FEASIBILITY OF 3D PRINTED MATERIALS INTO SPACE USE

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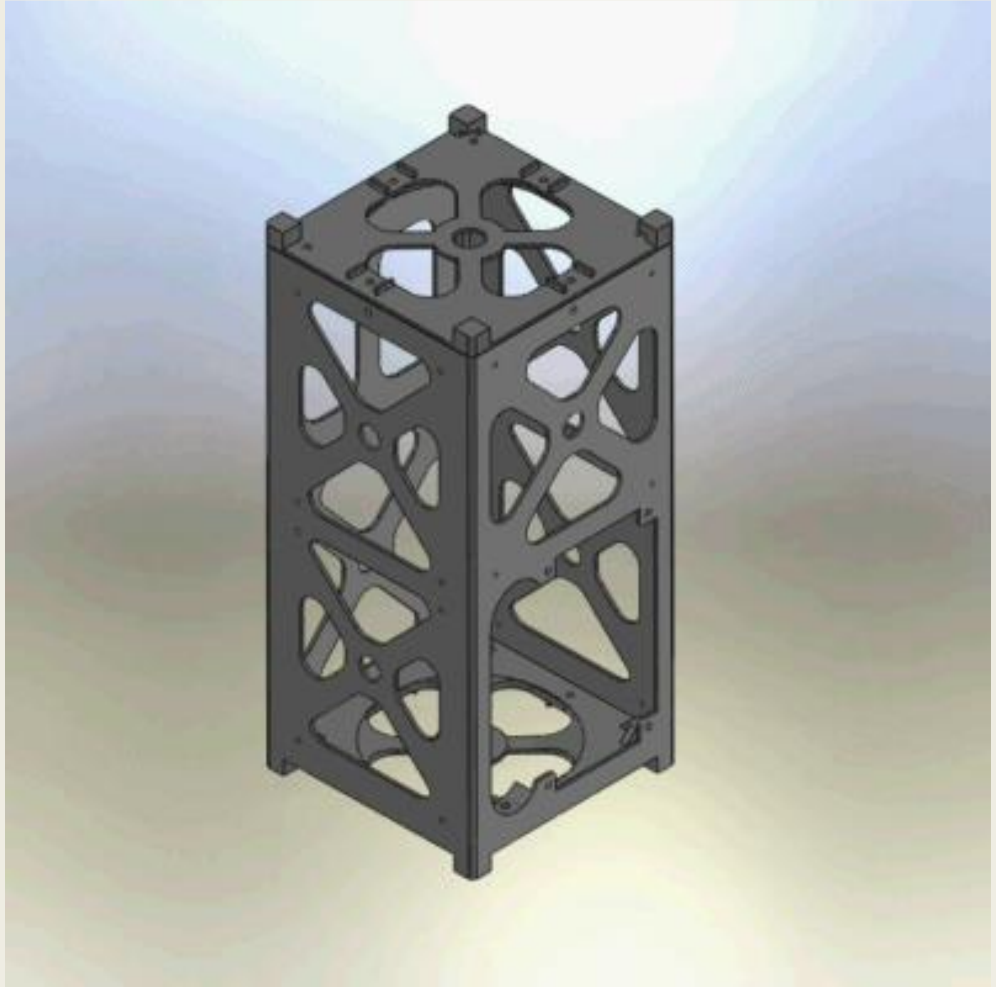
Why 3D printed Structures



