2023-2024 Landing Gear

RE: <@Charles Yang>

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Specifications

- *Weighs under 1.5 kg (without connection to bulkhead).*
- *Made for horizontal and vertical takeoffs and landings (includes nose wheel steering).*
- *Qualified for vertical landings of 2 m/s or less.*
- *Max load on landing gear system is around 50 lbs.*

Requirements

Requirements as defined here and agreed upon by system/subsystem stakeholders.

Functional Requirements			
#	**Description**	**Technical Requirement**	**Validation**
1	Landing Gears support weight of the plane.	The landing gear can carry 25 kg of mass and support the plane when 25 kg hits the ground at 2 m/s.	Put mass on top of plane and drop from around 20 cm off the ground
2	Landing Gear allows for horizonal and vertical landings.	The landing gear has ground steering.	Front Gear moves as servo moves
3	Landing Gear ensures plane will not tip in any direction.	Back landing gear must be behind CG and front landing gear must be in front of CG.	Find CG on new plane, and see where landing gears are installed
4	Landing Gear will not impede on the VTOL motors.	Landing Gear is not close to the VTOL motor systems.	VTOL motors spin without hitting landing gear
5	Landing Gear will create separation for push prop.	Since push prop is around 55 cm (21 inches), plane must be at least 27.5 cm off the ground	Push prop can spin
6	Landing Gear must not interfere with front camera /gimbal.	With gimbal around 15 cm out the fuselage, the front landing gear must be at least 12 cm from the camera to avoid it from being in camera FOV.	Camera cannot see the landing gear

Non-Functional Requirements			
#	**Description**	**Technical Requirement**	**Validation**
1	Be easy to install.	Landing Gear would not need to be detached from the fuselage.	Look 😐

2	Have as little drag as possible.	Avoid unnecessary area to cross section.	

Parts

Landing Gear Parts (Front)			
#	Name	Description	Path
1	Hitec D995TW Servo	The servo which powers the nose wheel steering. (Same size has Hitec D645MG servo)	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V2\servo HS 645 MG
2	SmallWheel-AMZ-a19012500ux0402	The wheel that was created to represent the real wheels on front landing gear of our plane.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\SmallWheel-AMZ-a19012500ux0402
3	AluminumRod-MCM-4634T323	Axle that is used for Spring Supports and Stops	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\AluminumRod-MCM-4634T323
4	ATLAS-SP-00032-01_LAND-Stops	Part that ensures landing gear does not go inside the fuse	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00032-01_LAND-Stops
5	LandingGearSpring-MCM-9620K28	Spring that is used to absorb shock of landings.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\LandingGearSpring-MCM-9620K28
6	RotaryShaft-MCM-1265K37	Axle to attach wheels to front landing gear	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\RotaryShaft-MCM-1265K37
7	ATLAS-SP-00024-03-2_LAND-CarbonTube1	First part of the strut right under the fuselage skin.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00024-03-2_LAND-CarbonTube1
8	ATLAS-SP-00024-03-2_LAND-CarbonTube2	Second part of the strut under the spring of the front landing gear.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00024-03-2_LAND-CarbonTube2
9	ATLAS-SP-00024-03-2_LAND-CarbonTube4	Third part of the strut above the fuselage skin inside the fuselage.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00024-03-2_LAND-CarbonTube4
10	ATLAS-SP-00028-01_LAND-SpringSupport1	Part attached to Carbon Strut 1 that keeps the spring from moving. Concentric to Spring Support 2.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00028-01_LAND-SpringSupport1
11	ATLAS-SP-00028-01_LAND-SpringSupport2	Part attached to Carbon Strut 2 that keeps the spring from moving. Concentric to Spring Support 1.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00028-01_LAND-SpringSupport2
12	ATLAS-SP-00026-03_LAND-Hinge1	Part of hinge that connects to Carbon Strut 1	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00026-03_LAND-Hinge1
13	ATLAS-SP-00026-03_LAND-Hinge2	Part of hinge that connects to Carbon Strut 2	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00026-03_LAND-Hinge2
14	ATLAS-SP-00030-01_LAND-ConnectionPoint	Part that connects Carbon Strut 1 to Carbon Fiber Tube 4 inside the fuselage.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00030-01_LAND-ConnectionPoint
15	ATLAS-SP-00031-01_LAND-Spacers	Spacer used to create offset between Spring Supports attached to Carbon Strut 1 and those attached to Carbon Strut 2.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00031-01_LAND-Spacers
16	ATLAS-SP-00035-03_LAND-Turning	Part attached to Carbon Fiber Tube 4 that allows linkages from the servo to connect to landing gear to steer the plane.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\ATLAS-SP-00035-03_LAND-Turning
17	ATLAS-SP-00058-01-1_LAND-CarbonTubeSpacer	Spacer for skin to turning thing and skin to stops.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00058-01-1_LAND-CarbonTubeSpacer
18	ATLAS-SP-00059-02-1_LAND-ServoMount	Laser cut piece to mount servo into.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00059-02-1_LAND-ServoMount
19	ATLAS-SP-00060-01-1_LAND-ServoStands	Four pieces that connects servo mount to the skin	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Front V3\Revisions V4\ATLAS-SP-00060-01-1_LAND-ServoStands

Landing Gear Parts (Back)			
#	Name	Description	Path
1	Back Strut	CAD of the back strut we will be buying.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Back

2	1310-0016-1006 Assembly. STEP	Part that will be screwed into back strut that will hold an axle for the wheels.	SOLIDWORKSPDM\cuair\2023 Aircraft\Airframe\Landing Gear\Back

Design

Brief Overview of System:

