



# Global Ecosystem Dynamics Investigation (GEDI) Structural Verification Unit (SVU) Vibration Test

Structures, Loads and Dynamics, and  
Mechanical Systems Early Career Forum  
August 21st – 24th, 2018

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G O D D A R D   S P A C E   F L I G H T   C E N T E R



# Agenda



- Introduction
- Overview
- Structural Verification Unit Description
- Instrumentation
- Limiting Requirements
- Force Limiting
- SVU Test Lessons Learned
- Protoflight Instrument Testing



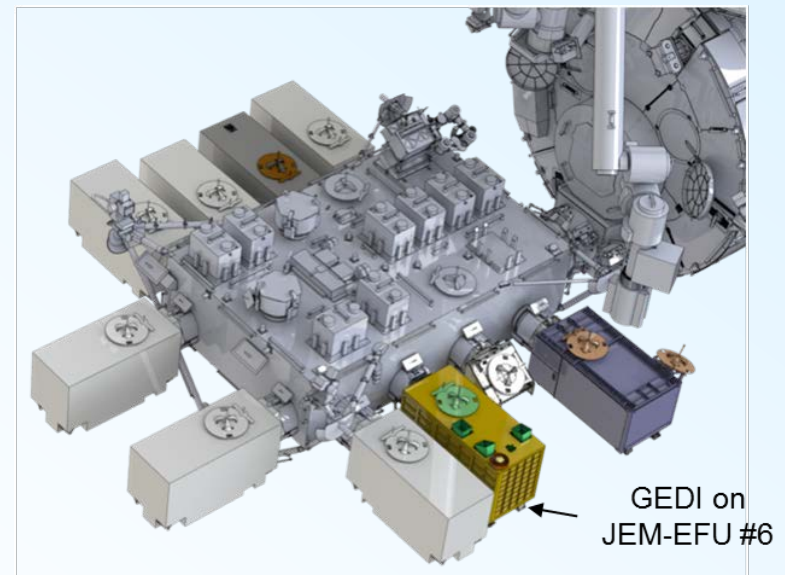


# GEDI Mission Overview



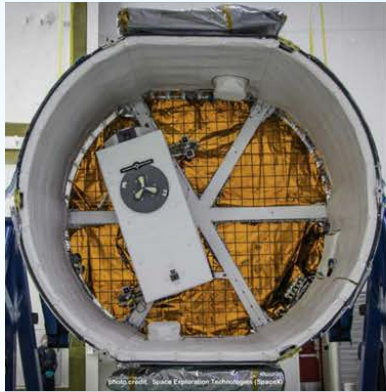
## What is GEDI?

- Global Ecosystem Dynamics Investigation
  - Multi-Beam LIDAR Experiment
- ISS payload
  - Dock to Japanese Experiment Module (JEM) external facility at Payload Interface Unit (PIU)
- SpaceX Falcon 9 Launch Vehicle
  - Integrate to Dragon Trunk payload flight support equipment (pFSE) Interface





# Journey to ISS



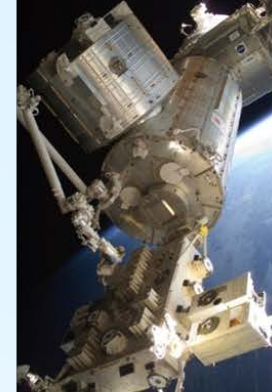
Integrate to Dragon Trunk  
pFSE Interface



