



NART-ST: NAnosatellite Reconfigurable Tools - Structure Design

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Outline

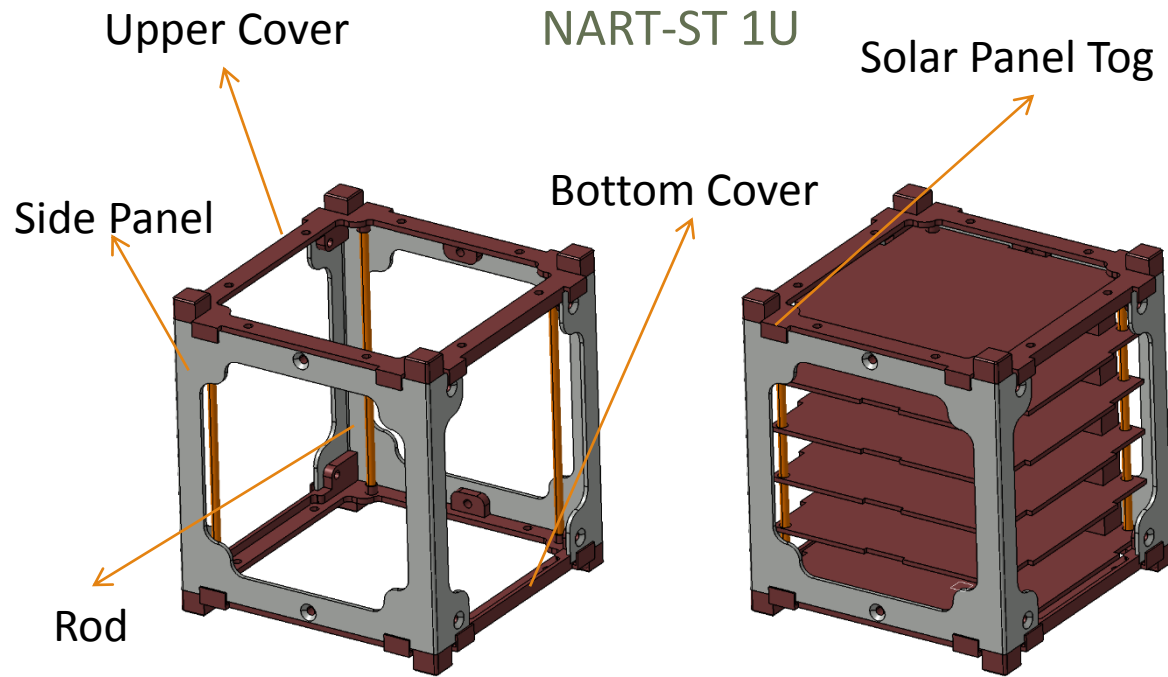
- Motivation
- Details of NART-ST Design
- FEM Analysis & Results
- Qualification Test
- Conclusion



Motivation

- Improving the capabilities of nano satellites
- Cost effective solution for CubeSat Design
- Modular for easy integration

