Detailed Design and Prototyping Report

A - Mockingjay

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Conceptual Design Report Summary

Our intent for this project was to design a portable airline seat suitable for children from ages 5-12 to use on Oceanic Express commercial flights. We started our design process by ideating features to include in the chair. We also interviewed parents about issues they face when traveling with kids to keep our ideas grounded, finding ways to incorporate solutions to these real issues into our prototype. By first focusing on making a simple folding and unfolding mechanism, then incorporating features while keeping the design as light, compact, and robust as possible, we intended to create an efficient and user-focused product for our intended audience.

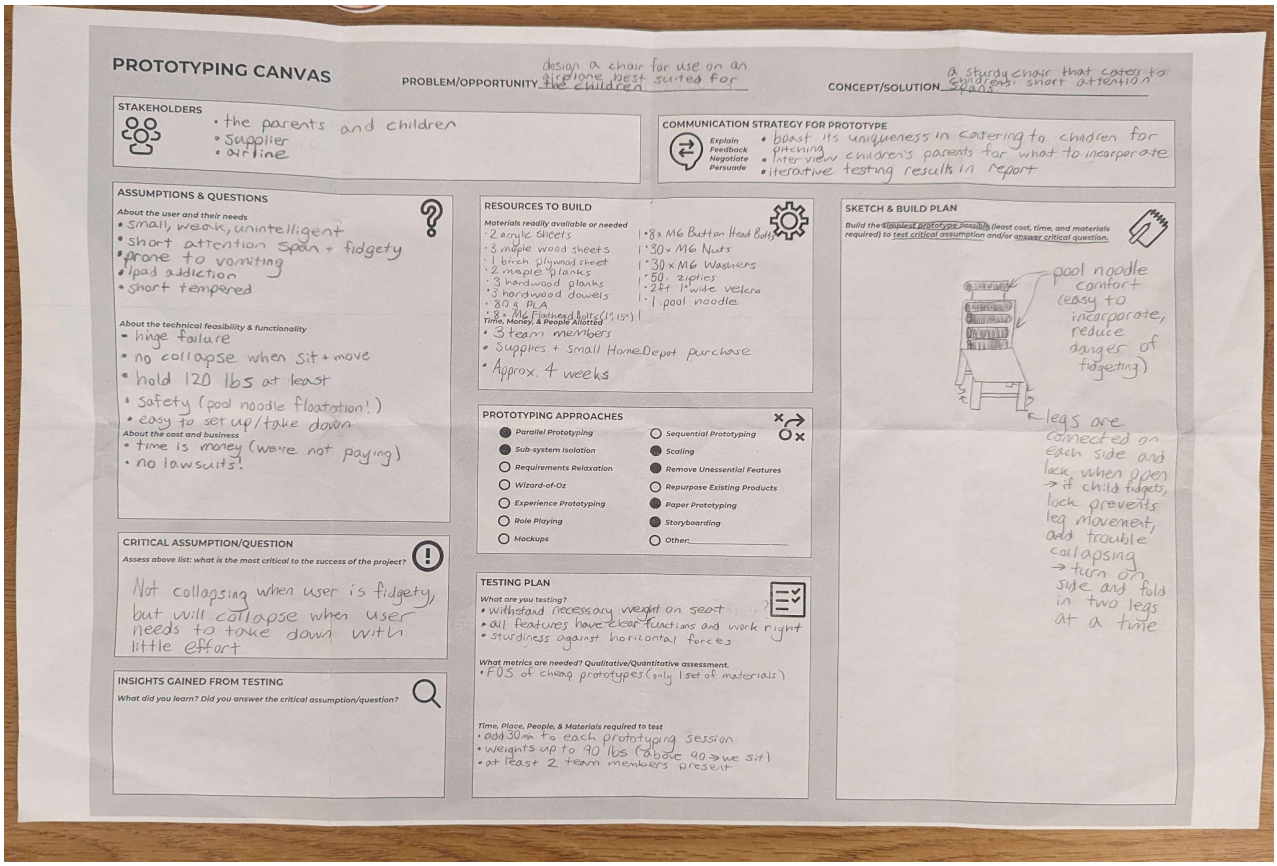
The main relevant issues we found that children have during traveling are short attention spans, limited capacity to carry heavy objects, and high dependence on parents that might be overwhelmed with the stresses of traveling. As such, these were the issues we placed the most emphasis on other than folding. For limited attention spans, we chose to include a detachable desk to the chair, for children's devices and hobbies. For limited carrying capacity, we chose to incorporate wheels for enhanced portability. Lastly, to encourage independence, we tried to design the chair so any child could set it up and take it down.