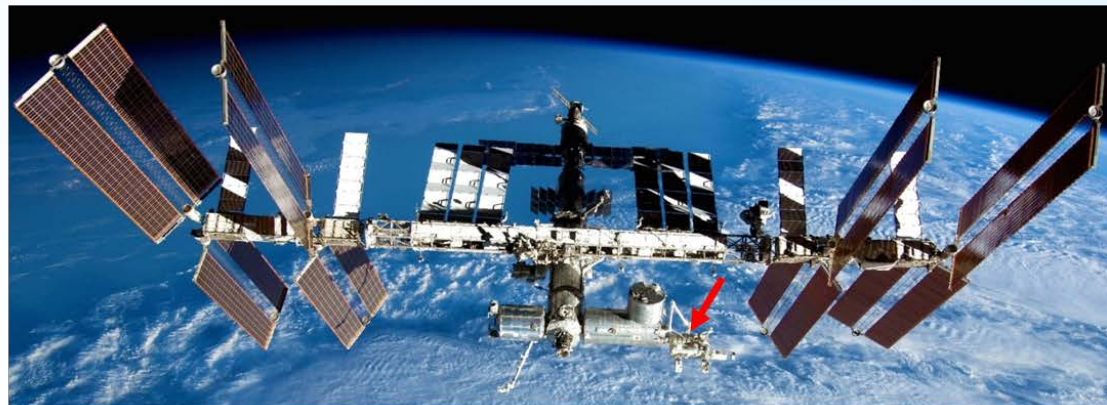
Falcon 9 Launch  
SpaceX 16



Remove from Trunk  
H-Fixture Interface



Handover to JEM RMS  
FRGF Interface



Dock to JEM External Facility at PIU Interface



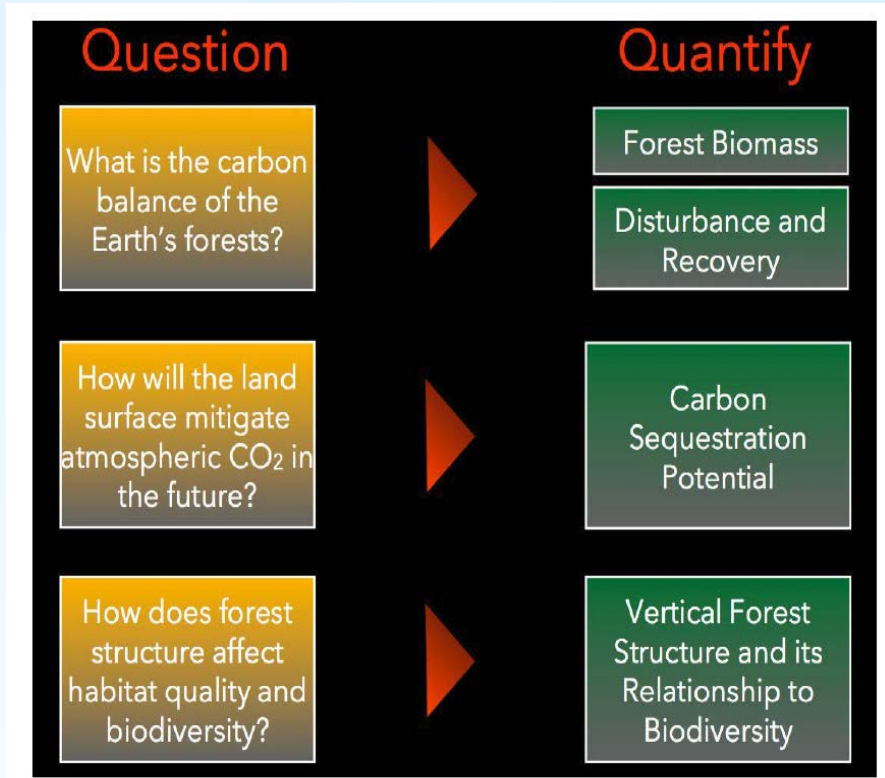


# GEDI Science Overview



## Science Objectives

- First complete high resolution laser ranging observations of 3D forest structure on Earth
- Precise measurements of forest canopy height, canopy vertical structure, and surface elevation
- Improve ability to characterize carbon and water cycling processes





# SVU Vibration Test Campaign Overview



## Objectives

- General Environmental Verification Standard (GEVS) provides requirements on guidelines to derive GEDI test campaign
- Strength qualification of primary structure
- Verification of stiffness through correlation of measured modal frequencies to finite element model
- Aperture Control Mechanism (ACM) assembly level random vibration verification
- Validation of the control approach for sine vibration for future protoflight instrument testing