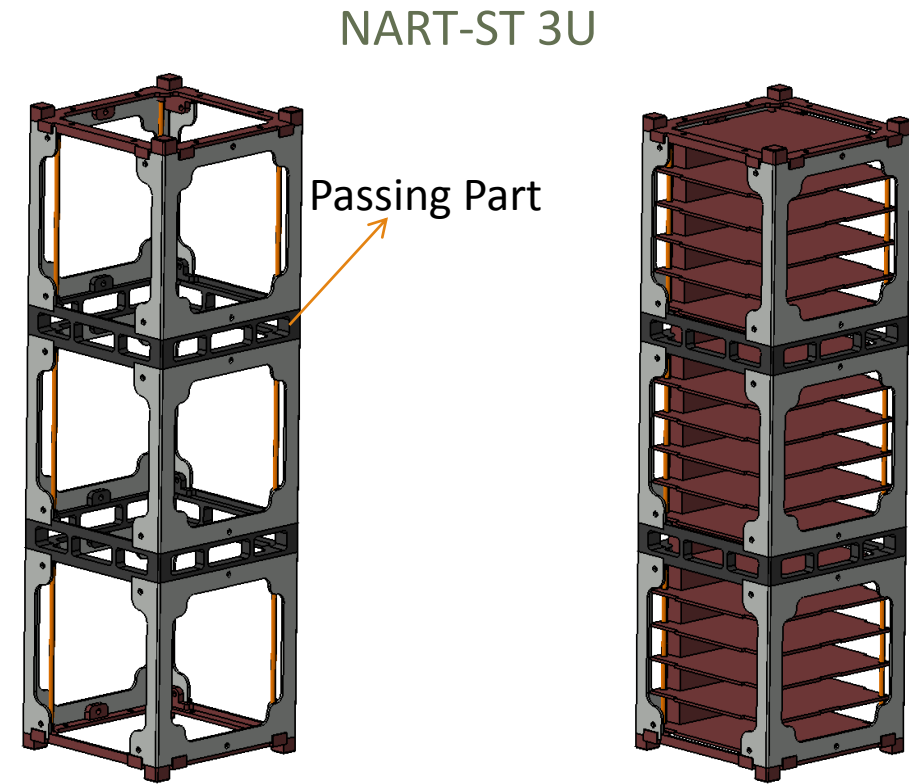
Details of NART-ST Design



NART-ST 1U

It is taken 6 regular PC104 PCBs

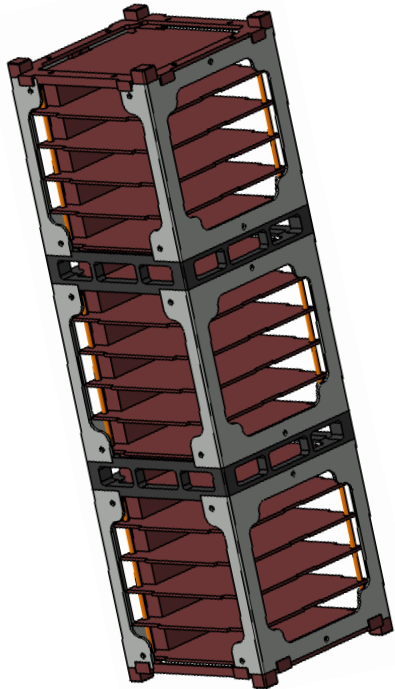
One regular PC104 PCB dimensions is 95.88 x 90.17 x 17 mm



NART-ST 3U

It can be taken 18 regular PC104 electronic cards

Details of NART-ST Design



Feature	NART-ST 1U	NART-ST 2U	NART-ST 3U
Mass	134 gr	270 gr	406 gr
External Envelope	100 x 100 x 113.5 cm	100 x 100 x 227 cm	100 x 100 x 340.5 cm
PCB Dimensions	PC/104 94 x 94 mm Custom Design	PC/104 94 x 94 mm Custom Design	PC/104 94 x 94 mm Custom Design
Electronic Card Assembly Integration	Vertical	Vertical	Vertical
Electronic Card Orientation Between 1U Unit Around Vertical Axis	No	Yes	Yes
Anodizing	Yes	Yes	Yes
Minimum Severity Unit	1U	1U	1U
Fastener Screw Number	12	24	36
Number of Elements For Assembly	4	7	10
Integration	1U	1U	1U
Sub-System Accessibility	Easy	Easy	Easy

FEM Analysis & Results

Free-Free Modal Analysis

Total Mass: 0.270 kg

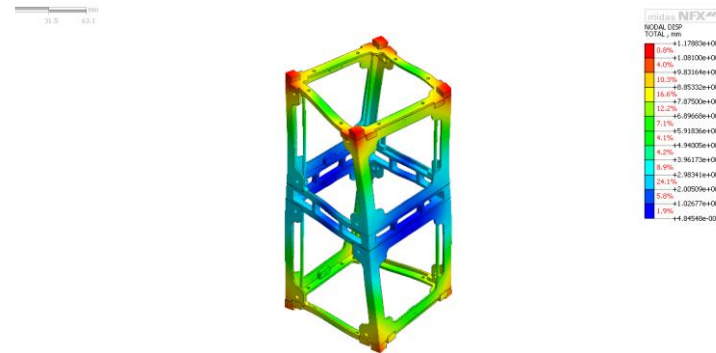
Contacts: Touch contact

Fastener: Screws 1D

Element

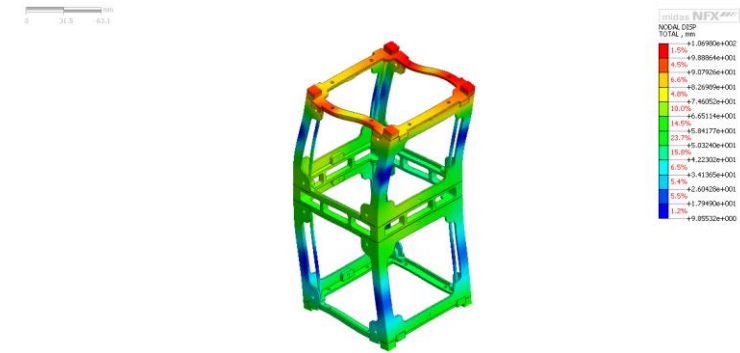
Material:

- Rod and screws: Steel
- **Other structure elements 6061 Alu**



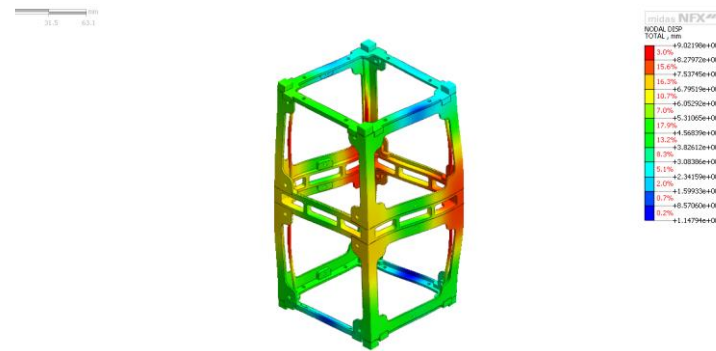
[DATA] Bin_Yydu, Eigenvalue (Required), MODE 7 (FREQ=5.9510e+002), [UNIT] N, mm

