Deployable Boom Arm for a Double Langmuir Probe

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Intro - Langmuir Probes

- Conducting element inserted into plasma
- Probe biased with respect to ground (of spacecraft)
- Bias varied to collect different data

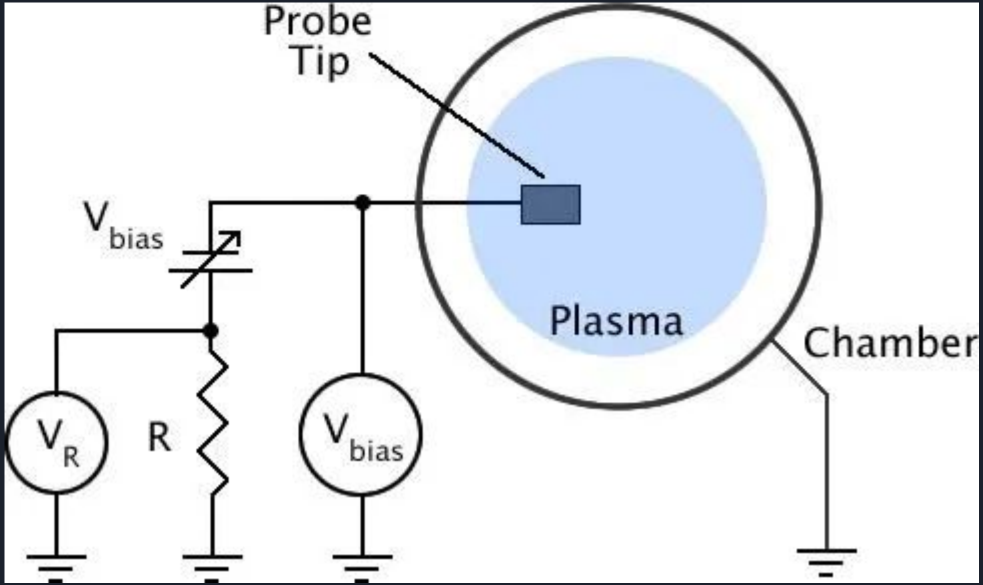


Image credit: David Pace

Double Langmuir Probes

- Uses two probes to avoid charging issues
- One probe set relative to the other probe
- Spacecraft state of charge does not affect results

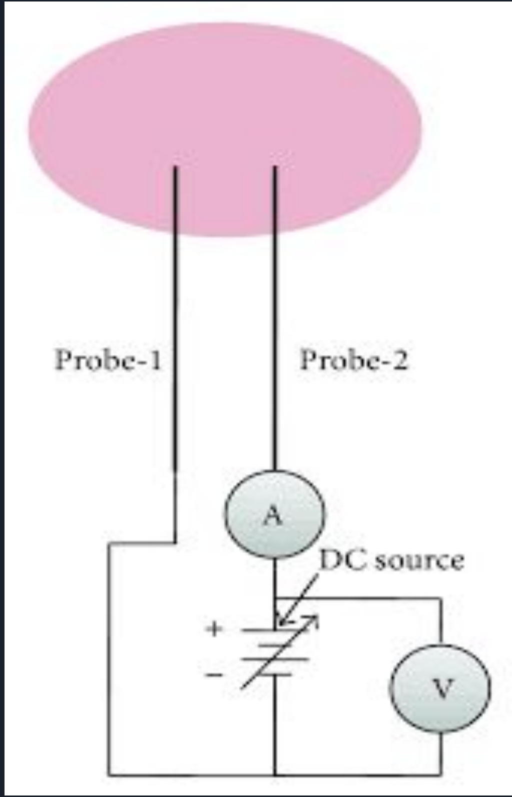


Image credit: M.Y. Naz

Project Goal

Goals:

- Design and simulate a deployer arm for a DLP for BIRDS-V
- Ensure that the deployer meets all requirements for launch, volume, and science

Deliverables:

