Design and prototyping of a modular JIG for the assembly of 1U to 3U CubeSat-type satellites

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Abstract*— The assembly of CubeSat-type satellites requires Ground Support Equipment (GSE) to ensure structural alignment and dimensional compliance. Commercial JIGs feature monolithic bodies with fixed capacities that are costly to import and store. This paper presents the iterative design and prototyping of a modular JIG block. By concatenating identical 1U modules, the architecture scales from 1U to 3U, adapting to different integration stages while reducing storage volume and enabling fabrication with small-format equipment. Guided by the CubeSat Design Specification, three design iterations using computer-aided design and finite-element analysis satisfied all ten defined structural and dimensional requirements. Iterations revealed a coupling between clamp height, clamping capacity, and bending stiffness, which was resolved by increasing clamp thickness. A 3D-printed PLA prototype validated the geometric layout, 1U–3U modularity, and base-concatenation concept. However, functional validations (clamp travel, alignment, fit check, and stability) failed due to fused deposition modeling tolerances causing excessive clearances and misalignment. These results demonstrate that a fully functional system requires CNC machining in engineering polymers (Delrin), establishing a framework for scaling toward larger configurations (6U–12U) and advancing domestic manufacturing capabilities for aerospace ground-support equipment.

***Keywords*-- Assembly JIG, CubeSat, Modular design, Ground Support Equipment, Frugal Innovation**

I. Introduction

In the satellite industry, an assembly JIG is a structure that holds and guides the assembly of certain satellites. Its use is essential to ensure the correct alignment of the parts and to avoid impacts while they are handled. The use of this type of structure becomes even more relevant given the tests these satellites must pass before being placed in orbit.

Among the satellites that use JIGs during assembly are CubeSats, a standard developed by Jordi Puig-Suari (Cal Poly) [1] and Robert Twiggs (Stanford University) [2]. A CubeSat is a nanosatellite measuring 100x100x113.5 mm with a mass of up to 2 kg, as detailed in the CubeSat Design Specification (CDS) [3]. This block is referred to as a unit and written in the form 1U, where the number indicates how many units make up the satellite. The CDS covers CubeSats of up to 12U.

CubeSats have standardized external dimensions, as mentioned above, and although their internal contents are not standardized, their components can be separated into two groups based on the CDS specifications [3]: structural and electrical.

The structural components include the rails—metallic elements, generally of aluminum 7075, 6061, 6082, 5005, and/or 5052 [3]—which, together with the rest of the mechanical structure, hold and protect the internal components while serving as the contact point with the rails of the dispenser that carries the satellite.

Both the mechanical and electrical components of the satellite must pass a series of tests once integrated: random-vibration, thermal-vacuum, and shock testing (usually not required), as well as visual inspections that include dimensional conformity (fit check) [3].

The fit check is a crucial test that determines whether the satellite can fit properly inside the dispenser [4]. To pass it, the satellite structure must not only have the specified dimensions but also the correct alignment among its structural components; otherwise, the satellite will not fit into the dispenser.

This modular design, on which the CubeSat is based, as defined by Walz, standardizes and adds flexibility to the use of a system according to what is required [5]. That is, it allows the system to be made more complex or simpler, helping those involved adapt to changes that occur over time, as expressed by Gershenson [6].

The industry currently offers JIGs with capacities for different CubeSat sizes: some with a 1U capacity [7], some for 1U to 3U [8], and some for 1U to 16U [9]. The main feature of some of these JIGs is that being a single body with movable clamping elements [9]—called clamps—they adapt to the CubeSat variants to be worked on. In all these cases, however, the tool is a single monolithic body. Its maximum capacity is fixed at the time of manufacture;

This paper addresses the development of a JIG module: a working block sized for a single 1U CubeSat that can be concatenated with identical modules to assemble CubeSats of up to 3U. The novelty of the proposal lies in this architecture. Instead of a single body with movable clamps, the tool is built from repeated instances of one part, which yields three advantages. First, scalability: capacity is determined by the number of blocks joined together, so the same design grows to a larger configuration without being redesigned. Second, working and storage volume: only the blocks required for the configuration being integrated occupy the workbench, and the tool is stored disassembled as a set of small blocks rather than as one large table. Third, manufacturability: because the largest part to be produced is a 1U block and not a full-size body, the tool can be fabricated with small-format machining or additive equipment and replicated one block at a time.

In a country with no aerospace manufacturing industry, mechanical ground support equipment must be imported at costs and lead times that are difficult to absorb for a first satellite mission. A tool whose largest component fits within

the working envelope of equipment already available in university and local workshops, and whose capacity grows by replicating that single component, lowers the barrier to producing this equipment domestically and to expanding it incrementally as the needs of the program evolve. The system presented here is therefore proposed not only as an assembly aid, but as a step toward building local capacity in the production of satellite ground support equipment.

II. Methodology

The design follows an iterative process (see Fig. 1), starting from a base idea proposed as a solution and optimizing the geometries and sizes of the model based on the validations performed and the requirements.

