MEM 492 Group 24 Electric Scooter Locker

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Abstract

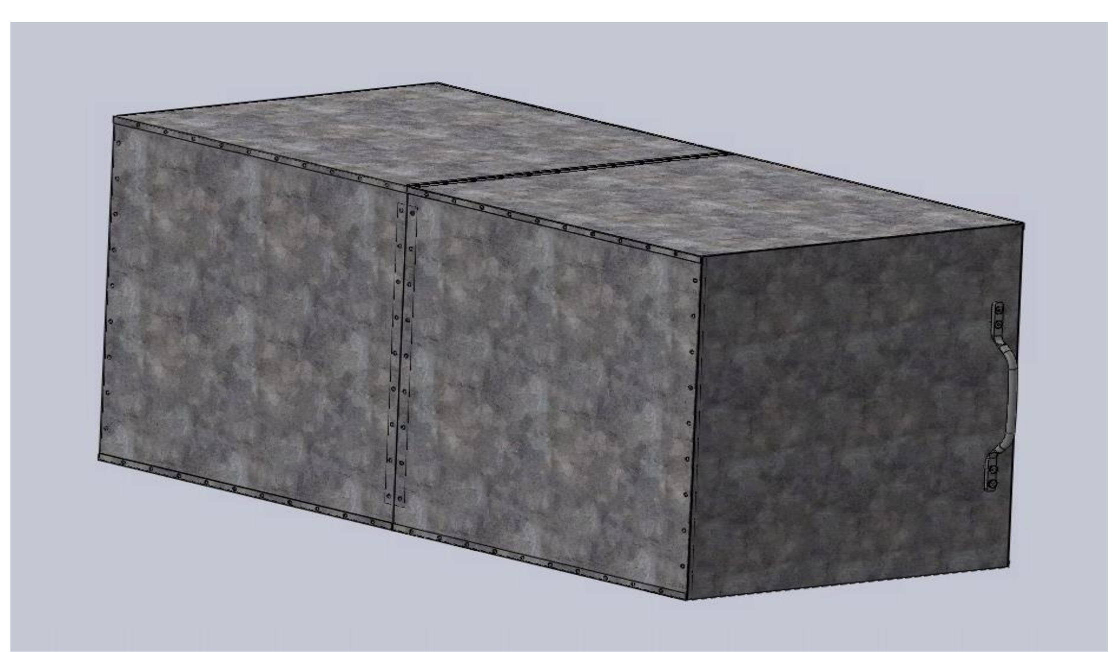
Traditional bike racks have stored bikes, scooters, and small electric vehicles with minimal security since the late 1970s. By relying on third-party locking mechanisms, these systems leave vehicles vulnerable to theft.

Drexel University's campus sees approximately two vehicle thefts per month from outdoor bike racks — a preventable problem requiring a modern solution. Through a fully enclosed public locker system, we can eliminate this risk.

We developed multiple 3D CAD models of potential designs capable of holding any foldable electric vehicle with an RFID-scannable lock mechanism. Multiple structural configurations were analyzed using full finite element analysis (FEA).

Each design was evaluated for resistance to bashing, drilling, sawing, and levering against the Sold Secure Gold Standard guidelines — requiring resistance to hand tools for five minutes with anti-pick protection. The locker also follows ASTM F476-23 for security of swinging doors.

Locker Design Parameters



Our design will have easy-to-use features that all Drexel University Students can access via RFID. The safety standard, Sold Secure Gold Standard, is a measure that no one can break into the locker in under 5 minutes, which will allow for complete security of any personal vehicle.