To further define the constraints of our chair, we aimed for the product to be as light as possible so that a child could bring it with them on their flight. Deciding to operate on a 10-point system for what we placed our efforts in, weight took up 4 of these points. Then, we constrained the max folded size of our chair to be 24'' x 16'' x 10'' to keep our chair within airline restrictions for carry-on luggage. This took up 3 points. Next up, ease of setup/take down was our next priority, with 2 points being allocated to this feature. It wasn't a must, but it is the unique feature that caters most to our user group, especially with how often kids get their fingers caught in complex mechanisms. Last on the list is compatibility with entertainment. Compared to the rest of the areas this is a luxury, but it is still a large enough part of our plan for the chair and catering to the audience that we thought we should assign a point to it.

As a team, we made sure to come up with a variety of features. These were also tested to some degree with low-fidelity prototypes, but the ones that ended up being most relevant were just the folding-friendly armrests, legs that could fold inwards, a pool noodle headrest that doubled as a handle, wheels on the bottom of the chair, the storage bag on the chair's back, and a desk that could attach to the desk's armrest and fit into said storage bag when not in use.

What got us started with knowing what direction to work in was the prototyping canvas. The canvas made us more aware of the resources we had and strategies we could use for making the project go smoothly, like prototyping approaches and plans for testing. Even if the plan didn't end up reflecting our journey to the final product, it did give us a good idea of our audience and the constraints we had as a result.

Design, Prototyping, and Testing



PROTOTYPING CANVAS

PROBLEM/OPPORTUNITY: design a chair for use on an airplane best suites for the children

CONCEPT/SOLUTION: A sturdy chair that caters to children's short attention spans

STAKEHOLDERS
- the parents and children
- supplier
- airline

COMMUNICATION STRATEGY FOR PROTOTYPE
Explain, Feedback, Negotiate, Persuade
- boast its uniqueness in catering to children for pitching
- interview children's parents for what to incorporate
- iterative testing results in report

ASSUMPTIONS & QUESTIONS
About the user and their needs
- small, weak, unintelligent
- short attention span + fidgety
- prone to vomiting
- ipad addiction
- short tempered

About the technical feasibility & functionality
- hinge failure
- no collapse when sit + move
- hold 120 lbs at least
- safety (pool noodle floatation!)
- easy to set up/take down

About the cost and business
- time is money (we're not paying)
- no lawsuits!

RESOURCES TO BUILD
Materials readily available or needed
- 2 acrylic sheets
- 3 maple wood sheets
- 1 birch plywood sheet
- 2 maple planks
- 3 hardwood planks
- 3 hardwood dowels
- 80 g PLA
- 8 x M6 Flathead Bolts (1", 1.5")
- 8 x M6 Button Head Bolts
- 30 x M6 Nuts
- 30 x M6 Washers
- 50 zipties
- 2ft 1" wide velcro
- 1 pool noodle

Time, Money, & People Allotted
- 5 team members
- Supplies + small Home Depot purchase
- Approx. 4 weeks

SKETCH & BUILD PLAN
Build the ~~simplest prototype possible~~ (least cost, time, and materials required) to test critical assumption and/or answer critical question.

PROTOTYPING APPROACHES

● Parallel Prototyping	○ Sequential Prototyping
● Sub-system Isolation	● Scaling
○ Requirements Relaxation	● Remove Unessential Features
○ Wizard-of-Oz	○ Repurpose Existing Products
○ Experience Prototyping	● Paper Prototyping
○ Role Playing	● Storyboarding
○ Mockups	○ Other:

CRITICAL ASSUMPTION/QUESTION
Assess above list: what is the most critical to the success of the project?