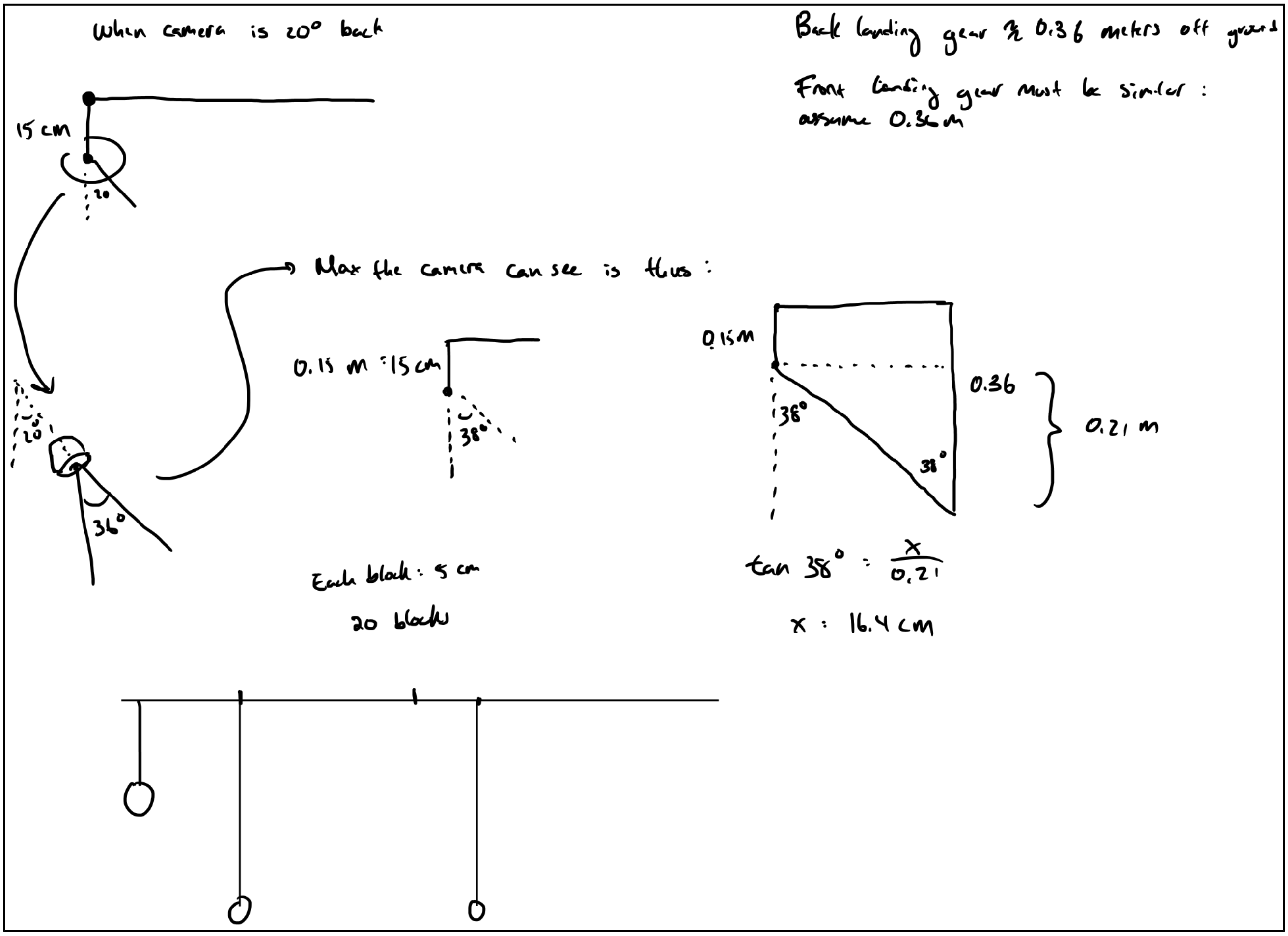
Landing gear is the only part of the plane that will touch the ground. It is responsible for ensuring no other part of the plane will touch the ground and also that the plane can move around on the ground.

Landing Gear Design Ideas and Brainstorming

- Should landing gear be retractable?
- What configuration should the landing gear be in? (triangle? skis?)
- Ground steering?
- Location?
- Suspensions?
- Brakes?
- Material?

Results

- The landing gear will not be retractable
    - Landing gear would be a 10 percent reduction in cross section. We are travelling at max 20 m/s.
        - Retractability will reduce drag but not by enough that its warranted.
- Triangle configuration would be best
    - This will allow for ground steering.
        - Ground steering allows for non-emergency horizontal landings.
        - Triangle reduces weight from current setup (double struts)
- Ground steering would be good
    - VTOL takeoffs take up around 2 of the 7 minutes of vertical battery we have. Having horizontal takeoffs would save time for vertical airdrop.
        - Horizontal takeoffs require ground steering
- We connect directly to fuse about 16.4 cm from gimbal.
    - This location is strong since the bottom of fuse will now be made from aluminum honeycomb.
    - Landing gears won't have to be disassembled every time we take the plane apart.



- We can have an Oleo Strut system in the front and just the classic leaf strut in the back
    - Oleo strut allows for easy ground steering, back struts don't have to be complicated
- We don't need brakes
    - The competition runway is 183 meters and friction itself will stop the plane in 33.22 meters.

Plane lands at 14 $\frac{m}{s}$ (30 mph)

Weight: 245N

Radius of Tires: 5cm

Deformation: 5mm

$$f = \frac{l}{\sqrt{R^2 - l^2}} N = \frac{0.005}{\sqrt{0.05^2 - 0.005^2}} \cdot 245 = 24.62 N$$

Three wheels: $24.6 \cdot 3 = 73.87 N$

$$F = ma$$
$$-73.87 = 25 a$$
$$a = -2.95 \frac{m}{s^2}$$

$$v_f^2 = v_i^2 + 2a\Delta x$$
$$0 = 196 - 2(2.95)\Delta x$$
$$\boxed{\Delta x = 33.22 m}$$

