Dzit Engineering

Lab Grading Rubric

Design			
Conceptual		10	10/10
DWGs	-5 full assy / agreed	20	15/20
BoM		3	3/3
Analysis			
FBD for all (all or nothing on grade)		10	10/10
Analysis	not sure buy all of it	15	20/20
Sol'n Circled		3	3/3
Report			
LoT		3	3/3
Cover		3	3/3
Executive Summary Intro		4	4/4
Overview		3	3/3
BC/IC		4	4/4
Mat'ls		4	4/4
Findings		13	13/13

excellent, perfect report. Very professional and marketable

~~95~~ 100 nice

100

Lab 1: Design and Structural Analysis Report

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1.0 Executive Summary:

1.1 Introduction:

Dził Engineering has been contracted to design a Beatles themed Yellow Submarine motion simulator ride inside of 2 buildings located in Germany and Japan. The design will be composed of three main parts: the baseplate, floor platform, and motion system and will be referred to as such throughout this report. The simulator is to fit inside a 9.73m in length x 13.08 m in width x 6m tall room. The sum of the weights of the cabin with passengers, baseplate, motion system, and floor platform must total to no more than 25000 lbf. The simulator must not distribute more than 53 psf load to the building. It must also fit through a double man door of the room for assembly. ~~The~~ simulator is to have 2 degrees of freedom and be capable of tilting in 5° in the roll and pitch directions of the sub at 1°/second. The design must accurately and repeatedly return riders to a platform located 0.5 m above the floor after each ride. The simulator must be designed within the technical specifications document and ANSI codes DIN4112-83A and -83B. Most importantly, it must be entirely safe for riders and operators. The engineering service provided will include several conceptual designs, a decision matrix to decide the best of these designs, and a structural analysis of the simulator and the base building interfaces. Also, a complete set of drawings is provided to the client and the appropriate materials and construction procedures are outlined. Our team has identified the three major components of the design to be the floor platform that supports the cabin of the ride, the motion system which drives any and all motion of the ride, and the baseplate which connects the ride to the superstructure of the building as well as the structure in which the motion system will attach to.

↳ it's just 1 code, in 2 PDFs

1.2 General Construction:

The overall design uses 6 linear electric actuators as the motion system in order to have the modifiable capability of adding a third degree of freedom as well as decreasing the stress on each actuator and therefore increasing the safety and durability of the simulator. The actuators are in pairs, with an approximate angle of 60° between each other. The actuators connect to the top of the cabin of the submarine at 3 points, one at the stern, one at the port, and one at the starboard. The port and starboard locations connect 2.1m from the bow while the third location is at the center of the stern. The angle between the set of actuators and the cabin is approximately 10° from the vertical. The bottom of the actuators are connected to the baseplate. The baseplate is bolted into the superstructure of the building. The baseplate structure is located partially underneath the cabin. It features 3 I- beam support structures measuring 9.45m long, 1.58m wide, and 0.45m tall at their thickest point with load dispersing 30° gussets. Two of the structures run along the sides of the cabin while the runs along the stern of the cabin. The baseplate system covers a total 491.4 square feet in order to distribute the weight of the simulator to the building. The floor of the cabin is horizontal at the top and bottom but will be angled 5° from the horizontal in the middle section to feature stadium seating for optimal viewing by the passengers. The floor platform frame and baseplate are

Nice

made out of 7075-T6 Aluminum in order to reduce weight while providing high strength. 5/8-inch-thick plywood will lie on top of the floor platform frame. The cabin will be erected directly above the floor platform. The entire structure is fabricated in pieces and bolted together at the final location.

1.3 Boundary Conditions:

The entire assembly must support the load of the cabin and its passengers as well as a 3G seismic load in any direction in worst case loading conditions of the ride. The worst case loading condition during movement of the simulator ride is where the ride has rolled and pitched 5° in the same direction. The load of the entire system to the floor will not exceed 53psf. The sum of weights of the baseplate, motion system, and floor platform must be no larger than 7000 lbf. The team assumed perfectly bonded bolted connections and welds during simulations included in this report. The floor platform must have 4 jacking points in order to perform maintenance. All welding must be performed prior to installation within the building, and all pieces of the design must fit through the double man door and can be maneuvered within the area of the room. The structure must be assembled within the building for all bolted connections. The simulator must have a safety factor of 2.5 according to DIN4112-83A specifications. The allowable values for deflection are calculated using the L/180 standard. Because the ride holds occupants inside a building with additional occupants, Dził Engineering will make its number one priority to design to a safety factor as high as possible.

1.4 Material:

- Structural Material: 7075-T6 Aluminum
  - U-shaped channel stock
  - Angle shaped channel stock
  - Flat plate stock
- Flooring Material: 5/8" Construction Grade Subfloor Plywood
- Note: With future deliverables material selection will be expanded upon to include additional necessary materials such as connections and actuators

1.5 Findings:

- The worst case scenario is 3G seismic loading at 45° and roll and pitch of the cabin at 5° in same direction.
- The total weight is equal to the maximum of 7000 lbf for this section of simulator design.
  - Floor assembly weight including plywood: 2,996 lbf
  - Baseplate weight: 2,292 lbf
  - Remaining weight for actuators: 1,712 lbf
- All factors of safety are greater than the minimum required factor of safety of 2.5 for stresses and 1 for deflections in worst case scenarios.

Table 1: Summary of Findings and Explicit Results

Component	Criteria	Material	Value	Allowable Value	Safety Factor	Minimum Safety Factor
Floor Assembly	Von Mises	7075-T6 Al	178.9 MPa	505 MPa	2.877	2.5
Floor Assembly	Deflection	7075-T6 Al	22.49 mm	46.5 mm	2.071	1
Baseplate	Von Mises	7075-T6 Al	184.1 MPa	505 MPa	2.743	2.5
Baseplate	Deflection	7075-T6 Al	3.197 MPa	52.5 mm	13.403	1
Superstructure Loading	Distributed Load	N/A	50.872 psf	53 psf	1.042	1

perfect!

2.0 Potential Designs:

2.1 Motion System:

Our team chose to start the design processes with selection of the motion system because it is the part of the design that brings the ride to life. We designed the system independent of the floor platform but with consideration of a general concept of the baseplate. Three designs were chosen during the brainstorming process. The three designs are listed below in Figures 1-3. Since our team is not responsible for the design of the cabin, the cabin will be represented by a black box in the figures throughout the body of this report. These designs were then weighted against 5 different criteria in a decision matrix, and the best design was chosen. The decision matrix complete with explanation can be seen below in Table 2 in section 3.0.

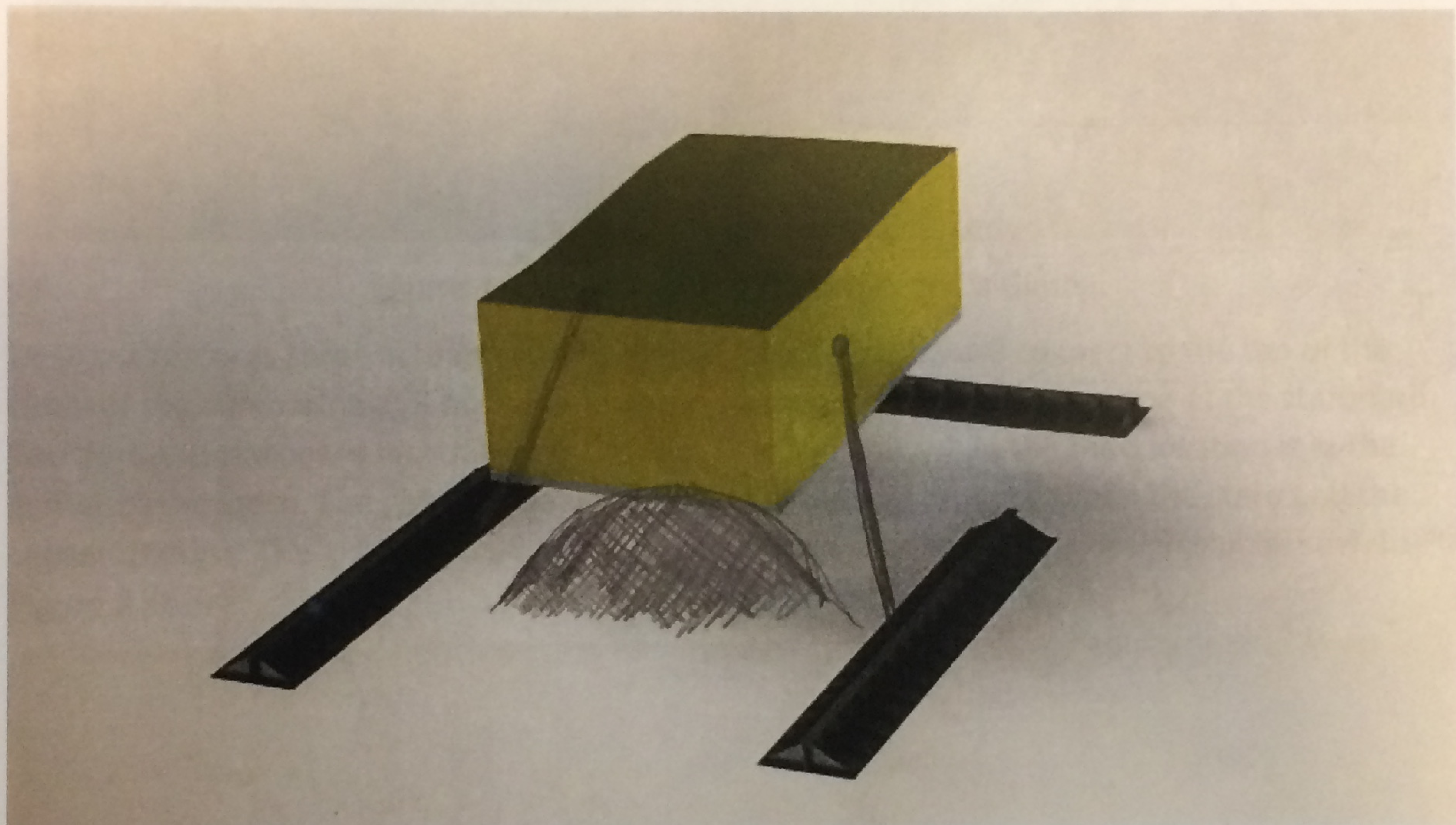


Figure 1: Design 1: Two Actuators and a Gimbal

Design 1 features two actuators and a gimbal. The actuators will connect to the top of the cabin of the submarine at 2 points, one at the port, and one at the starboard both near the bow while the third location is at the center of the stern. The gimbal would be located under the cabin between the stern and the center of mass. The gimbal would be made out of hardened steel. This design can be seen in Figure 1 above.

