216.85\ RPM$$

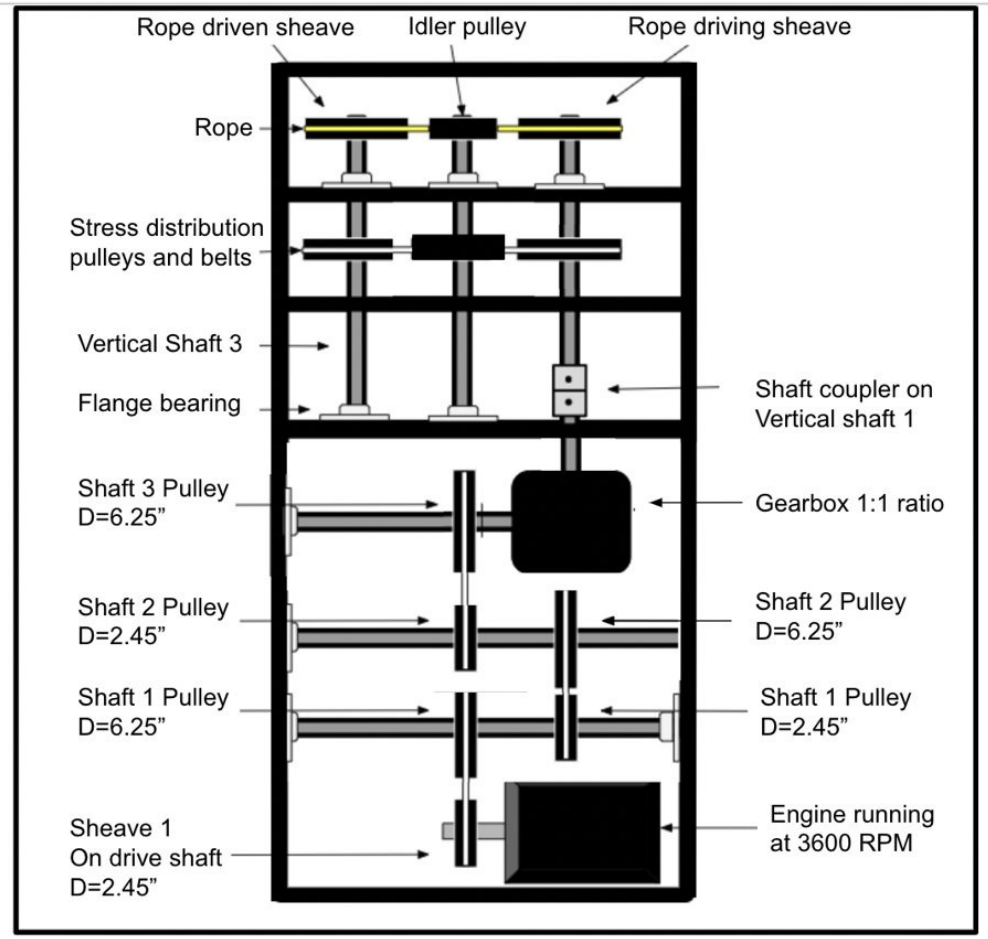
1:1 Ratio gearbox attached to Shaft 3 and Vertical Shaft 1
∴ Shaft 3 velocity = Vertical Shaft 1 Velocity

Driving Sheave fixed to Vertical Shaft 1
∴ Driving Sheave angular velocity = $216.85\ RPM$

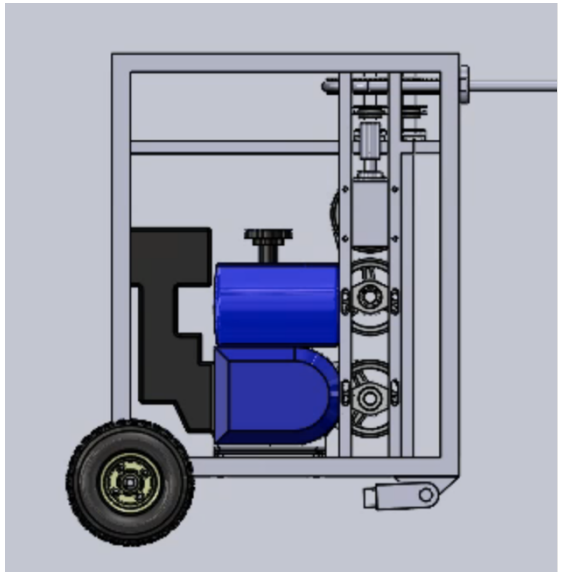
Converting angular velocity to linear velocity of Driving Sheave
Driving Sheave radius = 3 inches = 0.0762 meters