First Mod 595.10 Hz



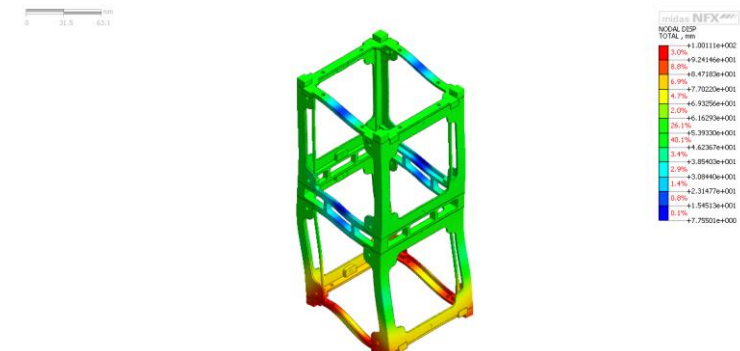
[DATA] Bin_Yydu, Eigenvalue (Required), MODE 8 (FREQ=6.4386e+002), [UNIT] N, mm

Second Mod 643.86 Hz



[DATA] Bin_Yydu, Eigenvalue (Required), MODE 9 (FREQ=6.5227e+002), [UNIT] N, mm

Third Mod 652.37 Hz



[DATA] Bin_Yydu, Eigenvalue (Required), MODE 10 (FREQ=7.3066e+002), [UNIT] N, mm

Fourth Mod 730.66 Hz

FEM Analysis & Results

Free-Free Modal Analysis

Total Mass: 3.0 kg

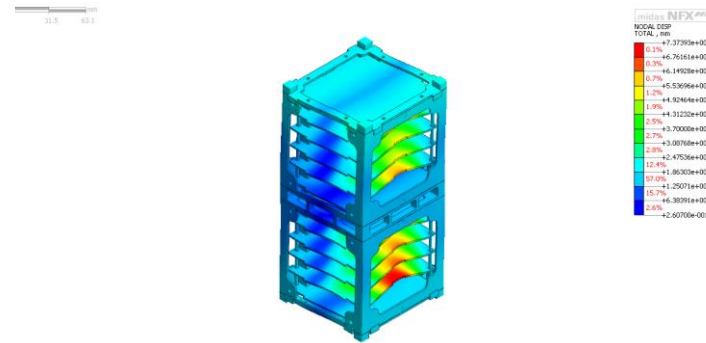
Contacts: Touch contact

Fastener: Screws 1D

Element

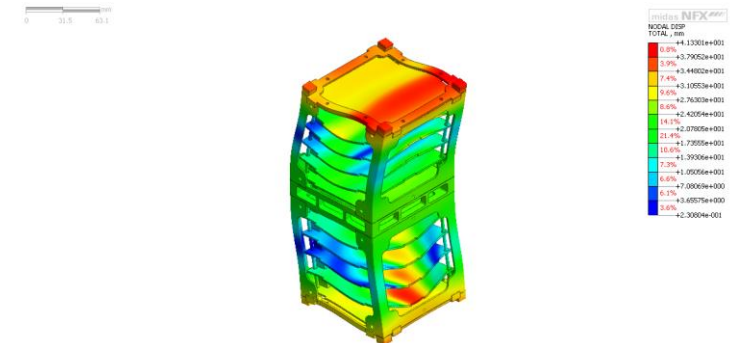
Material:

- **Rod Steel**
- **Other structure elements 6061 Alu**
- **Extra Mass FR4**



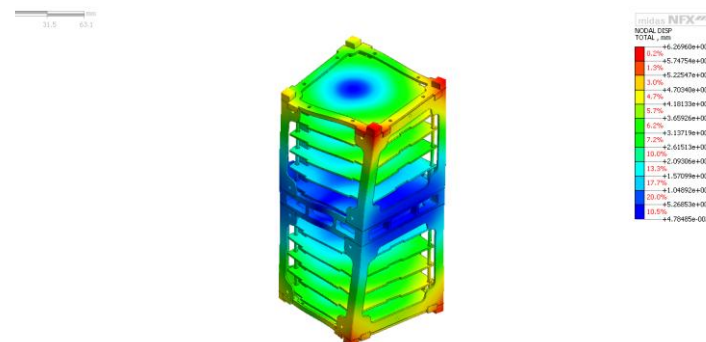
ATA] Yee[Kube-2.5kg, Eigenvalue (Required), MODE 7 (FREQ=3.0572e+002), [UNIT] N, mm

First Mod 305.72 Hz



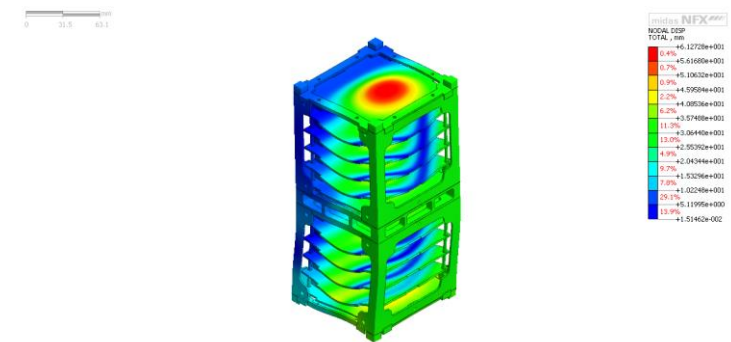
[DATA] Yee[Kube-2.5kg, Eigenvalue (Required), MODE 15 (FREQ=4.0245e+002), [UNIT] N, mm