The requirements and validations focus on a generic 3U CubeSat, modeled in-house, that meets the dimensions specified in the CDS and will be fabricated by 3D printing with dimensional tolerances of 0.1 mm according to the design requirements [3]. The validations are defined considering the manufacturing process of the JIG by 3D printing, so its tolerances differ from those of the digital model.

The main design requirement is dimensional: the dimensions of the different CubeSat configurations specified in the CDS [3] must be considered; these are compiled in Table I.

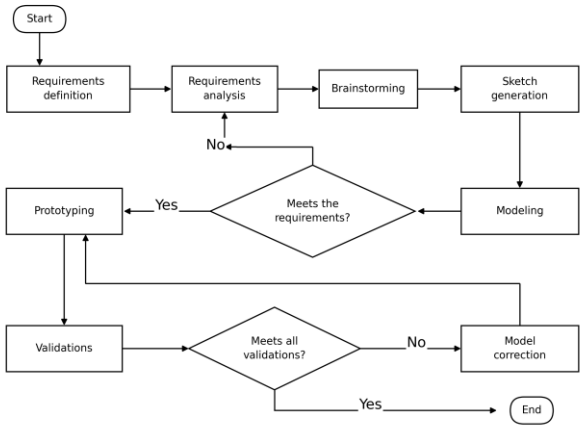


Fig. 1 Iterative design flowchart

TABLE I
DIMENSIONS OF THE DIFFERENT CUBESAT SIZES [3]

Size	Length x (mm)	Length y (mm)	Length z (mm)
1U	100	100	113.5
1.5U	100	100	170.2
2U	100	100	227
3U	100	100	340.5
U+	Variable dimensions		
6U	100	226.3	366.0
12U	226.3	226.3	366.0

An additional dimension must be considered: the rail width (see Fig. 2), which, for all CubeSat sizes, must be at least 8.5 mm. This dimension is key to the clamp design, since the clamp must be able to come into contact only with the satellite rails.

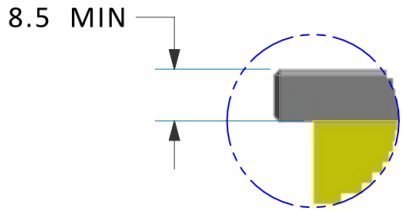


Fig. 2 Minimum rail width of a CubeSat [3]

During assembly, the CubeSat may need to be placed vertically or horizontally depending on the components being attached at that time; this must be considered not only for adapting the clamps to the CubeSat dimension, but also to identify what kind of support the structure needs to avoid deflections caused by the satellite mass, especially for the 6U and 12U, whose mass can reach 12 kg and 24 kg respectively.

It is important that the clamps can support the weight of the satellite and have enough rigidity to prevent deformation when subjected to lateral forces arising from the integration process.

The specific list of requirements and their compliance criteria define the JIG in terms of the CubeSat's specific dimensions and capacity range, the parts it may contact, its modular scalability, its structural rigidity under load, and its ability to hold the satellite securely during integration as seen in Table V, VI, VII, which also allows compliance tracking for each iteration performed. The deformation criterion adopted for requirements 7 and 8 is the maximum equivalent strain reported by the FEA module, limited to 1%.

This threshold is used as a conservative design screen rather than a functional limit: for a clamp of the heights considered here, keeping the strain below 1% keeps the resulting tip displacement well within the 0.1 mm dimensional tolerance required by the CDS [3], which is the functionally relevant quantity for the fit check.

Considering the requirements, a JIG base with channels that allow two-directional clamp movement is proposed. This base can be joined to other identical bases, enlarging the working area and the clamp range of motion. Fixation points for specific CubeSat sizes are also considered. The concept is illustrated in Fig. 3.

The clamps used must be designed to accommodate two-directional movement and fixation at specific points for rapid adaptation to the working conditions.

The proposed designs are modelled in Onshape, a cloud-based computer-aided design platform. It integrates a version-management system used to create working branches for each iteration performed. This keeps a record of the design changes and makes it possible to return to any branch as needed.

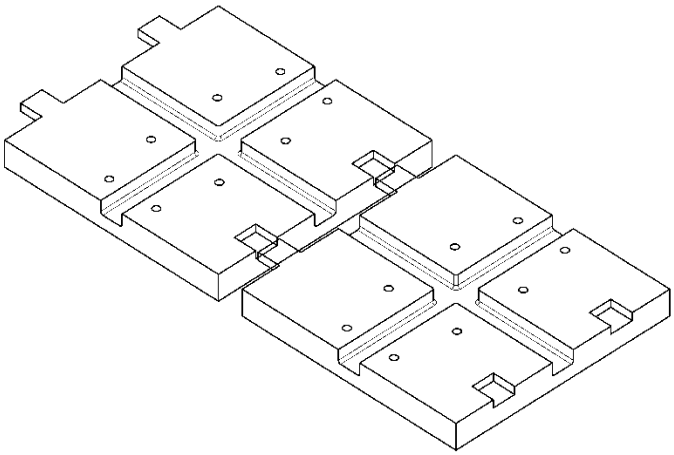


Fig. 3 Modular concept applied to the JIG base

The finished files are exported in 3MF format and then processed in PrusaSlicer software, a slicer that automatically generates the G-code for fabricating the model by 3D printing. The main slicing variables configured are presented in Table II.