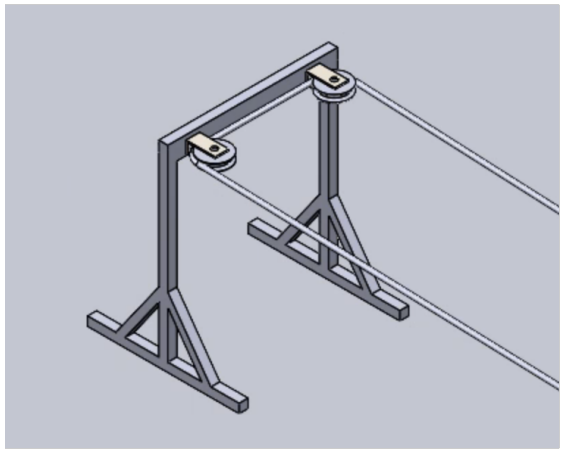
$$V_{Linear} = \frac{215.85\ RPM}{60\ s} \times 2\pi \times 0.0762\ m = 1.73\ \frac{m}{s}$$

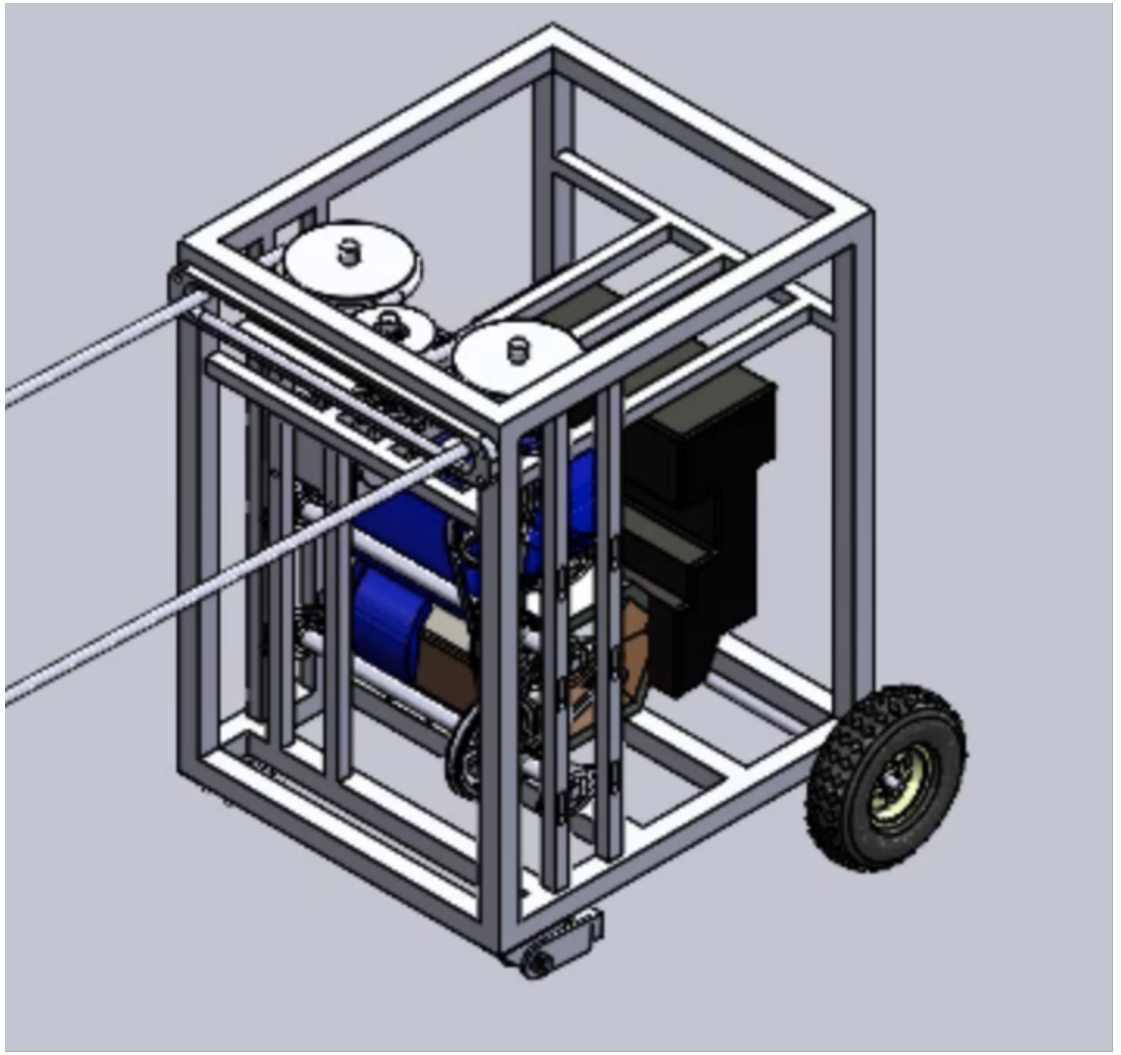
Driving Sheave linear velocity = Rope velocity = $\mathbf{1.73}\ \frac{m}{s}$