Not collapsing when user is fidgety, but will collapse when user needs to take down with little effort

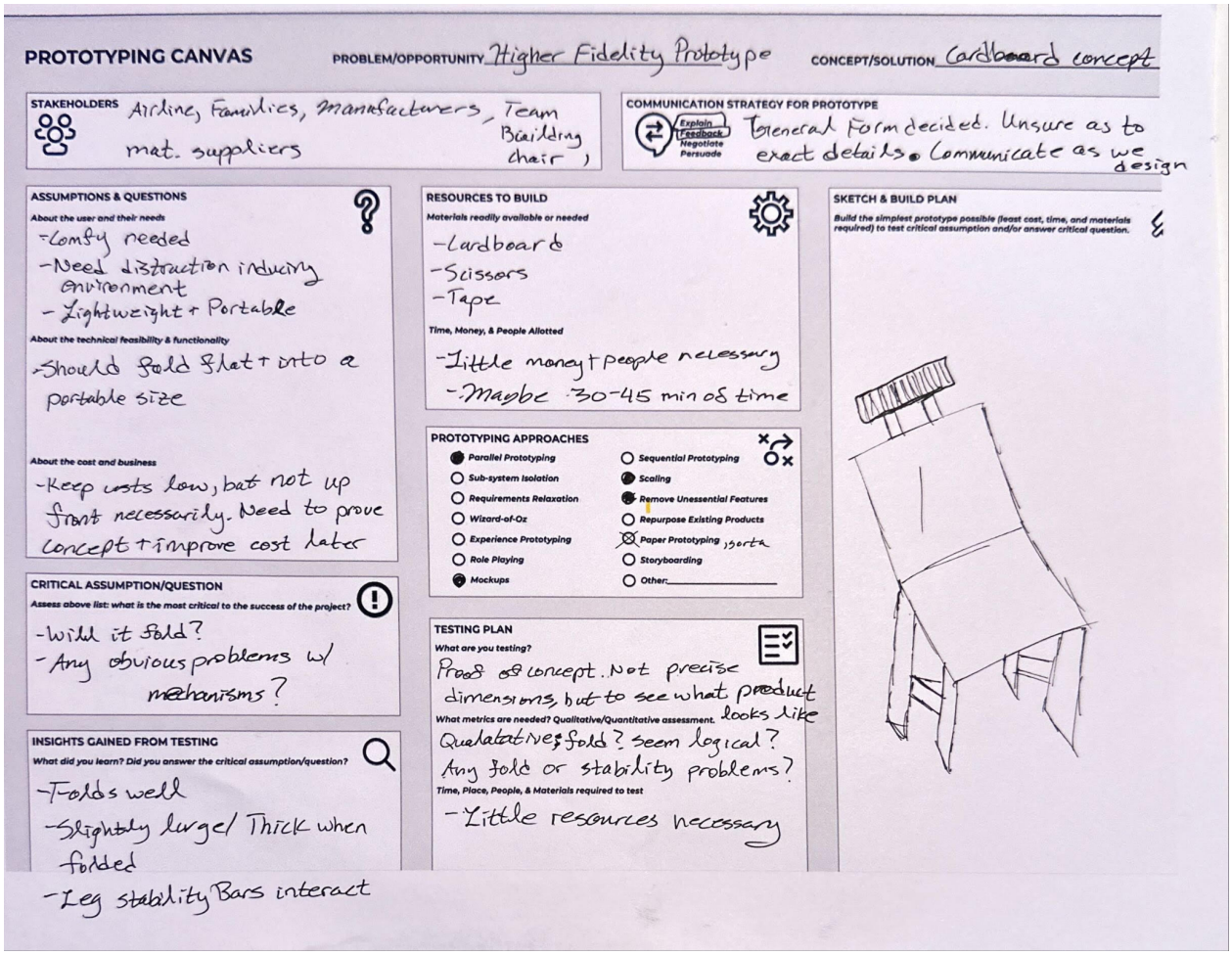
TESTING PLAN
What are you testing?
- withstand necessary weight on seat
- all features have clear functions and work right
- sturdiness against horizontal forces