$\Downarrow$

Does not include drag

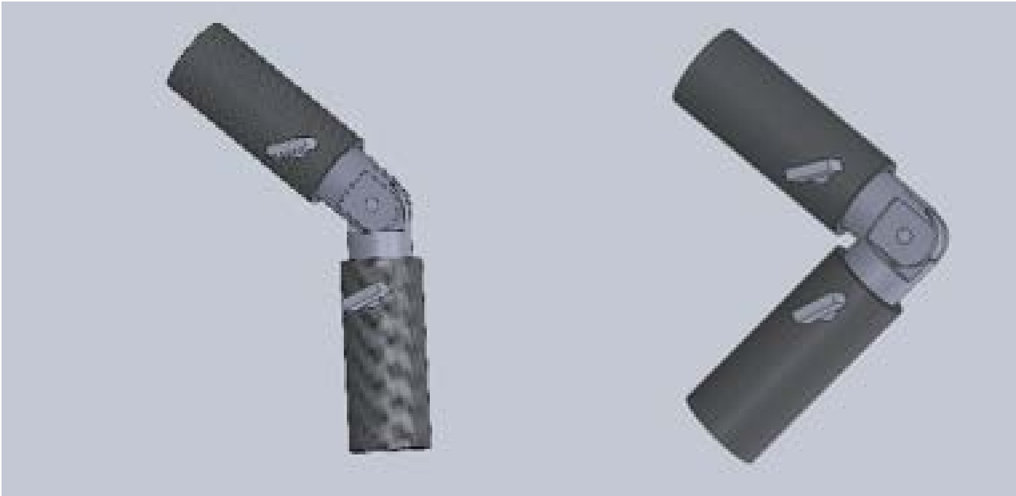
Rwy for HTOL is 70ft by 600ft

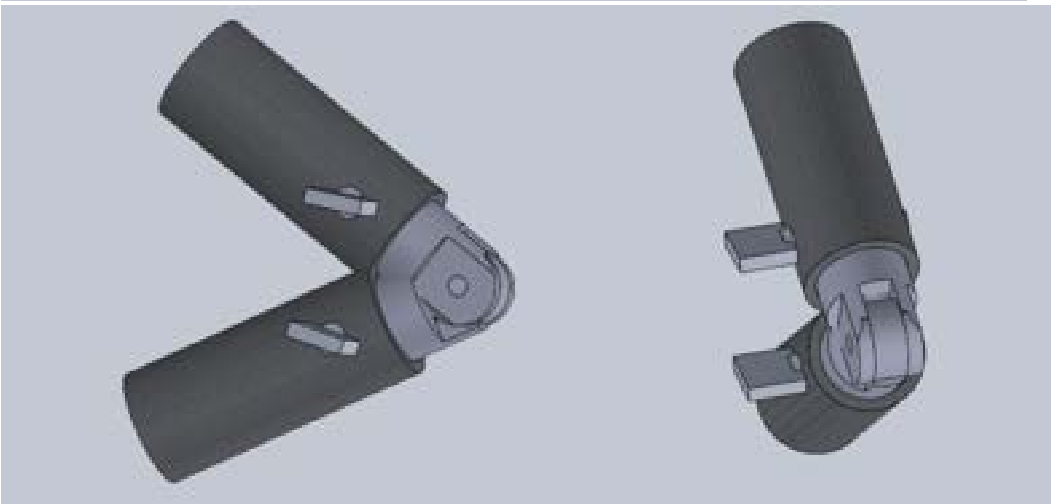
600ft ≈ 183 m

- I will make the landing gears with CF Nylon, composites and aluminum. This is because the landing gear systems has to be extremely strong but also lightweight.

Design Demo:

I first wanted to make sure that the front landing gear oleo strut system was feasible. I made a quick cad that projected where the spring would be and how everything would function.





The spring in this case would be between the two rectangular pieces. As the landing gear hinge bends, the spring will compress and absorb the landing shock/weight of the plane.

In the CAD, the grey items would ideally be made out of CF Nylon and the darker black pieces would be lightweight composites.

Next, I decided to make the first real version of the front oleo strut with the following things in mind:

- Correct dimensions of actual planned landing gear. This would be 36 cm tall because back strut is already set at 36 cm.
- Size the carbon fiber tube dimensions as said on product page of the following amazon page:

- Make sure the hinge is strong and can only bend one way (in demo design, the landing gear hinge can bend both ways; not ideal)
- Try to make some type of connection to the fuselage

Design V1

The spring would be where the concentric circles are at the hinge of the two carbon parts.

There is also a little connection point on the CAD which will prevent the gear from going into the fuselage.

Additionally, I did calculations to see what k constant I need for the spring to be able to absorb the shock of the landing.

$mu'' + bu' + ku = F(u)$ $\quad$ m: mass plane = 25 kg

$mu'' + ku = 0$ $\quad$ $u'(0) = -0.5 \quad u(0) = 0$

$u'' + \frac{k}{m} u = 0$

$r^2 + \frac{k}{m} = 0$

$$r = \frac{\pm\sqrt{-\frac{4k}{m}}}{2} = \frac{\pm 2\sqrt{\frac{k}{m}}\, i}{2} = \pm\sqrt{\frac{k}{m}}\, i$$

$$u(t) = C_1 \cos\left(\sqrt{\tfrac{k}{m}}\, t\right) + C_2 \sin\left(\sqrt{\tfrac{k}{m}}\, t\right) \qquad u'(t) = -\sqrt{\tfrac{k}{m}}\, C_1 \sin\left(\sqrt{\tfrac{k}{m}}\, t\right) + \sqrt{\tfrac{k}{m}}\, C_2 \cos\left(\sqrt{\tfrac{k}{m}}\, t\right)$$