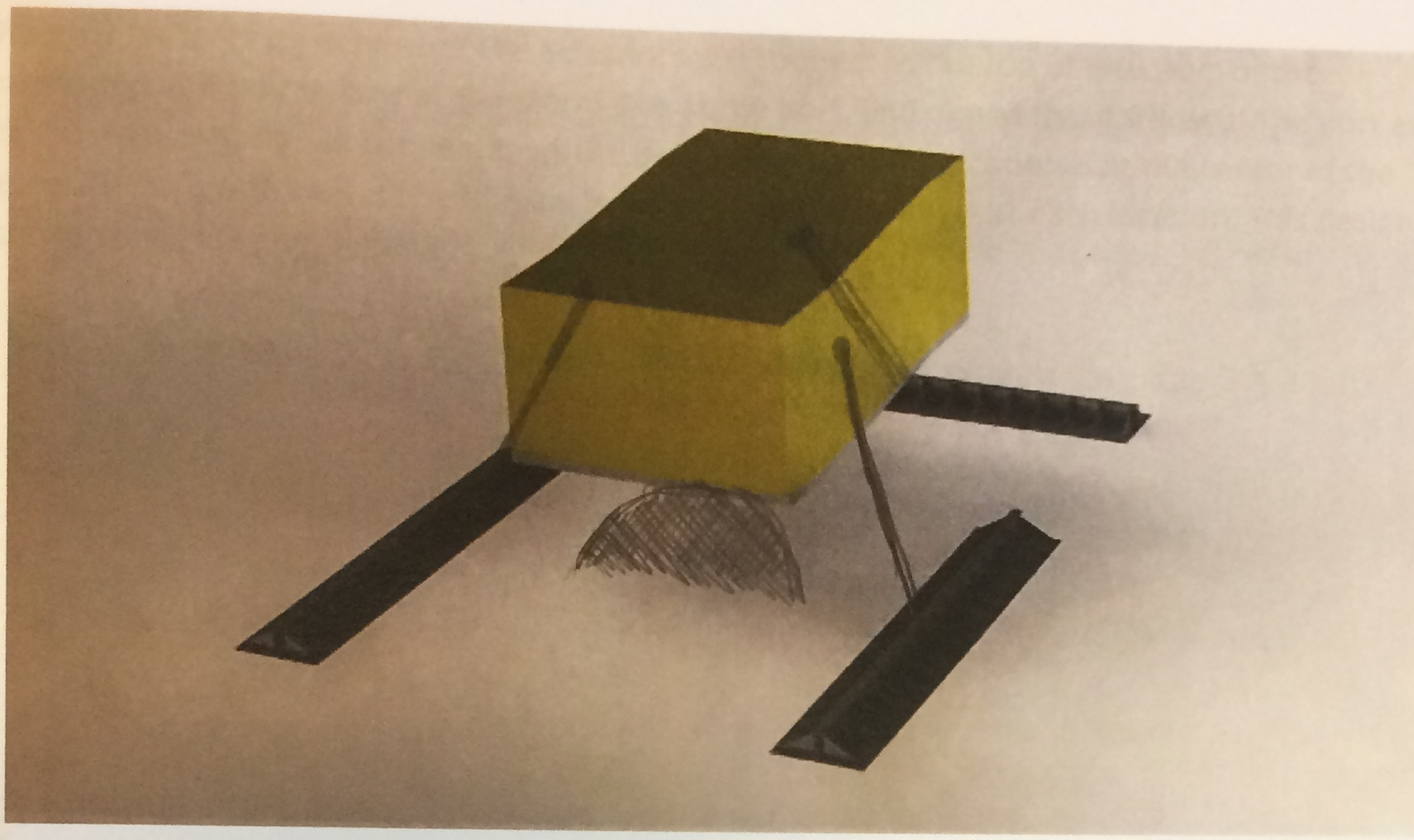


Figure 2: Design 2: Three Actuators and a Gimbal

Design 2 features three actuators and a gimbal. The actuators will connect to the top of the cabin of the submarine at 3 points, one at the stern, one at the port, and one at the starboard. The port and starboard locations will connect near the bow while the third location is at the center of the stern. The gimbal would be located under the cabin between the stern and the center of mass. The gimbal would be made out of hardened steel. This design can be seen in Figure 2 above.

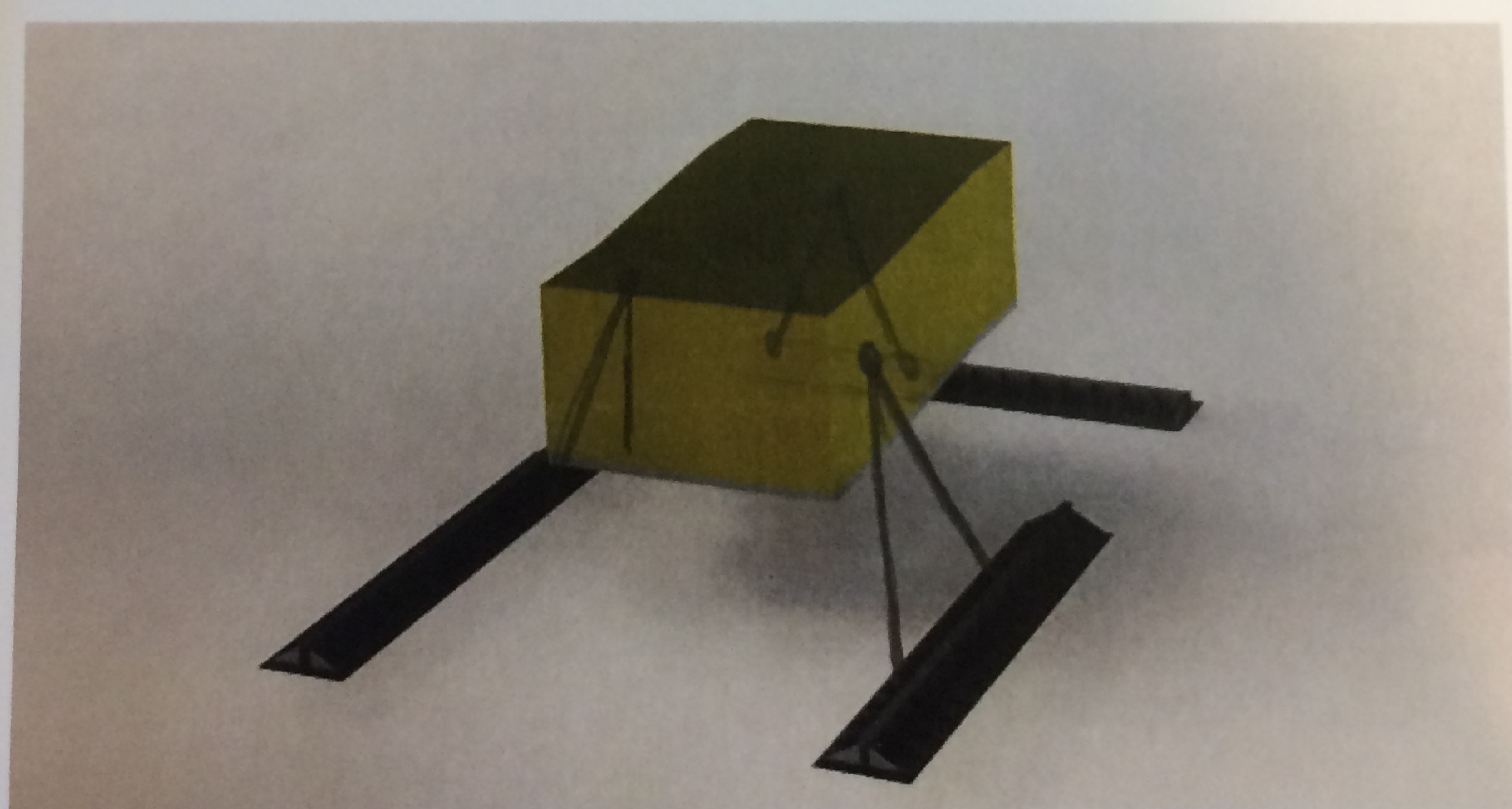


Figure 3: Design 3: Six Actuators

Design 3 features six actuators The actuators will connect to the top of the cabin of the submarine at 3 points, one at the stern, one at the port, and one at the starboard. The port and starboard locations will connect near the bow while the third location is at the center of the stern. The actuators would be in pairs in order to form a triangle at each location. This design can be seen in Figure 3 above.

3.0 Decision Matrix:

Table 2: Decision Matrix for Motion System

CRITERIA	WEIGHT	DESIGN 1	DESIGN 2	DESIGN 3
SAFETY	2	2	1	3
COST	1	1	2	2
MANUFACTURABILITY	1	1	2	3
DURABILITY	1	2	3	2
DESIGN ADAPTABILITY	1	2	2	3
TOTAL	-	**8**	**10**	**13**

3.1 Description:

Each criterion is explained in detail below, as well as how each design's score was determined for that criterion. In general, a score of 3 is the highest and most favorable, a score of 2 is moderate, and a score of 1 is the loser and is unfavorable.

- **Safety:** This criterion refers to the ability of the design to resist failure as well as how safe the system is to any person in the building especially including the passengers of the simulation. This criterion was weighted with a value of 2x because the client stressed the concern of safety. Design 1 scored a 2 because it has the ideal number of contact points for maximum safety, 3. However, the presence of the gimbal makes it very difficult to stop the ride immediately in an emergency. Design 2 scored a 1 because it has too many points of contact which results in larger stress concentrations on the structure which makes it more likely to fail. Design 3 scored a 3 because it also has the ideal number of contact points with the cabin but is scored higher than design 1 because the lack of a gimbal allows the actuators to be programmed to safely and immediately stop the ride in an emergency situation.
- **Cost:** This criterion refers to the total cost of the system. It is dependent on material and construction costs. Design 1 scored a 1 because the cost of the hardened steel used to manufacture the gimbal will be very high. Design 2 scored a 2 because like Design 1, it will have a high cost due to the steel gimbal. However, the gimbal will not have to be as large in size because of the third actuator. Design 3 also scored a 2 because while the actuators are also expensive, they are not nearly as expensive as steel.
- **Manufacturability:** This criterion refers to the ease of construction of the system. The structure needs to fit through a double man door, thus some of the construction must occur inside the room, it is important that this constraint is considered. Design 1 scored a 1 because the gimbal must be manufactured offsite. In addition, the size and weight of the gimbal may be impossible to fit through the double man door for assembly. Design 2 scored a 2 because it also faces the issue of offsite manufacturing and size, however the gimbal isn't as large as the gimbal in Design 1 and therefore leads to easier movement

for final assembly. Design 3 scored a 3 because the actuators will not need to be manufactured but are purchased pre made off the shelf. In addition, they are easy to maneuver through the double man door.

- **Durability:** This criterion refers to the expected life of the entire system. Design 1 scored a 2 because the gimbal takes the majority of the forces applied to the system and distributes in to the floor which takes a large amount of the load off the actuators which, in turn, increases the durability of the actuators. Design 2 scored a 3 because the gimbal also takes on a large amount of the load but in this design there are 3 actuators the remaining load is distributed to. Design 3 scored a 2 because the absence of a gimbal means that the actuators must support a large amount of load each. However, that load is distributed between 6 actuators. In addition, the absence of a gimbal allows for a third degree of freedom rather than a fixity which allows for the system to absorb forces by movement lowering the overall stress on each actuator.
- **Design Adaptability:** This criterion refers to the ability of the design to be modified for different speeds, pitches, and directions. Designs 1 and 2 scored a 2 because the gimbal prevents the simulator from moving up and down therefore not leaving much space in the room for additional pitch. However, the actuators allow for modifiable speeds. Design 3 scored a 3 because the absence of a gimbal allows for a programmable third degree of freedom and very easy adjustments of pitch and direction. The capability to modify Design 3 makes it unique and able to change with the client's constant creative ventures.

3.2 Conclusion:

Design 3 was rated the highest based on the criterion explained above. Design 3 scored a value of 13 and had a high or moderate score for each criterion. Design 2 had the next highest rating, with a score of 10. Design 2 scored moderate in most criterion but it scored low in safety which was the most important consideration. Design 1 had the lowest rating with a value of 8. Design 1 scored low to moderate in all criterion. Since scoring high was favorable for all criterion and safety was paramount, the design that scored the highest overall is the design we chose. Based on the results above we chose Design 3.

