**Design Report: Two-Axis Indexed CubeSat Assembly Jig**

Ben Philipson | LED SSRL Recruitment, Fall 2026 | 9/23/2026

## 1. Introduction

Before a CubeSat launches, it gets handled a lot during assembly and testing. A 3U CubeSat is about 100 × 100 × 340.5 mm and can weigh up to 6 kg (The CubeSat Program, 2022). Only the four corner rails are supposed to touch the launch deployer, so they can't get scratched or damaged. The other sides have solar panels, connectors, and switches on them. Without a stand, people usually rest the satellite on foam or hold it, which can damage it.

For this project I designed an assembly jig in Autodesk Inventor that holds a 1U, 2U, or 3U CubeSat by its rails. The satellite sits in a cradle that rotates around a horizontal (pitch) axis, and the cradle is mounted on a plate that rotates around a vertical (yaw) axis. Both axes can rotate a full 360 degrees and can be locked in increments of 30 degrees with a pin.

The upgrades I focused on were the cradle and the secondary axis. Most of the jigs I found while researching, like the EnduroSat rotary jig and a student-built jig from PeakSat, rotate the satellite around one axis (EnduroSat, n.d.; PeakSat, n.d.). That gives access to the four long sides but not the two ends, which is where deployment switches are often placed. Adding the pitch axis lets someone reach all six faces without taking the satellite out.

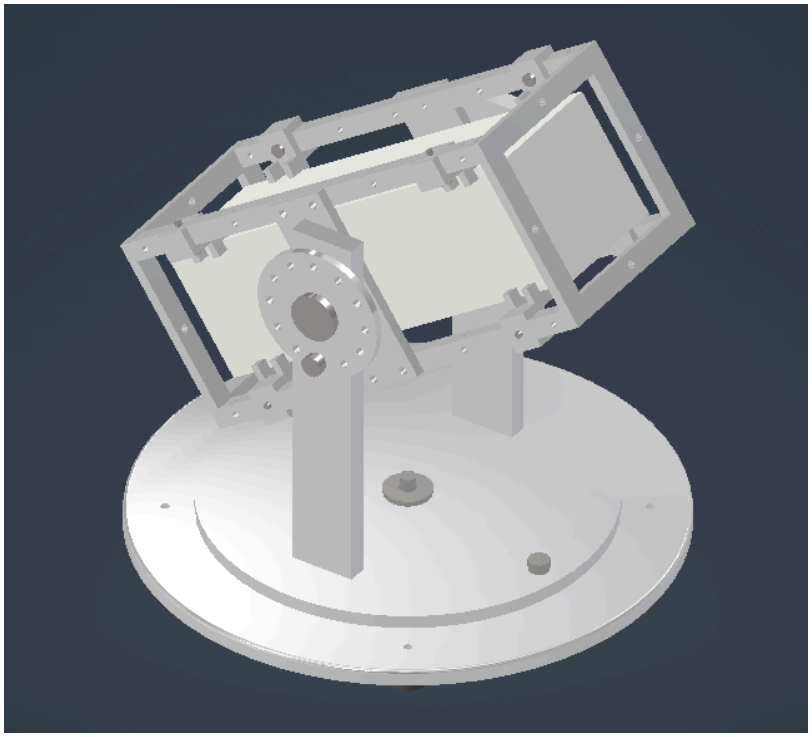


**Figure 1.** Two-axis CubeSat assembly jig with a 3U CubeSat installed.

## 2. Impact

While researching, I learned that a lot of CubeSats fail soon after launch. Langer and Bouwmeester (2016) studied 178 CubeSats and found that about 13% to 24% didn't work right after they were deployed. They said a big reason is that teams didn't test the finished satellite enough before launch. Swartwout (2013) found that almost half of university CubeSat missions failed, compared to less than 20% of industry missions.

A jig helps with this because the satellite can stay in it while it's being tested. It can be turned to reach a connector or switch without anyone picking it up. Other teams have made similar equipment. The HYPSO-1 team, for example, made custom plates and brackets to hold their hardware during testing (Prentice et al., 2022).