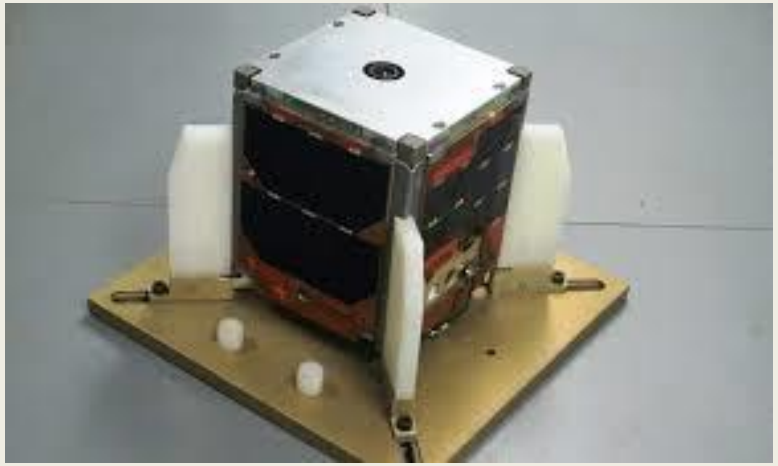
https://grabcad.com/challenges/the-cubesat-challenge

- Additive Manufacturing is uniquely suited to the complexity of space structures.

- Ideal for customization to suit a wide range of CubeSat payloads and purposes.

- Ease of accessibility for students, hobbyists, and start-ups.

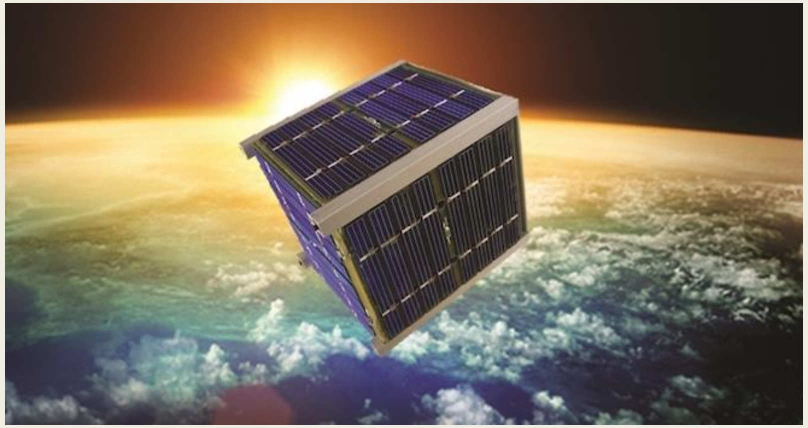
What are the challenges that a structure has to face up.



Ground Transportation and Handling

Launch environment

Orbit



Pictures from: http://www.cubesat.org/ and hindustantimes.com

Enviromental Testing requirements.

“Testing will be performed to meet all launch provider requirements as well as any additional testing requirements deemed necessary to ensure the safety of the CubeSats”

- **Random Vibration**

Random vibration testing shall be performed as defined by the launch provider.

- **Thermal Vacuum Bakeout**

Thermal vacuum bakeout shall be performed to ensure proper outgassing of components.

- **Shock Testing Shock**

Testing shall be performed as defined by the launch provider.

Taking from :CubeSat Design Specification Rev. 13 The CubeSat Program, Cal Poly SLO