- CAD model of deployer assembly
- 3-Views of deployer assembly
- Simulation results
- (If time permits) prototype model

Environment considerations

- In order to avoid interference from the spacecraft, the probe must sit outside the CubeSat's wake.
- This value is around 10cm

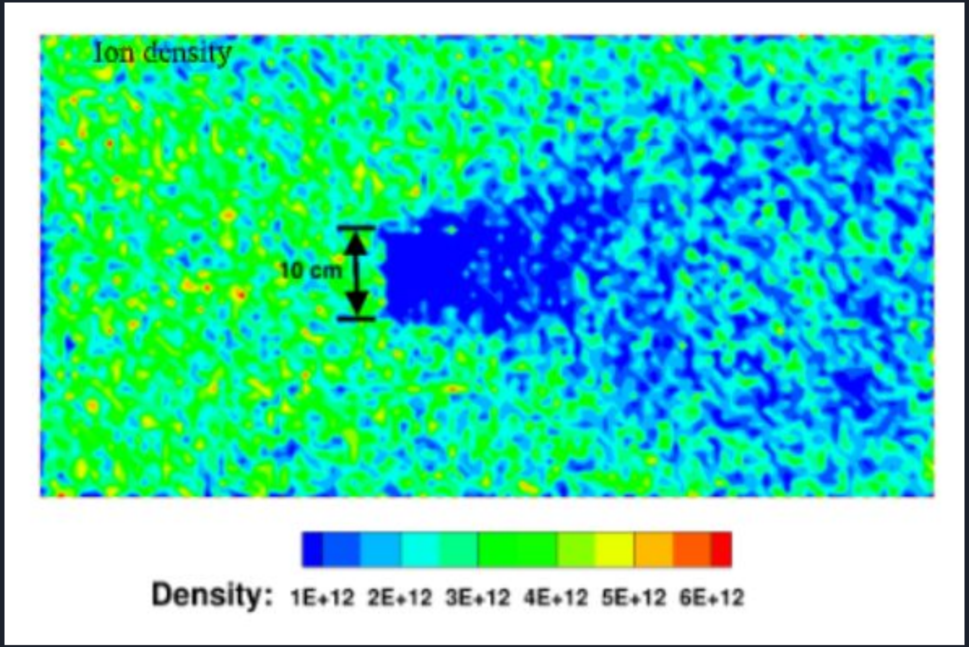
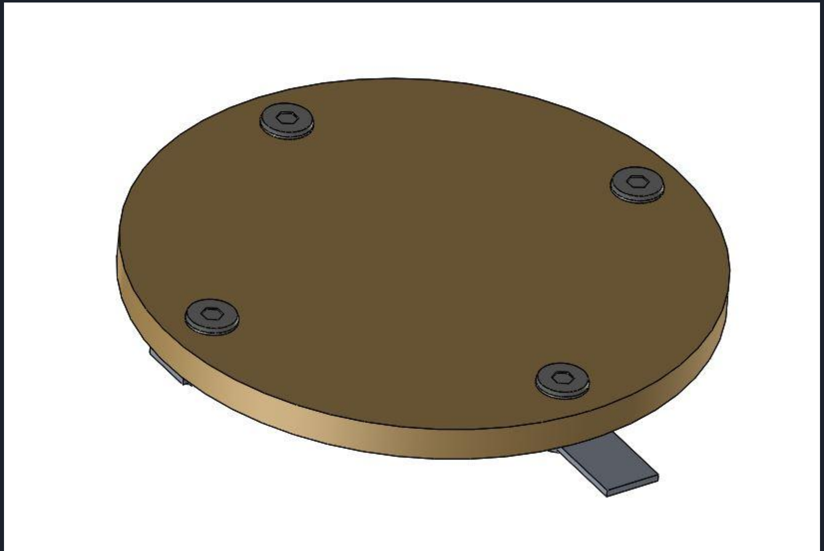