What metrics are needed? Qualitative/Quantitative assessment.
- FOS of cheap prototypes (only 1 set of materials)

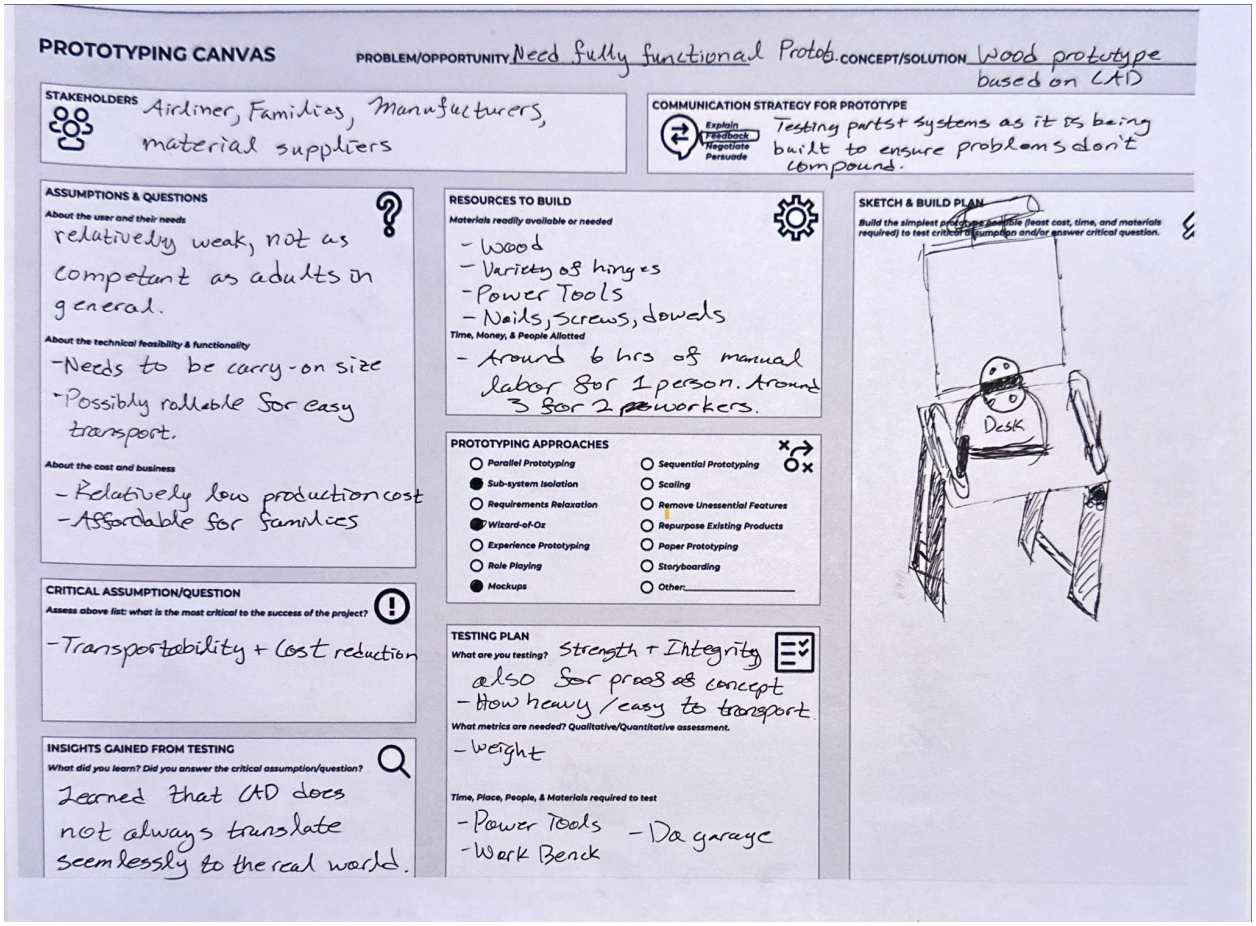
Time, Place, People, & Materials required to test
- add 30 min to each prototyping session
- weights up to 90 lbs (above 90 → we sit)
- at least 2 team members present

INSIGHTS GAINED FROM TESTING
What did you learn? Did you answer the critical assumption/question?