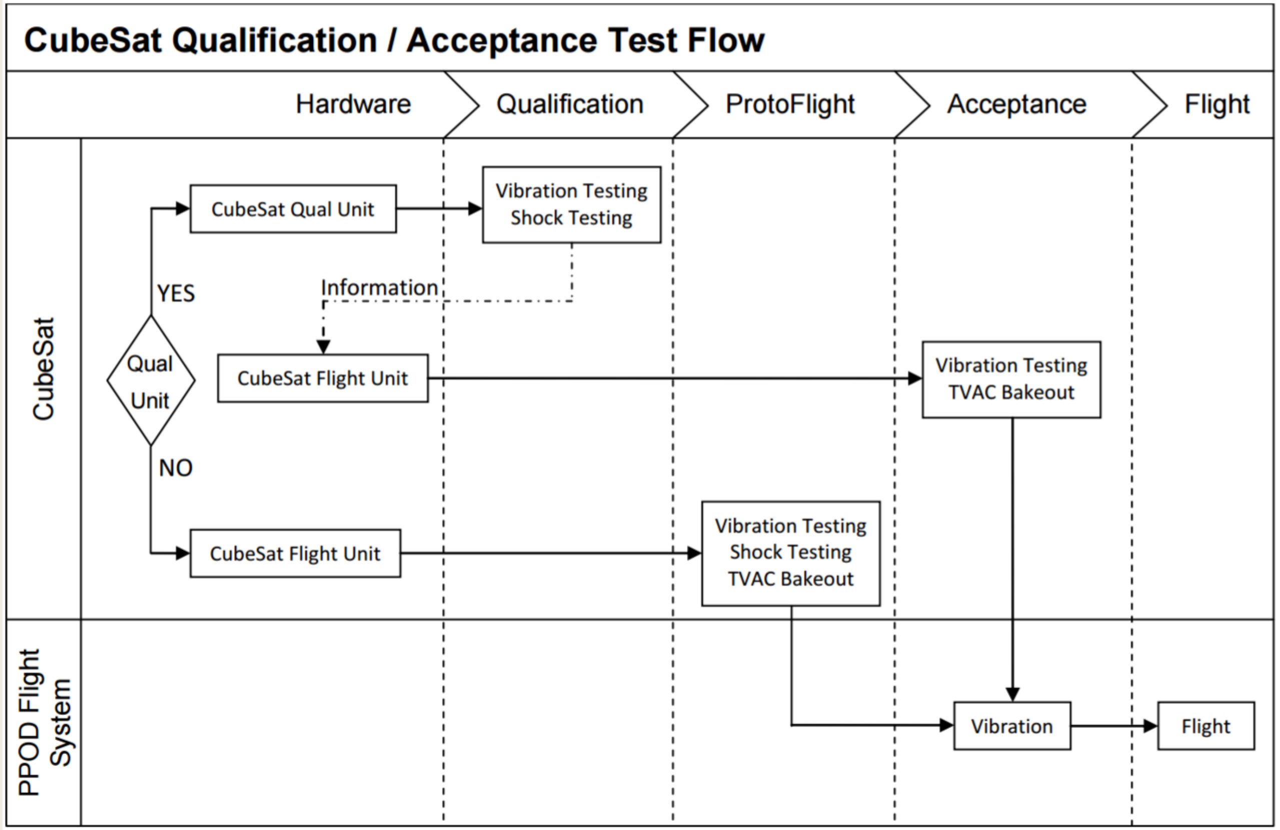


Figure 8: CubeSat General Testing Flow Diagram

- **Visual Inspection**

Visual Inspection Visual inspection of the CubeSat and measurement of critical areas will be performed

If a printed 3D structure can pass all these test, there still some other challenges.

CubeSat Mechanical Requirements

CubeSat Design Specification Rev. 13 The CubeSat Program, Cal Poly SLO

- 3.2.16 The CubeSat rails and standoff, which contact the P-POD rails and adjacent CubeSat standoffs, shall be hard anodized aluminum to prevent any **cold welding** within the PPOD.

JEM Payload Accommodation Handbook- Vol. 8 -Small Satellite Deployment Interface Control Document

- 2.1.3. (8)The rail surfaces which contact with the rail guides of the J-SSOD Satellite Install Case and the rail standoffs which contact with adjacent satellites shall be hard anodized aluminum after machining process. The thickness of the hard anodized coating shall be more than 10μm according to MIL-A-8625, Type3.

Cold Welding

Wikipedia:

Cold welding or contact welding is a solid-state welding process in which joining takes place without fusion/heating at the interface of the two parts to be welded… Flat surfaces of similar metal would strongly adhere if brought into contact under vacuum.

- These surfaces may be bare metals, or inorganically or organically coated metals and their alloys.

