Project Cubesat

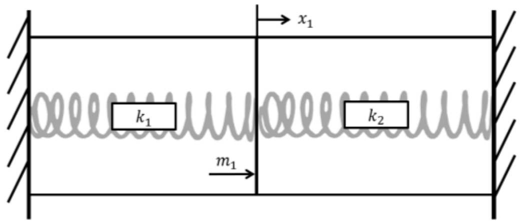
Molly Pearson, Chuanfu Zack He, and Kyra Hu

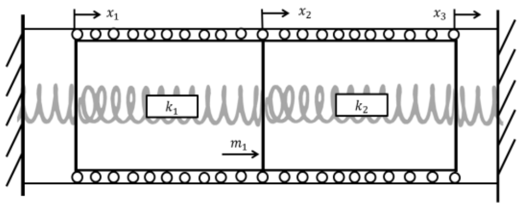
Project Statement

By performing both analytical and experimental analyses, we characterized the vibrational behavior of the CubeSat PVDX chassis, Brown Space Engineering's current project. Retrieving information such as the resonant frequencies and mode shapes of the structure allowed us to ensure the survivability of the chassis, the primary structural component of the satellite, under its harsh launch environment. This information shall aid in design decisions throughout the rest of the development of the satellite and in iterating the chassis design itself.

Modeling

Due to the position of the CubeSat chassis securely inside of a *NanoRacks* launch chamber, we discussed several modeling scenarios for the mode shape and frequency analyses. The two most relevant models are shown below: Figure 1a (right, top) depicts the chassis as constrained at both ends, similar to our actual test setup, and Figure 1b (right, bottom) shows the freer case with springs at either end, most similar to the real conditions in the launch vehicle.





Frequencies and Mode Shapes

Using Solidworks (2020), we applied the constraints described above and examined the natural frequencies and mode shapes of the two systems. These graphs are shown in Figure 2a and Figure 2b below.

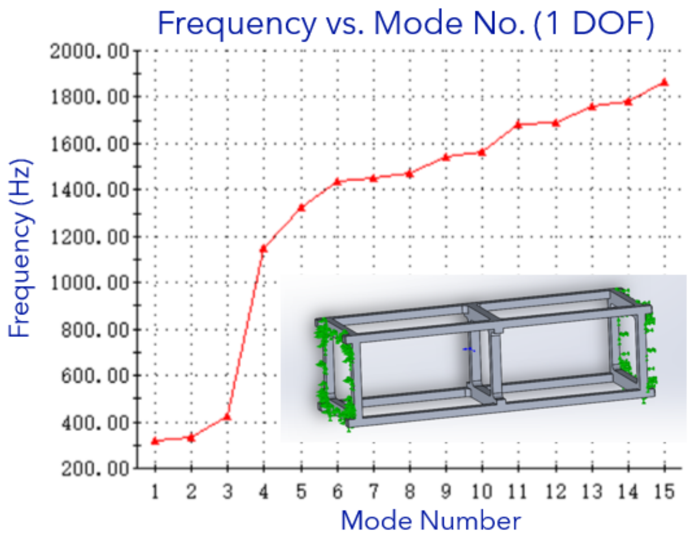


Figure 2a: Frequency vs. mode shape with 1 DOF; note the sharp increase at mode 4 and the 300 to 1900 Hz range.

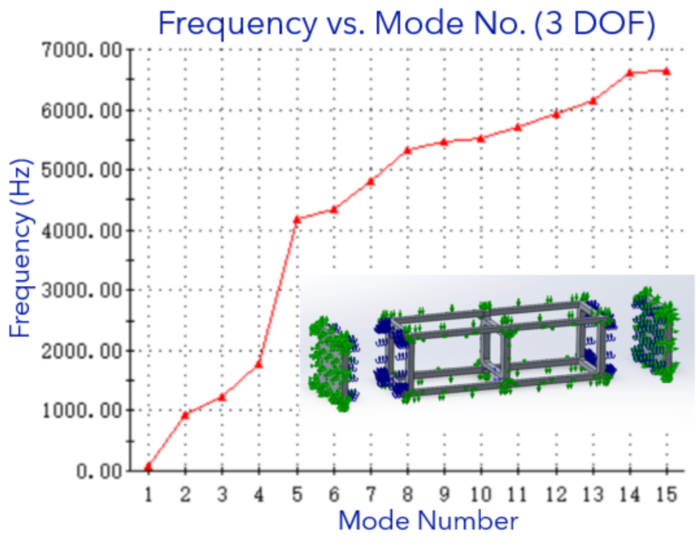


Figure 2b: Frequency vs. mode shape with 3 DOF; note the sharp increase at mode 5 and the 0 to 7000 Hz range.