Image credit: H.M. Elhaj/KyuTech

Probe must <u>deploy</u> at least 10cm outside spacecraft

Baselined Langmuir Probe

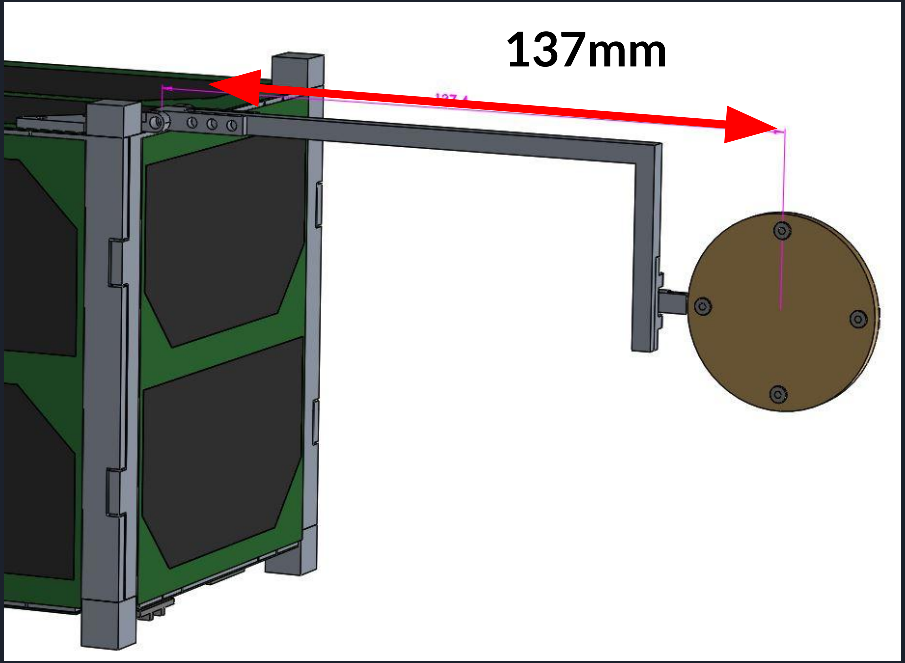
- Must be >1 Debye length
- Worst case Debye length: >30mm
- Planar design chosen over spherical due to volume constraints



Probe will be 40mm diameter

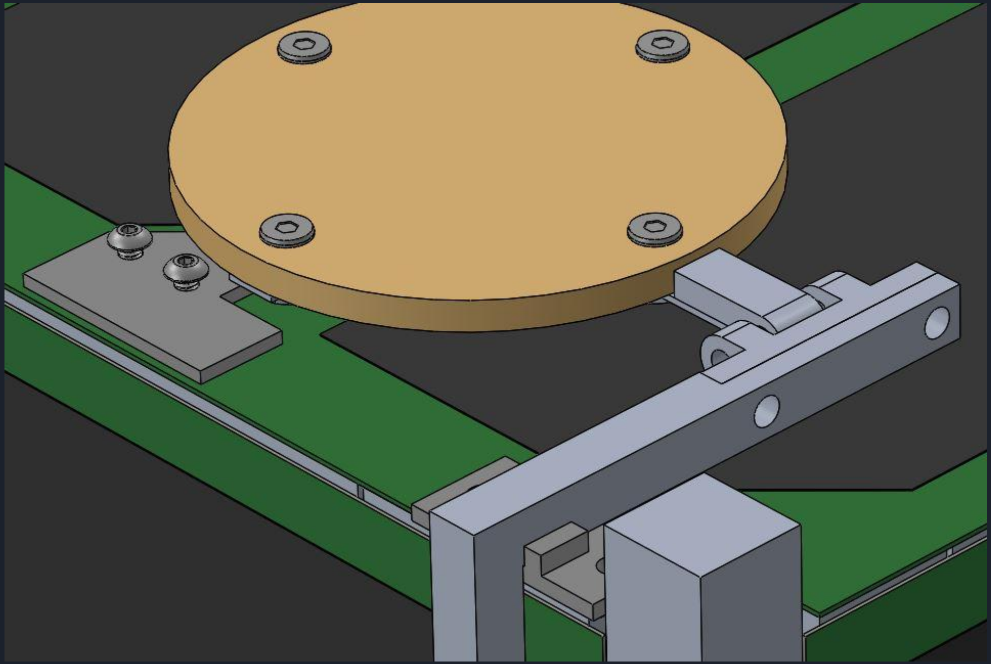
Baselined Langmuir Probe Deployer:

- Spring-loaded hinge mechanism on +Z face
- Boom connects to second hinge on -Z face
- Burnwire with Nylon fishing line to fix the assembly during launch
- Aluminium body acts as conductor
- Must attach to PCB and <u>not</u> metal structure



Baselined Langmuir Probe Deployer (cont.):

- Second hinge on -Z face orients probe
- PTFE/electrically insulating channel guides arm/supports 2 axes
- Burn wire circuit through PCB



Other Langmuir Probe Deployers:

Tape dispenser:

- High stowed volume (need to remove boards)

Scissor boom:

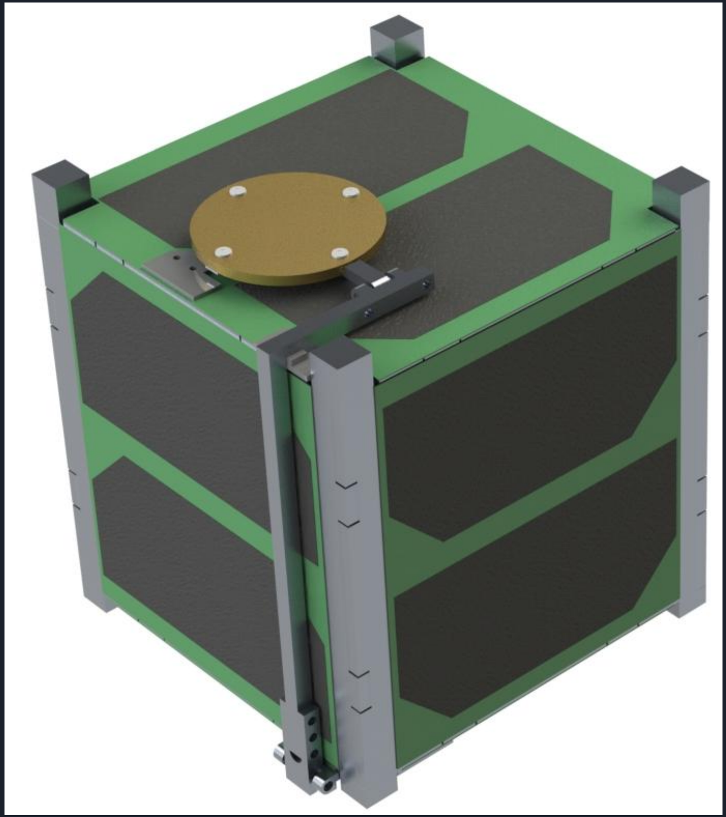
- High stowed volume
- Large area footprint (need to remove solar cells)

Image credit: NASA/DLR

Image credit: DICE / USU

Baseline Design

- Must not damage solar cells, impact structure, etc
- Goal of minimizing changes to current design/layout
    - Avoid new board layouts
    - Avoid new structural design



Simulation and Test

- Random Vibration Test: start with NASA GEVS at component level, tested to JEMs for Structure + Boom
- Shock: HII-A User's Guide
- Quasi-Static Loading from JEMs
- Natural frequency analysis