$0 = C_1$ $\qquad$ $-0.5 = 0 + \sqrt{\frac{k}{m}}\, C_2$

$C_2 = -0.5\sqrt{\frac{m}{k}}$

$$u(t) = -0.5\sqrt{\frac{m}{k}} \sin\left(\sqrt{\tfrac{k}{m}}\, t\right)$$

I have 30 mm of space

$0.5\sqrt{\frac{m}{k}} < 0.03$

$\sqrt{\frac{m}{k}} < 0.06$

$\frac{m}{k} < 0.0036$

$\frac{25}{k} < 0.0036$

$25 < 0.0036\, k$

$k > 6944$ N/m

$F = -kx$

$196.49 = -k(0.04)$ $\quad$ sp - 9730

$k = 4912.25$

$234.22 = -k(0.038)$ $\quad$ sp - 9731

$k = 6163.68$

$269.5 = -k(0.045)$ $\quad$ sp - 9733

$k = 5989$

$269.5 = -k(0.037)$ $\quad$ sp - 9735

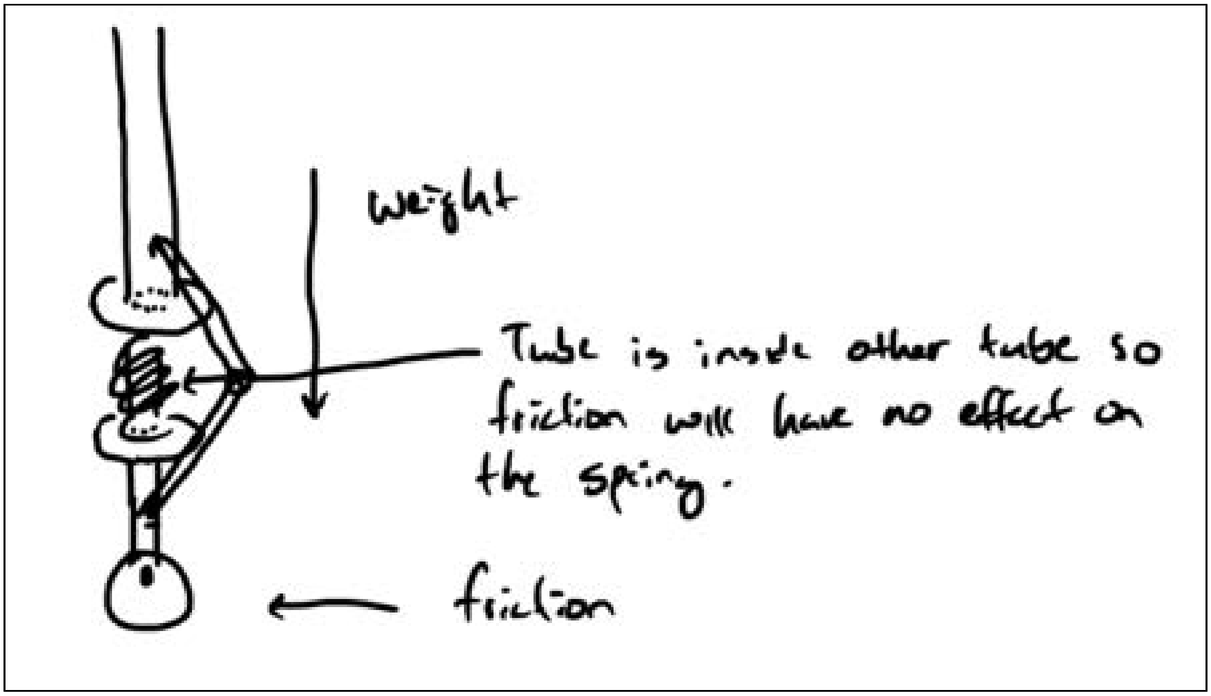
$\boxed{k = 7283.8 \text{ N/m}}$ - good

I found that the spring would need to have a k constant above 6944 N/m to support the plane's vertical landings.

After some searching, I found that the amazon springs below have a k constant of 7283.8 N/m with the correct dimensions. This spring was also one of the springs with the highest k constants at its dimensions.

With this spring in place, the design was complete.

I thought this was a really good design but the problem was that during landings, the forces in the x and y components of the landing (x from the friction with ground, y from vertical component of landing) would add up and thus, the spring would be fully compressed. This would cause damage to either the hinges of the landing gear, or the spring itself. This was the original motivation for another version of the landing gear. The new version will have the following kind of design:



This design would work well because the spring would only have to hold up the forces in the vertical direction and not the horizontal. Horizontal forces would go the bulkhead instead, which would not damage the landing gear.

Design V2

Note: The black parts are CF Nylon in this version

With this design, I fully implemented the linkage system that would work as the ground steering for the landing gears.

The fuselage skin will go between the two black pieces on the carbon fiber strut in the CAD.

I also added the spring component of the landing gear which looks great. Additionally, from PDR, I was directed to McMaster springs by Polina, which are almost twice as strong as the original amazon springs I used. The link to them is below:

https://www.mcmaster.com/9657K22/

- Design V2 Landing Gears are around 430 grams
- They are 360 mm from the outside of the fuselage skin to the bottom of the wheel when the spring is in equilibrium

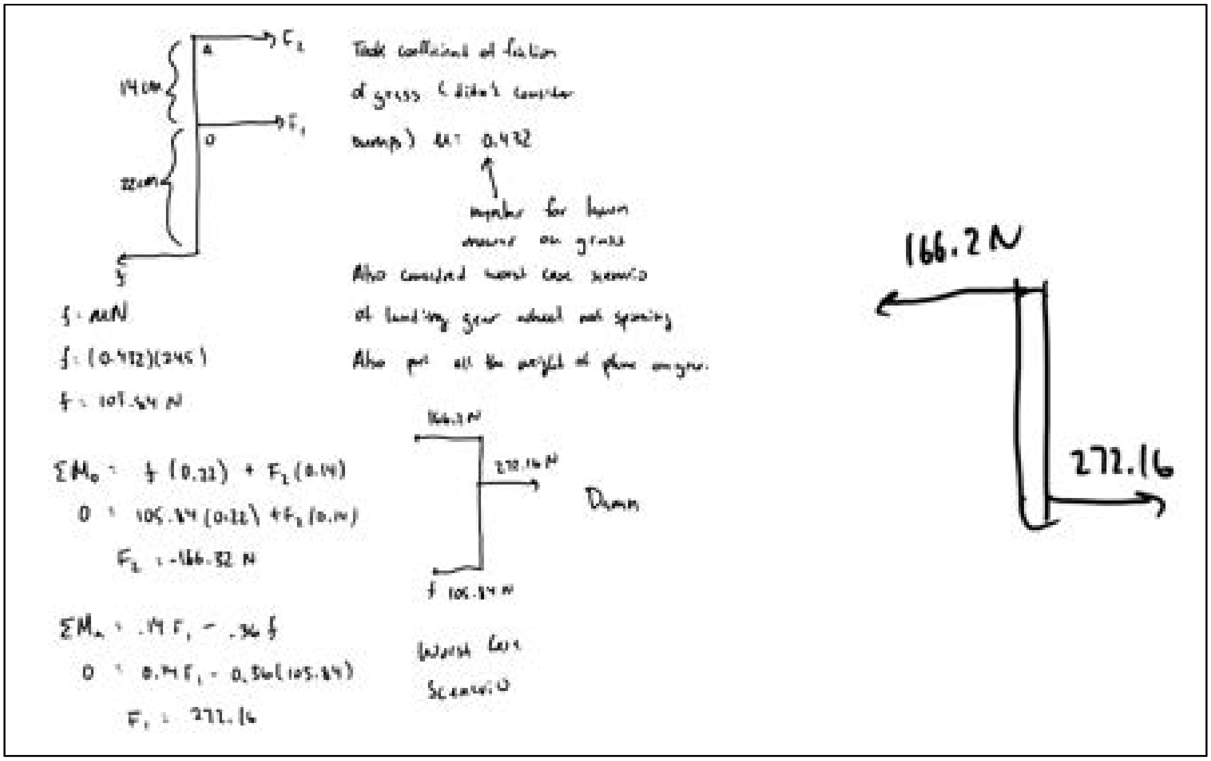
Bulkhead

After this design, I was told that I was also in charge of designing the bulkhead: I did the following first:

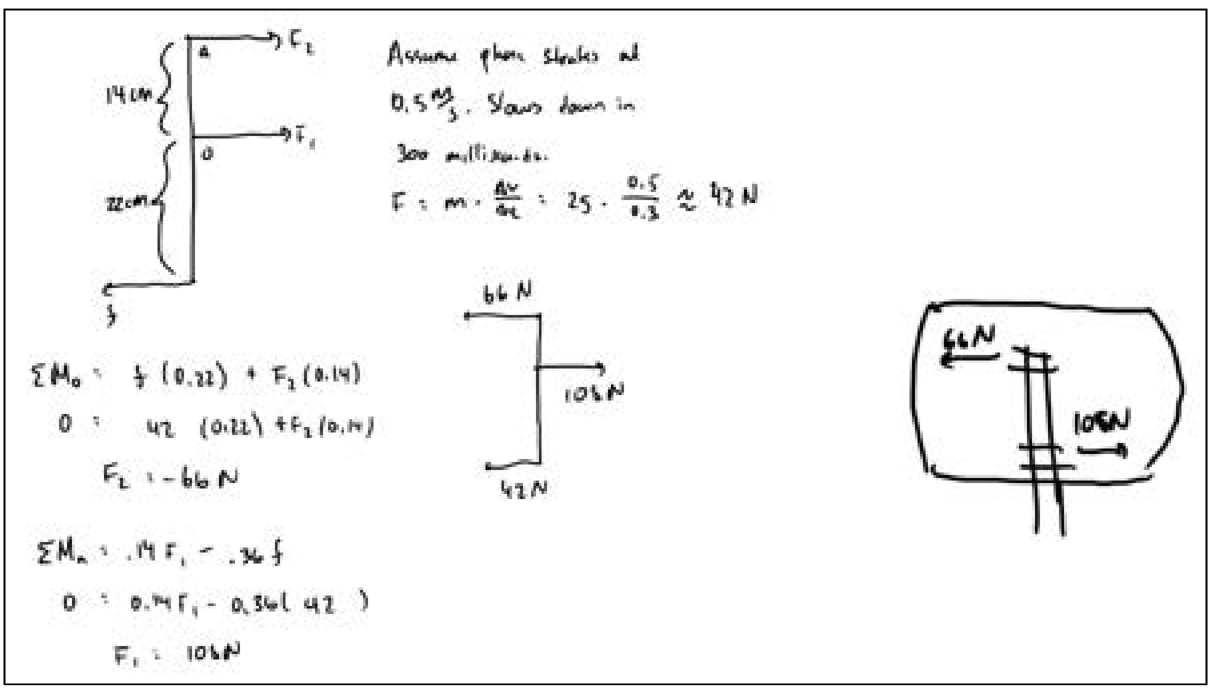
- Calculate the forces on the bulkhead during horizontal landings
- Calculate the forces on the bulkhead during vertical drift landings
    - These landings are when the plane is still moving a little left and right relative to the back of the plane when the plane comes down

The following are these calculations:

Forces on bulkhead during a horizontal landing on grass:



Forces on bulkhead during vertical drift landings:



The forces on the bulkhead are pretty high so there will be a version 3 of landing gears. This version will be similar to version 1. The idea of a new version was introduced during my CDR.

The difference between versions 1 and 3 are going to be the following:

- Correct dimensions
    - Use actual dimensions of carbon fiber tubes.
- The spring that is on version 3 will have a higher k constant

- With Polina introducing me to very strong springs on McMaster, I am able to use a spring that may be able to dampen both the forces in the horizontal and vertical directions at the same time.
- Incorporate the fuselage to landing gear connection

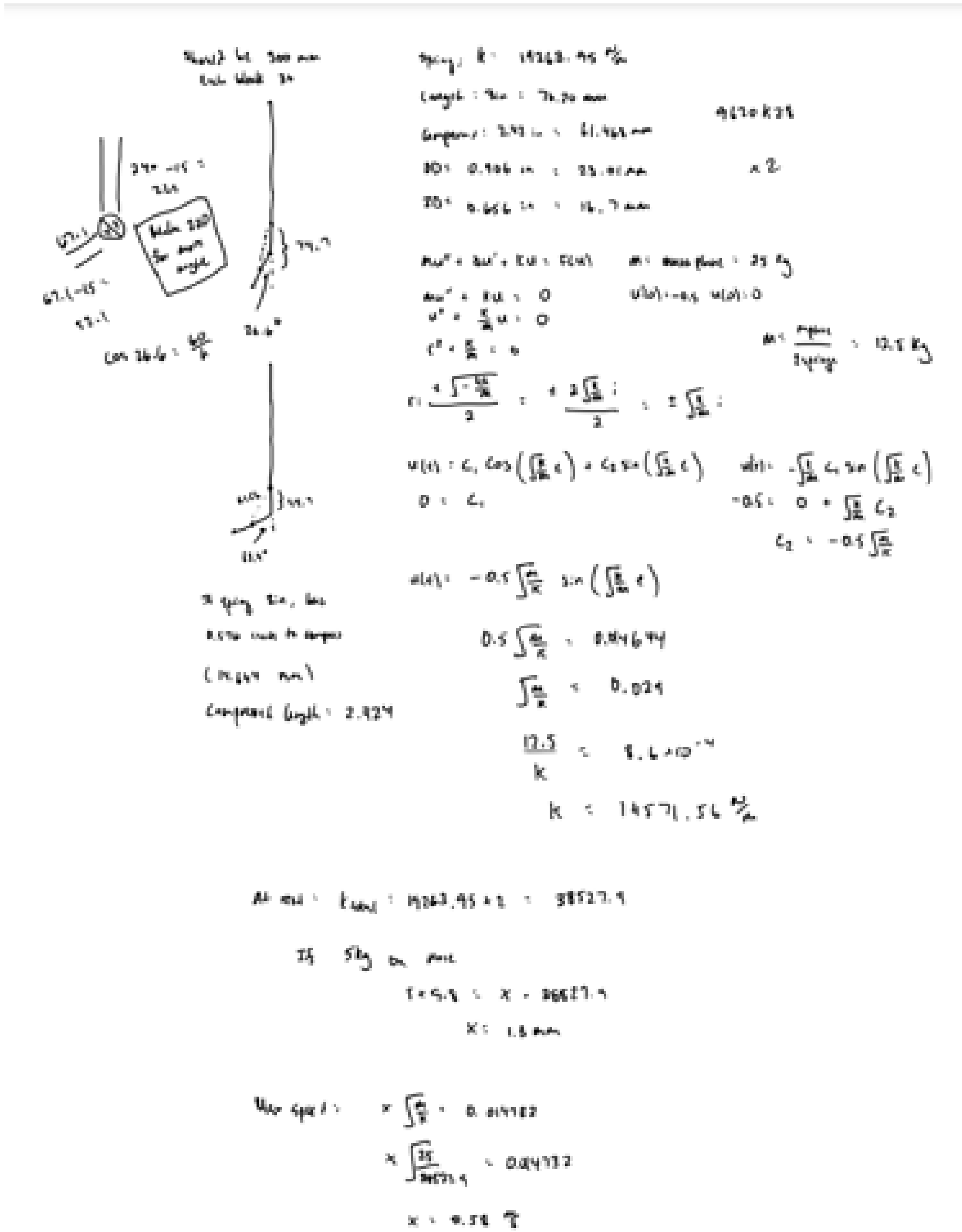
I will have to do calculations of forces on version 3 to see if the design is feasible and the k constant is high enough