Second Mod 402.45 Hz



UTA] Yee[Kube-2.5kg, Eigenvalue (Required), MODE 16 (FREQ=4.0377e+002), [UNIT] N, mm

Third Mod 403.77 Hz

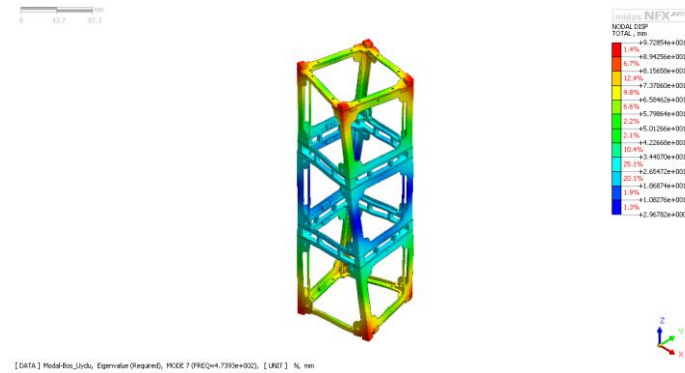


[DATA] Yee[Kube-2.5kg, Eigenvalue (Required), MODE 17 (FREQ=4.1745e+002), [UNIT] N, mm

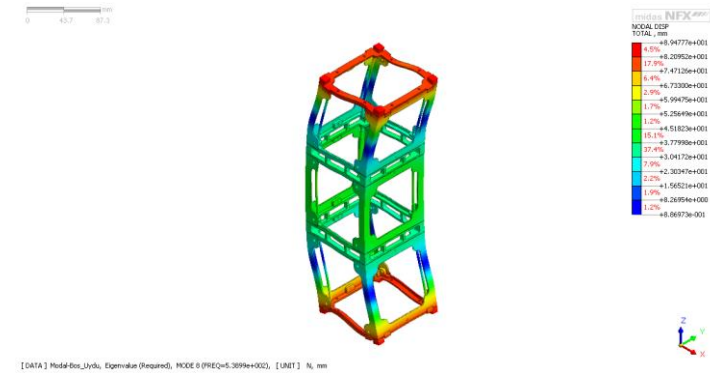
Fourth Mod 417.45 Hz

FEM Analysis & Results

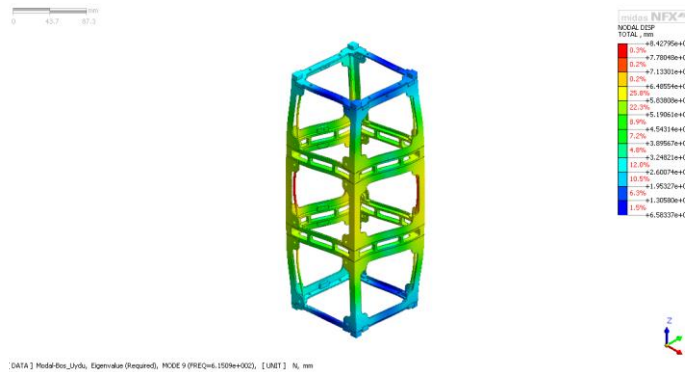
Free-Free Modal Analysis
Total Mass: 0.406 kg