Table 2.4.1-1 Random Vibration of each launch vehicle

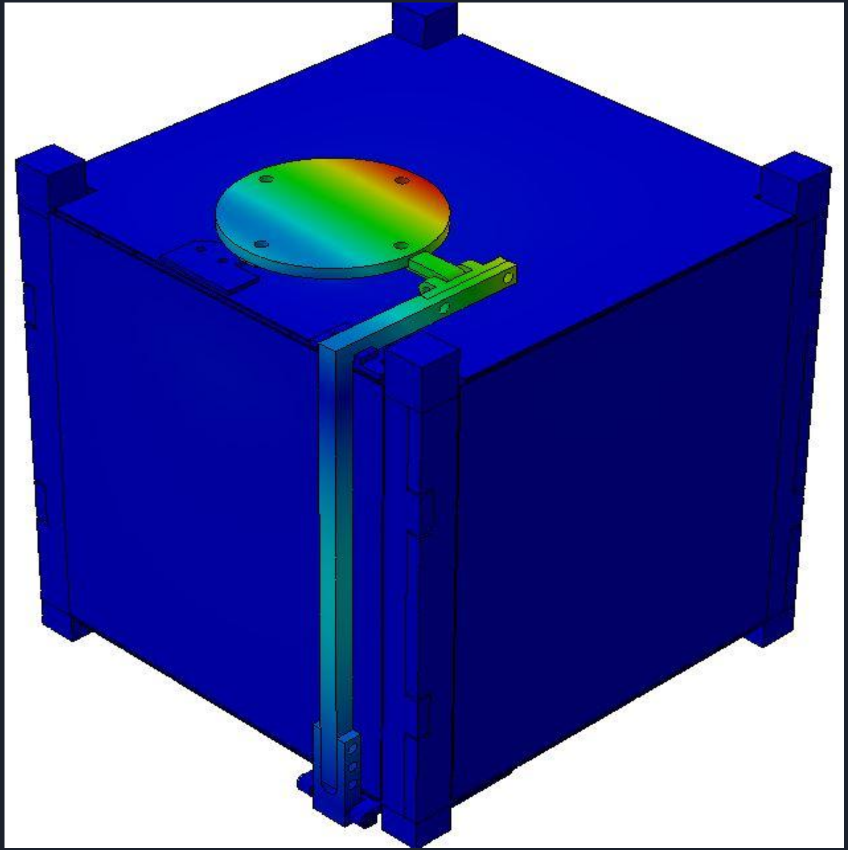
HTV		SpX Dragon		Orbital Cygnus	
Freq. (Hz)	PSD (g^2/Hz)	Freq. (Hz)	PSD (g^2/Hz)	Freq. (Hz)	PSD (g^2/Hz)
20	0.005	20	0.015	20	0.005
50	0.02	25.6	0.027	70	0.04
120	0.031	30	0.08	200	0.04
230	0.031	80	0.08	2000	0.002
1000	0.0045	2000	0.001		
2000	0.0013				
Overall (grms)	4.0	Overall (grms)	4.06	Overall (grms)	4.4
Duration (sec)	60	Duration (sec)	7.2	Duration (sec)	60

