General Atomics Bearing Fixture

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Abstract

Attaching a satellite to a spherical bearing allows it to rotate freely about any axis, but the force of gravity acting through the center of mass (COM) creates a torque about the bearing's center of rotation (COR). By moving the COM to precisely the same location as the COR, the force of gravity produces no torque which allows the satellite to maintain any arbitrary orientation.

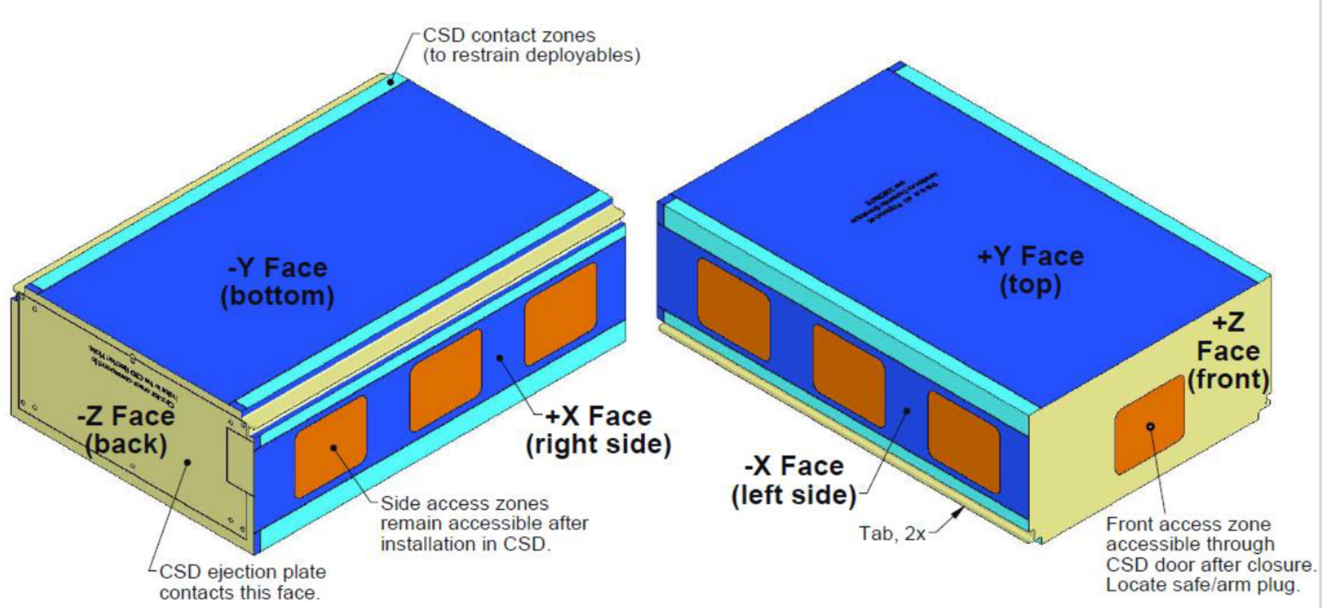
The goal of this project is to design a mounting fixture compatible with 3U, 6U, and 12U CubeSats which can achieve such COM/COR colocation. This is accomplished by shifting the satellite's position on the fixture, enabling colocation for a range of possible COM locations.

Requirements

- Compatible with CubeSat mounting rails
- Compatible with existing spherical bearing
- COM adjustable by 50mm in 3 axes
- COM of fixture sans-CubeSat at/below COR
- Minimize fixture weight
- CubeSat mounting should be easy and secure
- Allows 35° tilt, 360° rotation on bearing
- Compatible with 12U CubeSats

Stretch goal:

- Additonally compatible with 6U, 3U CubeSats



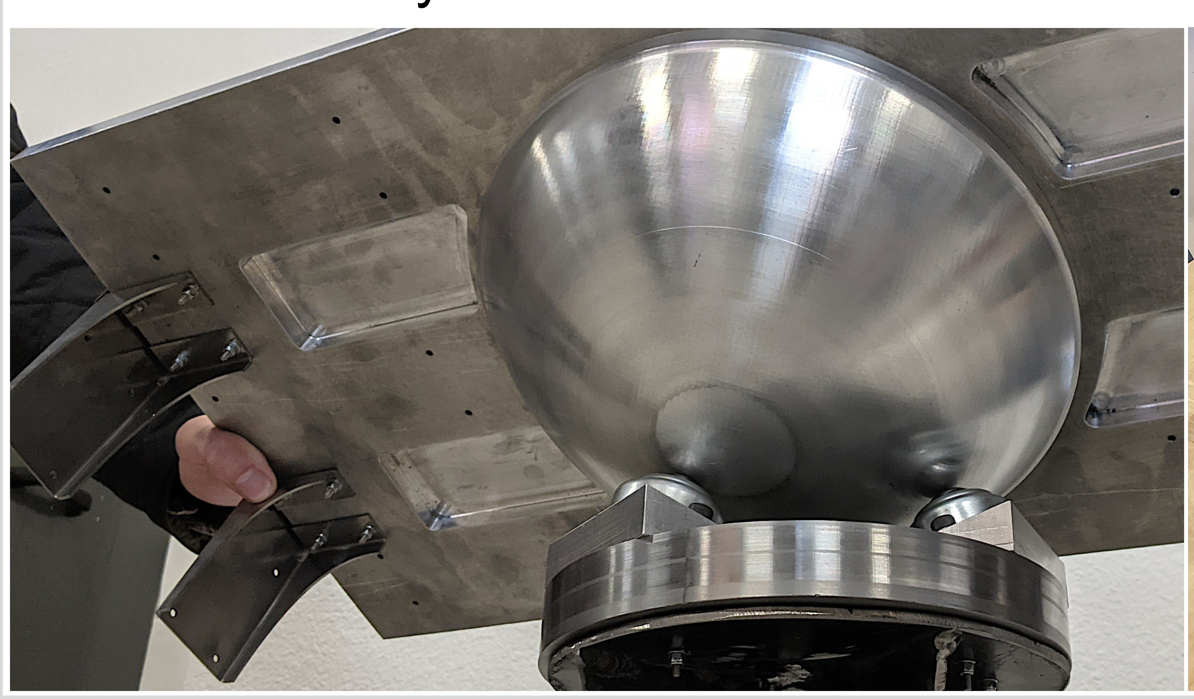
Methods

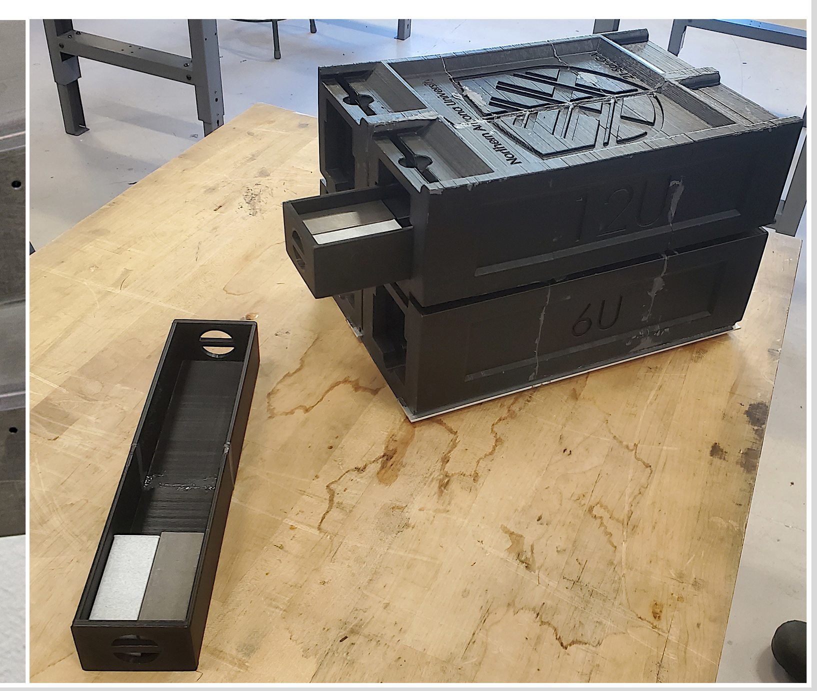
- 3D printed 1/3-scale model
- Low-cost proof of concept of lead screw, guide rod system
- Designed and manufatcured low-cost alternative to air bearing for testing
- Designed and manufactured modular 3U/6U/12U CubeSat system with variable COM for testing
- CubeSat position on fixture adjustable by motors, lead screws, guide rods
- Control system automatically repositions satellite for colocation
- Simulink simulation of control system
- Simscape simulation of fixture dynamics

Results

Simulations:
The Simscape model simulates the fixture's dynamics in response to satellite translations. This enabled the fine-tuning of the Simulink control system's PID parameters before the assembly of the fixture's mechanical components was completed. The control system uses feedback from an IMU to identify the satellite's COM location in X- and Z-directions by translating the satellite until the fixture is level. It then identifies the satellite's Y-direction COM location by inducing a known translation in the Z-direction and measuring the resulting angular deflection. This process takes approximately two minutes, and testing has identified that the calculated COM location is within ±1 mm of the actual value.