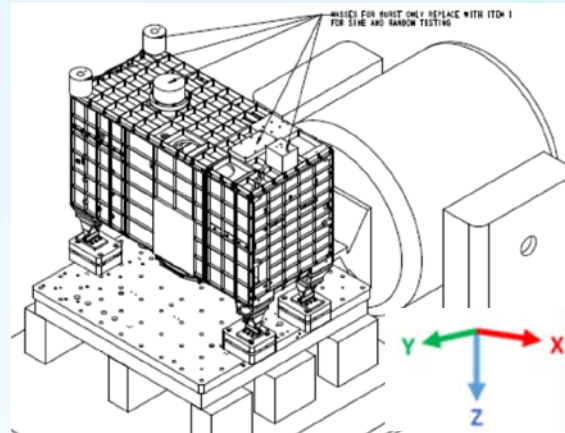


# GEDI Structural Verification Unit



## Description

- Prototype primary structure
  - Aluminum box structure comprised of bolted panels
- Protoflight Aperture Control Mechanism (ACM)
- Flight-like Instrument Optical Bench (IOB) flexures
- Mass mockups of subsystems to simulate flight mass levels
- Test masses for load development
- Two test configurations

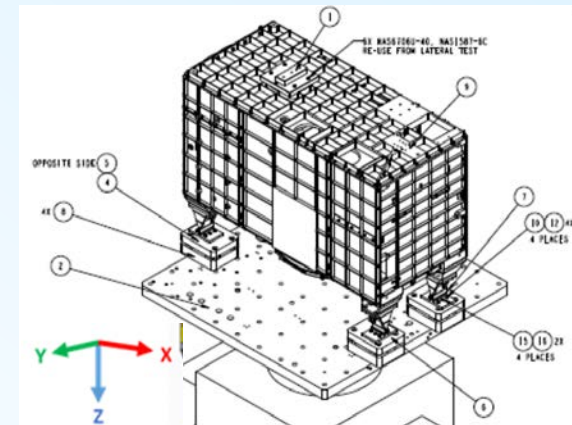


### Heavy Configuration:

- X and Y Sine bursts
- 1489 lbs
- CG: (-4.6", -0.6", -36.5")

### Light Configuration:

- Z Sine burst, all random and spec sine
- 1203 lbs
- CG: (-4.4", -0.6", -31.6")