Seen above was our initial prototyping canvas that was made after making our first low-level fidelity prototype in class. We had come up with a number of design considerations and were still at a very broad design choice. We knew that we needed a chair with specific features, but we were still unsure as to what our final product would look like.



Seen above is our Prototyping Canvas before our ¼ size cardboard prototype. Our main objective was to show that our concept showed promise as a final product and that the folding mechanisms would work. We found that the support bars for the legs were causing problems when it came to folding completely flat. We had a few ideas to work around this minor issue. Other than that, our design showed real promise for a full-scale prototype.

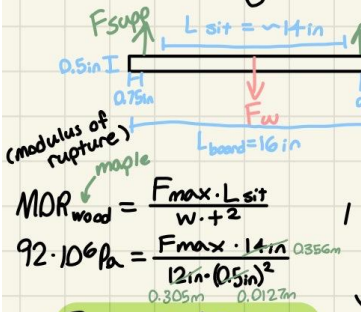


Shown above is our final prototyping canvas for our final working prototype. We opted to make our to-scale prototype out of wood for as much strength and durability as possible. Although transportation and ease of maneuverability were at the top of our design restrictions, and wood is quite dense and therefore heavy, we know that for mass-manufactured chairs, a much lighter material like aluminum would be used. This canvas helped us finalize specific ideas and restrictions for a final product. Even though this is our final prototype, we hope to learn a lot about what can be improved especially for mass production.

Hand Calculations, FEA, and Design Justification

Project 2 Hand Calculations

★ seat strength? (estimated)



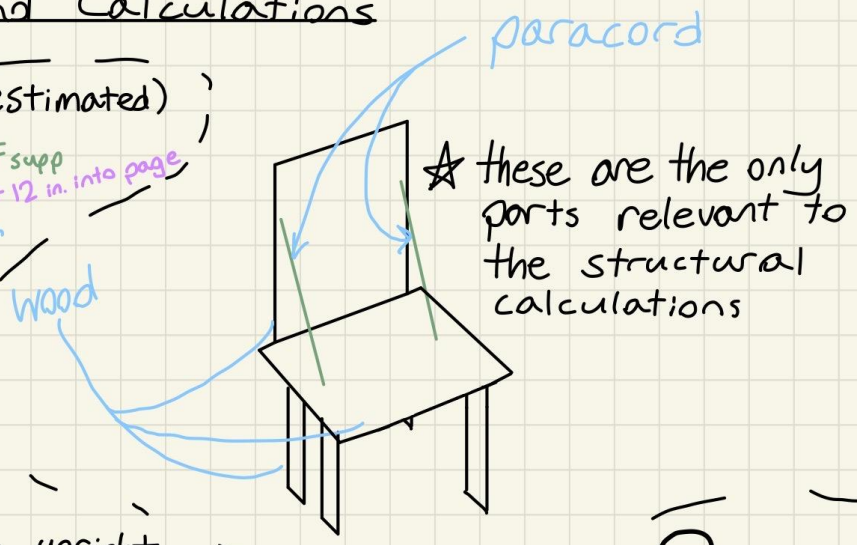
$$MOR_{wood} = \frac{F_{max} \cdot L_{sit}}{w \cdot t^2}$$