4.0 Design Overview:

The simulator assembly is designed with 6 linear electric actuators which attach to the cabin at 3 locations in order to suspend it. Each pair of actuators has an angle of 60° between the two. The cabin sits directly on top of the floor platform which is sloped at 5° from the horizontal but features horizontal top and bottom sections. The actuators are bolted to the baseplate at approximately 10° from the vertical. All parts of the design are made of 7075-T6 Aluminum. This material was chosen because it has a much lower density than steel, allowing the design to utilize a smaller footprint while still distributing its weight at less than 53 pounds per square foot. The design is unique for it has the capability of adding a third degree of freedom if the client desires to modify it in the future. The sum of the floor assembly, baseplate, and expected weights of actuators is approximately 7,000 lbf. The baseplate covers 491.4 square feet resulting in a distributed load of 50.87 psf to the floor of the building. It is able to withstand 3G and worst case scenario loading and all factors of safety for von Mises stresses are above 2.5 and above 1 for deflections. Background research was done into the effects of welding aluminum and have been considered in this design. It is designed to be manufactured and shipped in parts in order for ease of transportation and will be bolted together at the final location. The floor platform will be constructed in seven pieces which are designed to be shipped to the final assembly site. Welding will be performed on all connections for the fabricated pieces but the pieces will be bolted together once transported to the site. The floor platform separates into the four rectangular sections that make up the upper and lower landings of the platform, two side sections that provide structure to the riser section of the platform, and one center section where the remaining cross members are bolted together. The actuators are mounted to both the baseplates and structure of the simulator using pin connections. Upon design of the cabin structure, the team involved with this design and analysis will need to design for a 10" x 10" rectangular bolted pattern where the actuators will mount to the cabin wall. This connection point will need to be designed as a point of stress concentration and if will at minimum need to be tested under the reaction forces stated in Figure 5 and Figure 9. A similar 10" x 10" rectangular bolted connection will be designed for the other mounting side of the actuators once a specific actuator has been decided upon for the design. Analysis will be re-run on the baseplates once these connections are developed to ensure that the results stated in this deliverable are in fact correct. The complete design can be seen in Figure 4 below.

good
specify
location

a bit redundant,
but a nice
addition

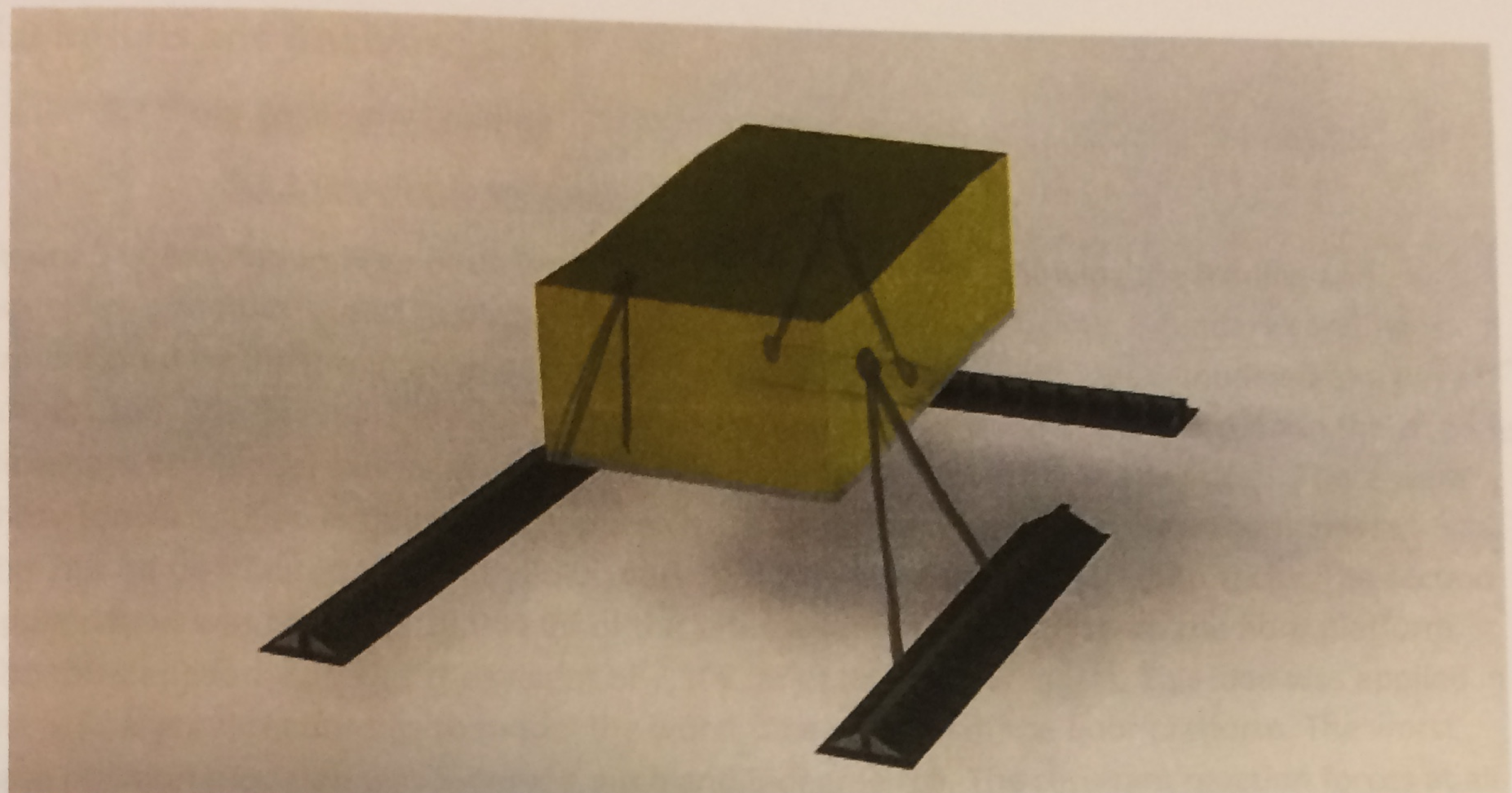


Figure 4: Isometric View of Complete Design

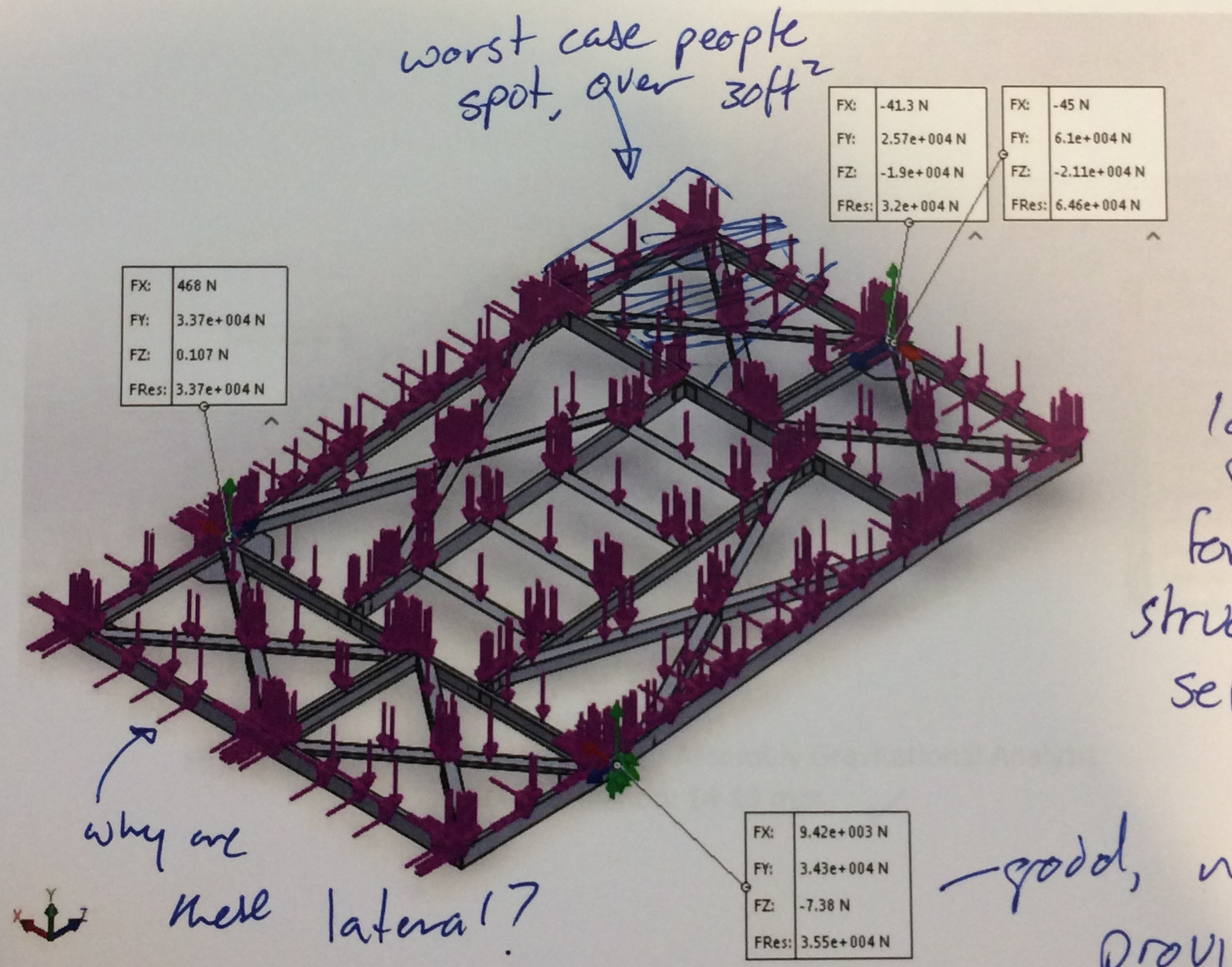
5.0 Results and Analysis:

5.1 Floor Assembly Loading

5.1.1 Gravitational Analysis

Figure 5 below shows Free Body Diagram of the floor assembly showing the loading and boundary conditions used to obtain the results in Figure 6 and 7 below. Boundary conditions are denoted by the green arrows. Each of the three boundary conditions is modeled as a pin connection. This prevents motion in the x and y directions and allowed translation in the z why ? direction. The global axis used can be seen in the bottom left corner of the image. There were three forces applied in this simulation which are all shown as purple arrows. The first was the 768 lbf distributed load of the plywood floor over all of the contacting surfaces. The second applied load was from the 18,000 lbf of the cabin around the perimeter of the floor platform. The third applied load was the weight of 7,500 lbf of the 30 passengers. This load was applied in the x, y, and z directions as to model the worst case position of the floor platform. The worst case position modeled was 5-degree pitch and 5-degree roll. The resultant reaction forces at all of the connections are also pictured below. These are the forces translated through the actuators into the baseplates and are used in the baseplate loading analysis.

worst case people spot, over 30ft²



1g down for structure self-weight

why are these lateral?

—good, now provide

Figure 5: Free Body Diagram of Floor Assembly Gravitational Analysis

BB max. w/ locations

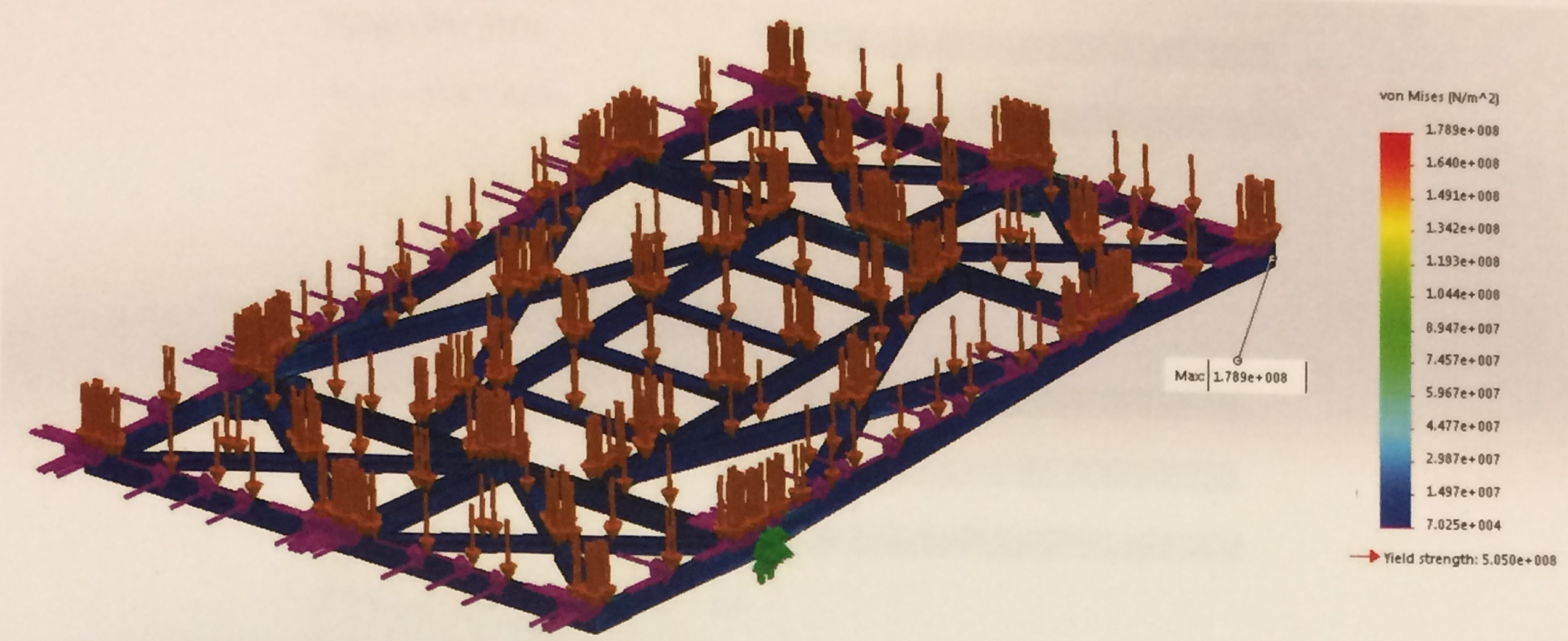


Figure 6: Von Mises Results of Floor Assembly Gravitational Analysis
Max Von Mises: **175.5 MPa** ✓