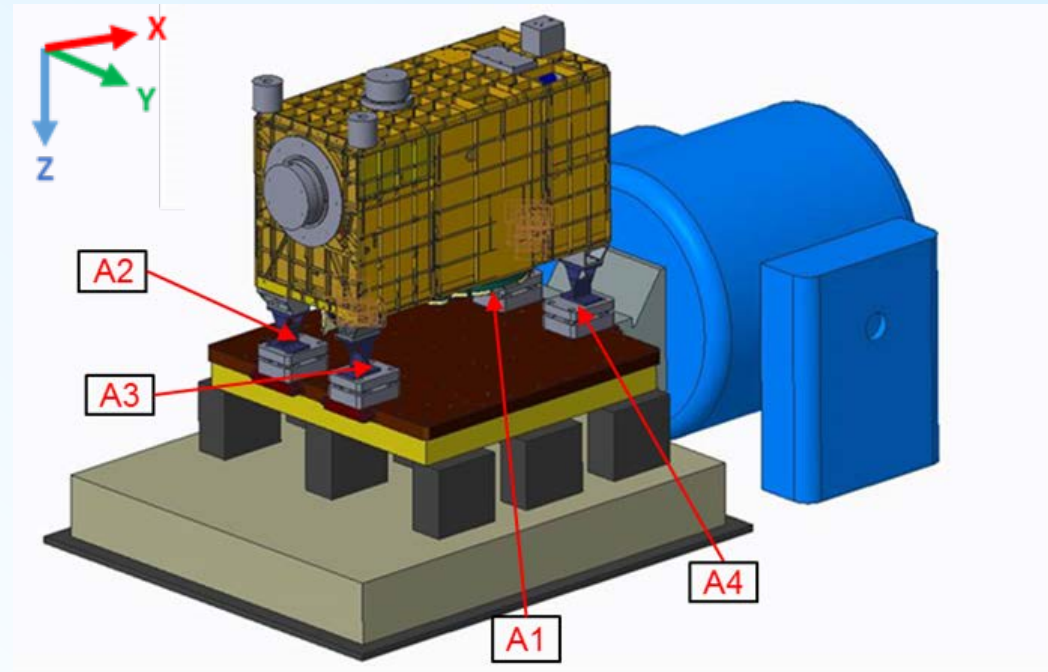




# Vibration Test Plan



- 3 orthogonal axes of vibration
- Low amplitude signature sine sweeps before and after each vibration test to check frequency shifts
- sine vibrate (5-100 Hz), sine burst, random vibrate
- 4 tri-axial control accelerometers
- Backup monitor accelerometer for over-test protection
- 17 tri-axial response accelerometers
  - Response limiting on select channels
- 16 tri-axial force gauges
  - Force and moment response limiting







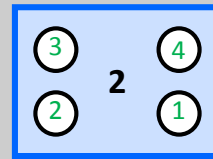
# Force Gauge Layout



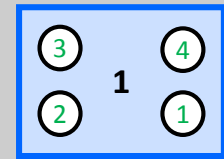
- GEDI's flexures bolt on top of force gauge assembly

- 8 force signals at each interface

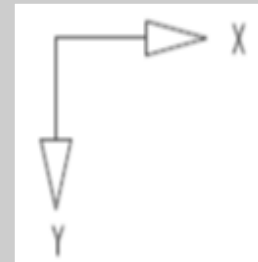
- $F1_z$
- $F2_z$
- $F3_z$
- $F4_z$
- $F1_x + F2_x$
- $F3_x + F4_x$
- $F1_y + F4_y$
- $F2_y + F3_y$