Update 9/16/23

Design V3

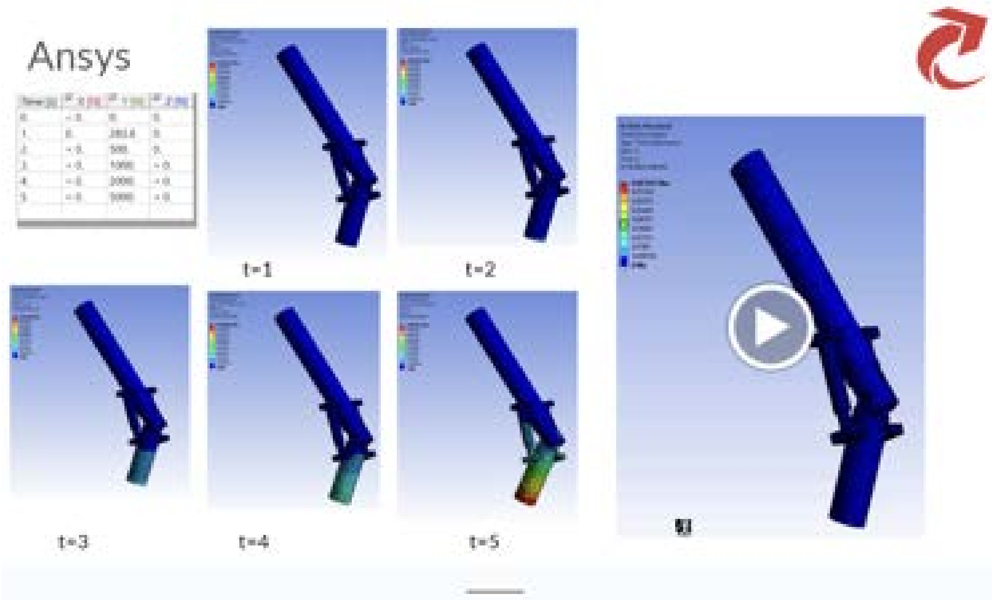
Note: Black is CF Nylon, gridded pattern tube are carbon fiber struts.

After a lot of calculations, I determined the springs and dimensions for the 3rd version of the landing gears. They are below:



Using this design, the landing gears should be able to absorb the shock of the landing both vertically and horizontally, reducing the force on the bulkhead from the previous design. Having two springs with k constants of around 19000 N/m will really damping the impact. The springs can be found here: https://www.mcmaster.com/9620K28/

I have also done some Ansys that assumes the springs are not present and even without the springs, the landing gear can take the full force of a landing.

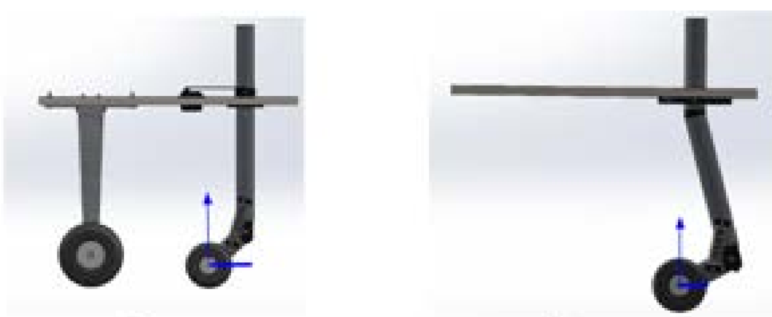


There are different forces at different times. t1 is the weight of the plane, t2 is around double the weight of the plane and anything above is extra. As the picture above shows, the landing gear can take the landing pretty well.

Updated 12/7/23

Design V4

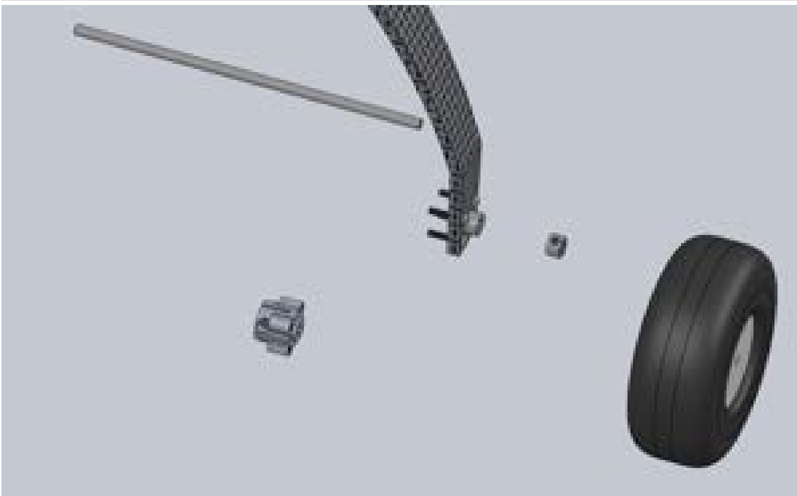
Design V4 is the same as Design V3 expect for the fact that the entire front landing gear is rotated as shown below:



Before After

We can see that after the shift, there is less moment on the landing gear initially when the plane is at rest as the lever arm (in blue) is smaller.

Rear Landing Gears



The rear landing gear will be connected to the aluminum honeycomb skin via potted inserts. We do not have to disassemble the landing gears because they are connected to the fuselage. The entire fuselage can fit inside a car.

There will be five holes drilled on the carbon fiber struts. These holes allow for the axle and wheels to be attached to the strut.

Here is the link to the rear landing rear struts. These struts are around 355 grams. With all connections to the wheels added, The rear strut is around 530 grams. Together with the front landing gear, the total landing gear weight is around 960 grams.

https://www.espritmodel.com/landing-gear-carbon-fiber-hd-18-3-4---26-3-4-475mm—680mm.aspx

Updated 12/7/23

Design V2

After testing, I decided to add two wheels on the inside of the back struts. The reasoning for this is in the testing portion of this documentation.