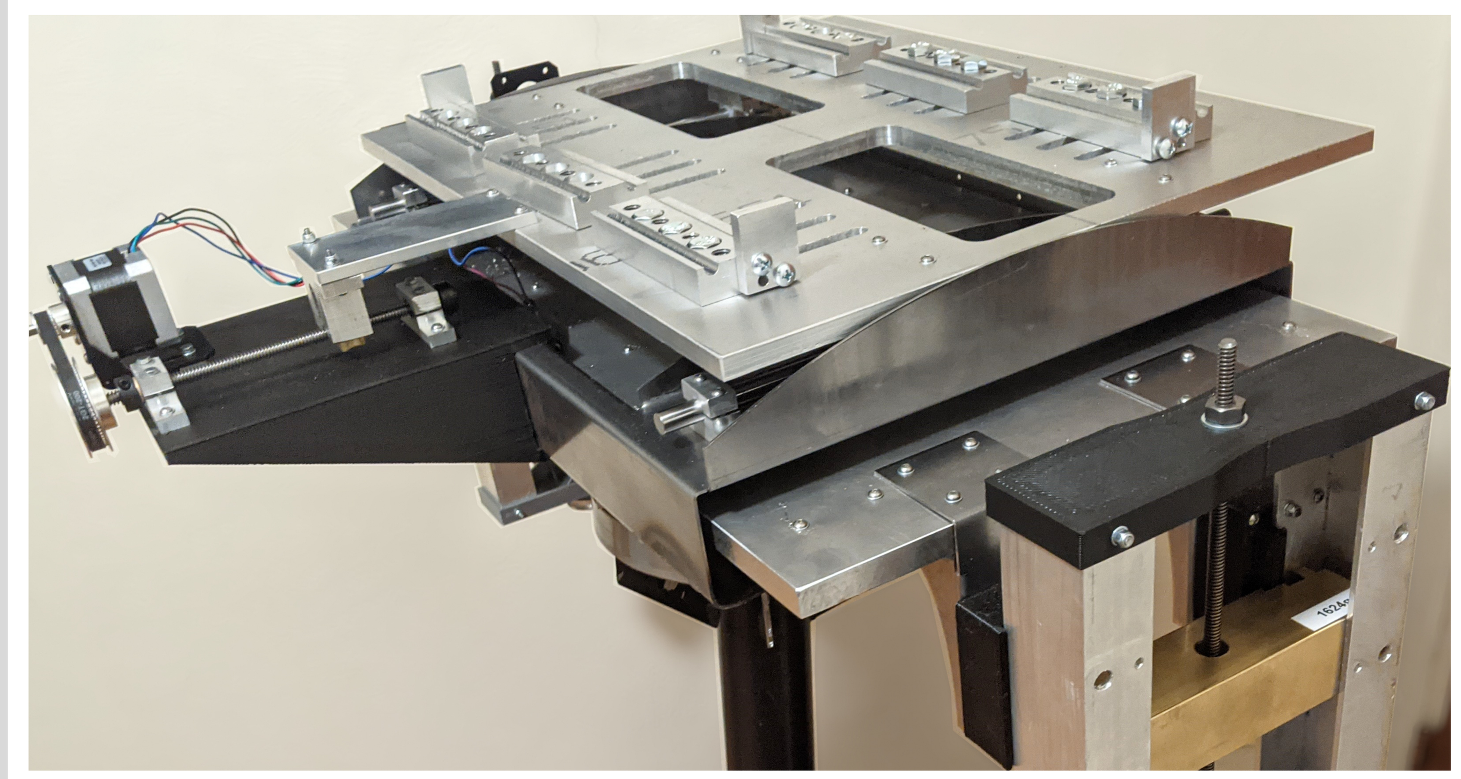
Construction:
The fixture has a total mass of 22 kg and accommodates COM translation of 51 mm, 31 mm, and 52 mm in X-, Y-, and Z-directions, respectively. It permits bearing rotation over the full 35° of tilt and 360° of rotation. Satellite mounting hardware resists at least 250 N of force before displacement of the satellite may occur.





Conclusions

Based on the accuracy of the COM relocation, nearly all of the customer requirements have been met. The stretch goal was also achieved through the use of the adjustable satellite mounting brackets. The alternative bearing designed for testing functions remarkably well for the comparatively low cost of manufacturing. One area for improvement is increasing the Y-axis COM translation, which falls short of the 50 mm requirement. The modular test satellite may also be improved, as its minimum COM location in the Y-direction is roughly 5 mm higher than that of a true 12U CubeSat. Future work on the project would include another iteration of the test satellite with additional weight positions. Future work may also include further refinement of the control system including shortening response time, optimizing COM identification, and integrating additional sensors (e.g., force transducers) to improve accuracy.



References

“Payload Specification for 3U, 6U and 12U.” Planetary Systems Corporation, Aug. 06, 2018.

Acknowledgements

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