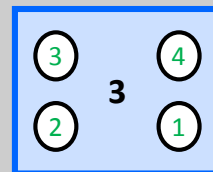
Interface #2



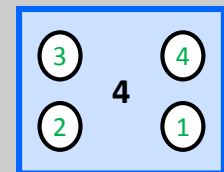
Interface #1



Vibration Fixture Plate



Interface #3



Interface #4



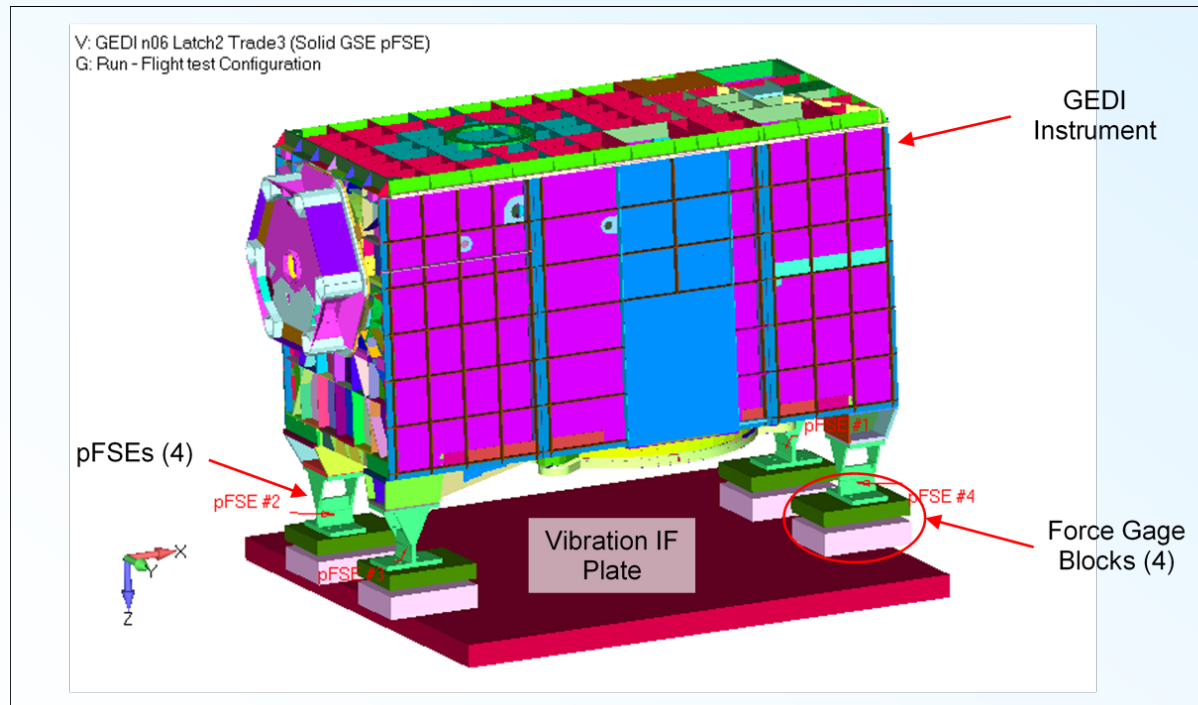


# Why is force limiting necessary?



- Impedance mismatch

- Shaker mounting interface has higher impedance than launch vehicle mounting interface
  - Results in higher loads to the test item for a given base acceleration
- Force limits are implemented at structure resonances to mitigate risk of over-testing





# Real Time Limiting Requirements



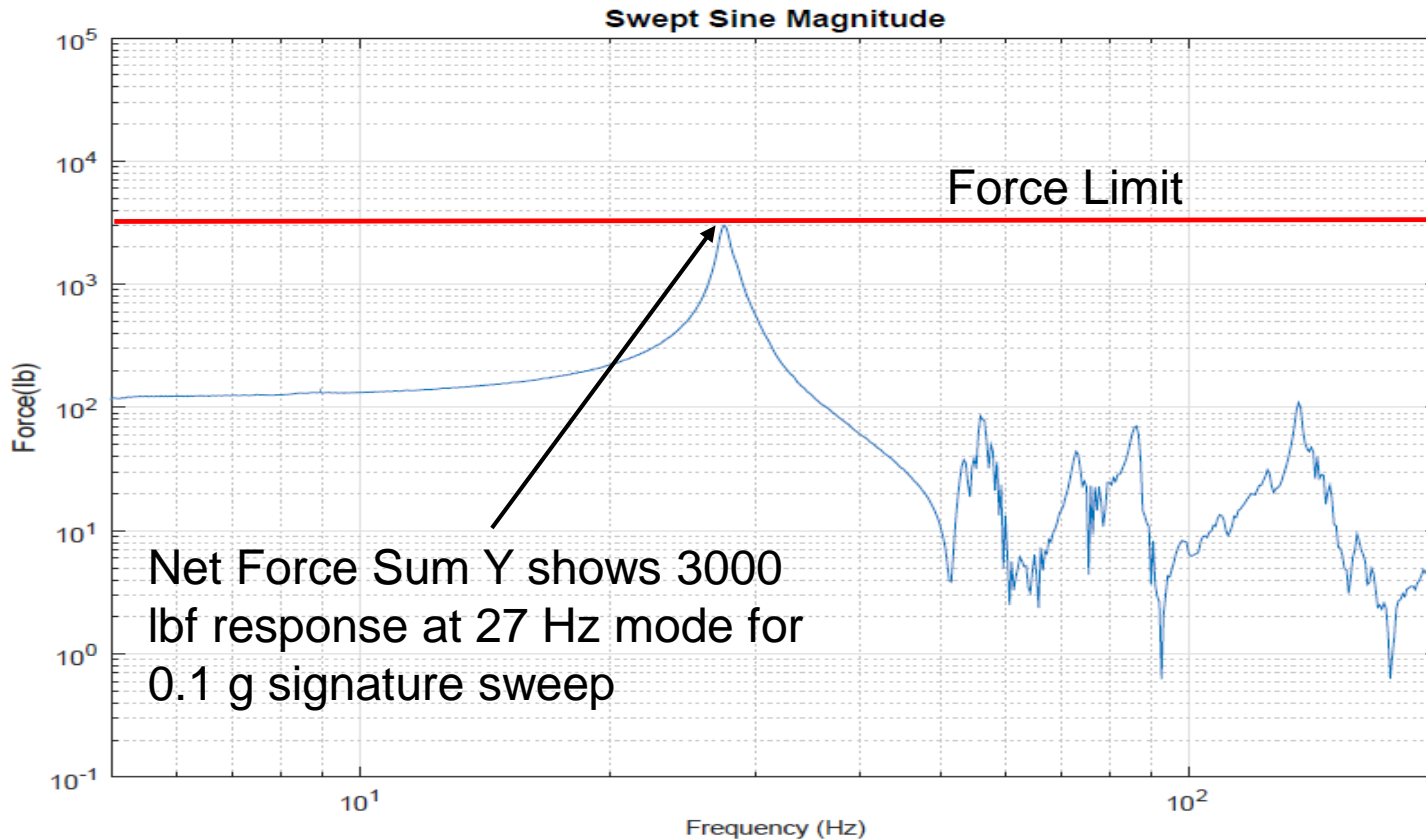
- Acceleration Response
  - PIU Simulator Outer Center (A5)
  - IOB Simulator Center (A6)
- Net Force Sums
  - $\sum F_x$
  - $\sum F_y$
  - $\sum F_z$
- Net Moment Sums
  - $\sum M_x$
  - $\sum M_y$
- Instrumentation setup verified through MATLAB force and moment calculations