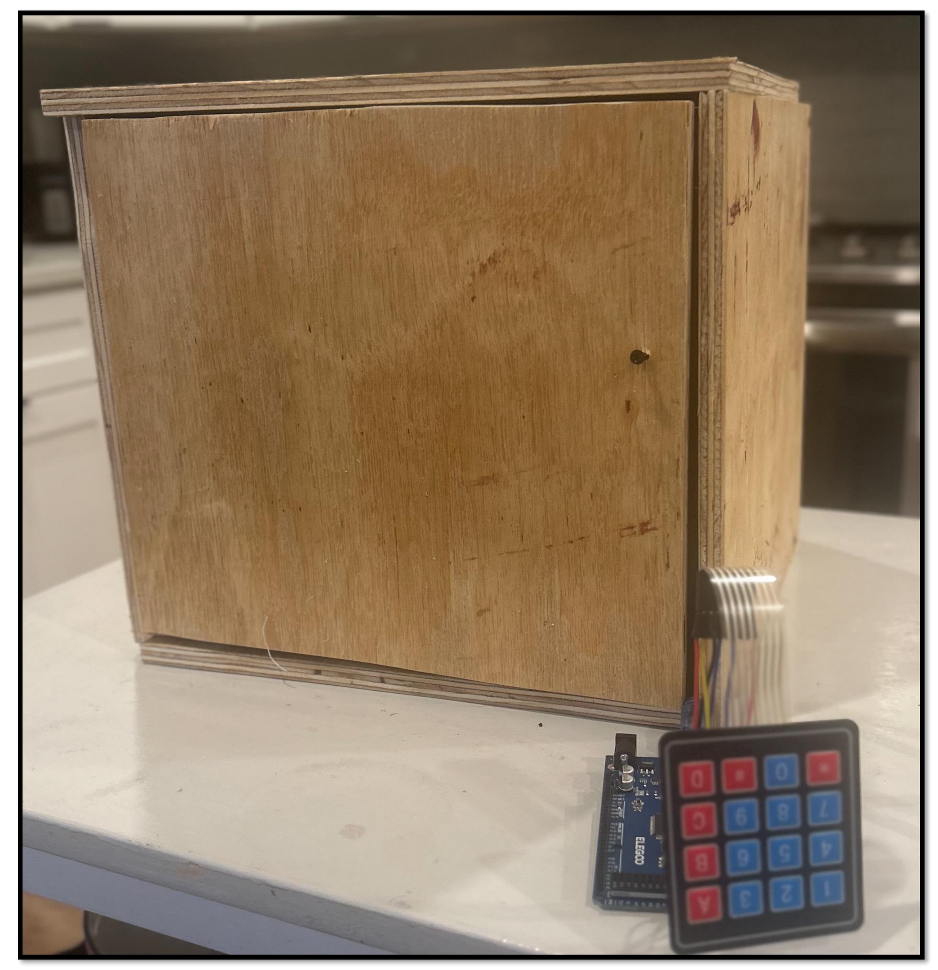
· RFID keyless entry via campus ID card
· Drill, bash, saw, and lever resistant
· ASTM F476-23 compliant swinging door
· Anti-pick lock cylinder

Methods

Our method for prototyping was building a simple box that was not focused on strength but on function. This allowed us to focus on the actual interaction with the box. We utilize finite element analysis to determine the best structural configuration for our locker.

Results of Prototype Testing

We made a locker design for testing the door and electrical designs out of wood and Arduino instruments. The prototype validated the number pad access workflow, electronic latch actuation, and overall user interaction.



Test Results Summary

Test	Component	Result
RFID Scan	Arduino + RC522	Fail
Door Latch	Solenoid lock	Pass — secure engagement
Frame Load	40 lbf interior	Pass — no deflection
Access Control	Student ID fob	Fail
Door Seal	Rubber gasket	Pass — weather resistant
Number Pad	Arduino + 4x4 Keypad	Pass – accepted multiple entries

Conclusions

After creating multiple designs and completing different FEAs, we found the best way is to weld all of the sheet metal sides together with structural framing on the inside. This way it will be totally secure and stay within our standards and design parameters.

The locker will fulfill our requirements of being able to withstand any drilling, bashing, grinding, cutting, and punctures. Our design will have easy-to-use features that all Drexel University Students can access via RFID.