TABLE II
MAIN PRINTING PARAMETERS OF THE PROTOTYPE

Parameter	Value	Unit
Layer height	0.1	mm
First-layer height	0.1	mm
Perimeters	3	-
Top solid layers	3	-
Bottom solid layers	3	-
Infill density	10	%
Supports	Yes, automatic	-
Printing speed	60	mm/s

Fused deposition modeling (FDM), or fused filament fabrication (FFF), is performed with a Creality Ender 3 V3 SE printer fitted with a 0.4 mm nozzle and automatically calibrated. The filament used is 1.75 mm PLA. The quantities used for each part are specified in Table III.

Dimensional validation of the fabricated parts is performed with a digital vernier caliperl (Mitutoyo model CD-6” ASX) with 0.01 mm resolution and a 0.02 mm error margin. Alignment is checked using a Truper EC-12 square.

TABLE III
FILAMENT USAGE (IN GRAMS) FOR 3D PRINTING THE JIG PROTOTYPE

Element	Quantity	Total filament weight (g)
Base	3	121.48
Rail guide	4	1.41
Guide stop	4	0.72
Lever	4	0.99
Carriage	4	15.39
Clamp	4	41.64
3U CubeSat model	1	531.45
Total	23	713.08

The validations are listed in Table IV, where, as with the requirements, compliance can be tracked to facilitate the process.

TABLE IV
PROTOTYPE VALIDATION CHECKLIST

Prototype validation checklist for the modular JIG				
No.	Requirement	Compliance condition	Meets	
			Yes	No
1	Vertical-arrangement dimensions	x-axis: 100.10 mm +0.10 mm		
2		y-axis: 100.10 mm +0.10 mm		
3	Horizontal-arrangement dimensions	x-axis: 100.10 mm +0.10 mm		
4		y-axis: 340.60 mm +0.10 mm		
5	Modularity	Multiple bases can be properly concatenated		
6	Clamp travel	The clamps can move freely along all rails		
7	Clamp fixation	The clamps stay fixed when reaching each fixation hole		
8	Alignment	The clamp surfaces that will contact the CubeSat rails are coplanar		
9	Fit check	The reference CubeSat fits with the proper clearance (0.1 mm tolerance)		
10	Stability	The CubeSat placed on the clamps remains stable when simulating component-integration tasks		

The deformation analyses are performed with Autodesk Fusion, a computer-aided design software that integrates a finite-element analysis (FEA) module, which allows a part or a mechanical assembly to be analyzed under different loading conditions and yields values such as factors of safety, displacements, and deformation.

Deformation analyses are performed using Autodesk Fusion’s finite-element analysis (FEA) module to assess maximum displacements, equivalent strain, and structural compliance under lateral integration forces. A fundamental methodological distinction is established between the numerical simulation and the physical prototype: FEA validates the structural rigidity and compliance for the target operational material (Delrin homopolymer: Young’s modulus E = 2.66GPa, density ρ= 1.356g/cm^3, whereas the 3D-printed prototype in PLA is deployed exclusively to validate geometric envelopes, base-concatenation modularity, and assembly ergonomics. In the simulation setup, fully fixed boundary constraints (Ux = Uy = Uz = 0) are applied to the

mating interfaces between the clamp and the carriage. The structure is subjected to a lateral force of 15N applied horizontally at the top face of the clamp body, representing the distributed lateral load during satellite integration. The final iteration geometry was discretized using a solid tetrahedral mesh comprising 2,472 elements (100% volume representation), with a minimum edge length of 0.124mm, maximum aspect ratio of 11.8, and a worst Jacobian ratio of 3.66, ensuring numerical stability and capturing localized bending gradients.

III. RESULTS

A. Requirements iteration

The design process in the requirements phase was carried out in three iterations, each resolving the compliance problems of the previous one. The model was prototyped by 3D printing for its validations.

1) Iteration 1

For the first iteration, the requirement-verification results are shown in Table V.

TABLE V
REQUIREMENTS VERIFICATION RESULTS FOR ITERATION I

Design requirements verification checklist for the modular JIG				
N	Requirement	Compliance condition	Meets	
			Yes	No
1	Vertical-arrangement dimensions	x-axis: 100.10 mm +0.05 mm		X
2		y-axis: 100.10 mm +0.05 mm		X
3	Horizontal-arrangement dimensions	x-axis: 100.10 mm +0.05 mm		X
4		y-axis: 340.60 mm +0.05 mm		X
5	Clamp contact area	Extension < 8.5 mm	X	
6	Modularity	The JIG capacity can be increased by concatenating multiple bases of the same design	X	
7	Load capacity	The clamps can support the CubeSat mass (6 kg max.) without significant deformation (<1%)	X	
8	Bending resistance	The clamps can withstand a significant force equal to the weight of the supported CubeSat, applied horizontally at the top of their body, without significant deformation (<1%)	X	
9	Clamping capacity	The clamps maintain contact with the CubeSat surface so that it cannot move during integration (except for the motion required to remove the CubeSat from the JIG); visual inspection		X
10	Interferences	No JIG part contacts any satellite part other than the rails, in compliance with requirement 3.	X	

Fig. 4 and Fig. 5 show the dimensions of the clamp working area; note that the dimensions correspond to the exact size of a CubeSat, whereas the requirements consider the 0.1 mm tolerance defined by the CDS.