$$F_x = \sum_{j=1}^4 \sum_{i=1}^4 FG_{jix}$$
$$F_y = \sum_{j=1}^4 \sum_{i=1}^4 FG_{jyi}$$
$$F_z = \sum_{j=1}^4 \sum_{i=1}^4 FG_{jiz}$$
$$M_x = \sum_{j=1}^4 \sum_{i=1}^4 (P_{jyi} \times FG_{jiz})$$
$$M_y = -\sum_{j=1}^4 \sum_{i=1}^4 (P_{jix} \times FG_{jiz})$$
$$M_z = \sum_{j=1}^4 \sum_{i=1}^4 (-P_{jyi} \times FG_{jix} + P_{jix} \times FG_{jyi})$$





# SVU Vibration Response to 0.1 G Sine Input



**Notes:**

**Maximum Amplitude:**  
3e+03 lb @ 27.47 Hz  
**Minimum Amplitude:**  
0.63 lb @ 92.49 Hz

GEDI : SVU  
Run 77 : Y-Axis : Sweep : 0.1g : 5-200Hz  
Location: Net Sum Y (NETFY)  
Transducer Type: 9067/9068 S/N: S/N

Test Date: 18-AUG-2017 14:51:40.953  
DDAS Channel: 54  
Low Pass Filter: 3686.4 Hz