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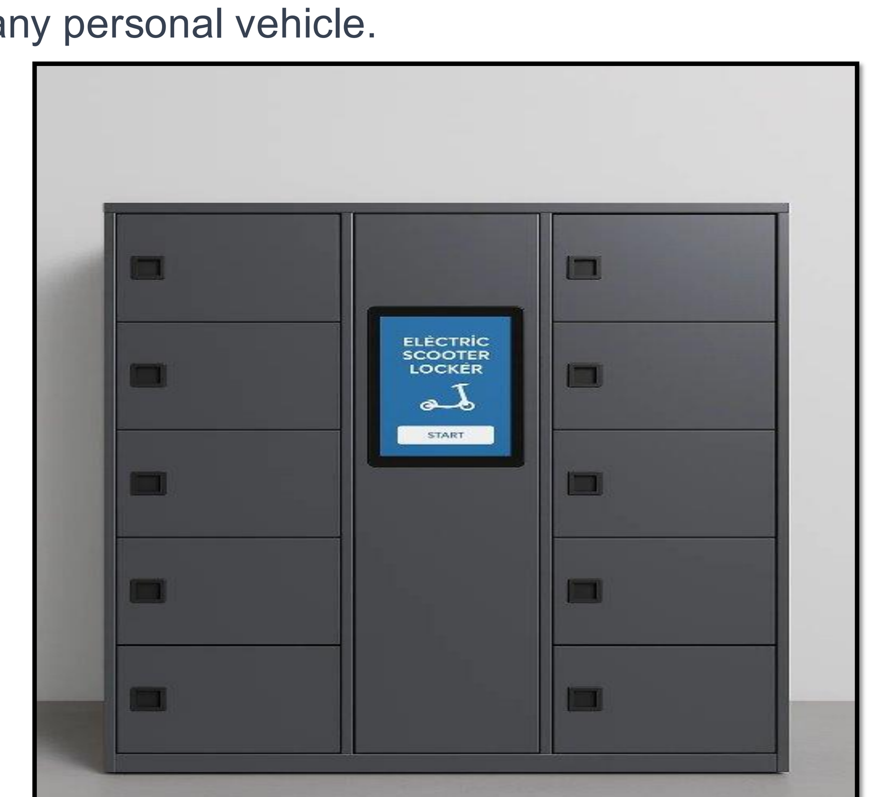
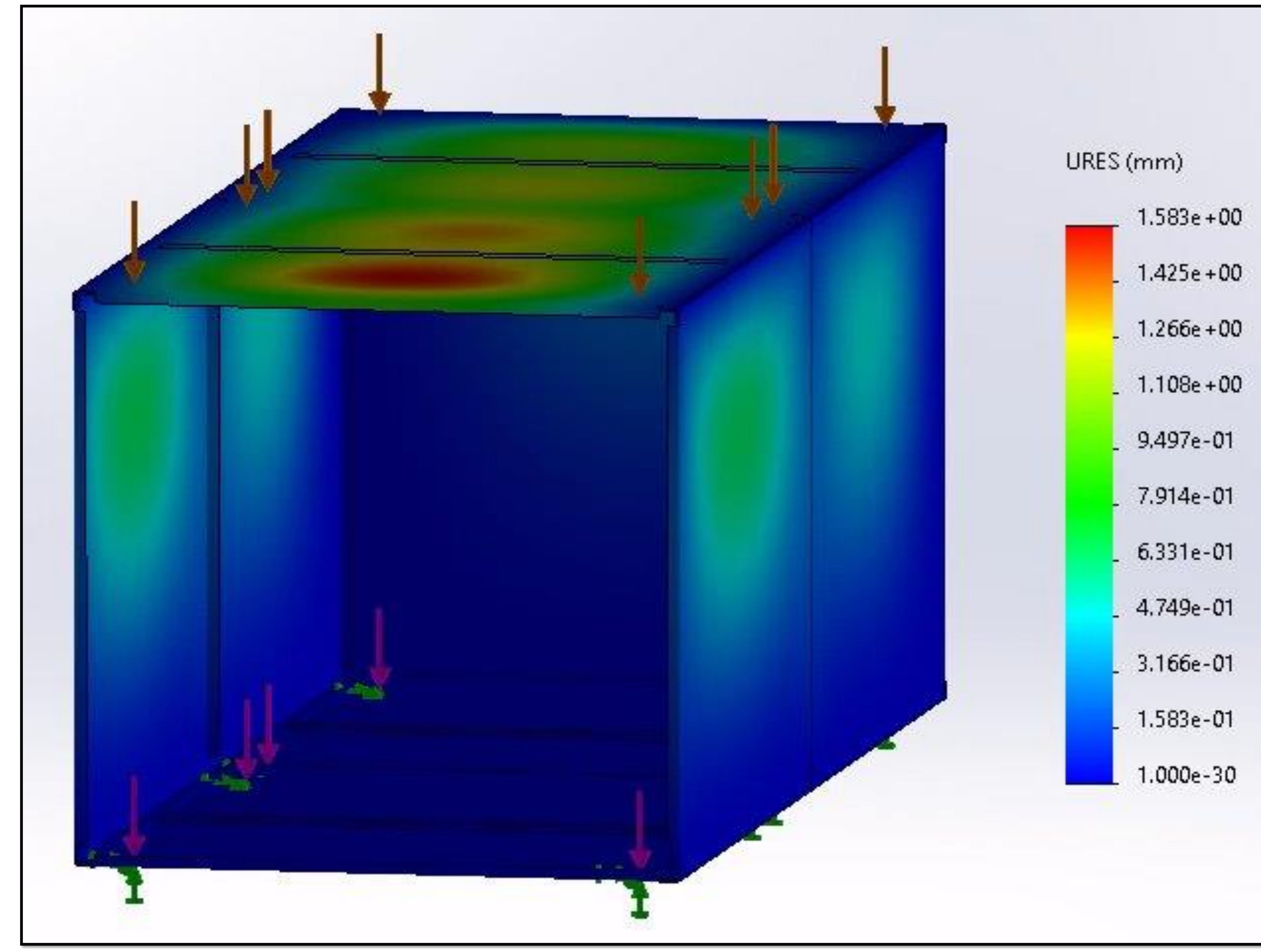