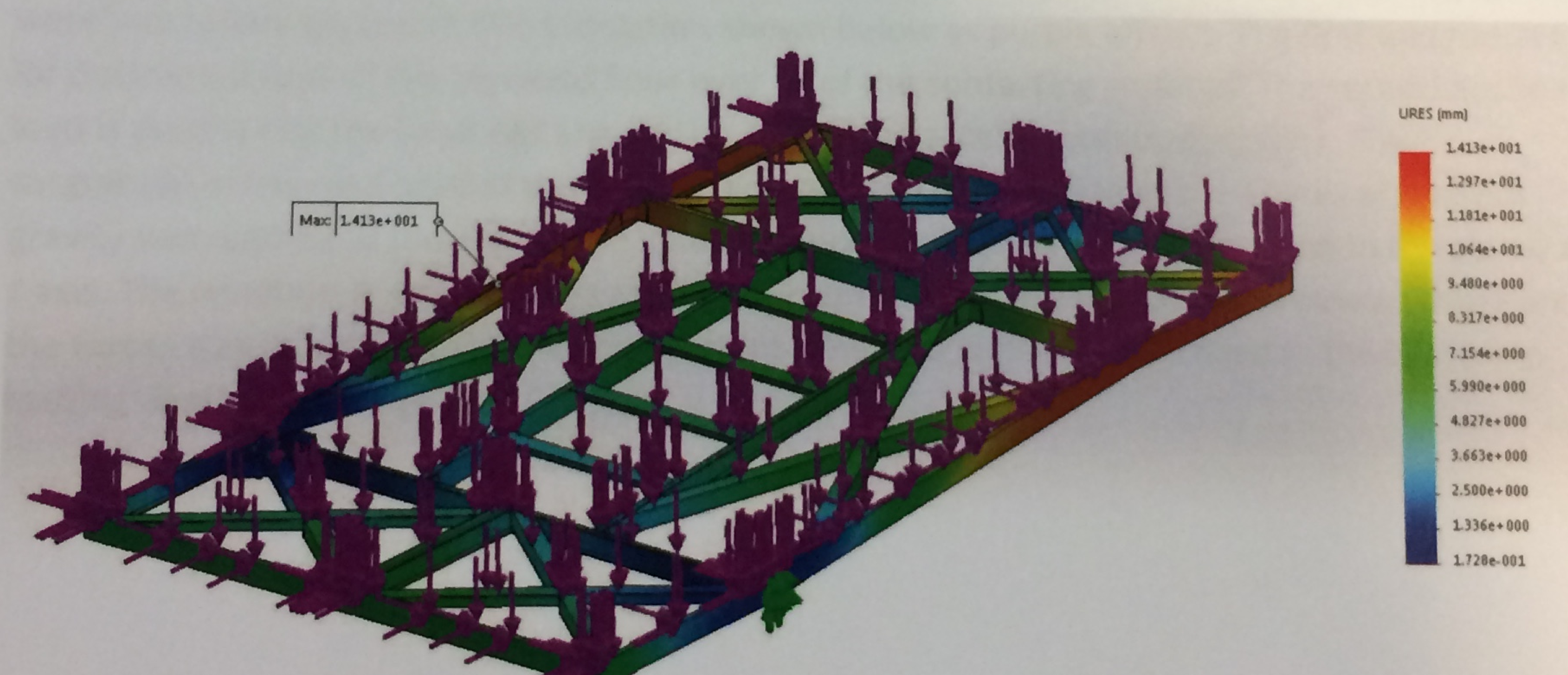


Figure 7: Deflection Results of Floor Assembly Gravitational Analysis
Max Deflection: **14.13 mm** ✓

Factor of Safety - von Mises

$\sigma_{yield} := 505\ MPa$ — Yield Strentgh of 7075-T6

$\sigma_{SWS} := 175.5\ MPa$ — Maximum von Mises Stress from SWS Study

$$FOS_{VM} := \frac{\sigma_{yield}}{\sigma_{SWS}} = 2.877$$

Factor of Safety - Deflection

$L_{sub} := 8.3825\ m$ — Length of Simulator

$\delta_{max} := \frac{L_{sub}}{180} = 46.569\ mm$ — Maximum deflection

$\delta_{SWS} := 14.13\ mm$ — Maximum deflection from SWS study

$$FOS_{deflection} := \frac{\delta_{max}}{\delta_{SWS}} = 3.296$$

Figure 8: Factors of Safety Results of Floor Assembly Gravitational Analysis

5.1.2 Failure Mode Effects Analysis

Figure 9 below shows a Free Body Diagram of the floor assembly with the loading and boundary conditions used to obtain results in Figure 9. Boundary conditions are denoted by the green arrows. Each of the three boundary conditions was modeled as a pin connection. This prevented motion in the x and y directions and allowed translation in the z direction. There were two forces applied in this simulation shown below as purple arrows. The first was the 768 lbf distributed load of the plywood floor over all of the contacting surfaces. The second applied load is denoted by the large red arrow. This load is the acceleration from gravity. The magnitude of the load used in this simulation was 3G. The direction of the acceleration from gravity was applied to the worst case loading which was along a 45-degree plane in the global x-z axis. The resultant reaction forces at all of the connections are also pictured below. These are the forces translated through the actuators into the baseplates and are used in the baseplate loading analysis.

again, why?

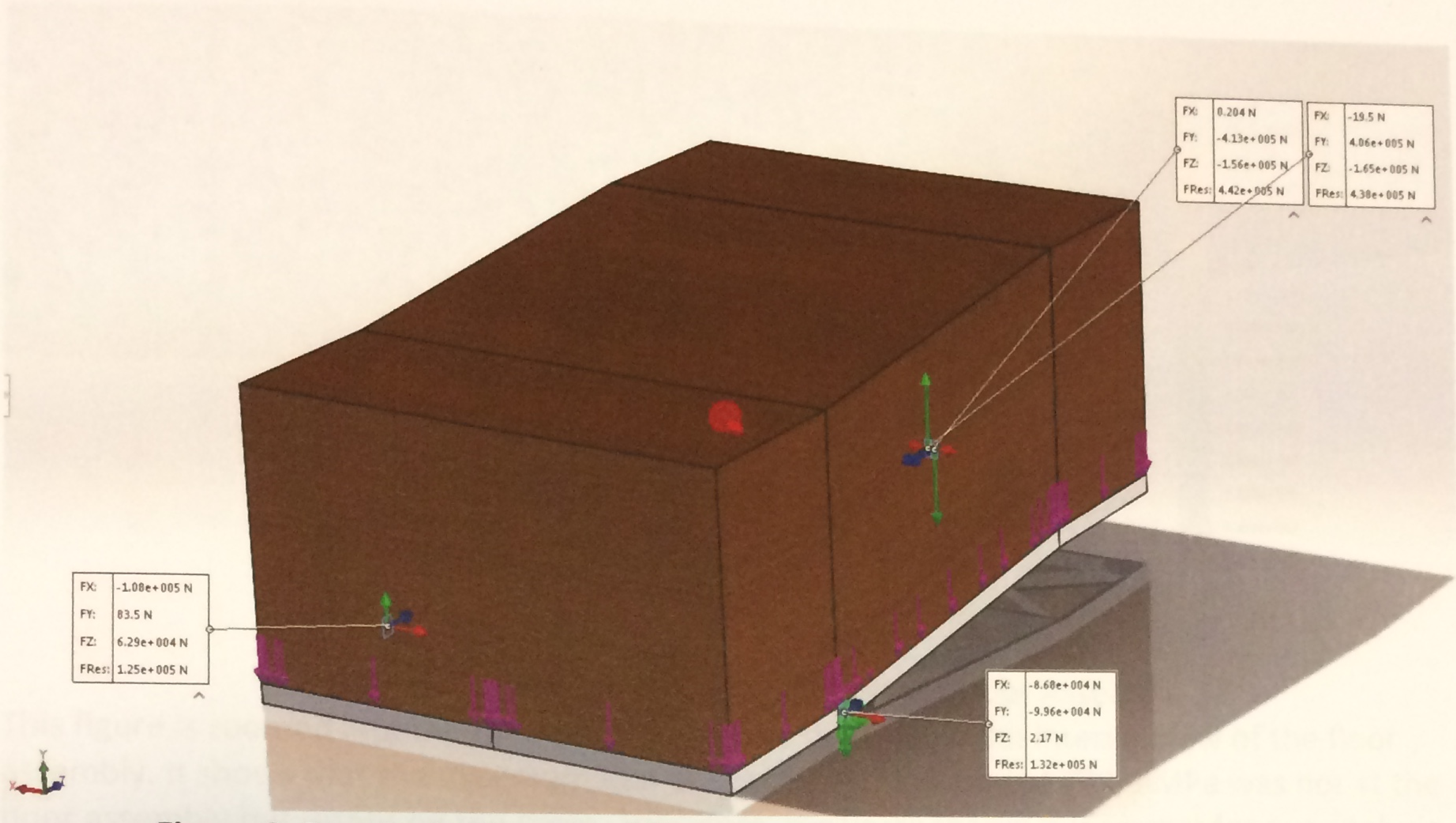


Figure 9: Free Body Diagram of Floor Assembly Failure Mode Effects Analysis

how is box modeled? mat'l?