Fig. 6 shows the extension of the clamp faces that contact the CubeSat rails; all clamps are identical. The 5 mm extension meets the planned requirement.

Fig. 7 shows the joining of three modular bases, extending the working capacity from 1U to 3U, thus meeting the stated requirement.

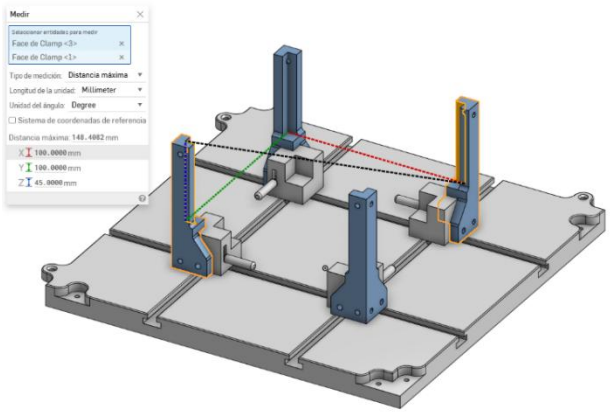


Fig. 4 Vertical-arrangement dimensions of iteration I

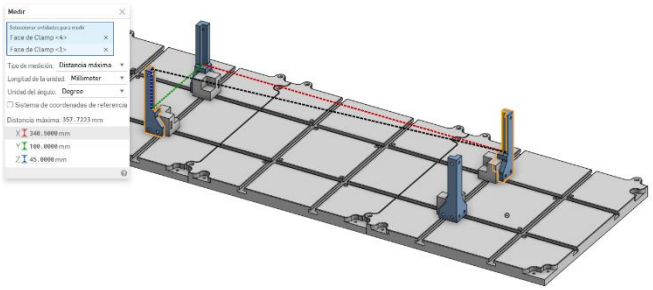


Fig. 5 Horizontal-arrangement dimensions of iteration I

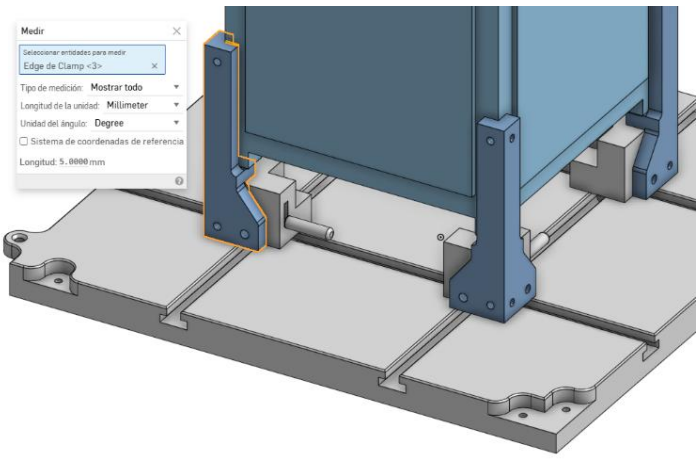


Fig. 6 Extension of the clamp contact surface with the CubeSat

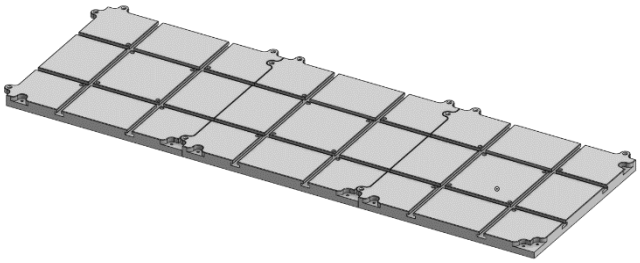


Fig. 7 Modular bases concatenated to extend the working capacity from 1U to 3U

Fig. 8 and Fig. 9 show the result of the finite-element analysis performed on the clamp for the load and bending requirements; the values shown on the reference bar are dimensionless, and multiplying them by one hundred gives the deformation percentage, which in both cases is below 1%, as specified bellow 0.5mm.

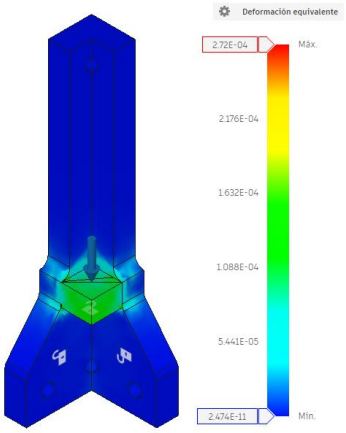


Fig. 8 FEA for the load capacity of the iteration I clamp

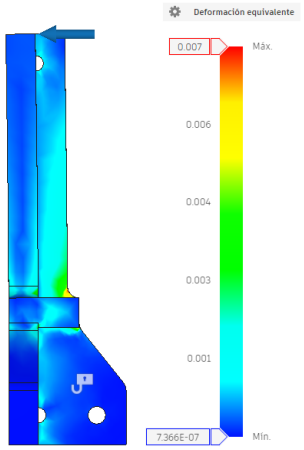


Fig. 9 FEA for the bending case of the iteration I clamp

Fig. 10 shows the contact of the clamps with the CubeSat rails in the horizontal arrangement; note that only the lower rails can contact the clamp.