Image credit: JAXA

Results

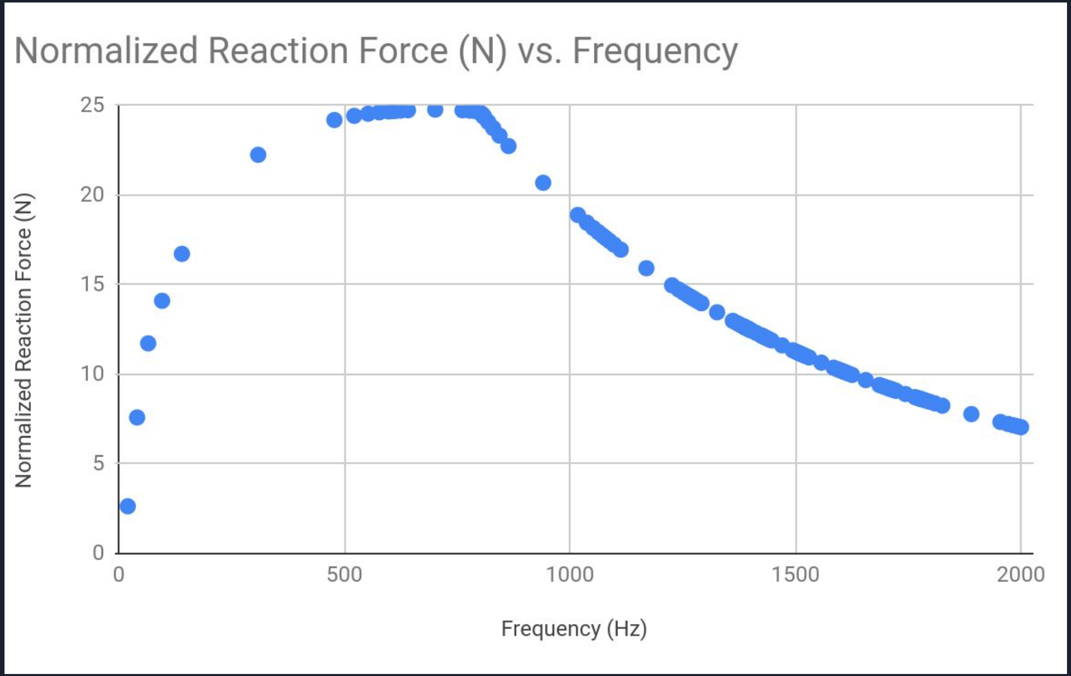
Mode No.	Frequency(Hz)
1	579
2	785
3	1090
4	1540
5	2120

First mode > 100 Hz



Results (cont.)

- Resultant loading:
  - 25N at ~800Hz
- Tie down cable may take that load
- Must have strength > 25N for Safety Factor > 1
  - Nylon fishing line with tensile strength >100N is readily available
- From NASA GEVS profile (14.1Grms)



Results (cont. 2)

Requirement	Result
Deploy probes >10cm	110mm
Direct probes into velocity direction	Yes (second hinge mechanism)
Conform to JEMs Payload Volume Requirements	Yes (1mm clearance)
Conform to JEMs Random Vibrations Requirements	Yes (no part failure, boom does not damage other parts)
Minimize hardware changes from BIRDS-IV	Requires drilling into +Z, -Z structure and Printed Circuit Boards (PCBs) No change to +/-X, +/-Y faces

Future Work:

Update configuration

Run shock test for launch profile

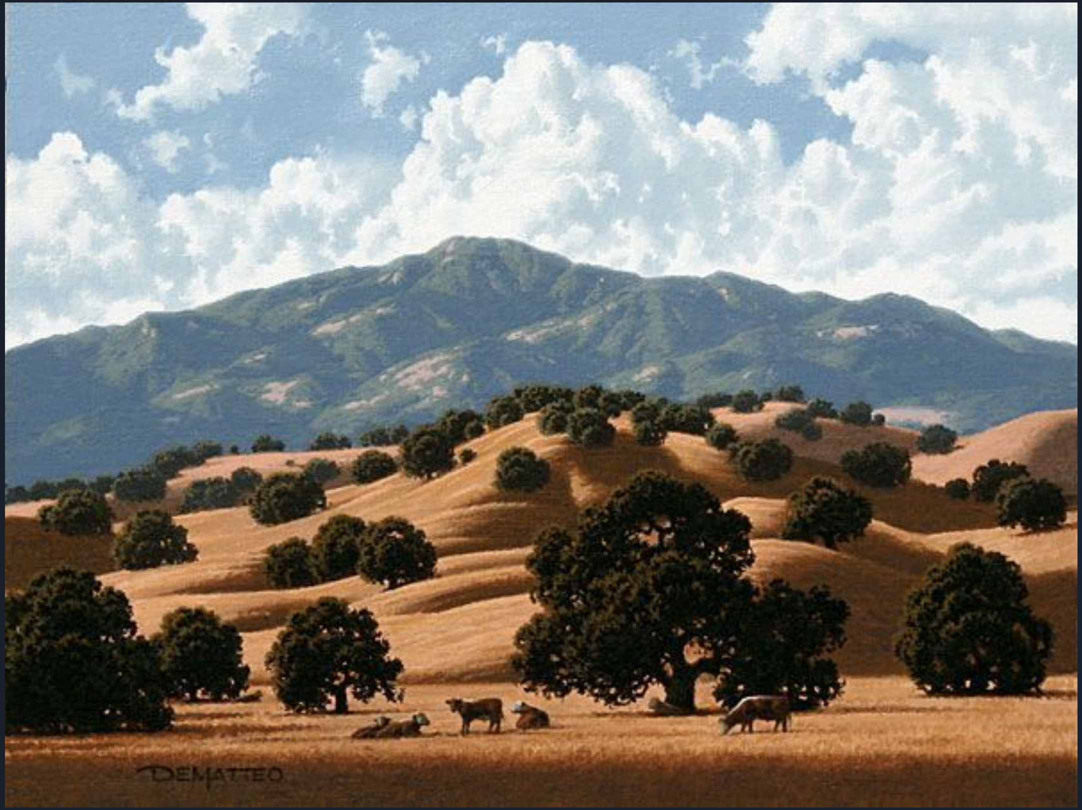
Order materials

Test burn wire, vibrations

Document tests, design

Travel to California

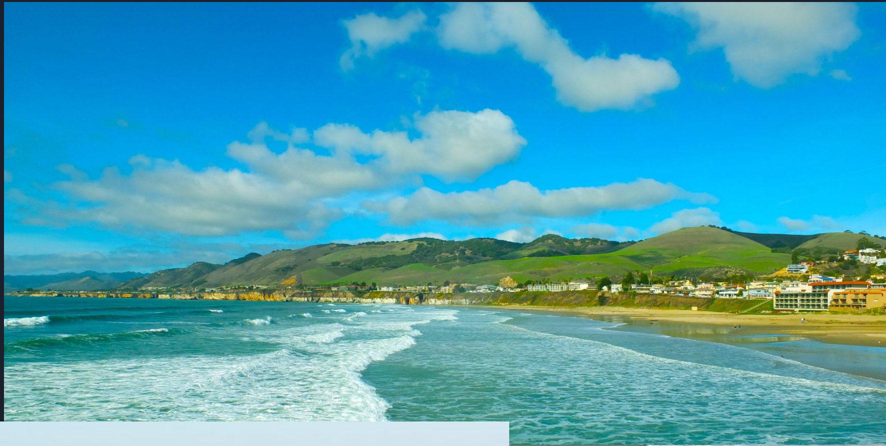
Travel to California



Travel to California

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
90 (32)	89 (32)	92 (33)	104 (40)	102 (39)	108 (42)	111 (44)	107 (42)	114 (46)	109 (43)	98 (37)	92 (33)	114 (46)
61.1 (16.2)	62.0 (16.7)	63.6 (17.6)	66.4 (19.1)	69.3 (20.7)	73.0 (22.8)	76.0 (24.4)	76.9 (24.9)	76.8 (24.9)	73.7 (23.2)	67.3 (19.6)	61.1 (16.2)	69.0 (20.6)
52.3 (11.3)	53.4 (11.9)	54.7 (12.6)	56.7 (13.7)	59.3 (15.2)	62.6 (17.0)	65.2 (18.4)	65.9 (18.8)	65.5 (18.6)	62.6 (17.0)	57.2 (14.0)	52.1 (11.2)	59.0 (15.0)
43.6 (6.4)	44.8 (7.1)	45.8 (7.7)	47.0 (8.3)	49.2 (9.6)	52.1 (11.2)	54.5 (12.5)	54.8 (12.7)	54.3 (12.4)	51.5 (10.8)	47.1 (8.4)	43.1 (6.2)	49.0 (9.4)

Travel to California



Travel in California

Thank you!

Any questions?