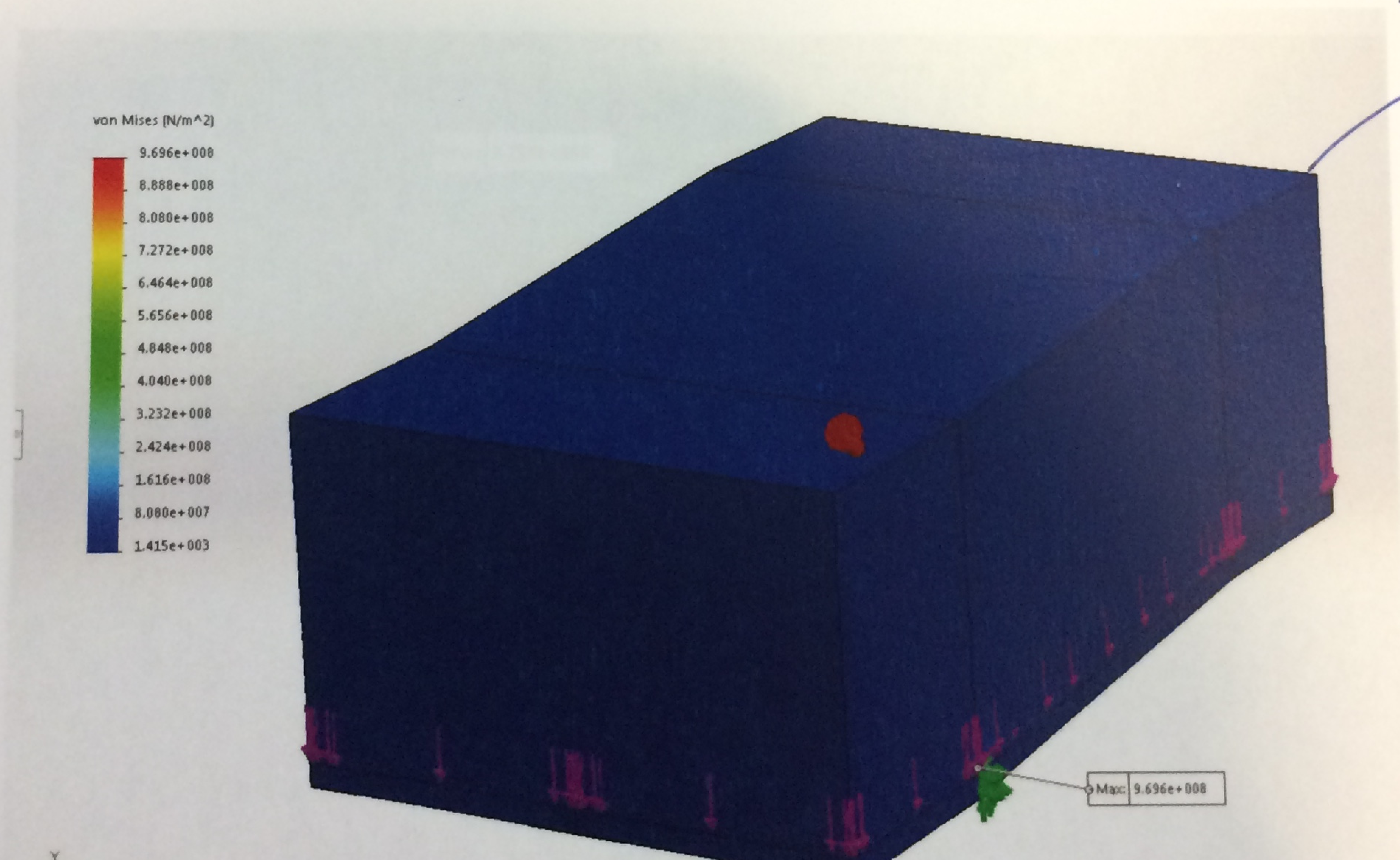


Figure 10: Von Mises Results of Floor Assembly Failure Mode Effects Analysis

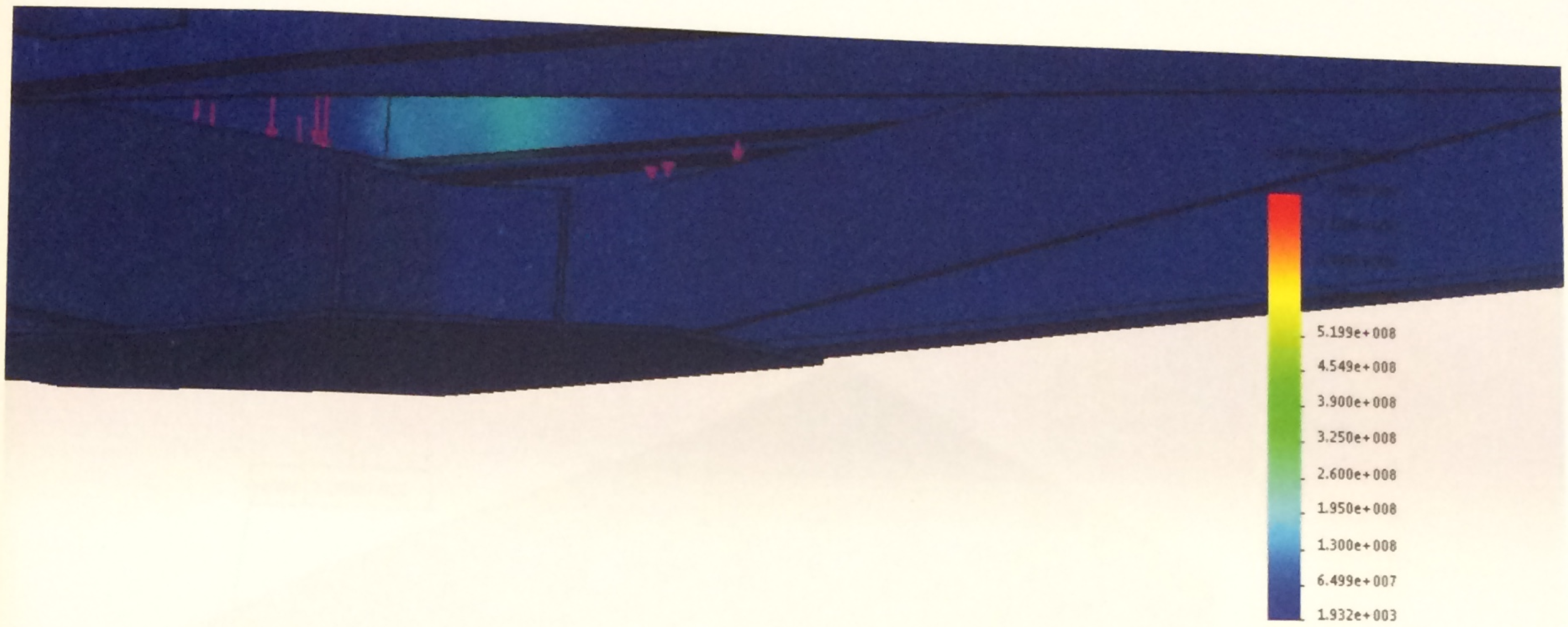


Figure 11: Zoomed-In Von Mises Results of Floor Assembly
This figure is zoomed into the maximum Von Mises stress from the interior view of the floor assembly. It shows that the maximum Von Mises stress calculated of 779.9 MPa was not at the floor assembly but rather on the cabin. Therefore, the value shown is incorrect for our analysis of the floor assembly.

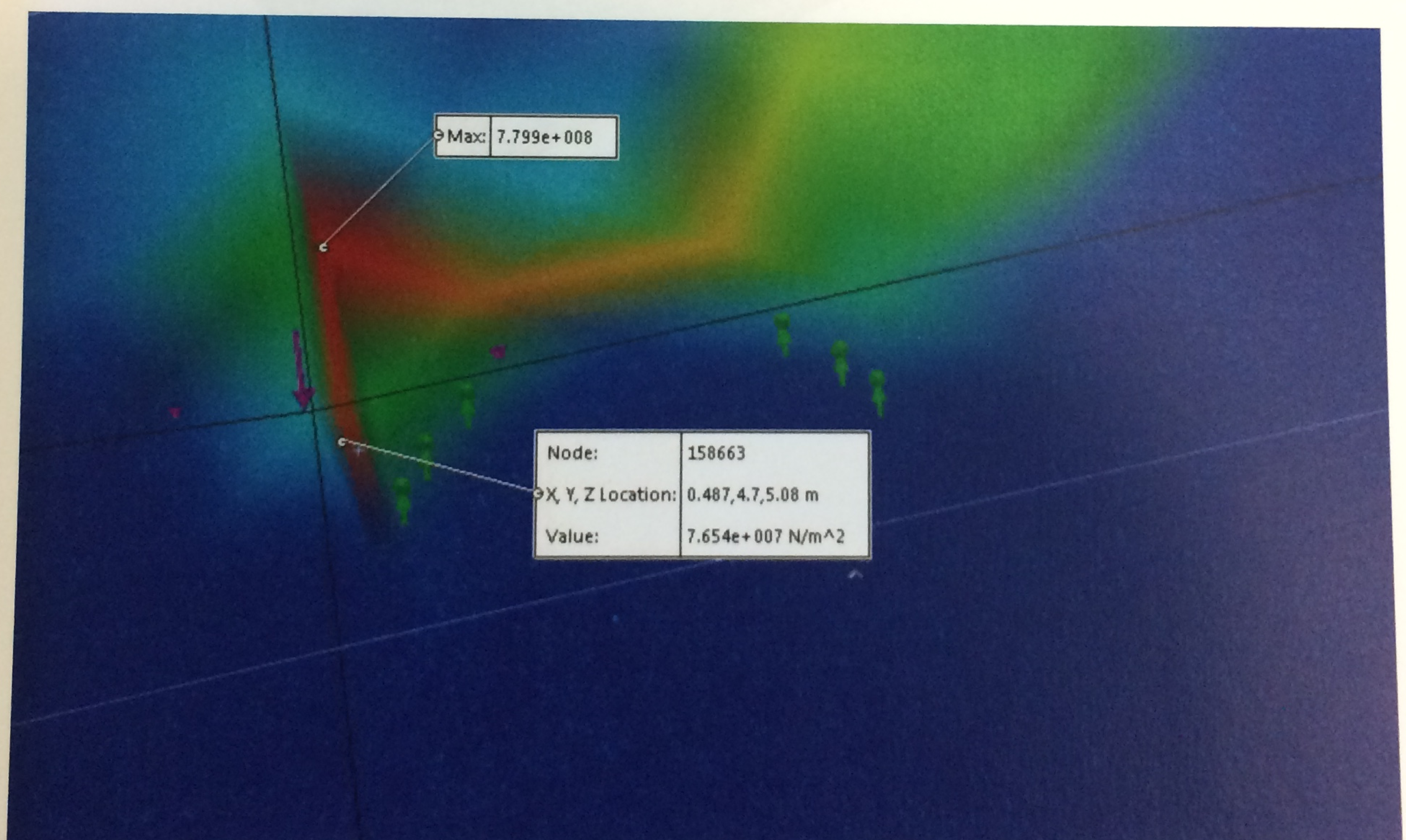


Figure 12: Probing Floor Assembly for correct Von Mises Results
This figure is zoomed into the Von Mises stress plot from the exterior view of the floor assembly (below horizontal black line) and the cabin (above horizontal black line). This is the

location of the maximum Von Mises stress on the floor platform. Upon probing this area, it is clear that the maximum stress in the floor platform itself is well below the yield stress.

Max Von Mises: **76.54 MPa**

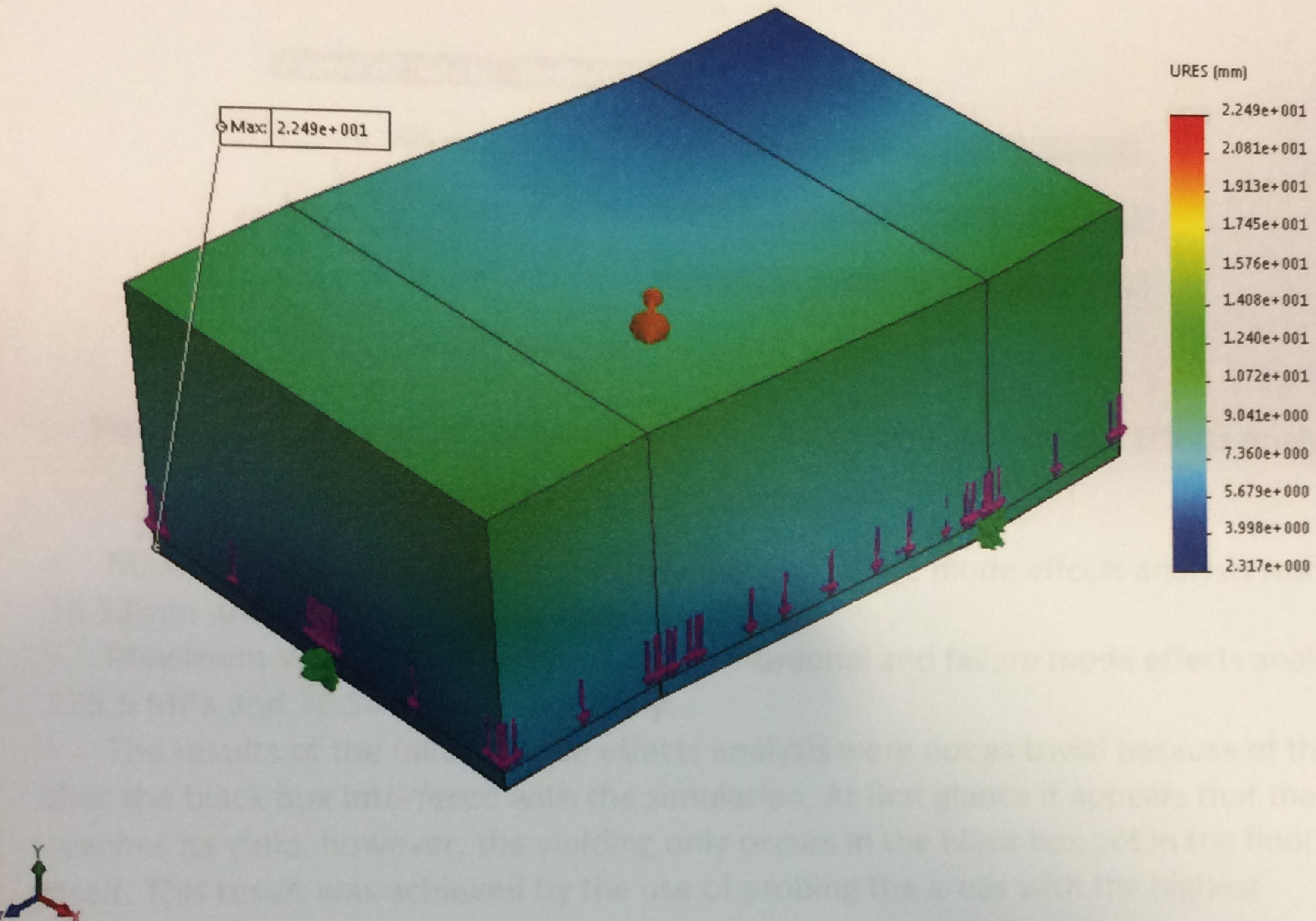


Figure 13: Deflection Results of Floor Assembly Failure Mode Effects Analysis

Max Deflection: **22.49 mm**

Exec.