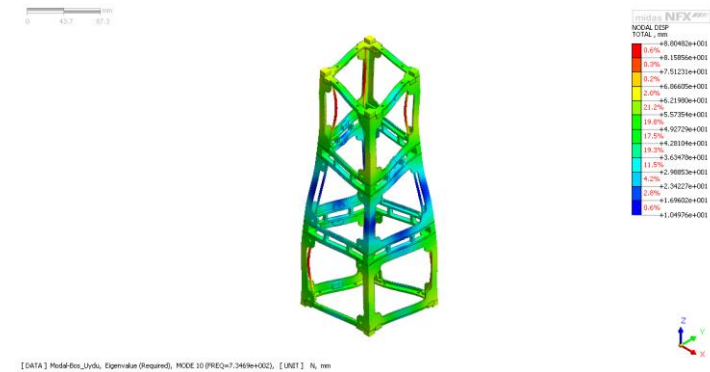
First Mod 473.93 Hz



Second Mod 538.99 Hz



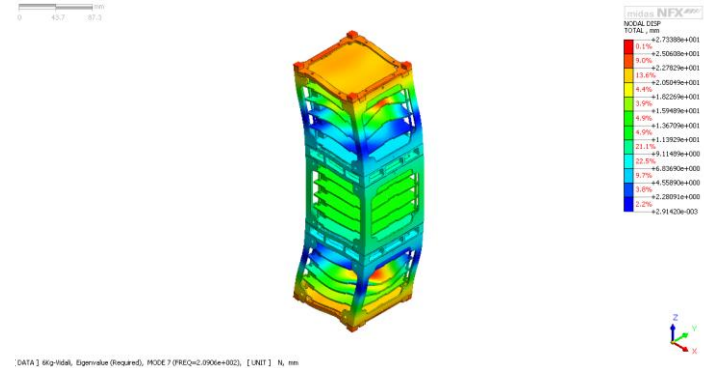
Third Mod 615.09 Hz



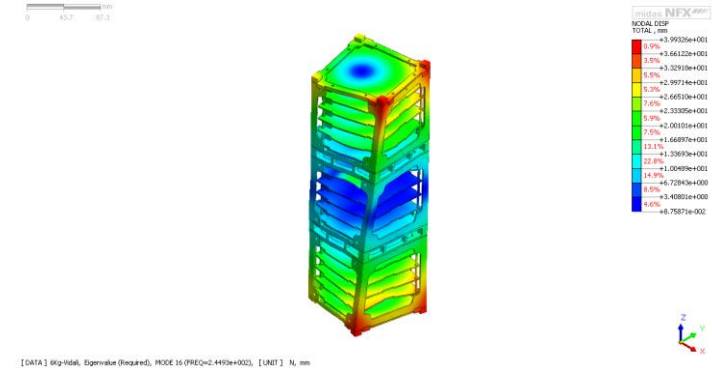
Fourth Mod 734.69 Hz

FEM Analysis & Results

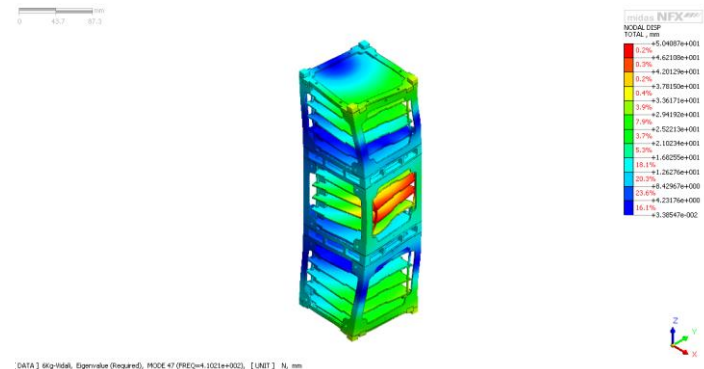
Free-Free Modal Analysis
Total Mass: 6 kg



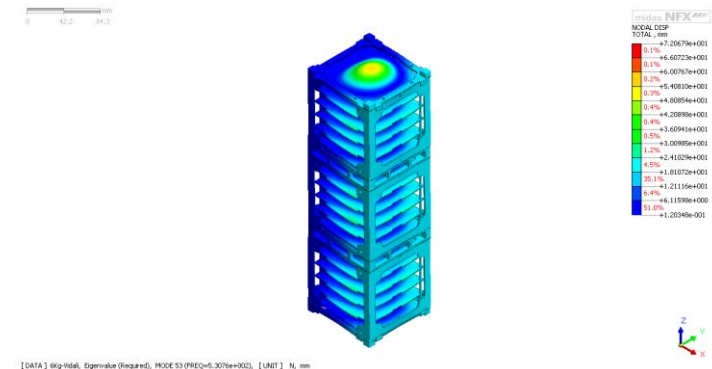
First Mod 209.6 Hz



Second Mod 244.93 Hz



Third Mod 410.21 Hz

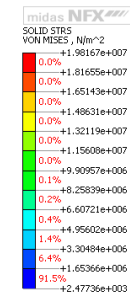
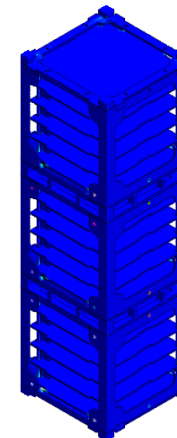
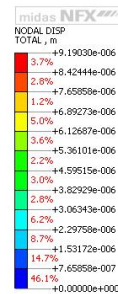
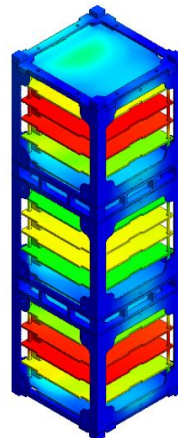
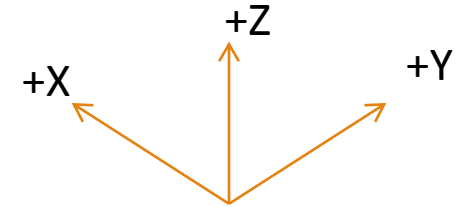