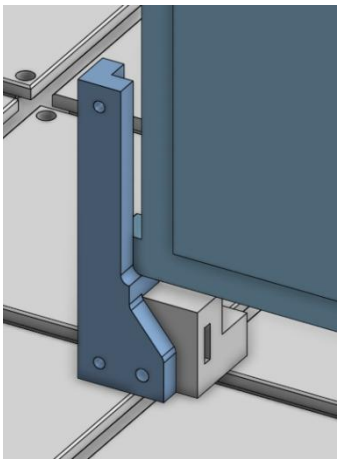


Fig. 10 Clamping capacity of the clamps in horizontal arrangement for iteration I

Regarding clamping in the vertical position, Fig. 6 shows that the clamps touch the CubeSat along their full extension; however, since they do not provide sufficient support in the vertical position, the requirement is considered not met.

Fig. 11 shows the interference analysis performed; note that there is no interference between the JIG parts and the CubeSat, so the requirement is met.

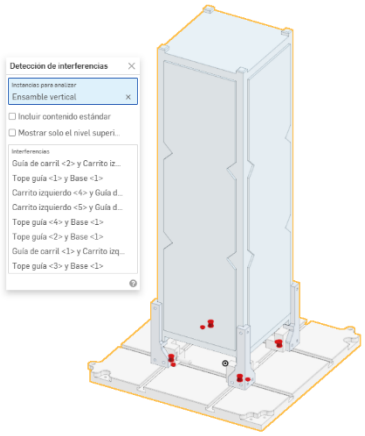


Fig. 11 Interference analysis for the iteration I design

2) *Iteration II*

The requirement-verification results of the second iteration are shown in Table VI.

This iteration improves on the previous one in the vertical- and horizontal-arrangement dimension requirements (by adjusting the base) and in clamping capacity (by increasing the clamp height). The remaining features are unchanged, so compliance with the other requirements is inherited, except for bending resistance, as shown in Fig. 14.

Fig. 12 and Fig. 13 show the new working-area dimensions, meeting the stated requirement.

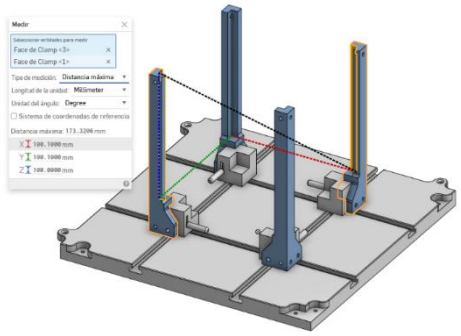


Fig. 12 Vertical-arrangement dimensions for iteration II

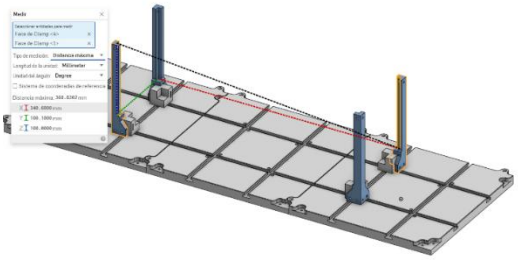


Fig. 13 Horizontal-arrangement dimensions for iteration II

TABLE VI
REQUIREMENTS VERIFICATION RESULTS FOR ITERATION II

Design requirements verification checklist for the modular JIG				
N	Requirement	Compliance condition	Meets	
			Yes	No
1	Vertical-arrangement dimensions	x-axis: 100.10 mm +0.05 mm	X	
2		y-axis: 100.10 mm +0.05 mm	X	
3	Horizontal-arrangement dimensions	x-axis: 100.10 mm +0.05 mm	X	
4		y-axis: 340.60 mm +0.05 mm	X	
5	Clamp contact area	Extension < 8.5 mm	X	
6	Modularity	The JIG capacity can be increased by concatenating multiple bases of the same design	X	
7	Load capacity	The clamps can support the CubeSat mass (6 kg max.) without significant deformation (<1%)	X	
8	Bending resistance	The clamps can withstand a significant force equal to the weight of the supported CubeSat, applied horizontally at the top of their body, without significant deformation (<1%)		X
9	Clamping capacity	The clamps maintain contact with the CubeSat surface so that it cannot move during integration (except for the motion required to remove the CubeSat from the JIG); visual inspection	X	
10	Interferences	No JIG part contacts any satellite part other than the rails, in compliance with requirement 3.	X	

Fig. 14 shows that, in the bending-resistance case, the clamp exhibits a 1.6% deformation, higher than that specified in the requirement, so it is considered non-compliant at 4.6mm.

Fig. 15 shows the clamps meeting the clamping-capacity requirement, since their contact with the CubeSat rails in the horizontal arrangement provides proper support.