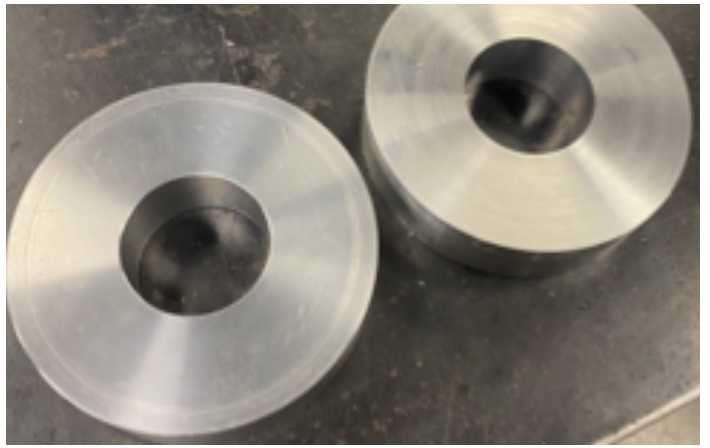


Second Iteration (Final Design)









Manufacturing

- Many design iterations were created through the process of the manufacturing
- Issues with tolerancing led to different ways of securing pulleys and sheaves
- Gearbox mount ran into issues with frame and location

Bill of Materials

2021-2022 Ski Haus Tow Rope
Bill of Materials

Team Name:	Ski Haus Tow Rope	Team #:	21F09_SkiHaus	Date:	1/11/2022
		City:	Flagstaff	State:	Arizona