$$92 \cdot 10^6 Pa = \frac{F_{max} \cdot 14in}{12in \cdot (0.5in)^2}$$

0.305m 0.0127m 0.356m

→ $F_{max} = 13{,}000N$

OR $m_{max} = 1{,}330kg$



★ these are the only parts relevant to the structural calculations

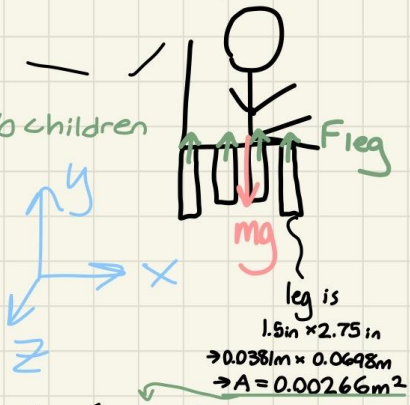
Case 1: Child sitting upright

$$\sum F_x = 0$$
$$\sum F_z = 0$$
$$\sum F_y = -mg + 4(F_{leg}) = 0$$

using m = 70 kg for upper end of 12 y/o children

$$= -100kg \cdot 9.81 \frac{m}{s^2} + 4(F_{leg}) = 0$$

→ $F_{leg} = 245.25N$ ★ each



Compression strength lower quality wood ≈ 30MPa → $F_{yield} = 30Pa \cdot 10^6 \cdot 0.00266m^2$

$F_{yield} = 79{,}780N > F_{leg}$

Case 2: Child leaning

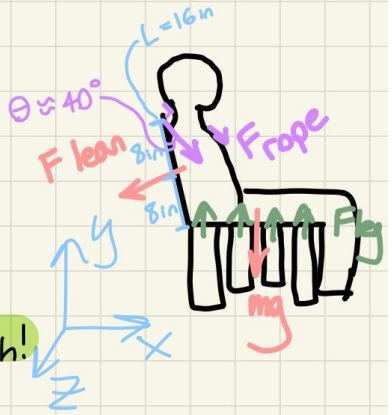
★ here we focus on the cords, neglect changes in weight distribution since legs are more than strong enough

$$\sum M_y = 0 \text{ (ignore)}$$
$$\sum M_z = 0$$
$$\sum M_x = -F_{lean} \cdot 8in + 2[F_{rope} \cdot \sin(40°) \cdot 8in] = 0$$

~ ½ wt.

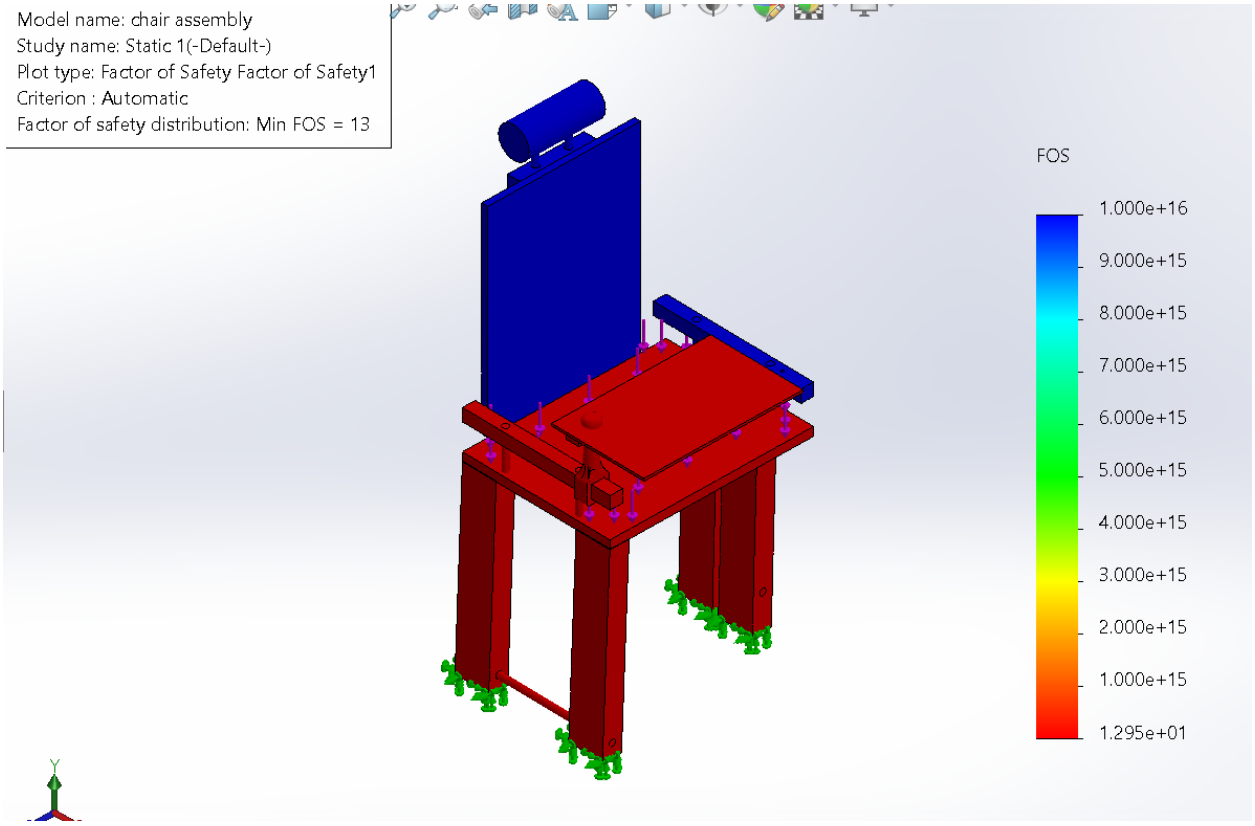
$$= -50kg \cdot 9.81 \frac{m}{s^2} \cdot 8in + 2[F_{rope} \cdot \sin(40°) \cdot 8in] = 0$$