Fourth Mod 530.76 Hz

FEM Analysis & Results

Quasi-static Acceleration Analysis

Total mass: 6 kg
Acceleration: 10 g
Direction: X



[ATA] Yercelimi-10G-X, Linear Static (Required), [UNIT] N, m

Maximum Displacement 9.19 e-6 m

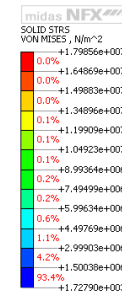
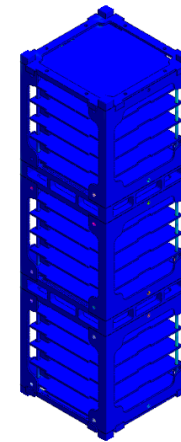
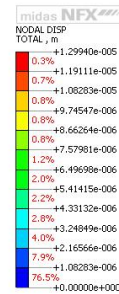
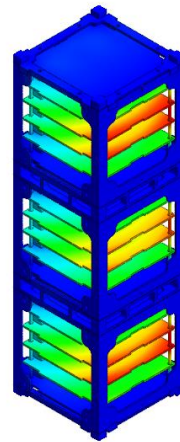
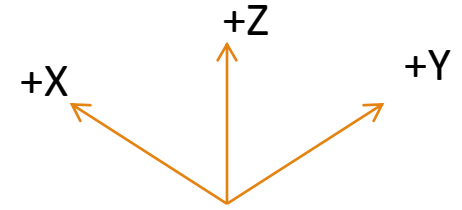
[DATA] Yercelimi-10G-X, Linear Static (Required), [UNIT] N, m

Von Mises Stress, Maximum Stress 19.8 MPa

FEM Analysis & Results

Quasi-static Acceleration Analysis

Total mass: 6 kg
Acceleration: 10 g
Direction: Y



[ATA] Yercekimi-10G-Y, Linear Static (Required), [UNIT] N, m

[DATA] Yercekimi-10G-Y, Linear Static (Required), [UNIT] N, m

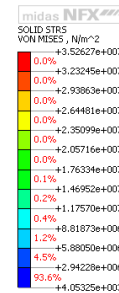
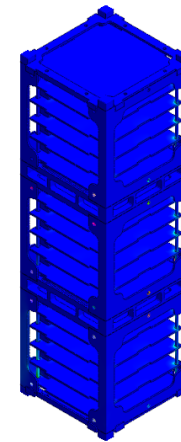
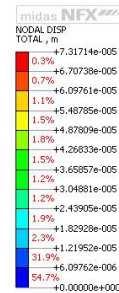
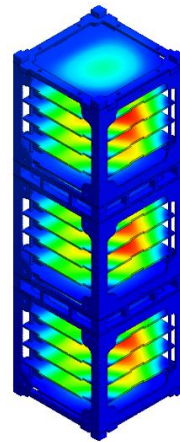
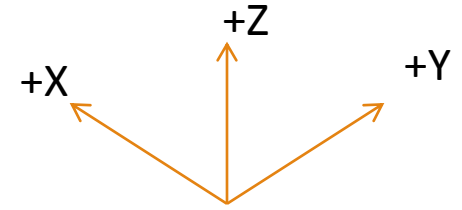
Maximum Displacement 1.29 e-5 m

Von Mises Stress, Maksimum Stress 17.9 MPa

FEM Analysis & Results

Quasi-static Acceleration Analysis

Total mass: 6 kg
Acceleration: 10 g
Direction: Z



[ATA] Yercekimi-10G-Z, Linear Static (Required), [UNIT] N, m

[DATA] Yercekimi-10G-Z, Linear Static (Required), [UNIT] N, m

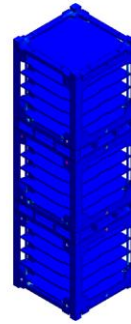
Maximum Displacement 7.31 e-5 m

Von Mises Stress, Maximum Stress 35.2 MPa

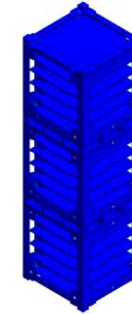
FEM Analysis & Results

Random Vibration Analysis Total Mass: 6 kg

0.0415 0.0031



0.0415 0.0031



[ATA] ModalRandomAnalysis-X, Modal Random Analysis, RMS, [UNIT] N, n (1 Sigma - 68.26894%)

X Direction RMS Von Mises Stress 8.56 MPa

[DATA] ModalRandomAnalysis-Y, Modal Random Analysis, RMS, [UNIT] N, n (1 Sigma - 68.26894%)

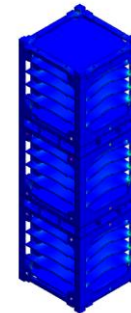
Y Direction RMS Von Mises Stress 8.21 MPa

Frequency (Hz)	Qualification PSD g^2/Hz	Acceptance PSD g^2/Hz
20	0.002	0.001
110	0.002	0.001
250	0.034	0.015
1000	0.034	0.015
2000	0.009	0.004

Random Vibration values are taken from Polar Satellite Launch Vehicle.

Von Mises Stress [MPa]					
Frequency Values [Hz]	20	110	250	1000	2000
X Axis	1.98	2.06	2.40	0.996	0.180
Y Axis	1.80	1.86	2.14	1.04	0.182
Z Axis	1.89	2.30	17.3	0.131	0.0312

0.0415 0.0031



[DATA] ModalRandomAnalysis-Z, Modal Random Analysis, RMS, [UNIT] N, n (1 Sigma - 68.26894%)