Item	Description	Material	Source (Primary Vendor)	Manufacturer	Lead Time	Part Status	Quantity	Measurement	Unit Price	Total Cost
Major System Names Here	*Describe the Part (Axle, Bearing, Lifter, Solenoid)*	*What is it made from*	*Buy or Make (Home Depot, Machine Shop, Supply House, Etc.)*	*Who manufactured the item*	*Expected lead time from purchase time*	*Purchased, Arrived, or To be purchased/made*	*How Many*	*Piece, Inch, Etc.*	*Cost Per Unit ($)*	
Subsystem 1: Drive Unit										
motor	driving power system	aluminum, steel, plastic	Generator Factory Outlet	Duromax	n/a	Purchased, Arrived	1	n/a	$414.00	$414.00
Sheaves	spinning track for rope	aluminum	Made in NAU Machine Shop	Ski Haus Team	1 week	To be made week of 2/7	3	6in and 4in dia.	TBD	-
flange bearings	support shafts with pulleys	cast iron	amazon	PGN bearings	1 week	to be ordered 2/1	2	1" bore	25.85	51.7
bearings	support roation of sheaves and shafts	chromium bearing steel	Big Bearing Store	Grainger	1 week	To be purchased week of 2/1	5	25mm bore, 52mm OD	$3.74	$18.70
v-belt pulleys	transmitting and gearing down power	zinc	zoro	zoro	2 week	To be purchased week of 2/1	3	4 in	$14.53	$43.59
v-belt pulleys	transmitting and gearing down power	zinc	zoro	zoro	2 week	To be purchased week of 2/1	1	6 in	$20.36	$20.36
shafts	mounts for the sheaves and	carbon steel	Made in NAU Machine Shop	Ski Haus Team	1 week	To be made week of 2/1	3	21" length, 1.5" dia.	40	-
Shafts	mounts for the sheaves and	carbon steel	Made in NAU Machine Shop	Ski Haus Team	1 week	To be made week of 2/1	1	6" length, 2" dia.	40	-
v-belts	connects the pulleys	EPDM rubber	McMaster Carr	McMaster Carr	1 week	To be purchased week of 2/1	2	26" length	$9.65	$19.30
Shaft couplings	connects two shafts together	mild steel	The Big Bearing Store		1 week	To be purchased week of 2/1	1	1 in bore, 3 in length	9.25	9.25
shaft keys	sectures the rotating element to the shaft	carbon steel	NAPA auto parts	NAPA auto parts	1 week	18-Feb	1	1/8"x1/8", 1/2"	$2.69	$2.69
gear box	transmits the vertical motion horizontally	steel	SpinCo	SpinCo	3 days	Purchased, on hand	1	1:1	$134.99	$134.99
rope	for pulling the riders and running through the system	polypropylene	Uline	Uline	3 days	Purchased, on hand	1	600 ft	$380.00	$380.00
									Subtotals:	$1,094.58
Subsystem 2: Housing										
Aluminum frame	protects the drive unit	Aluminum	Coast Aluminum	Coast Aluminum	1 Day	Purchased, on hand, process of being welded	3	20'x1.5"x1.5"x.125"	$70.00	$210.00
PVC sheets	encloses the frame and allows for visual inspection	PVC	Zoro	Zoro	1 week	To be purchased week of 2/18	3	3ftx3ft	$48.90	$146.70
steel sheets	encloses the frame	steel	metal recycling center	metal recycling center	1 day	To be purchased week of 2/18	5	3ft x 3ft	2	10
skis	would attach to the boase for each transport	wood	Ski Haus	Ski Haus	1 day	on hand	2	3ft x 4in	$0.00	$0.00
bolts	for securing all the framing pieces and securing the drive unit	steel	home depot	home depot	1 day	To be purchased week of 2/7	1	M6 - 1.0 x 25mm	$15.18	$15.18
hinges	for attaching the top for easy access for maintenance	steel	home depot	home depot	1 day	To be purchased week of 2/18	6	2 inches	$3.47	$20.82
latch	to securely close the top	stainless steel	home depot	home depot	1 day	To be purchased week of 2/18	6	2 in x 1in	$3.34	$20.04
									Subtotals:	$422.74
Subsystem 3: Top Pulley										
Sheaves	spinning track for rope	aluminum	Made in NAU Machine Shop	Ski Haus Team	1 week	To be made week of 1/16	2	4in dia.	TBA	-
steel posts	for the creation of a structure that holds the top pully	steel	online metals	online metals	1 week	To be purchased week of 2/7	5	15'x1"x1"x0.12"	$16.69	$83.45
bolts	for securing the brackets to the sheaves	steel	home depot	home depot	1 day	To be purchased week of 2/18	2	M6 - 1.0 x 25mm	-	-
nuts	secure the bolts	Steel	home depot	home depot	1 day	To be purchased week of 2/18	4	1"	$0.90	$3.60
brackets	to attach the pully to the post and create a tie down point	steel	life easy supply	life easy supply	1 week	To be purchased week of 2/18	1	58mm	$33.27	$33.27
									Subtotals:	$120.32
Extras for demo										
ratchet straps	to tie down the top pulley system	Abrasion-resistant polyester webbing	home depot	home depot	1 day	Purchased, on hand	2	2in x 27 ft	$18.49	$36.98
gasoline	to fuel the IC engine	87 octane	gas station	gas station	1 day	Purchased	1.5	n/a	$3.79	$5.69
									Subtotals:	$42.67
									Totals:	$1,680.31




Final Build

Initial Testing

Speed

Test	Time (s)
Test 1	1.68
Test 2	1.88
Test 3	1.81
Average	1.79

Portability

Component	Weight (+/- 1 lb)
Engine	75 lbs
Drive unit frame	35 lbs
Drive unit components	55 lbs
Top pulley	25 lbs
Rope (including spool)	101 lbs
Total Weight	291 lbs

Component	Area (+/- 1")
Rope spool	452.39 in^2
Drive unit + Top Pulley	756 in^2
Total Area	1208.39 in^2

Area Results

$A = L \times W$

$A_{Spool} = \pi r^2 = \pi(122) = 452.39\ in^2$

$A_{Total} = \sum A_{Spool} + A_{Drive\ Unit} + A_{Top\ Pulley} \leq A_{Truck\ Bed}$

Area of F150 short bed (client's truck)= $\mathbf{4858\ in^2}$

(Length=77.75" X W=62.49")