3/13

Factor of Safety - von Mises

$\sigma_{yield} := 505\ MPa$	Yield Strentgh of 7075-T6
$\sigma_{SWS} := 76.54\ MPa$	Maximum von Mises Stress from SWS Study

$$FOS_{VM} := \frac{\sigma_{yield}}{\sigma_{SWS}} = 6.598$$

Factor of Safety - Deflection

$L_{sub} := 8.3825\ m$	Length of Simulator
$\delta_{max} := \frac{L_{sub}}{180} = 46.569\ mm$	Maximum deflection
$\delta_{SWS} := 22.49\ mm$	Maximum deflection from SWS study

$$FOS_{deflection} := \frac{\delta_{max}}{\delta_{SWS}} = 2.071$$

Figure 14: Factors of Safety Results of Floor Assembly Failure Mode Effects Analysis

should table I

all of this also be in

5.1.3 Floor Assembly Loading Conclusion

- Maximum deflections of the gravitational and failure mode effects analysis were 14.13mm and 22.49mm, respectively.
- Maximum Von Mises stresses of the gravitational and failure mode effects analysis were 175.5 MPa and 76.54 MPa, respectively.
- The results of the failure mode effects analysis were not as trivial because of the way that the black box interfered with the simulation. At first glance it appears that the material reaches its yield, however, the yielding only occurs in the black box not in the floor platform itself. This result was achieved by the use of probing the areas with the highest concentrations of stresses.
- With respect to the maximum VM stress and deflections, the lowest factors of safety are for 2.877 VM stress and 2.071 for deflection. Both exceed the minimum allowable factors of safety.
- Results can also be seen in Table 1

can you justify by location that $w = \frac{W}{3}$?

5.2 Baseplate Loading

5.2.1 Gravitational Analysis

Regardless of the simulations and free body diagrams of the floor platform our team completed a study of the baseplate that shows that it is able to support the maximum allowable weight of 25,000 lbs. This was simulated by dividing the maximum allowable weight into 3 forces of 8,333 lbs in the z direction applied to the locations of the actuators. They are represented as purple arrows. The green arrows represent the fixtures for the simulation, which are applied to the bottom face of the baseplate. This fixture is a fully fixed type because the baseplate will be resting on the floor of the room and then bolted to the room via the most appropriate connection to suit the building structure. The floor and bolting will prevent movement in the x,

you need to determine

y, and z directions for all three baseplates. The baseplates are designed to be of the same size and to be mounted to the simulator in the same manner so therefore only one study was run on this assembly.

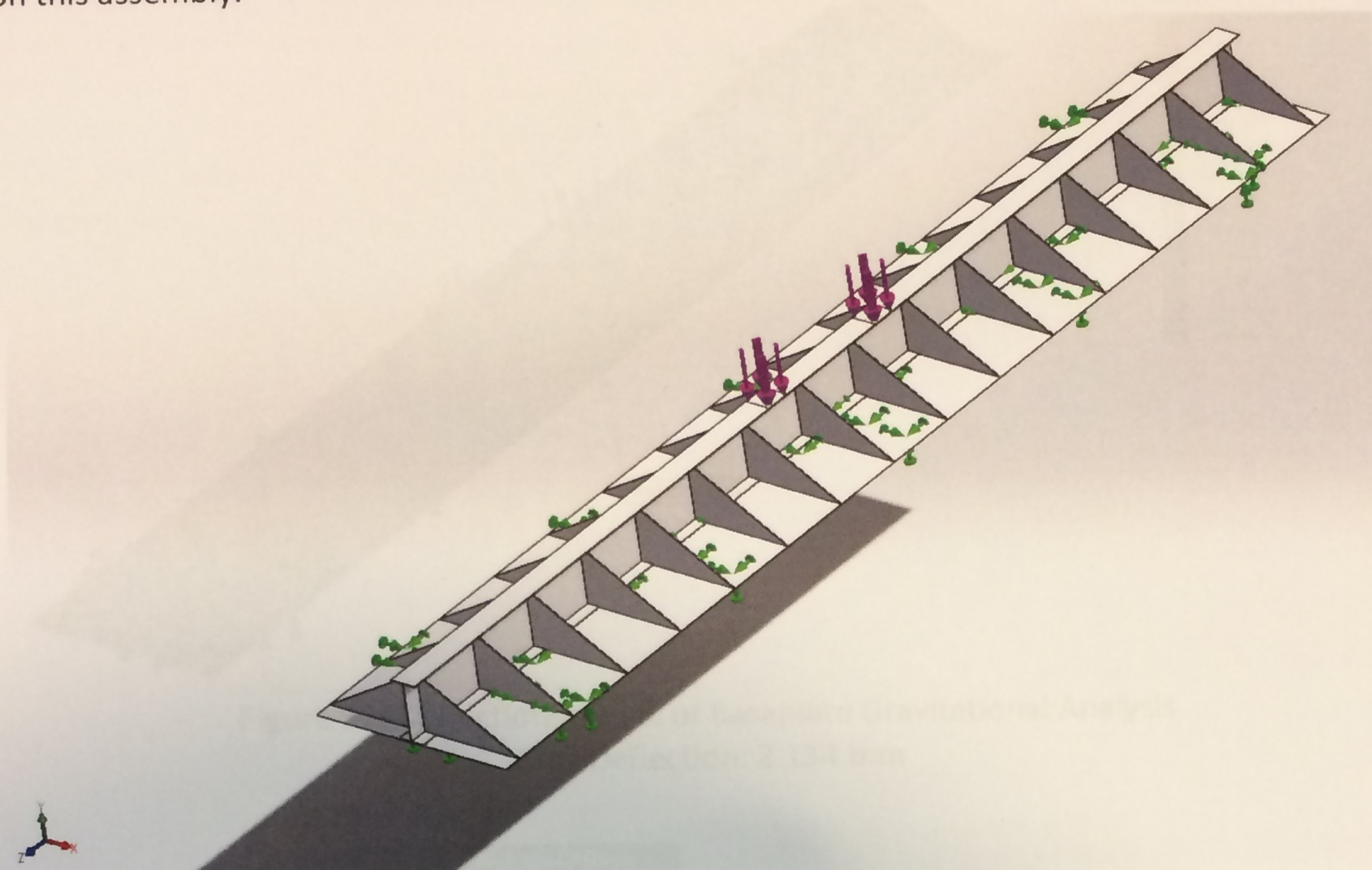


Figure 15: Free Body Diagram of Baseplate Gravitational Analysis

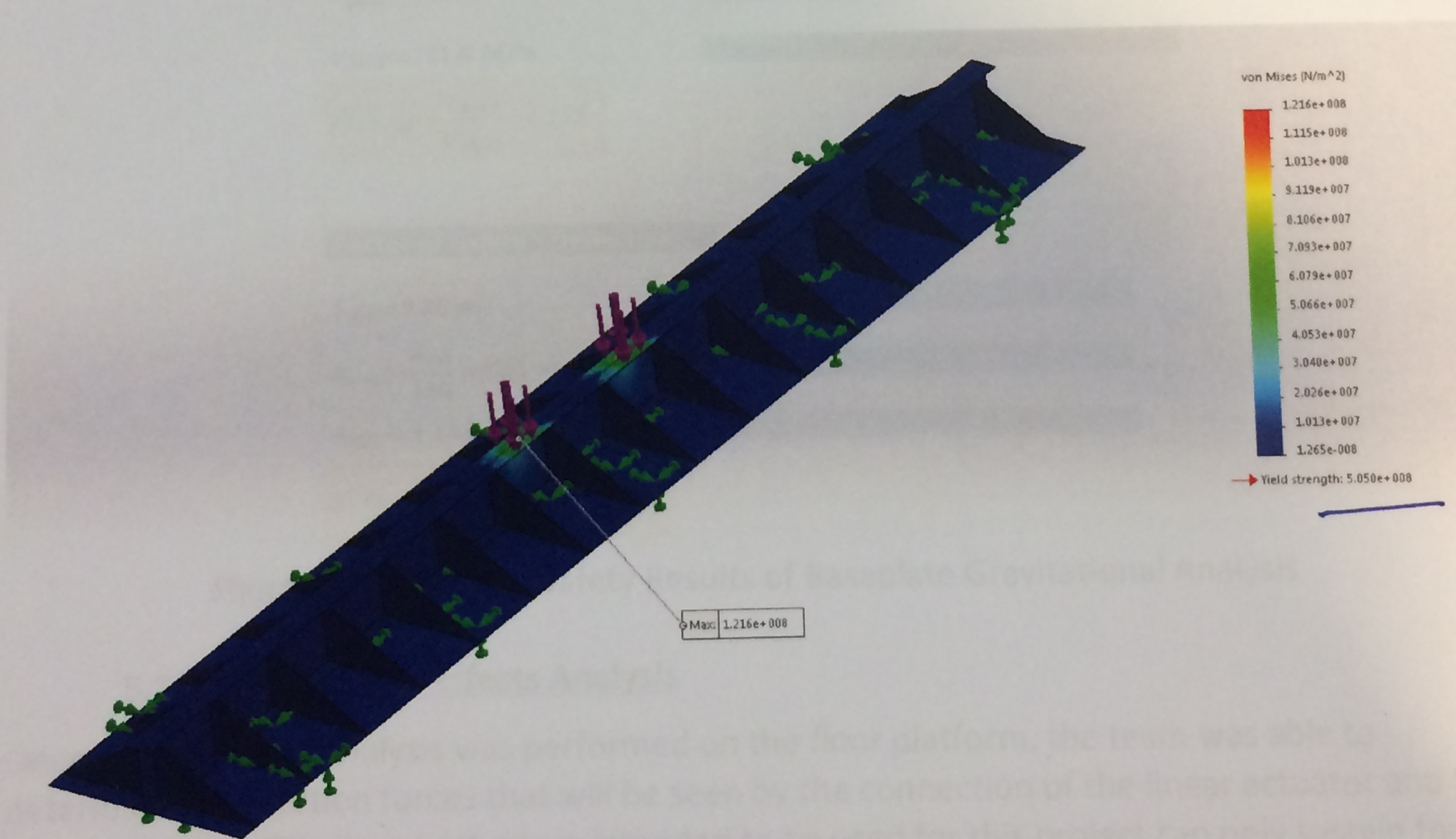


Figure 16: Von Mises Results of Baseplate Gravitational Analysis
Max Von Mises: **121.6 MPa**