It also means more testing can be done in our own lab, so we only pay for outside facilities when we need something like vibration or thermal vacuum testing (NASA Goddard Space Flight Center, 2021). And since the cradle adjusts from 1U to 3U, one jig works for most missions.

## 3. Technical Approach

### Requirements and assumptions

From the CubeSat Design Specification, the jig needs to fit 1U (113.5 mm), 2U (227 mm), and 3U (340.5 mm) CubeSats that weigh up to 6 kg (The CubeSat Program, 2022). It should only touch the rails, using plastic (POM) pads, rotate on two axes with locking positions, and be something UGA could build. I assumed the only loads are the satellite's weight and people working on it.

### Design

The base is a Ø400 × 12 mm aluminum plate on four rubber feet. A stainless steel shaft goes up through the center, and the Ø300 mm yaw plate rotates on it over a plastic washer. An M12 stud on the shaft and a retainer washer keep the yaw plate from lifting off. Two uprights (15 × 50 × 280 mm) hold the pitch shafts 220 mm above the yaw plate. The cradle is four 15 mm square rails between two 150 × 150 mm end frames, with hub plates on the sides that connect to the pitch shafts. Twelve holes in the base plate and an indexing disk let a Ø6 mm pin lock each axis every 30°.

I put the center of the satellite where the two axes cross. That way the weight stays centered however the jig is turned, so it doesn't swing when the pin is pulled out. It also makes the jig harder to tip. I estimated it would take about 70 N of sideways push at the pitch axis to tip it over with a 6 kg satellite inside. While 70N is not a large number, it can easily be increased with a thicker base; therefore raising production costs.

The cradle has stop brackets on each rail that can be pinned in three spots, one each for 1U, 2U, and 3U. I set up an iLogic rule in Inventor so I can change one number and all the brackets move. I tried two other versions that adjusted all four rails with one knob, but they

covered part of the satellite's ends, which is what the second axis is supposed to open up. So I went back to the simple pinned brackets.

To check the hub plates, I did a simple bending calculation. Each plate holds about 41 N (half the weight of the cradle and satellite) at 67.5 mm from the shaft. I assumed the plate bends in its thinnest direction, which is the worst case:

Sigma = Moment/(Section modulus of rectangle) = (41*67.5)/(50*8^2/6) = 5.2MPa

The yield strength of 6061-T6 aluminum is about 276 MPa (Glemco, n.d.), so the safety factor is about 53. That meant my first plate (130 × 150 mm) was way bigger than it needed to be. I cut it down to a 50 mm wide strap, which saved 0.52 kg and covered much less of the satellite's side.

**Materials, fabrication, and cost**

I chose 6061-T6 aluminum for most of the parts because it is commonly used in aerospace parts and has excellent machinability (Glemco, n.d.). The shafts and pins are 304 stainless steel, and the washer and pads are POM plastic so they won't scratch the satellite. The plates could be cut on a waterjet or mill, and the shafts and pins made on a lathe. Using prices from an online metal supplier (Speedy Metals, n.d.), I estimated the materials at about $600. If lab members make the parts in the university shop, that is most of the cost. If a machine shop made everything, I estimated about 30 hours of machine time. At typical US rates of $35–60 per hour for milling and $50–100 per hour for lathe work (Fabcon, 2026), that adds roughly $1,100–2,000 before setup fees.

**Risks and remaining work**

The main risks are the jig tipping over, electrostatic discharge, and someone forgetting to put the locking pin back in. Keeping the weight centered and spreading the feet out on a wide circle helps with tipping. The jig should be grounded to the ESD bench (ESD Association, 2021), and the POM pads keep bare metal off the satellite. A lanyard on each pin keeps it attached to the jig.

## 4. Challenges

Since I'm new to small satellites, one of the first challenges was figuring out what the jig actually had to do. I had to find the CubeSat Design Specification and pull out the sizes, the 6 kg mass limit, and the rule that only the rails can touch the deployer (The CubeSat Program, 2022). A lot of my design choices, like the size of the cradle opening and where the stop brackets go, came straight from those numbers.