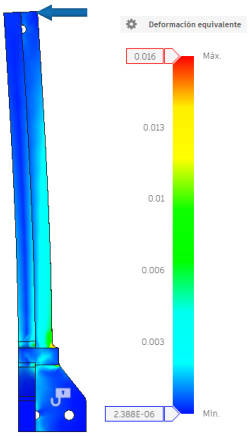


Fig. 14 FEA for the bending resistance of the iteration II clamp

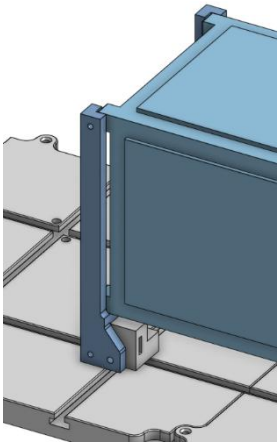


Fig. 15 Clamping capacity of the clamps in horizontal arrangement for iteration II

3) *Iteration III*

The third iteration meets all requirements, as shown in Table VII. It inherits the compliance of the previous versions and corrects the deficiency in the bending resistance of the clamps, as shown in Fig. 16, where the deformation is below 1% at 1.39mm.

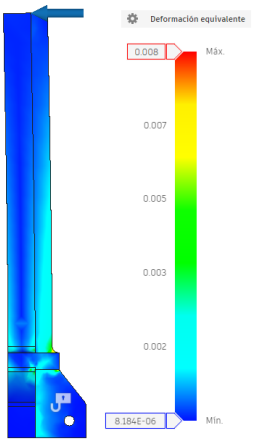


Fig. 16 FEA for the bending resistance of the iteration III clamp

TABLE VII
REQUIREMENTS VERIFICATION RESULTS FOR ITERATION III

Design requirements verification checklist for the modular JIG				
N	Requirement	Compliance condition	Meets	
			Yes	No
1	Vertical-arrangement dimensions	x-axis: 100.10 mm +0.05 mm	X	
2		y-axis: 100.10 mm +0.05 mm	X	
3	Horizontal-arrangement dimensions	x-axis: 100.10 mm +0.05 mm	X	
4		y-axis: 340.60 mm +0.05 mm	X	
5	Clamp contact area	Extension < 8.5 mm	X	
6	Modularity	The JIG capacity can be increased by concatenating multiple bases of the same design	X	
7	Load capacity	The clamps can support the CubeSat mass (6 kg max.) without significant deformation (<1%)	X	
8	Bending resistance	The clamps can withstand a significant force equal to the weight of the supported CubeSat, applied horizontally at the top of their body, without significant deformation (<1%)	X	
9	Clamping capacity	The clamps maintain contact with the CubeSat surface so that it cannot move during integration (except for the motion required to remove the CubeSat from the JIG); visual inspection	X	
10	Interferences	No JIG part contacts any satellite part other than the rails, in compliance with requirement 3.	X	

The final JIG model can be seen in exploded view in Fig. 17, which also labels the parts that make it up, the same ones listed in Table III.

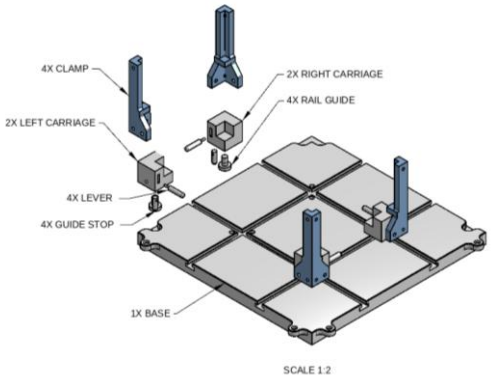


Fig. 17 Final JIG model in exploded view

B. Validations

The 3D-printed system, with the CubeSat mounted in the vertical and horizontal arrangements, can be seen in Fig. 18 and Fig. 19, respectively.



Fig. 18 Assembly of the JIG-module prototype and the 3U CubeSat in the vertical position



Fig. 19 Assembly of the JIG-module prototype and the 3U CubeSat in the horizontal position

The validation result is given in Table VIII. Dimensional compliance of the base of the clamp working area is observed, as shown in Fig. 20, Fig. 21, and Fig. 22. The base-concatenation capability for extending the working capacity is visible in Fig. 23.

Clamp travel and fixation were checked by visual inspection; these validations were found non-compliant because the fit between the prototype parts was not adequate, hindering movement along the base rails and leaving too much play between parts. For the same reason, stability was found non-compliant.

The fit check performed, shown in Fig. 24 and Fig. 25, reveals gaps in the upper zone of the CubeSat, due to the misalignment of the clamps (see Fig. 26 and Fig. 27) resulting from the misfits in the rest of the JIG elements. Therefore, both validations were not met.