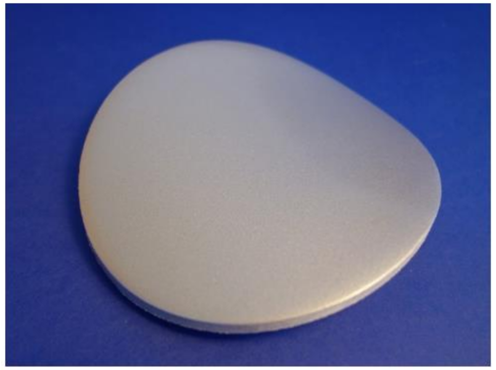
Rails will have a surface roughness less than 1.6 μm

- *CubeSat Design Specification Rev. 13 The CubeSat Program, Cal Poly SLO requirement* 3.2.6 ***Mechanical Requirements***
- *JEM Payload Accommodation Handbook- Vol. 8 -Small Satellite Deployment Interface Control Document* 2.1.3.(4) ***Rails***

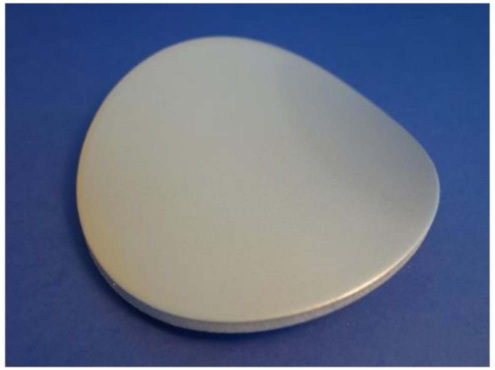
Achievable values with 3D printing

ABS (178μm layers)	POLYAMIDE (60μm layers)	RESIN (28μm layers)
1.8 μm	1.4 μm	1.8 μm

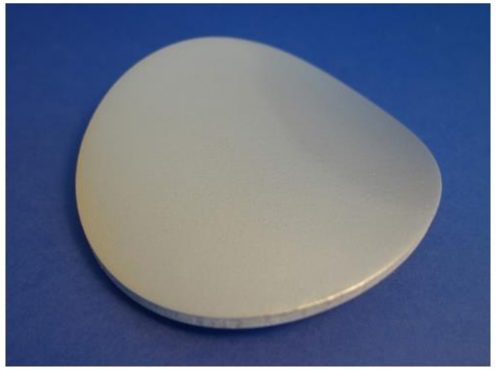
https://www.sculpteo.com/blog/2015/09/07/the-ultimate-finish-from-3d-printed-to-final-product-look/