The jig has about 40 parts, and a lot of them are small, like the pins, stop brackets, washers, and shafts. Getting all of them to line up and constraining them correctly in Inventor took a lot of time. At one point the cradle could slide around when it was only supposed to rotate, because mating two axes in Inventor only makes them parallel, not lined up. I fixed it by redoing the motion with constraints for the whole assembly.

I also learned that changing one part usually meant changing a lot of others. When I found out the 3U didn't fit, lengthening the rails from 346.5 mm to 400 mm also meant moving the end frames, re-spacing the index holes on every rail, and moving the bolt holes for the hub plates. Parameters and the iLogic rule made this easier, but every change still had to be checked across the whole assembly.

The design still has some tradeoffs. The four rails run along the corners of the satellite, so from some angles they block part of its edges and sides. I cut down the hub plates to open up more space, but the rails have to be there to hold the satellite, so some blocked areas can't be avoided. The jig is also kind of expensive to make, especially if a machine shop builds it. Even so, it should still be cheaper than buying a commercial jig that's confined to one plane (from EnduroSat for $7500+).

## 5. Conclusion

Overall, this jig holds a 1U to 3U CubeSat by its rails and lets you reach every side by rotating it on two locking axes. It would let the lab do more handling and testing on its own. For the next steps, I need to finish the bolt pattern for the uprights, run the FEA, and get real quotes for machining.

## References


EnduroSat. (n.d.). *Rotary jig*. Retrieved September 23, 2026, from https://www.endurosat.com/products/rotary-jig/

ESD Association. (2021). *ANSI/ESD S20.20-2021: Protection of electrical and electronic parts, assemblies and equipment (excluding electrically initiated explosive devices)*. https://www.esda.org/store/standards/product/314/ansiesd-s20-20-2021/

Fabcon. (2026, March 30). *CNC machining hourly rates 2026: Complete U.S. pricing guide*. https://blog.fabcon.com/precision-cnc-machining/cnc-machining-hourly-rate-us/

Glemco. (n.d.). *Aluminum 6061-T6 material information & specifications*. Retrieved September 23, 2026, from https://www.glemco.com/capabilities/material-expertise/aluminum-6061-t6/

Langer, M., & Bouwmeester, J. (2016). Reliability of CubeSats—Statistical data, developers' beliefs and the way forward. In *Proceedings of the 30th Annual AIAA/USU Conference on Small*

*Satellites* (Paper SSC16-X-2). Utah State University. https://repository.tudelft.nl/record/uuid:4c6668ff-c994-467f-a6de-6518f209962e

NASA Goddard Space Flight Center. (2021). *General environmental verification standard (GEVS) for GSFC flight programs and projects (GSFC-STD-7000B)*. NASA. https://standards.nasa.gov/standard/GSFC/GSFC-STD-7000

PeakSat. (n.d.). *CubeSat assembly jig* [GitHub repository]. Retrieved September 23, 2026, from https://github.com/PeakSat/cubesat-assembly-jig

Prentice, E. F., Honoré-Livermore, E., Bakken, S., Henriksen, M. B., Birkeland, R., Hjertenaes, M., Gjersvik, A., Johansen, T. A., Aguado-Agelet, F., & Navarro-Medina, F. (2022). Pre-launch assembly, integration, and testing strategy of a hyperspectral imaging CubeSat, HYPSO-1. *Remote Sensing, 14*(18), Article 4584. https://doi.org/10.3390/rs14184584

Speedy Metals. (n.d.). *5/16″ 6061-T651 aluminum plate*. Retrieved September 23, 2026, from https://www.speedymetals.com/p-2409-516-6061-t651-aluminum-plate.aspx

Swartwout, M. (2013). The first one hundred CubeSats: A statistical look. *Journal of Small Satellites, 2*(2), 213–233. https://www.jossonline.com/storage/2014/12/0202-The-First-One-Hundred-Cubesats.pdf

The CubeSat Program. (2022). *CubeSat design specification* (Rev. 14.1). California Polytechnic State University. https://www.cubesat.org/cubesatinfo