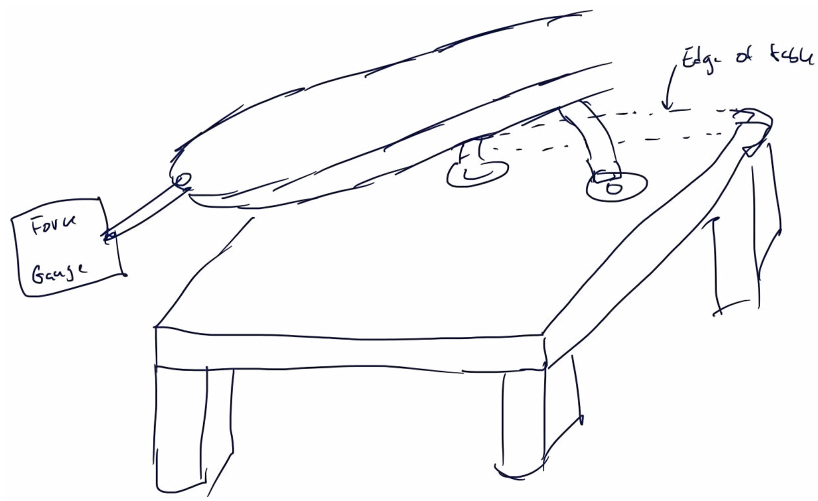
This made the landing gear strong and fully able to carry the weight of the plane. I made sure to use stainless steel axles.

I tried to use aluminum axles, but that didn't work:

Updated 5/2/24

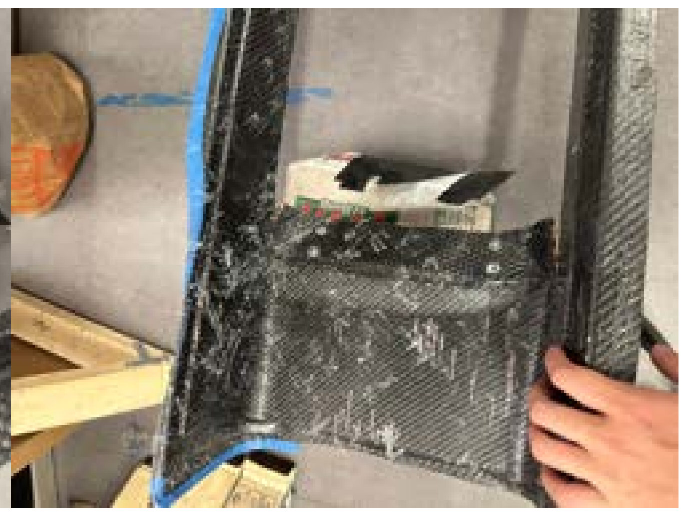
To install the landing gear components, I put in potted inserts for all the screws.

I also needed to conduct a shear test for the back landing gear. I installed the back landing gear on a testing fuse and placed the fuse on a table with the back landing gear off the back and pulled with a force gauge as shown below.



I was able to apply around 225 N of force on the landing gear without any damage. This is thanks to the potted inserts and the extra shear strength it gives the fuse.

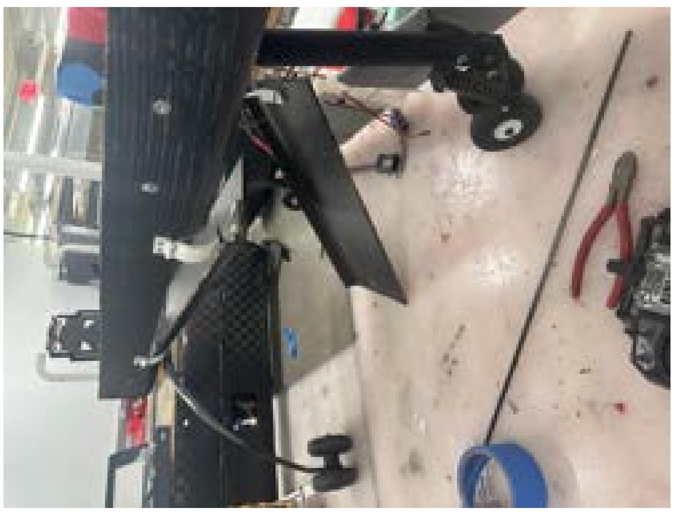
When I put 50 lbs of sand on the back of the plane however and lifted the nose, I heard a loud noise and realized that there was damage on the fuselage.



What I realized was that there was a huge stress concentration on the corner of the landing gear due to the cutout for baydoors. In addition, the airframe has some issues between the interface on the nomex and aluminum honeycomb layups, which allowed for the landing gear to further break. These is a lesson that we learned and we will use RDR for the interface in the future. In addition, I added L brackets on the new fuse so that this situation would not happen on the actual plane.

Here are the L brackets I made installed to the new fuselage. I installed potted inserts to the fuse so that the screws can not shear through the nomex.

I then installed the front landing gear that has no issues and the system worked perfectly. Here is what it looks like now:



The total mass breakdown of the final project (servos and L brackets)

Front Landing Gear: 503 grams

Back Landing Gear 557.9 grams

Servo/Linkage: 118.5 grams

Brackets: 37 grams x2

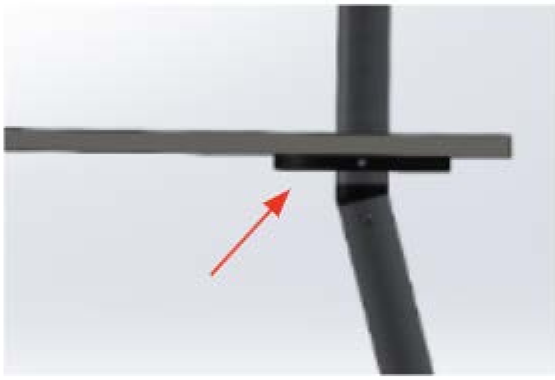
Total: 1253.4 grams

This is around 250 grams under my allotted weight of 1500 grams (16.44%).

Update 5/524

I ended up changing the servo for the front landing gear from the Hitec 645MG (133 oz/in) servo to the Hitec D955TW servo (405 oz/in). This is because the first servo did not produce enough torque.

I also reduced the size of the stops part and reduced the radius from 120 to 60. This was to reduce the friction between the skin of the fuse and the 3D printed part.



To Do List

- Wait for the plane to fly

Qualification and Acceptance

Detail your qualification plan(s) in this section. For each plan describe the test or analysis performed, the technical requirements it is addressing, how it is verifying those requirements, and the results if the tests have been performed. Can post links to external documents which cover the analysis or testing but always provide a summary and conclusion on this page. The validation section of the requirements table should point to the relevant qualification plan(s) here. Qualification plans should verify requirements and qualify systems using qualification by test (QBT), by analysis (QBA), and by similarity (QBS) all of which are described here. Also include any acceptance test protocols (ATP) required prior to use in this section.