→ $F_{rope} = 380N$ (each)

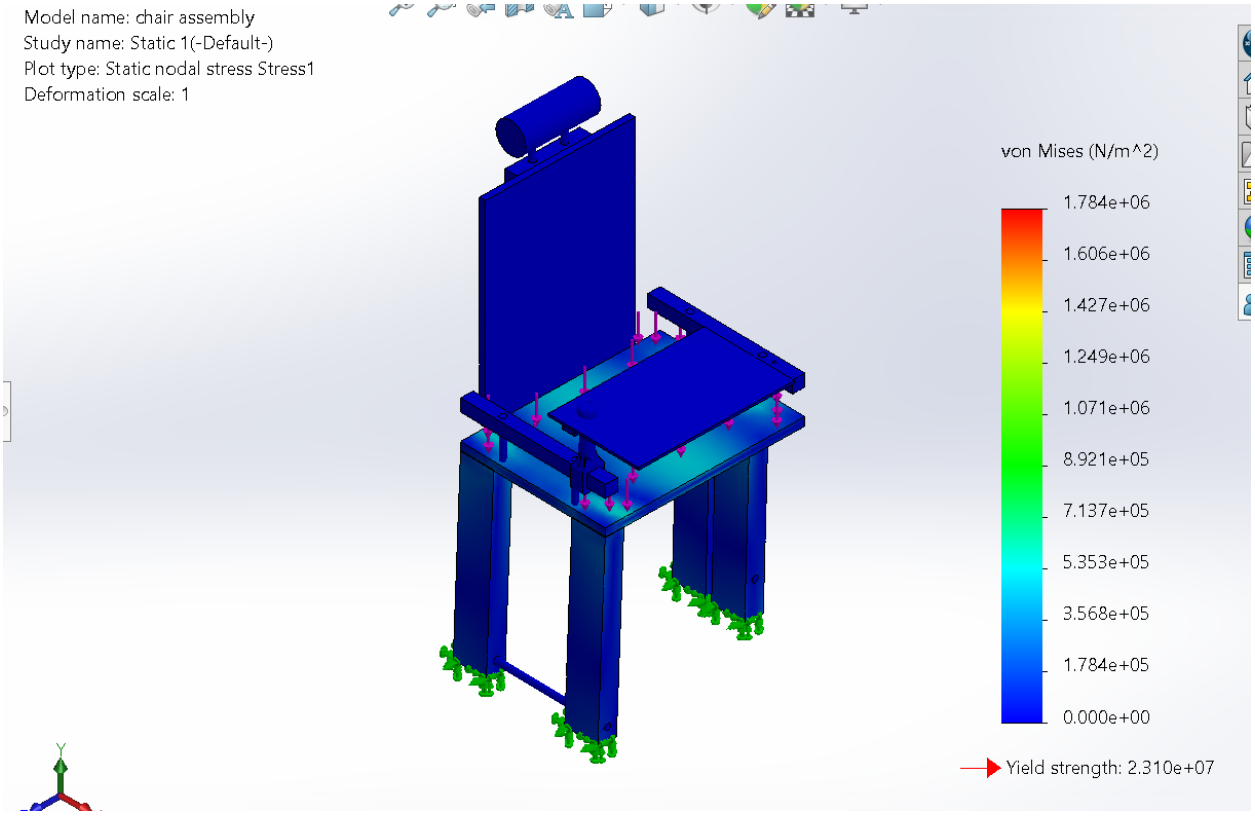


Paracord can hold 2000N +, so more than strong enough!