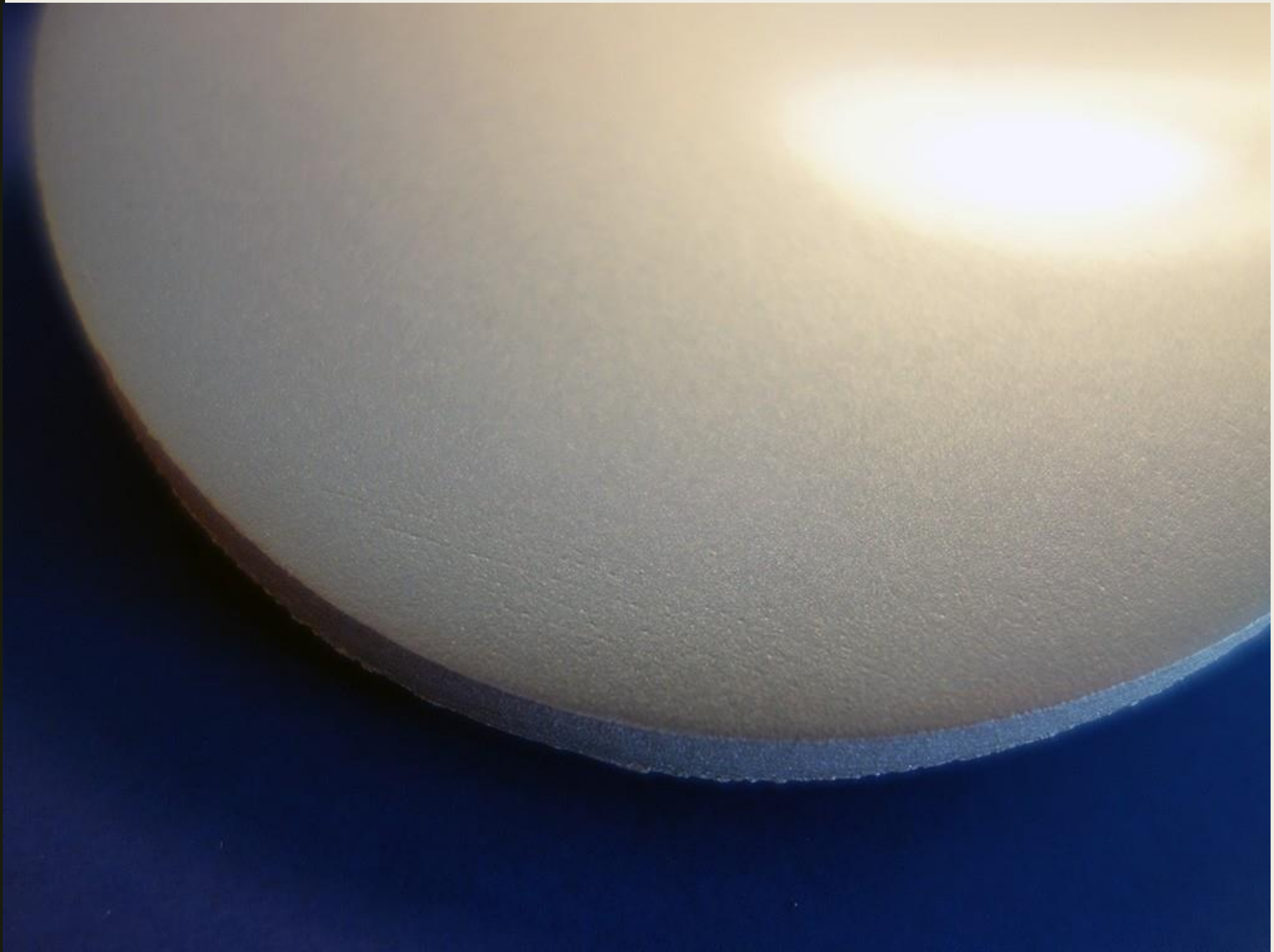
ABS



Polyamide



Resin



“Unfortunately our ABS printer could only print with 178µm layers, which is easily exceeded by other ABS printers”

https://www.sculpteo.com/blog/2015/09/07/the-ultimate-finish-from-3d-printed-to-final-product-look/

Out-gassing

JEM Payload Accommodation Handbook- Vol. 8 -Small Satellite Deployment Interface Control Document

- 2.5. Out-gassing Rating “A” materials which are identified in MSFC-HDBK-527F (JSC-0904F) or MAPTIS1 shall be used for a satellite. When using materials other than Rating “A”, an individual review and approval through MUA is needed.2 (As for MUA, refer to the section 3.2.1 (3).)

JEM Payload Accommodation Handbook- Vol. 8 -Small Satellite Deployment Interface Control Document

- 3.2.15 . Aluminum 7075, 6061, 5005, and/or 5052 will be used for both the main CubeSat structure and the rails. If other materials are used the developer will submit a DAR and adhere to the waiver process.

MSFC-HDBK-527F:

Rate A material: A unit which has leak rate of 10^-4 sscs (Standard Cubic Centimeter per second) or less of He, with a partial pressure differential of 14.7 psia

ABS (Acrylonitrile-Butadiene-Styrene)

- ABS is a low cost engineering plastic that is easy to machine and fabricate. ABS is an ideal material for structural applications when impact resistance, strength, and stiffness are required. *(http://www.plasticsintl.com/abs.htm)*