Implications and Survivability

One of the main goals of this project was to understand the survivability of the PVDX chassis due to its natural frequency, even without loading conditions. Through an analysis of the chassis's stress in Solidworks, we saw that the resultant stress was far below the yield strength of 6.305 x 10^7 N/m^2, as seen in Figure 3a and 3b below. The labels confirm that the stresses are far below this yield strength, with the closest value at 6.901 x 10^4 N/m^2 for the 3 DOF model.

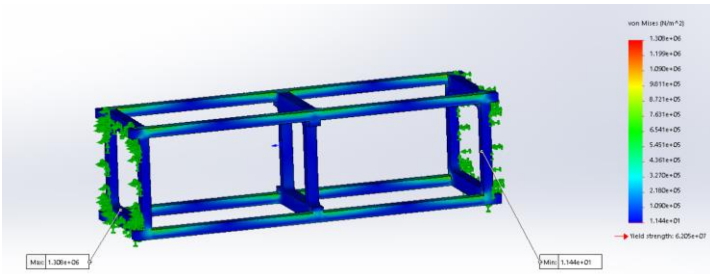


Figure 3a: Stress distribution of our 1 DOF model.

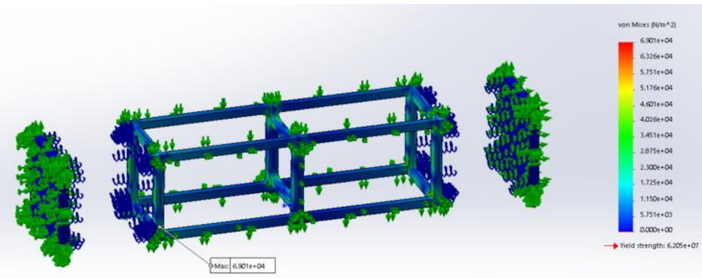


Figure 3b: Stress distribution of our 3 DOF model.

Experimental Results

In order to obtain more realistic results, we also analyzed the chassis experimentally with a modal shaker and Arduino. By setting up the test rig (Figures 4a and 4b), fixed at both ends, we used eight accelerometers to obtain natural frequency data. While our technological constraints did not allow us to reach the higher frequencies in the Solidworks models, we did find the below resonant frequencies and relative amplitude. These frequencies have, on average, a 21 percent difference from the simulation results with the same boundary conditions. There is a reasonable correlation between these values, so we were able to validate our simulation results for these boundary conditions.

Table 1: Experimental data for the first three modes for frequency and relative amplitude.

Frequency (Hz)	**Relative Amplitude ($X_{output}/X_{driving}$)**
240	5.35
276	1.69
337	1.16

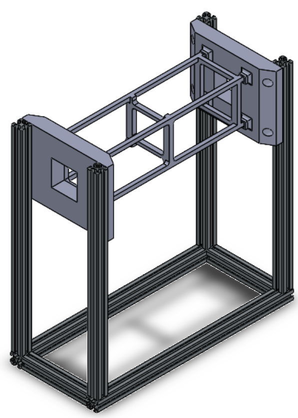


Figure 4a: CAD model of the test setup

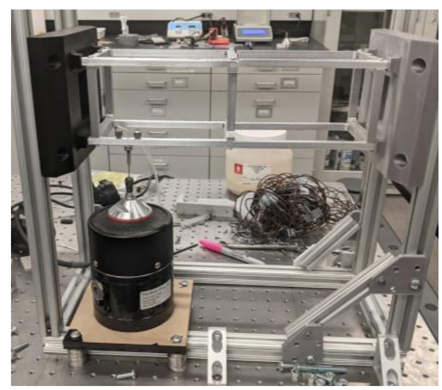


Figure 4b: Physical test setup

Conclusions

The modeling and testing simulations allowed us to better understand the characteristics of the chassis in its mode shapes, natural frequencies, and stress distributions. While the Solidworks and experimental approaches yielded slightly different results, both were valuable in providing more information to Brown Space Engineering and any other interested parties about the features of the chassis. Next steps for the project include experimental validation of the mode shapes using accelerometer data, as well as characterization of the vibration response of the test stand itself.

More Information

Full details about each section described above can be found at our Notion page, "Project CubeSat." In addition, we have provided access to various files, animations, and code for easy repeatability of our project. Navigating the subpages should answer any questions you may have about Project CubeSat!