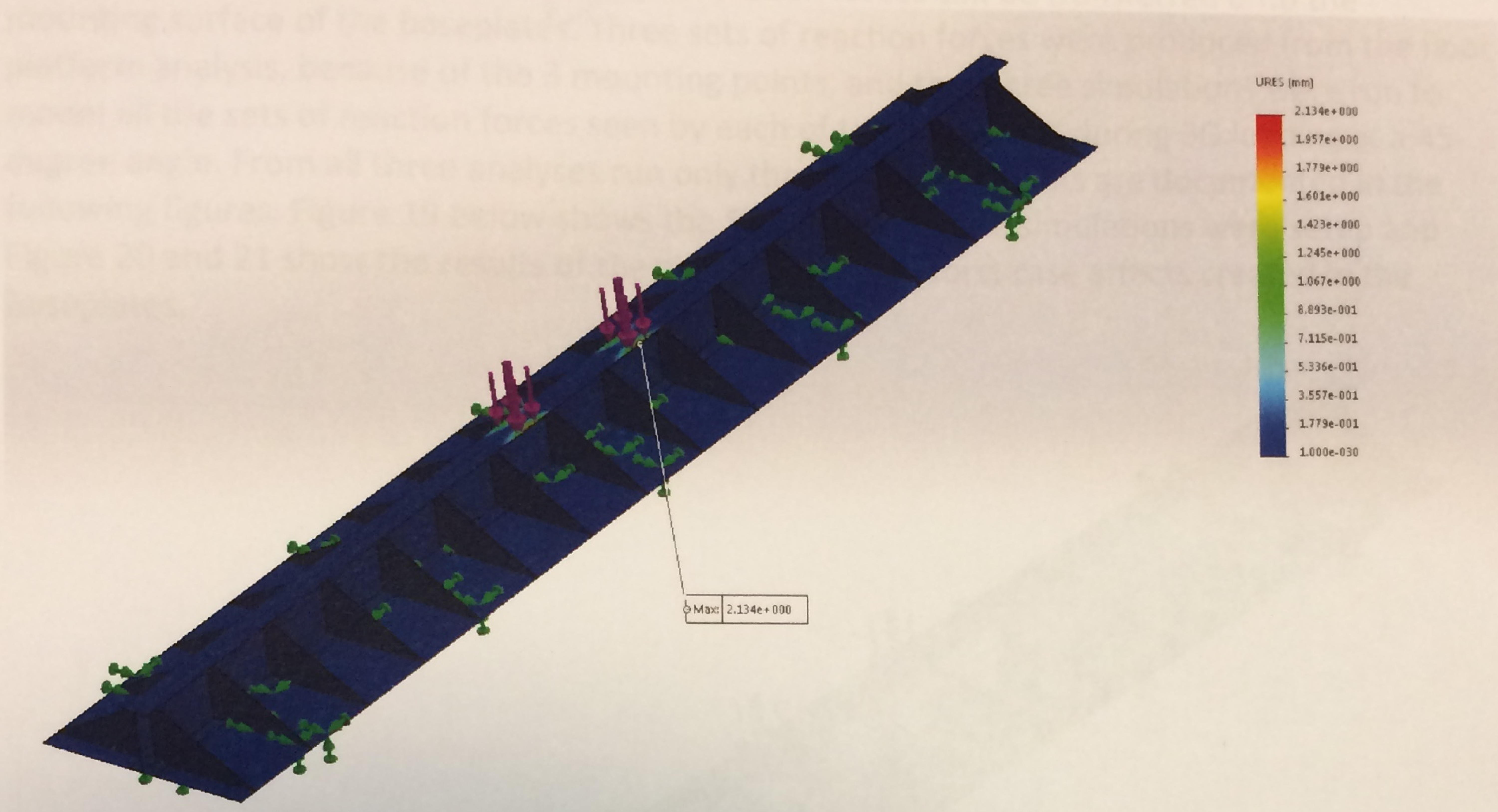


Figure 17: Deflection Results of Baseplate Gravitational Analysis
Max Deflection: **2.134 mm**

Factor of Safety - von Mises

$\sigma_{yield} := 505\ MPa$ — Yield Strentgh of 7075-T6

$\sigma_{SWS} := 121.6\ MPa$ — Maximum von Mises Stress from SWS Study

$$FOS_{VM} := \frac{\sigma_{yield}}{\sigma_{SWS}} = 4.153$$

Factor of Safety - Deflection

$L_{sub} := 9.45\ m$ — Length of Simulator

$\delta_{max} := \frac{L_{sub}}{180} = 52.5\ mm$ — Maximum deflection

$\delta_{SWS} := 2.134\ mm$ — Maximum deflection from SWS study

$$FOS_{deflection} := \frac{\delta_{max}}{\delta_{SWS}} = 24.602$$

Figure 18: Factors of Safety Results of Baseplate Gravitational Analysis

5.2.2 Failure Mode Effects Analysis

Once the 3G failure analysis was performed on the floor platform, the team was able to determine the reaction forces that will be seen by the connection of the linear actuator and the simulator cabin. The linear actuators intended to be used for this project can only sustain forces and not moments about their central axis so all the actuators on the design must be modeled and treated as two force members. Since the reaction forces at one end of the actuators were determined in previous analyses, the same reaction forces can be transferred onto the mounting surface of the baseplates. Three sets of reaction forces were produced from the floor platform analysis, because of the 3 mounting points, and thus three simulations were run to model all the sets of reaction forces seen by each of the baseplates during 3G loading at a 45-degree angle. From all three analyses run only the worst case results are documented in the following figures. Figure 19 below shows the FBD for how these simulations were setup and Figure 20 and 21 show the results of the analysis and the worst case affects created in the baseplates.

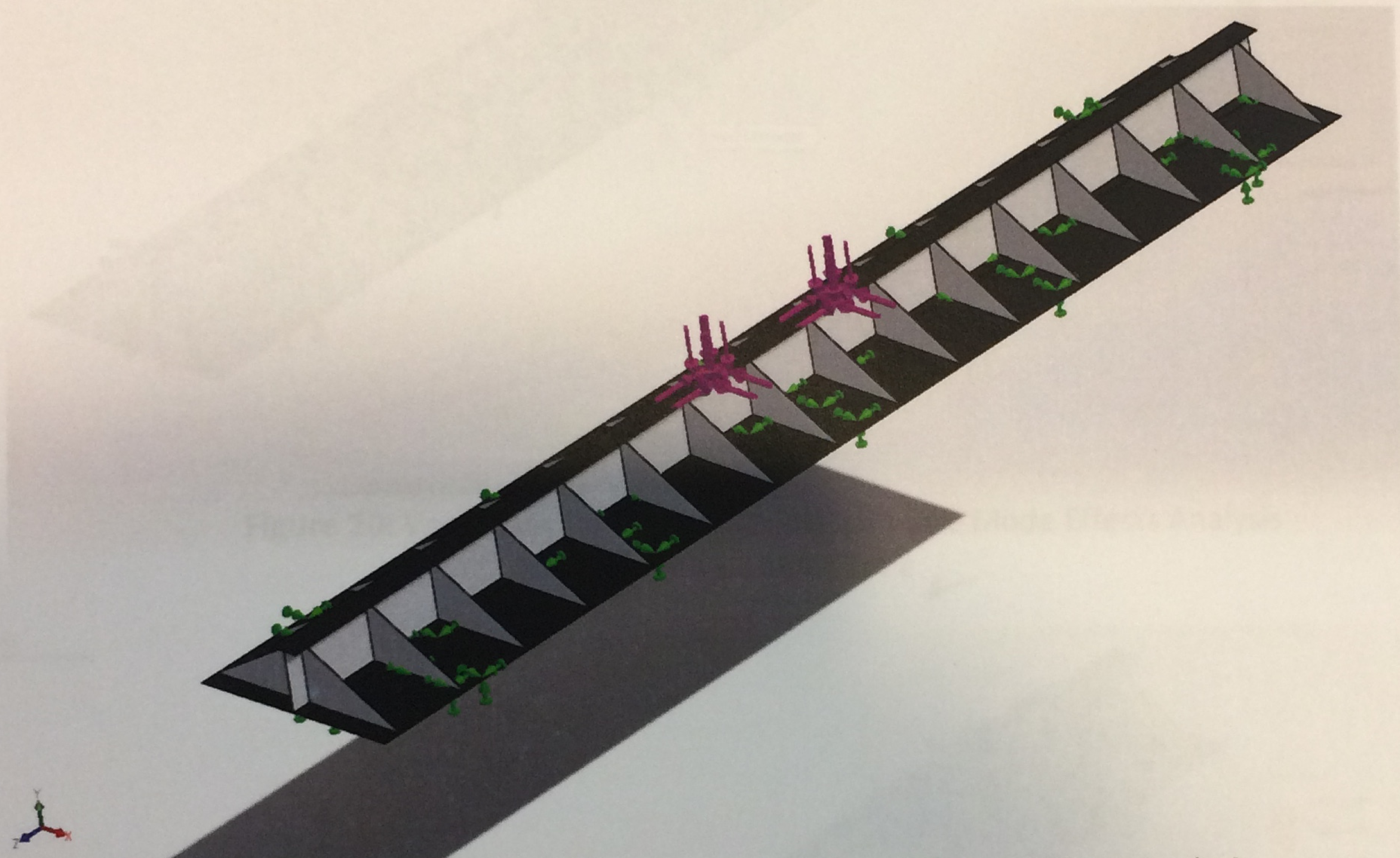


Figure 19: Free Body Diagram of Baseplate Failure Mode Effects Analysis

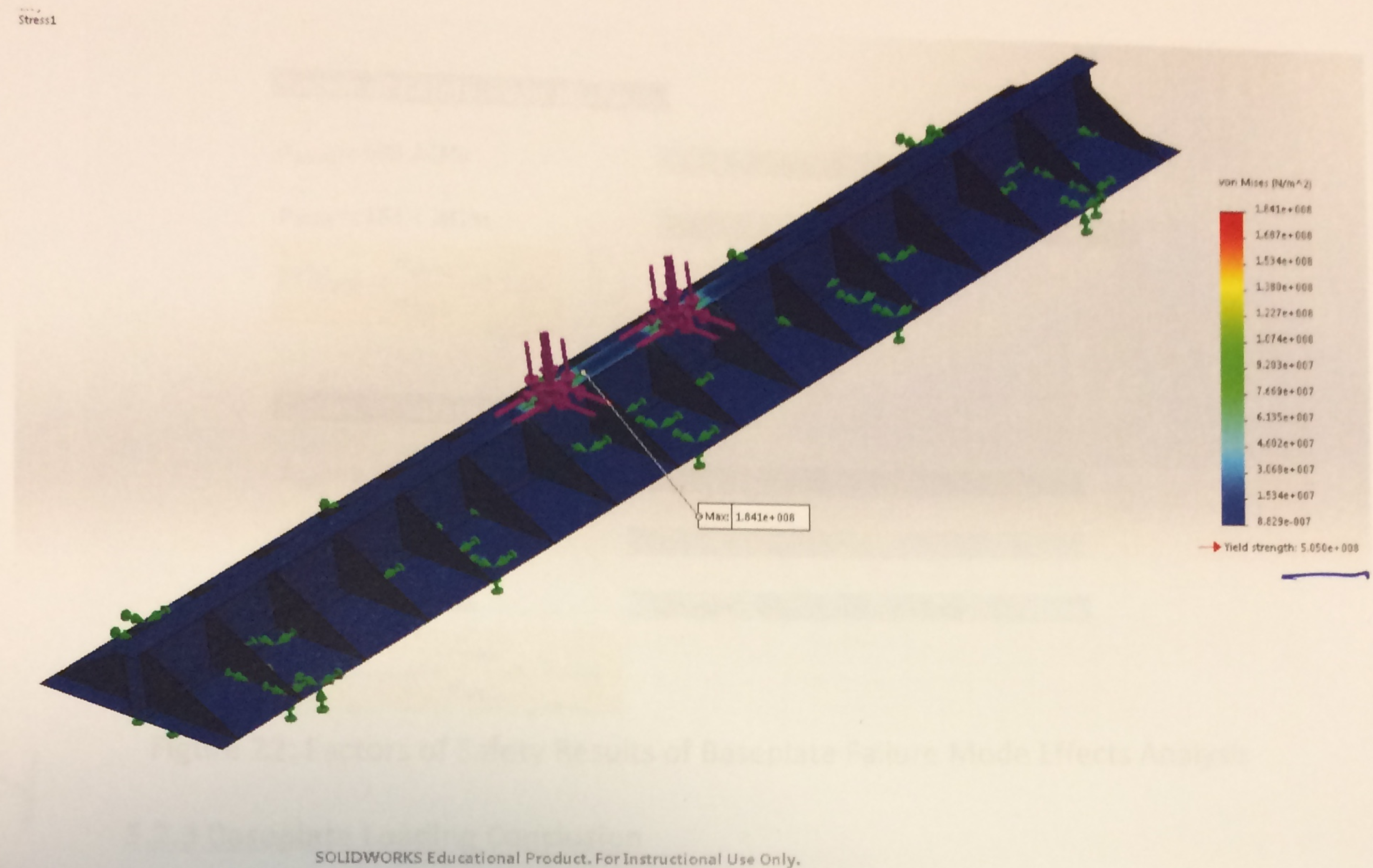


Figure 20: Von Mises Results of Baseplate Failure Mode Effects Analysis
Max Von Mises: **184.1 MPa**