Qualification Plan 1 (QBT)

Technical Requirements Addressed: Plane can land vertically without gears breaking.

Description: We connect the landing gears to a piece of wood and then put a 50lb mass on top of the wood. Then, we drop the system from 20 cm off the ground, which will result in a landing velocity of 2 m/s.

Rationale: From previous landing gear designs, we know that vertical landings will be at 2 m/s. We model this landing by dropping the landing gear system with masses from 20 cm off the ground.

Results:

After testing the original design (front gear V3 and back gear V2), I noticed that the plane likes to tip forward due the the front landing gear having a moment even at rest. In addition, the back landing gears experienced sheer forces that broke the wheels in half.

In the picture, it is obvious that the back gears are having issues. That is why I created design V2 for the back landing gears. There are now two wheels so there is less sheer. I also upgraded the front landing gear to V4 and did the test again. This time, there was no deformations and I even went up to a height of 50 cm, which results in a landing speed of 3.13 m/s.

Qualification Plan 2 (QBT)

Technical Requirements Addressed: Plane can land horizontally without gears breaking.

Description: Attach back landing gear on sheet of aluminum honeycomb, then apply force to see at what point the aluminum honeycomb starts to sheer. Hoping that force is over 13 kg.

Rationale: The push prop mount can have a shear of 13kg with three screws on top and three screws on the bottom. The landing gear can hopefully be able to take more sheer than that given there are also similar amount of screws.

Results: Did layup for aluminum honeycomb, but at different density to actual aluminum honeycomb on plane so did not use layup. Will do layup when correct aluminum honeycomb density comes in.

Update 4/10/24

I installed the landing gear on a test fuse and did the test as described as the update in 5/2/24. I could apply at least 225N of force, which equates to around 23kg. Big Success!

Bill of Materials

V3									
	Part	Quantity	3D Print?	How Much?	Price Per	Total Price	Do We Have?		URL
	Nylon Unthreaded Spacer (93657A544)	3	No	N/A	$3.19	$9.57	No		https://www.mcmaster.com/93657A544
	Rotary Shaft (1482K61)	3	No	N/A	$8.87	$26.61	No		https://www.mcmaster.com/1482K61/
	Rotary Shaft (1265K37)	1	No	N/A	19.11	$19	No		https://www.mcmaster.com/1265K37/
	Wheel	2	No	N/A	N/A	$18	Yes		https://www.amazon.com/uxcell-Airplan
	Wheel small	2	No	N/A	N/A	$14	No		https://www.amazon.com/uxcell-Airplan
	Carbon Steel Set Screw Collar (6056N14)	4	No	N/A	$2	$8	Yes		https://www.mcmaster.com/6056n14/
	Servo Hitec 645 MG	1	No	N/A	$35	$35	Yes		https://www.amazon.com/Hitec-32645S
	Nylon Unthreaded Spacer (93657A233)	1	No	N/A	$2.90	$2.90	No		https://www.mcmaster.com/93657A233
	18-8 Stainless Steel Hex Nut (91828A231)	8	No	N/A	N/A	$6.59	Yes		https://www.mcmaster.com/91828A231
	18-8 Stainless Steel Hex Nut (91828A211)	1	No	N/A	N/A	$4.73	Yes		https://www.mcmaster.com/91828A211
	BM4 20mm (92095A196)	6	No	N/A	N/A	$8.69	Yes		https://www.mcmaster.com/92095A196
	BM4 30mm (92095A198)	4	No	N/A	N/A	$13.43	Yes		https://www.mcmaster.com/92095A198
	BM4 40mm (92095A200)	1	No	N/A	N/A	$8.44	Yes		https://www.mcmaster.com/92095A200
	BM4 45mm (92095A205)	2	No	N/A	N/A	$7.43	Yes		https://www.mcmaster.com/92095A205
	BM4 55mm (92095A330)	1	No	N/A	N/A	$9.20	Yes		https://www.mcmaster.com/92095A330
	BM3 55mm	1	No	N/A	N/A	$9.28	Yes		https://www.mcmaster.com/92095A120
	Carbon Struts 1,2,3	1	No	N/A	$32	$32	No		https://www.amazon.com/gp/product/B0
	Back Strut	1	No	N/A	$125	$125	Yes		https://www.[illegible]
	1310 Series Hyper Hub	2	No	N/A	$8	$16	No		https://www.gobilda.com/1310-series-hy
	Compression Spring (9620K28)	2	No	N/A	$6.56	$13.12	Yes		https://www.mcmaster.com/9657K22/
	Hinge 1	1	Yes	43.65	0.116	5.0634	Yes		https://www.matterhackers.com/store/l/
	Spring Supports 1	2	Yes	11.34	0.116	2.63088	Yes		https://www.matterhackers.com/store/l/
	Spring Supports 2	2	Yes	10.03	0.116	2.32696	Yes		https://www.matterhackers.com/store/l/
	Hinge 2	1	Yes	25.97	0.116	3.01252	Yes		https://www.matterhackers.com/store/l/
	Spacer	2	Yes	0.27	0.116	0.06264	Yes		https://www.matterhackers.com/store/l/
	Stopping Thing	1	Yes	28.42	0.116	3.29672	Yes		https://www.matterhackers.com/store/l/
	In Fuse	1	Yes	57.53	0.116	6.67348	Yes		https://www.matterhackers.com/store/l/
	Turning	1	Yes	6.3	0.116	0.7308	Yes		https://www.matterhackers.com/store/l/
	Multipurpose 6061 Aluminum (#634T323)	2	No		3.04	6.08	No		https://www.mcmaster.com/634T32/
	U Bracket	2	No	No		?	No		
				Total:		$416.98		$126.27	

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Manufacturing

Detail your manufacturing plan and any lessons learned during manufacturing in this section. The system/subsystem mDoc should be linked in this section as it details the entire manufacturing process.

mDoc

Update List *(Things that need to be added to the above mDoc, should ideally be empty if mDoc is kept up to date)*

Lessons Learned

Problem	Solution

Issues and Risk

Record known issues here along with any risk they bring into the system and preferably order them from highest to lowest risk.

This is where you should look for new member/bored member projects

Issue	Risk

Bibliography

- Rob's CDR #2 (FA22)
- Rob's CDR #1 (FA22)
- Rob's Confluence Page
- Steph's Landing Gear (EDR)
- Steph's PDR