Backup

Backup

NASA GEVS:

- 14.1 Grms
- Not necessarily for ISS missions

Table 2.4-3
Generalized Random Vibration Test Levels
Components (ELV)
22.7-kg (50-lb) or less

Frequency (Hz)	ASD Level (g^2/Hz)	
	Qualification	Acceptance
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 G_{rms}	10.0 G_{rms}

The acceleration spectral density level may be reduced for components weighing more than 22.7-kg (50 lb) according to:

	Weight in kg	Weight in lb	
dB reduction	= 10 log(W/22.7)	10 log(W/50)	
$ASD_{(50\text{-}800\ Hz)}$	= 0.16•(22.7/W)	0.16•(50/W)	for protoflight
$ASD_{(50\text{-}800\ Hz)}$	= 0.08•(22.7/W)	0.08•(50/W)	for acceptance

Where W = component weight.

The slopes shall be maintained at + and - 6dB/oct for components weighing up to 59-kg (130-lb). Above that weight, the slopes shall be adjusted to maintain an ASD level of 0.01 g^2/Hz at 20 and 2000 Hz.

For components weighing over 182-kg (400-lb), the test specification will be maintained at the level for 182-kg (400 pounds).

Backup

Cantilever with Mass Concentrated at the End

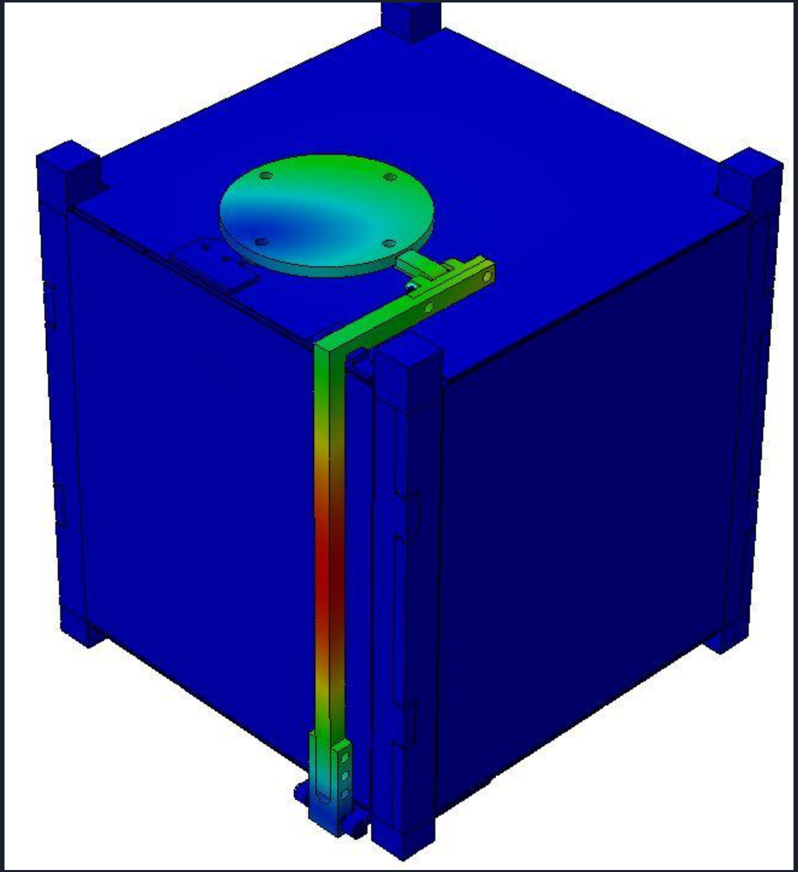
For a cantilever structure with the mass - or dead load due to gravitational force - concentrated at the end, the natural frequency can be estimated as

$$f = (1 / (2 \pi)) (3 E I / F L^3)^{0.5} \qquad (7)$$

Backup

Mode 2: 785 Hz

Expected simple beam frequency: 560 Hz



Backup

Mode 3: 1090 Hz

Expected simple beam frequency: 870 Hz