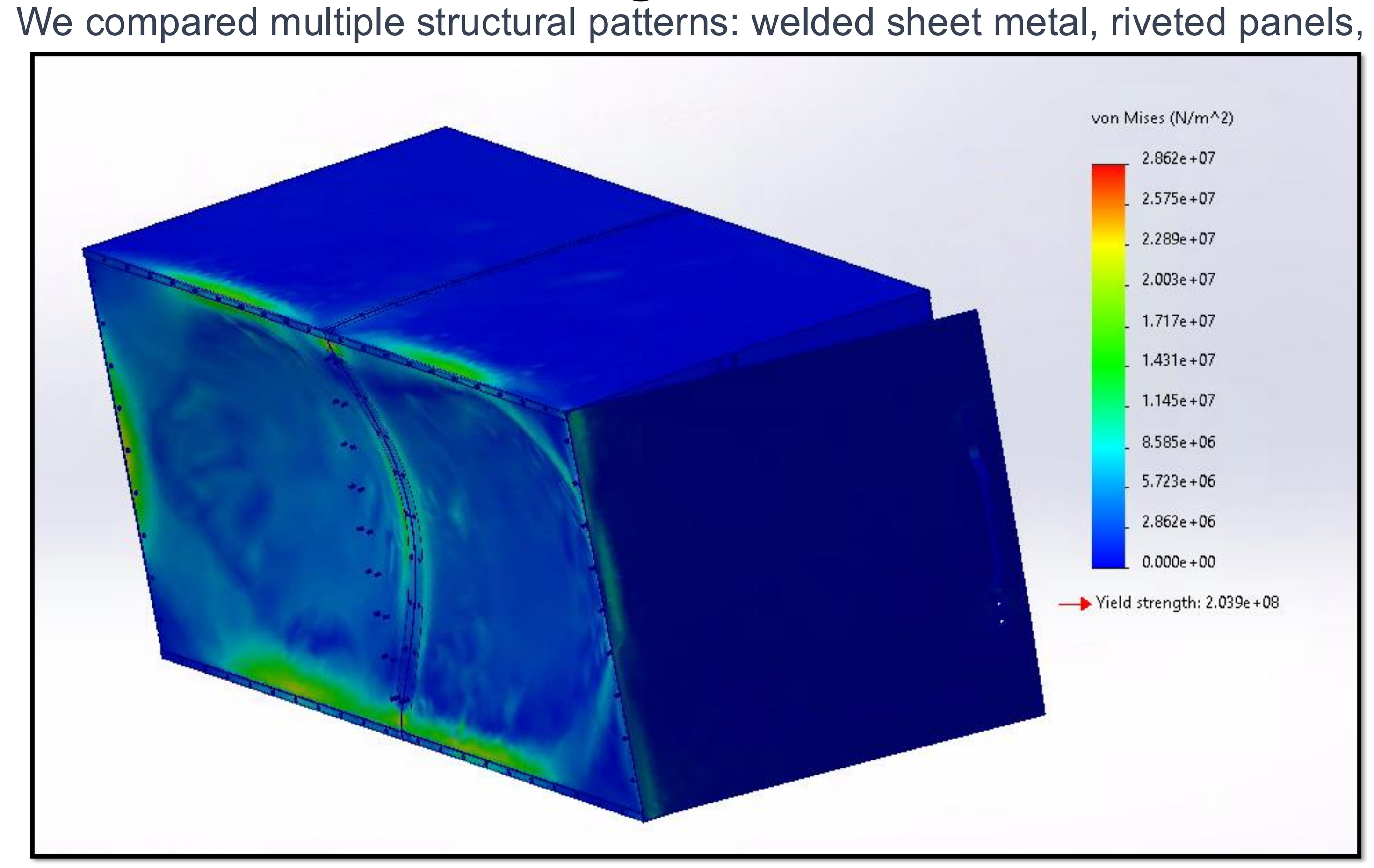
Results of the Finite Element Analysis

Details about the model and the parameters used. Boundary conditions: base fixed; 154 lbf applied to top surface; 40 lbf to interior walls.



Additional FEA Configurations

We compared multiple structural patterns: welded sheet metal, riveted panels, and hybrid internal framing.



This model aims to show the stresses induced by a force to the side panel. This uses pins instead of rivets to hold the structure vertically. However, it is susceptible to side forces. This prompted an improvement to use rivets in our design.

1.6 mm
Max deflection (top, door detached)

1.2 mm
Deflection with door structure attached