Z Direction RMS Von Mises Stress 26.4 MPa

Qualification Test

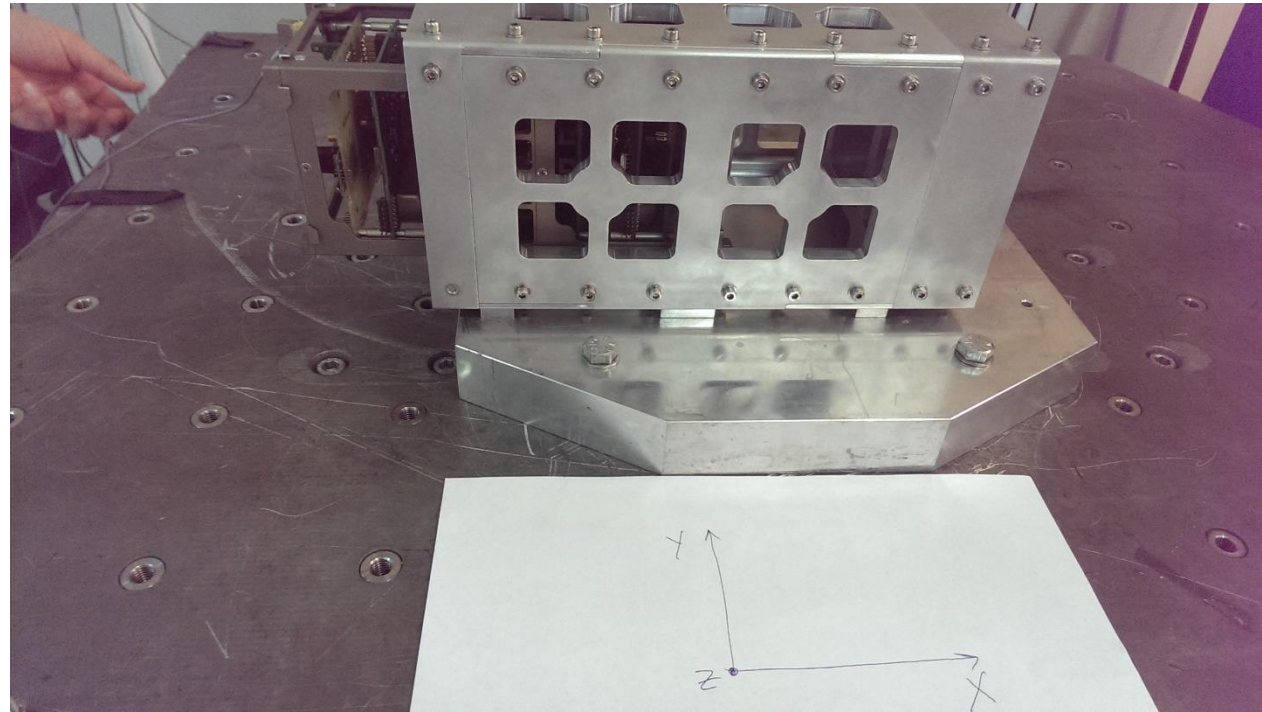
Qualification test made for 2U

Four tests applied:

- Resonance Survey
- Quasi-static acceleration
- Sinusoidal Vibration
- Random Vibration

Test profiles are taken from QB50 requirements.

Tests were performed at Istanbul Technical University Labs.



Qualification Test

Table 6: Acceleration (quasi-static) test characteristics

	Qualification	Acceptance	Protoflight
Reference Frame	{BRF}	{BRF}	{BRF}
Direction	X, Y, Z		X, Y, Z
Amplitude	13 g		10.8 g
Method	Test	Not Required	Test

Table 7: Resonance survey test characteristics

	Qualification, Acceptance or Protoflight	
Resonance survey test	Required	
Reference Frame	{BRF}	
Direction	X, Y, Z	
Type	Harmonic	
Sweep rate	2 oct/min	
Profile	Frequency, [Hz]	Amplitude, [g]
	5	0.15*
	100**	0.15*

Tables are taken from QB50 website, [QB50 Systems Requirements issue 7.pdf](#)

Qualification Test

Table 8: Sinusoidal vibration test characteristics

	Qualification	Acceptance	Protoflight
Sine vibration test	Required	Required	Required
Reference Frame	{BRF}	{BRF}	{BRF}
Direction	X, Y, Z	X, Y, Z	X, Y, Z
Sweep rate	2 oct/min	4 oct/min	4 oct/min
Profile	Frequency, Amplitude, [Hz] [g]	Frequency, Amplitude, [Hz] [g]	Frequency, Amplitude, [Hz] [g]
	5 - 100 2.5	5 - 100 2	5 - 100 2.5
	100 - 125 1.25	100 - 125 1	100 - 125 1.25

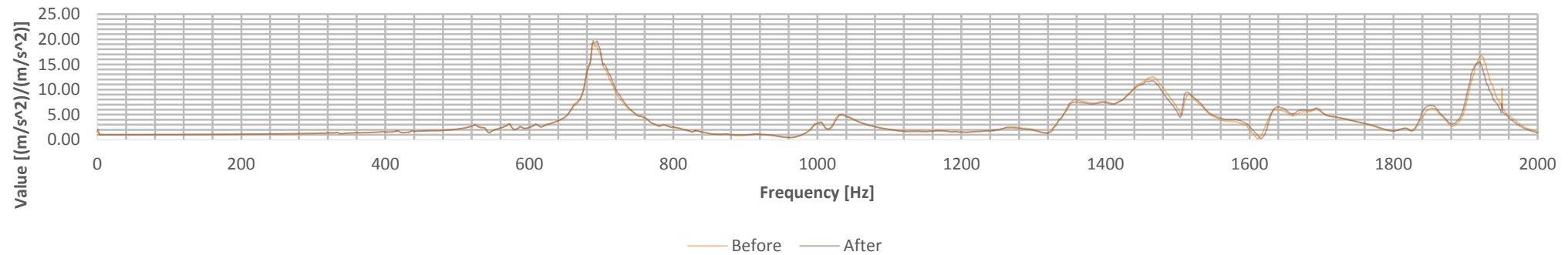
Table 9: Random vibration test characteristics