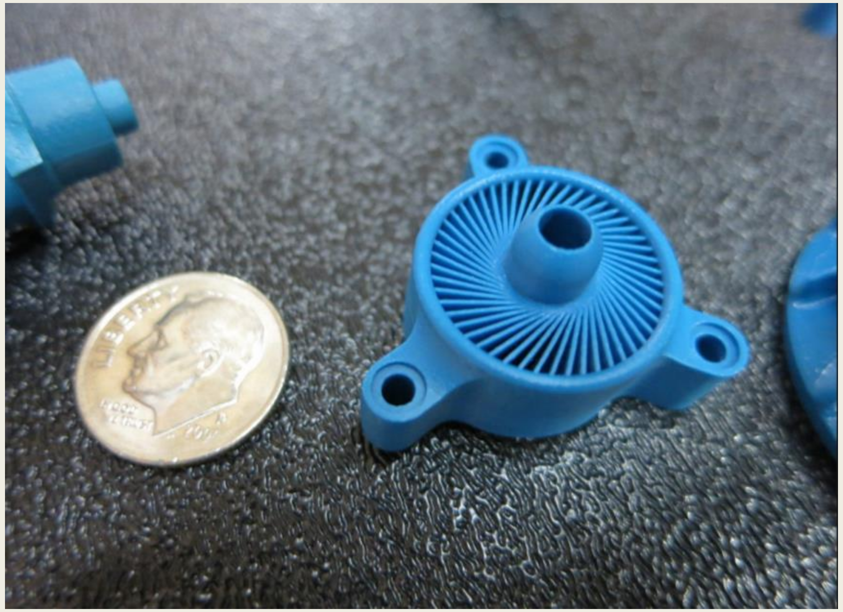
MATERIAL	TML %	CVCM %	CURE TIME	CURE TEMP	AT-MOS	% WVR	DATA REF	APPLICATION	MFR CODE
ABS PLASTIC, 3D PRINTED	0.94	0.04				0.25	GSC35076	MOULDING COMPOUND	CIM

https://outgassing.nasa.gov/cgi/uncgi/search/search.sh

Materials meeting criterias: a maximum total mass loss (TML) of 1.0 percent and maximum collected volatile condensable material (CVCM) of 0.10 percent.
https://outgassing.nasa.gov/og_desc.html