TABLE VIII
VALIDATION VERIFICATION OF THE PROTOTYPED JIG MODEL

Prototype validation checklist for the modular JIG				
No.	Requirement	Compliance condition	Meets	
			Yes	No
1	Vertical-arrangement dimensions	x-axis: 100.10 mm +0.10 mm	X	
2		y-axis: 100.10 mm +0.10 mm	X	
3	Horizontal-arrangement dimensions	x-axis: 100.10 mm +0.10 mm	X	
4		y-axis: 340.60 mm +0.10 mm	X	
5	Modularity	Multiple bases can be properly concatenated	X	
6	Clamp travel	The clamps can move freely along all rails		X
7	Clamp fixation	The clamps stay fixed when reaching each fixation hole		X
8	Alignment	The clamp surfaces that will contact the CubeSat rails are coplanar		X
9	Fit check	The reference CubeSat fits with the proper clearance (0.2 mm tolerance)		X
10	Stability	The CubeSat placed on the clamps remains stable when simulating component-integration tasks		X


Fig. 20 Measurement of the right-side clamp separation

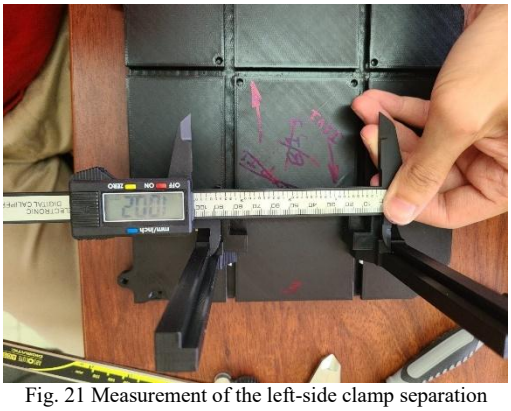

Fig. 21 Measurement of the left-side clamp separation


Fig. 22 Measurement of the clamp separation in z (horizontal position)


Fig. 23 Base-concatenation test

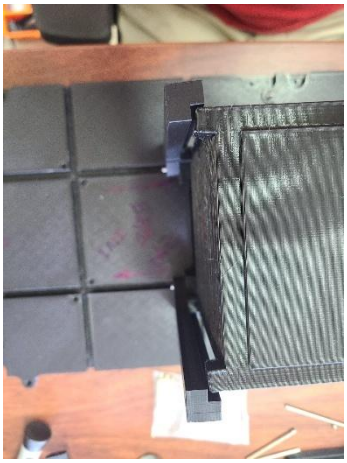


Fig. 24 Deviation of the left-side clamps during the fit check

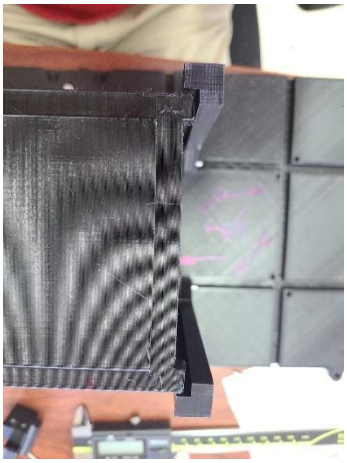


Fig. 25 Deviation of the right-side clamps during the fit check

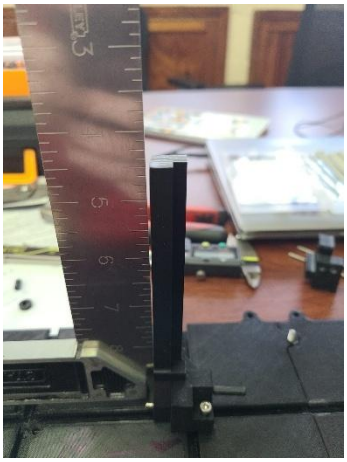


Fig. 26 Deviation of the left-side clamp



Fig. 27 Deviation of the right-side clamp

IV. Discussion

The iterative design process shows a progressive improvement in requirement compliance when applied together with a verification checklist that makes it possible to trace the initial direction and the direction of the corrections and improvements to be made at each iteration.

Between iterations I and II, a characteristic of the design process becomes apparent: changing one variable can significantly affect the others. In the first case, the clamp deformation was below 1%, but its clamping capacity did not meet the requirement. Increasing the clamp height to achieve greater contact with the CubeSat rails significantly increased the bending stress and deflection, producing a 1.6% deformation, above the established limit. A third iteration corrected the low clamp stiffness while maintaining its clamping capacity by increasing its thickness.

The finite-element analysis applied to the clamps indicates that the design meets the specified strength requirements; however, this analysis is performed under ideal static-loading conditions and perfectly defined constraints. It should also be noted that the FEA was carried out for the intended material (Delrin homopolymer), whereas the prototype was printed in PLA, so the simulated structural response does not correspond to the physical prototype that was tested. Further analyses under more realistic conditions, or physical tests on clamps fabricated in the target material, may therefore be necessary.

Observed non-compliances in clamp travel and coplanar alignment stem directly from FDM tolerance stack-up. Typical FDM dimensional deviations (0.20–0.35 mm) and surface roughness (Ra≈10~15µm) produced cumulative clearances exceeding 0.65 mm, inducing angular play and clamping face tilt (>1.2°). Under ISO 286, these sliding interfaces require an H7/h6 or H8/f7 fit, constraining clearance to +15µm to +45 µm—precision unattainable via desktop FDM. Because the design targets CNC machining in end-use materials, validation can be refined through optimized print parameters, higher-precision additive processes, or design adjustments tailored to prototyping constraints.