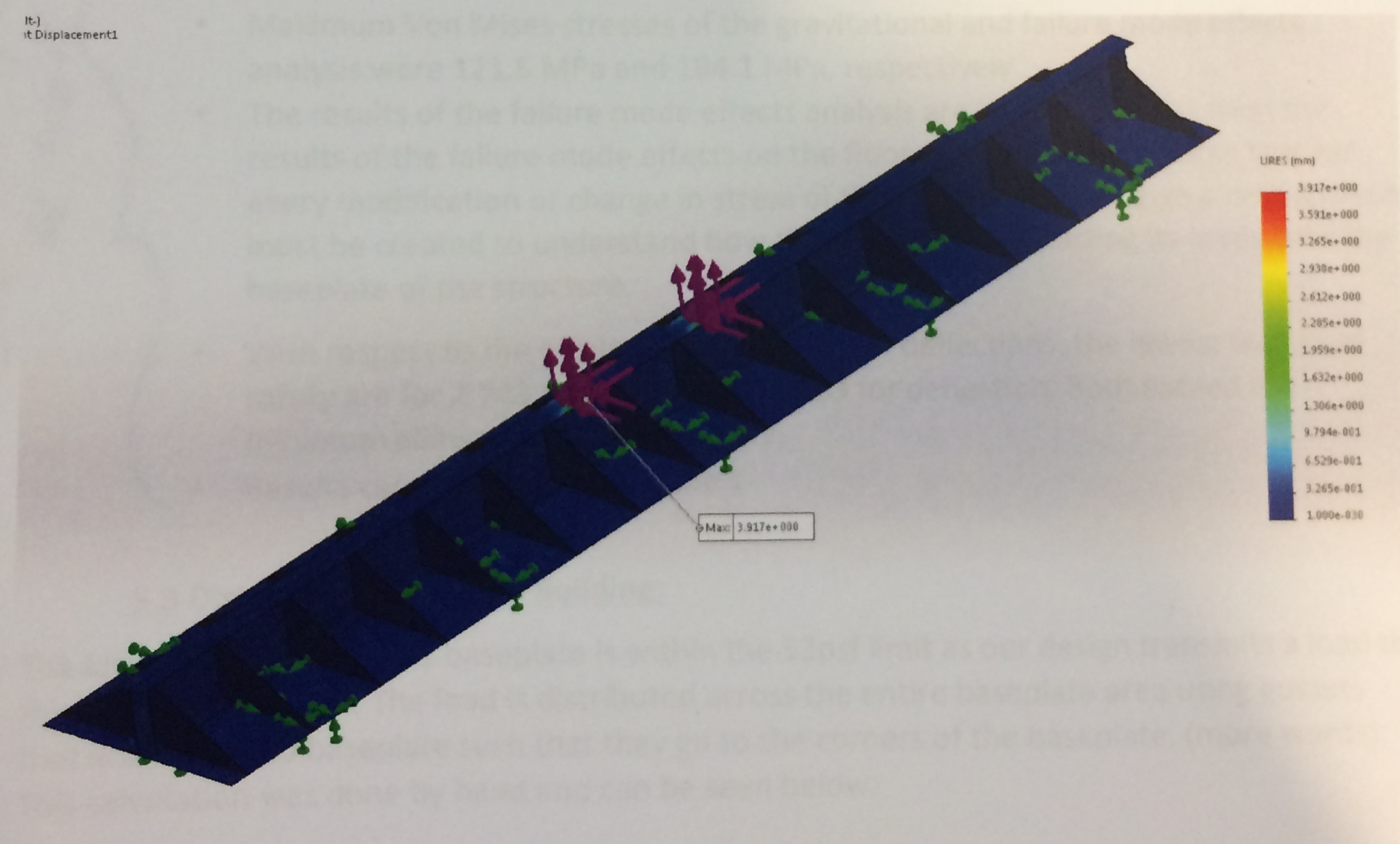


Figure 21: Deflection Results of Baseplate Failure Mode Effects Analysis
Max Deflection: **3.917 mm**

Factor of Safety - von Mises

$\sigma_{yield} := 505\ MPa$ — Yield Strentgh of 7075-T6

$\sigma_{SWS} := 184.1\ MPa$ — Maximum von Mises Stress from SWS Study

$$FOS_{VM} := \frac{\sigma_{yield}}{\sigma_{SWS}} = 2.743$$

Factor of Safety - Deflection

$L_{sub} := 9.45\ m$ — Length of Simulator

$\delta_{max} := \frac{L_{sub}}{180} = 52.5\ mm$ — Maximum deflection

$\delta_{SWS} := 3.917\ mm$ — Maximum deflection from SWS study

$$FOS_{deflection} := \frac{\delta_{max}}{\delta_{SWS}} = 13.403$$

Figure 22: Factors of Safety Results of Baseplate Failure Mode Effects Analysis

5.2.3 Baseplate Loading Conclusion

all in Table I as well

- Maximum deflections of the gravitational and failure mode effects analyses were 2.134mm and 3.917mm, respectively.
- Maximum Von Mises stresses of the gravitational and failure mode effects analysis were 121.6 MPa and 184.1 MPa, respectively.
- The results of the failure mode effects analysis are derived straight from the results of the failure mode effects on the floor platform. This requires that for every modification or change in stress of the floor platform design a new analysis must be created to understand how that platform is imparting its loads onto the baseplate of the structure.
- With respect to the maximum VM stress and deflections, the lowest factors of safety are for 2.743 VM stress and 13.403 for deflection. Both exceed the minimum allowable factors of safety.
- Results can also be seen in Table 1

5.3 Distributed Loading to Building:

The load to the floor via the baseplate is within the 53psf limit as our design transmits a load to the floor of (value) psf. The load is distributed across the entire baseplate area using gussets that are welded to baseplate such that they go to the corners of the baseplate. (more words). This calculation was done by hand and can be seen below:

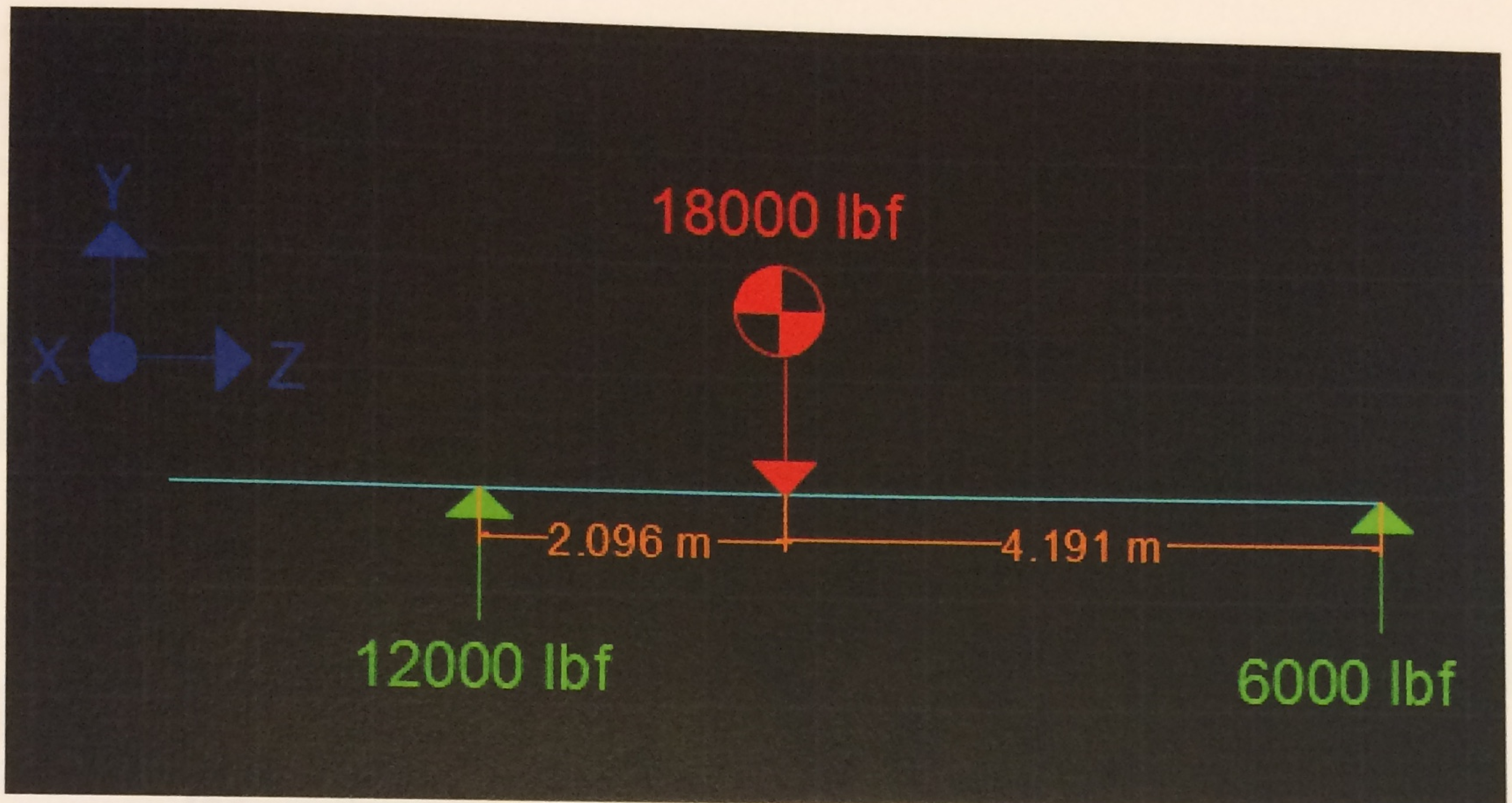


Figure 23: Free Body Diagram of Distributed Loading

Weights

Note: Weights were taken from Solidworks which was based on th specific materials used in structure design.

$W_{bbox} := 18000\ lbf$ — Black Box Weight

$W_{floor} := 2996\ lbf$ — Floor Platform Weight

$W_{baseplate} := 2292\ lbf$ — Baseplate Total Weight

$W_{actuators} := 1712\ lbf$ — Estimated Actuators & Connections Weight Motion System Ananlyis will come later. This is an estimated weight budget for this system.

Loading Conditions

$F_{max} := 53\ \frac{lbf}{ft^2}$ — Max loading for Base Building

$W_{total} := W_{bbox} + W_{floor} + W_{baseplate} + W_{actuators} = \left(2.5 \cdot 10^4\right)\ lbf$ — Total Weight

Baseplate Surface Area

$w := 63.41\ in$ — Baseplate Width

$l := 372\ in$ — Baseplate Length

$A := l \cdot w = 163.809\ ft^2$ — Baseplate Area

$A_{total} := 3 \cdot A = 491.428\ ft^2$ — Total Baseplate Area

Actual Building Loading

$$F_{actual} := \frac{W_{total}}{A_{total}} = 50.872\ \frac{lbf}{ft^2}$$

$F_{actual} \le F_{max}$

$50.872 \le 53$

Factor of Safety - Loading

$$FOS_{loading} := \frac{F_{max}}{F_{actual}} = 1.042$$

Figure 24: Distributed Loading Calculations

5.4 Conclusion:

- Two analysis were performed on both the floor assembly and the baseplate: gravitational analysis and failure mode effects. Total, these simulations accounted for the weights of the entire system as well as 3G seismic loading at the worst case loading scenario of 5° pitch and roll.
- The required factor of safety for the von Mises stresses was 2.5. The lowest factors of safety calculated in the simulation exceeded this requirement.
- The required factor of safety for the deflection was 1. The lowest factors of safety calculated in the simulation exceeded this requirement.
- A hand calculation was performed to analyze the results of the entire system's loading to the building. The required factor of safety for the distributed loading was one. The factor of safety calculated by hand using free body diagrams exceeded this requirement.
- In conclusion, all safety factors are met for deflection, von Mises stress, and distributed loading of the entire system.
- The assembly meets the requirements of being able to fit through the double man door in the building and is able to be assembled on site without the use of welding.
- The simulator is able to roll and pitch 5° as well as move at 1 deg/s. It is also able to repeatedly return to its home position.

6.0 Appendix A: Bill of Materials

Part Name	Material	Quantity	Amount Required	Spec
Floor Assembly				
	5/8" Plywood Sheet 4' x 8'	16	512 ft^2	Construction Grade Sub-Floor Plywood Sheet
	Size 8 x 18.75 U-Shaped Structural Channel – 20'	11	185 ft	7075-T6 Aluminum U Channel
	6 x 6 x 3/8" Structural Angle Stock 20' lengths	20	176 ft	7075-T6 Aluminum Angle Channel
	½" Aluminum Plate 4' x 8'	2	40 ft^2	7075-T6 Aluminum Sheet
Baseplate				
	18.5" x 0.19" x 8" Wide Flange H-Beam Structure – 20'	5	100 ft	7075-T6 Aluminum Wide Flange H-Beam
	¼" Aluminum Plate 4' x 8'	11	320 ft^2	7075-T6 Aluminum Sheet
	1/8" Aluminum Plate 6' x 10'	9	511.5 ft^2	7075-T6 Aluminum Sheet

7.0 Appendix B: Drawing Package

List of Drawings