3D Printer Precision

Some Structural parts required a precision in their measures up to 0.1mm

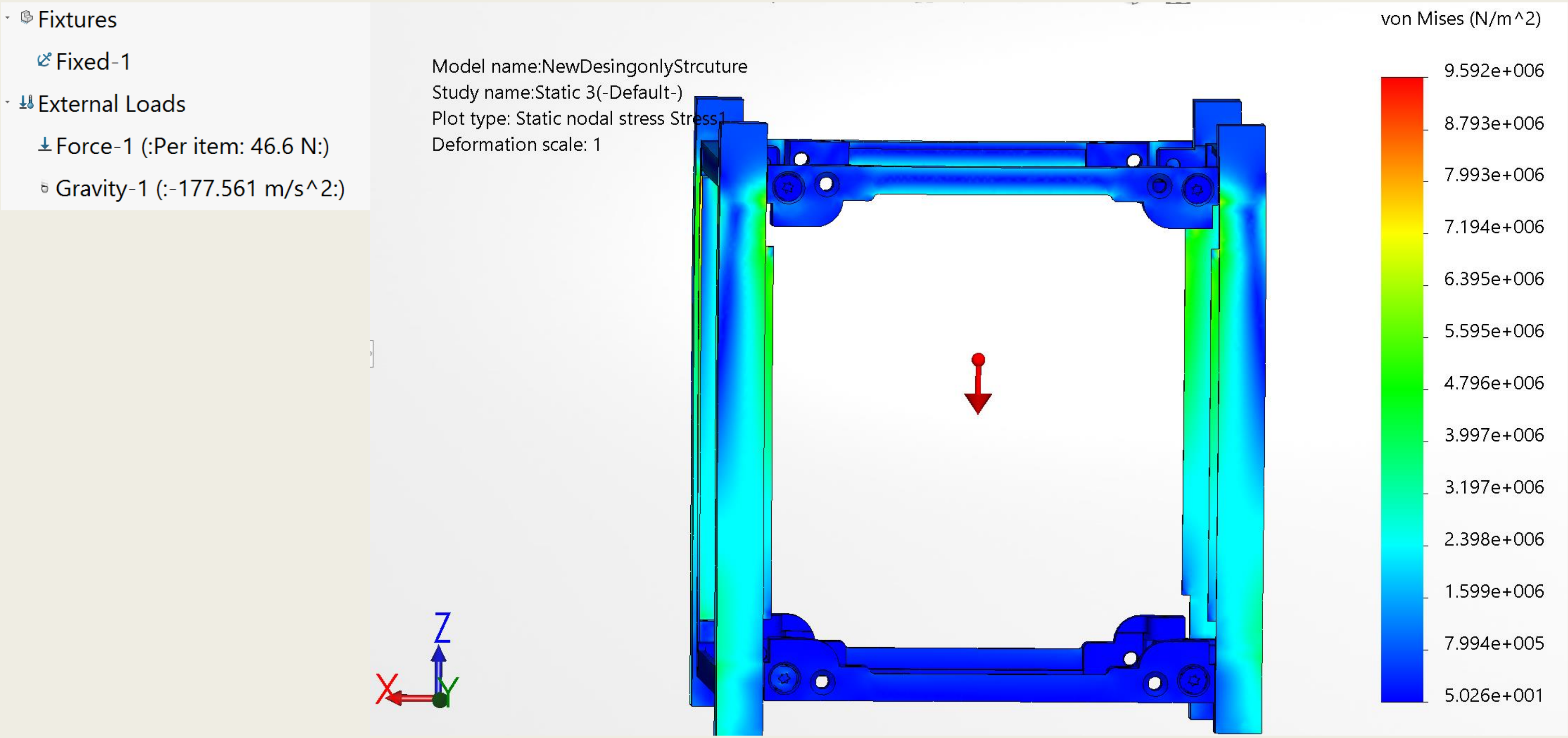


The precision of a 3D printer is determined by the minimum feature size of the XY plane and the Z-axis resolution.

The critical factor is the layer thickness, the Z axis resolution so 3D printers are categorized by this value.

It possible to find 3D printers with layer thickness down up to
50 -100 microns. (0.05mm – 0.1mm)