Alternative Area Result

Frame + Top Pulley = 27" x 28"

Rope spool diameter = 24"

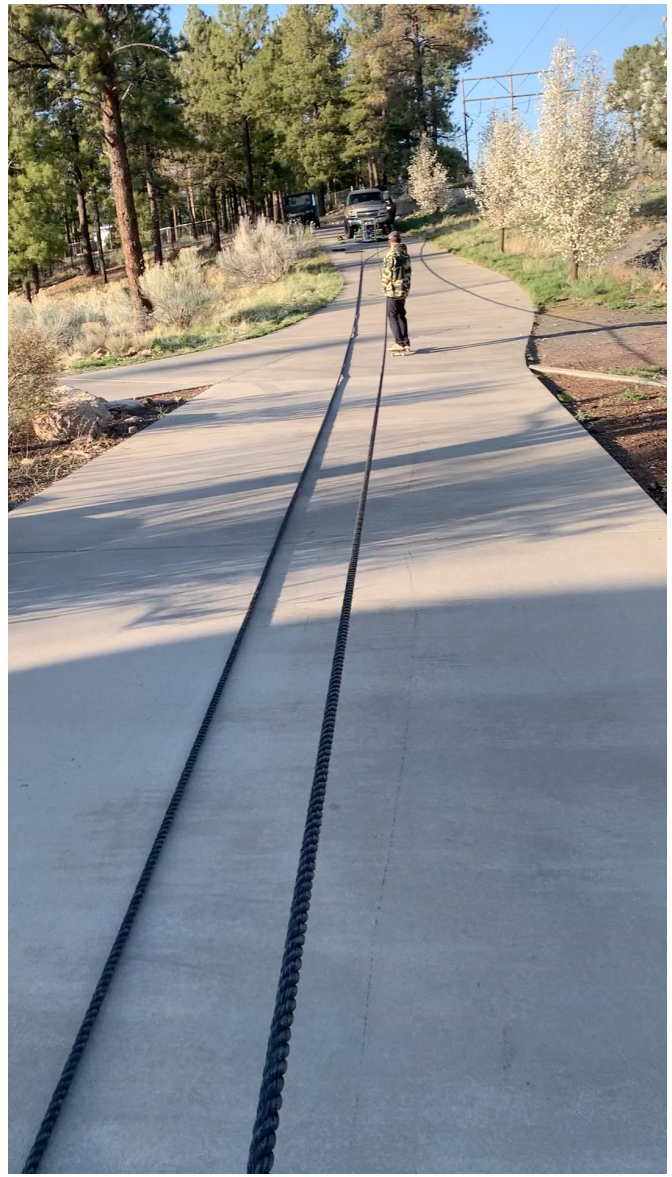
Truck bed dimensions = 77.75" x 62.49"

Components Loaded = 52" x 28"

Final Testing

- Final testing for speed on snow up a slope
- Final testing with the 600 ft rope
- Final testing for how many people can be loaded at a time
- Safety testing for clutch and stopping time

Engineering Requirement	Target	Tolerance	Measured/Calculated value	ER met? (✓ or X)	Client acceptable? (✓ or X)
ER1 –people on the rope	5 people	+/- 2 people	5 people	✓	✓
ER2 – people/ hour travel	60 people/hour	+/- 10 people	60 people/hour	✓	✓
ER3 – distance traveled	250 ft	+/- 50 feet	300 ft	✓	✓
ER4 – weight of unit	300 lbs.	+/- 50 lbs.	291 lbs	✓	✓
ER5 – number of safety features	2 features	- 1 feature (no limit for maximum)	2 safety features	✓	✓
ER6 – factor of safety	3	+/- 1	3	✓	✓
ER7 – material durability	250 MPa	+/-50 Mpa	276 MPa	✓	✓



Future Work

- The Tow rope will be utilized in Ski Haus rail jam competitions held at the Nordic center
- The device will require monthly running in the off season
- Belts will need to be analyzed for wear and replaced when necessary
- Addition of angle supports for the welds to increase durability during transport

Jesse

Acknowledgments

- Ski Haus, Davis Bendient & Josh Bangle (sponser and client)
- Treedogs Media, Forrest Wilson (fundraising)
- Rich Phillips with Collective (fundraising)
- David Willy (professor and advisor)
- Perry Wood (professor and machine shop manager)
- Wyatt Watson (welding)
- Meyorga's Welding (welding)
- Austin Escalante (assembly and testing advisor)

Questions?