Model name: chair assembly
Study name: Static 1(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Factor of safety distribution: Min FOS = 13



Model name: chair assembly
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1



1. Assembly and Disassembly

   Assembly and disassembly was a major feature of the chair we wanted to focus on, so we are confident that this requirement was met. The back of the chair only needs to be pushed forwards for disassembly and backwards for assembly, and folding/unfolding the legs only involves four latches on the bottom of the chair (two of which were connected with a 3D-Printed lever, to make this process even more simplified). The latches are very sturdy and the back of the chair is held up with strong paracord. Plus, the velcro strap included on the back attaches to the bottom of the chair when folded to ensure nothing comes out of place when it shouldn't. Assembly and disassembly for our chair design is very straightforward, intuitive, and reliable.

2. Collapsibility

   Our chair significantly reduces in size when folded. Since the legs fold within the size restrictions of the seat and the back folds completely flat, the chair is extremely portable without being too small when fully assembled. The chair has ample room for a wide variety of children, yet when collapsed, it's smaller than the average carry-on luggage.

3. Portability

   Overall, combined with the folded version of our chair being small, the addition of wheels makes our design very portable. It is short enough when rolled that, even with childrens' short stature, they will be able to roll it along comfortably. As such, even if the chair could be an uncomfortable weight to lift for long periods of time within the lower end of our age demographic, they will have no need to do anything but roll it until they board the plane.

4. Novelty

   The design of our chair was a product of numerous tests and ideation sessions, and we couldn't find any chairs online that functioned like ours. The novelty was enhanced because of the fact that we were tasked with using solid wood; most children's chairs are made of plastic and/or hollow metal rods, so our material constraints made us think outside of the box from the beginning. For example, the desk being able to slide off of the armrest and be stored in the bag was novel compared to folding desks, as if we made the desk foldable instead, it would add more variables for the chair failing in transport and children could get their fingers or hair caught in the folding mechanisms. The complexity of our desk design is comparable to playing with legos. It also caters more to the user, as the users who don't want a desk don't need to deal with it being permanently attached to their chair.

5. Cost

In total, the most expensive part of our chair was the locking hinges on the bottom ($14) and the spring hinge for the back of the chair ($13). Adding on all the materials we *used*: a portion of the wood provided for all teams, some of the wood and the wheels we bought with our budget, and the PLA and acrylic that we used for the desk (plus all other minimal costs, such as the length of paracord and the bag attached to the back, being estimated at $1), the total cost of construction for the chair is around $50. Although not the cheapest, most wooden child chairs are less functional, priced above $90, and cater to a smaller range of kids, so we believe this requirement has been met and the manufacturer could easily make a profit.

6. Weight

    This is the first of three constraints the team came up with. Overall, the weight of our chair is not at all excessive for a child to bring around using its wheels. The chair weighs around 15lbs. This is around the weight of a small dog, so a child shouldn't have much trouble maneuvering it around if needed. Given that the constraint of using solid wood made it more difficult to keep the weight at a reasonable level, this requirement has been fulfilled for our audience.

7. Compatibility with entertainment

    Our chair is very compatible with entertainment once the desk is placed onto the armrest, which as mentioned earlier, is very easy for a child to do. The bulb holding the desk in place doubles as a phone stand if needed, and the child can use the desk for things such as coloring books, building blocks, tablets, etc. As far as a chair goes, this one can easily cater to children in the modern age.

8. Storage

    Having a bag as large as the back of the chair with a wide opening more than fulfills the requirement of having ample storage space that we set. Even with the desk stored away, you can fit as much in the back of the chair as you can a small backpack. The storage is also not compressed when the chair is folded, so whatever is in the chair can stay even while in transport.