Structural strength

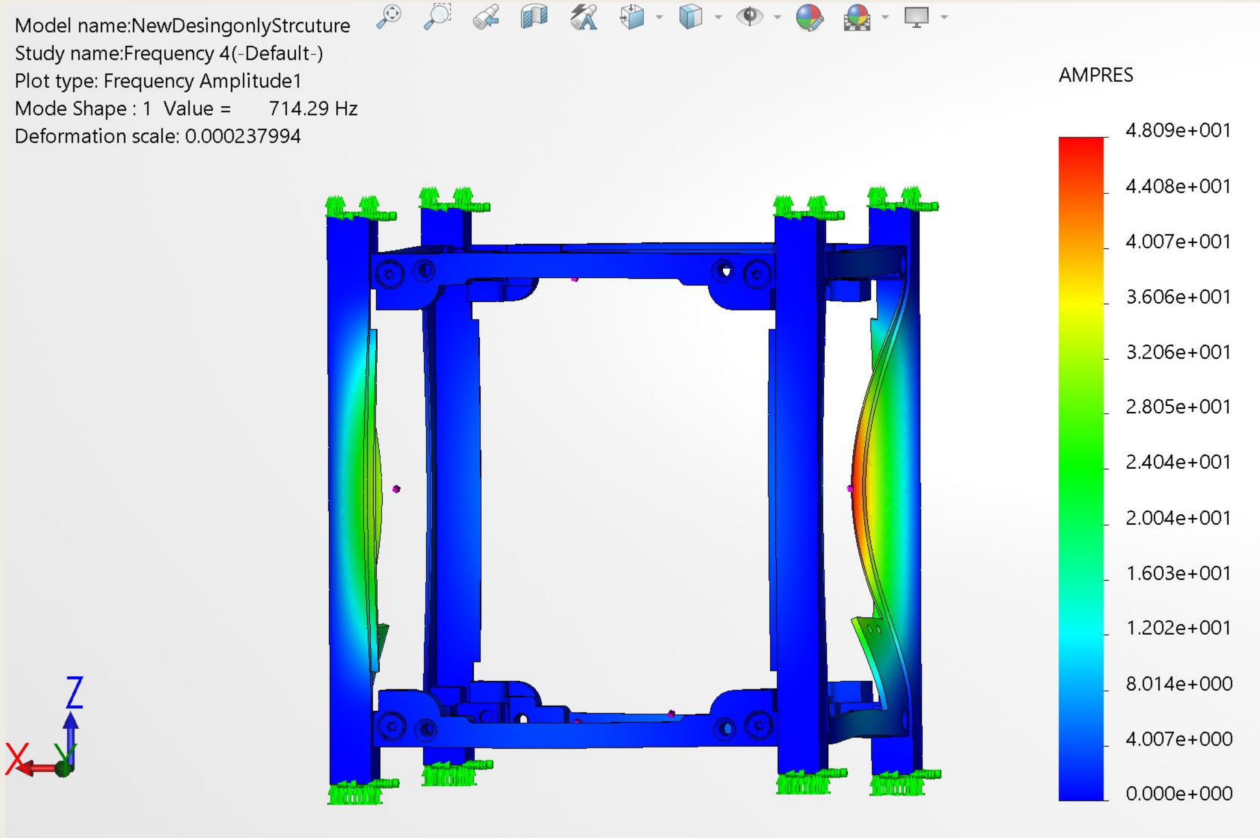


Material	Density (g/cm^3)	Ultimate Tensile Stress (Mpa)	Yield Stress (Mpa)	Youngu`s Modulus (Gpa)	Max stress	Tensige margin of Safety	Yield margin of Safety
ABS	1.02	30	60.6	2	9.45	0.59	3.3
AL6061	2.7	310	275	69	9.45	15.4	18.4

Structural stiffness

2.1.9. Stiffness

The minimum fundamental frequency of a satellite shall be no less than 100 [Hz] on the condition that the four rails +/-Z standoffs are rigidly fixed.



Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	4488	714.29	0.0014
2	4493.4	715.15	0.0013983
3	4604.4	732.81	0.0013646
4	4604.9	732.89	0.0013645
5	5039.9	802.12	0.0012467

- Appendix

CubeSat Design Specification
Deviation Waiver Approval Request (DAR)

Date: August 1, 2009 Rev. 12

CubeSat Developers only fill out sections 1 through 9 and 15(optional). Email to: standards@cubesat.org

1. MISSION NAME:	2. DAR NUMBER:	3. DATE:
4. INITATOR	5. INITIATING ORGANIZATION:	
6. SPECIFIED REQUIREMENTS NUMBERS:	7. JUSTIFICATION FOR DAR:	8. WAIVER TYPE ☐ DIMENSIONS or MASS ☐ STRUCTURE ☐ ELECTRICAL ☐ OPERATIONS ☐ TESTING ☐ OTHER

9. DESCRIPTION OF DEPARTURE FROM REQUIREMENTS:

10. CSEP DISPOSITION: ☐ ACCEPTED ☐ REJECTED ☐ CONDITIONALLY ACCEPTED	11. ACCEPT/REJECT JUSTIFICATION:		
CSEP AUTHORIZED REP.	SIGNATURE	ORGANIZATION	DATE

12. ACCEPTANCE CONDITIONS

13. LAUNCH VEHICLE INTEGRATOR APPROVAL AUTHORITY: ☐ APPROVED ☐ DISAPPROVED ☐ CONDITIONALLY APPROVED	14. LVI APPROVAL/DISAPPROVAL JUSTIFICATION:		
LVI AUTHORIZED REP.	SIGNATURE	ORGANIZATION	DATE

15. APPROVAL CONDITIONS

1. MISSION NAME:	DEVIATION WAIVER APPROVAL REQUEST CONTINUATION PAGE	2. DAR NO.	3. DATE:

16. CONTINUATION (indicate item or block number):