A cost-benefit trade study was conducted comparing the proposed design with commercial Mechanical Ground Support Equipment (MGSE). Commercial rotary fixtures (e.g., EnduroSat 3U–16U JIG) cost around $7,700, plus 25%–40% in shipping and import duties. Conversely, domestic fabrication costs were estimated using operational rates from the manufacturing center at UNAH Valle de Sula, located in San Pedro Sula—the country's primary industrial hub. Based on their modern machine shop and expertise in 3-axis and 5-axis CNC machining, standard 3-axis milling is priced at 1,000–1,500 HNL/h ($40–$60/h). At this rate, producing a 1U module requires 5.0–6.0 machining hours. Factoring in raw stock and hardware (~$50), direct costs total ~$320–$390 per 1U module and under $900 for a 3U assembly. This approach yields over 88% in direct cost savings and reduces lead times to 1–2 weeks.

The modular capability offers an alternative and an advantage over other JIG types, since it allows the tool to be scaled according to the needs presented and adapted in real time to the assembly conditions that arise. However, this approach presents challenges—such as guaranteeing rail-to-rail alignment, the stiffness of the joints when concatenating bases, and the fixation system for the various CubeSat sizes—that must be considered in future improvements.

Finally, the compliance with the design requirements for the JIG module for 1U–3U CubeSats is noteworthy. Scaling to larger dimensions requires re-evaluating the structure with respect to load capacity and bending resistance, as well as introducing auxiliary clamps to support heavier satellites.

The design of this system remains open to improvements arising from feedback based on satellite-assembly experience and from its use once fabricated.

V. Conclusions

A modular JIG with a working capacity from 1U to 3U was designed, meeting all ten design requirements—derived from the CubeSat design specification—at the CAD and finite-element-analysis level after three design iterations.

3D printing provided a low-cost means to build and inspect the prototype and validated the geometric and modular concept, the dimensional conformity of the working area and the base-concatenation capability. The printed prototype did not, however, pass the functional validations (clamp travel, clamp fixation, alignment, fit check, and stability): the dimensional and surface-finish limitations of FDM produced excessive clearances between parts and clamp misalignment, indicating that a functional version requires fabrication in the intended engineering material (Delrin) by CNC machining.

The iterative design process, supported by verification checklists, made it possible to identify and correct deficiencies against the stated requirements, functioning as an effective design method; the coupling observed between clamp height, clamping capacity, and bending stiffness illustrates its value.

A basis was established for future work: fabrication in the target material, scaling toward larger configurations (6U–12U)—which will require re-evaluating load capacity and bending resistance and adding auxiliary clamps—and validation under real operating conditions. The work also contributes to building national capacity in the production of aerospace ground-support equipment, an industry currently absent in the country.

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References

[1] J. Puig-Suari, C. Turner, and W. Ahlgren, "Development of the standard CubeSat deployer and a CubeSat class picosatellite," in Proc. IEEE Aerospace Conf., vol. 1, 2001, pp. 1/347–1/353, doi: 10.1109/AERO.2001.931726.

[2] H. Heidt, J. Puig-Suari, A. S. Moore, S. Nakasuka, and R. Twiggs, "CubeSat: A new generation of picosatellite for education and industry low-cost space experimentation," in Proc. 14th Annu. AIAA/USU Conf. Small Satellites, Logan, UT, USA, 2000. [Online]. Available: https://digitalcommons.usu.edu/smallsat/2000/All2000/32

[3] California Polytechnic State University (Cal Poly). "CubeSat Design Specification (CP-CDS-R14.1)," 2022. [Online]. Available: https://static1.squarespace.com/static/5418c831e4b0fa4ecac1bacd/t/62193b7fc9e72e0053f00910/1645820809779/CDS+REV14_1+2022-02-09.pdf

[4] NASA, "CubeSat 101: Basic concepts and processes for first-time CubeSat developers," NASA CubeSat Launch Initiative, Tech. Rep., Oct. 2017. [Online]. Available: https://www.nasa.gov/content/cubesat-launch-initiative-resources

[5] G. A. Walz, "Design tactics for optimal modularity," in Proc. AUTOTESTCON, Piscataway, NJ, USA: IEEE, Nov. 1980.

[6] J. K. Gershenson, G. J. Prasad, and Y. Zhang, "Product modularity: Definitions and benefits," J. Eng. Design, vol. 14, no. 3, pp. 295–313, 2003, doi: 10.1080/0954482031000091068.

[7] Serenum Space, "Vertical support JIG — assembly JIG for satellite." [Online]. Available: https://www.satnow.com/products/assembly-jigs/serenum-space/137-1255-vertical-support-jig

[8] Serenum Space, "MGSE." [Online]. Available: https://www.serenumspace.com/products/mgse

[9] EnduroSat, "Satellite rotary jig for CubeSat assembly," Sep. 26, 2025. [Online]. Available: https://www.endurosat.com/products/rotary-jig/

[10] Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits, ISO Standard 286-1, 2010.

[11] Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts, ISO Standard 286-2, 2010.

[12] Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out, ISO Standard 1101, 2017.