	Qualification	Acceptance	Protoflight
Random vibration test	Required	Required	Required
Reference Frame	{BRF}	{BRF}	{BRF}
Direction	X, Y, Z	X, Y, Z	X, Y, Z
RMS acceleration	8.03 g	6.5 g	8.03 g
Duration	120 s	120 s	120 s
Profile	Frequency, Amplitude, [Hz] [g ² /Hz]	Frequency, Amplitude, [Hz] [g ² /Hz]	Frequency, Amplitude, [Hz] [g ² /Hz]
	20 0.01125	20 0.007	20 0.01125
	130 0.05625	50 0.007	130 0.05625
	800 0.05625	200 0.035	800 0.05625
	2000 0.015	640 0.035	2000 0.015
		2000 0.010	

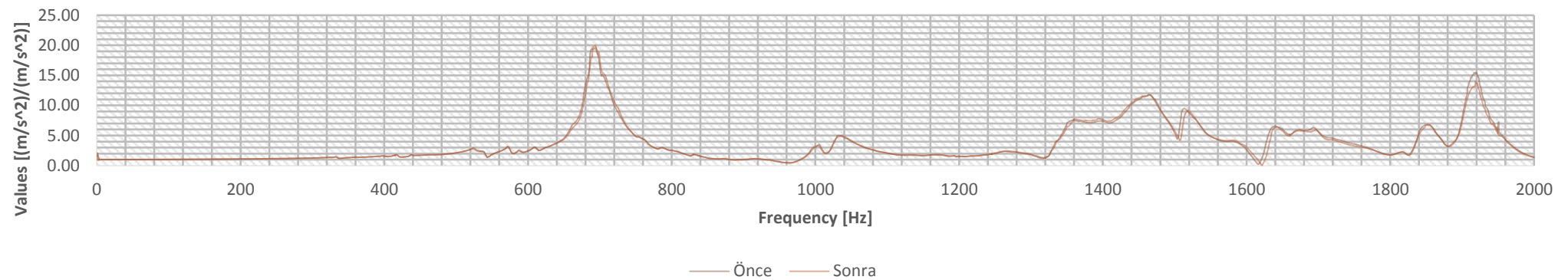
Tables are taken from QB50 website, [QB50 Systems Requirements issue 7.pdf](#)

Qualification Test

Before and After of Quasi-Static Test for X Axis Resonance Survey Test Results

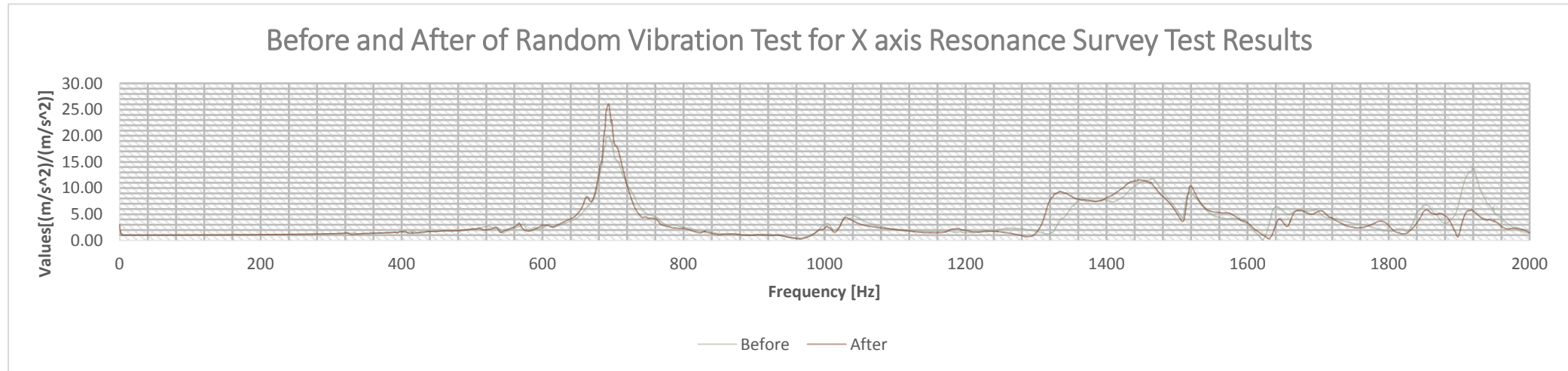


Before and After of Sinusoidal Vibration Test for X Axis Resonance Survey Test Results



**Önce-Befor
Sonra-After**

Qualification Test & Conclusion



- NART-ST was passed qualification tests and it will have space heritage at QB50 projects with BeEagleSat and HAVELSAT CubeSats.

**THANK YOU!
QUESTIONS?**

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