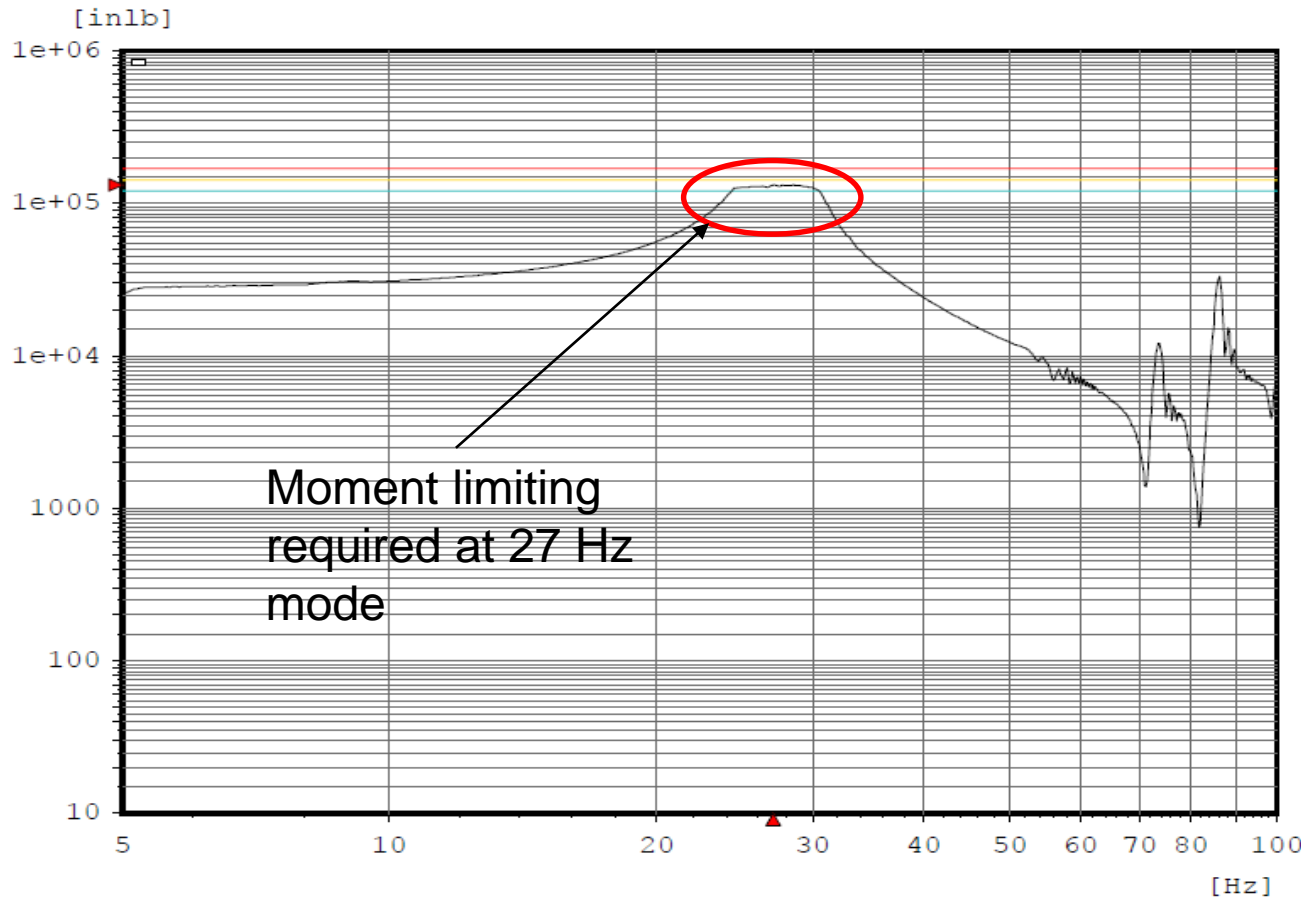
# SVU Moment Limit Example



Max: 27.09 Hz 1.318e+005

Sine  
Test ID: YSwp86

Net Moment X



Moment limiting  
required at 27 Hz  
mode

Chan. no: 32  
Chan. type: W Filtered  
Sweep type: logarithmic  
Sweeps done: 1  
Sweeps ref.: 1  
Sweep direct.: up  
Sweep rate: 4.00 Oct/min  
Contr. strat.: Maximum  
Unit: inlb  
Peak (curr.): 131807 inlb  
Peak (ref.): 0 inlb  
Contr. strat.: Closed loop

-- Testing time --  
elapsed: 000:01:04  
remaining: 000:00:00

Date: 08-21-17  
Time: 11:13:23  
Product version:

Project: GEDI  
Test Item: SVU  
WD-32154  
Standard Sine Sweep  
0.75 gpk 5-100Hz 4 Oct/min

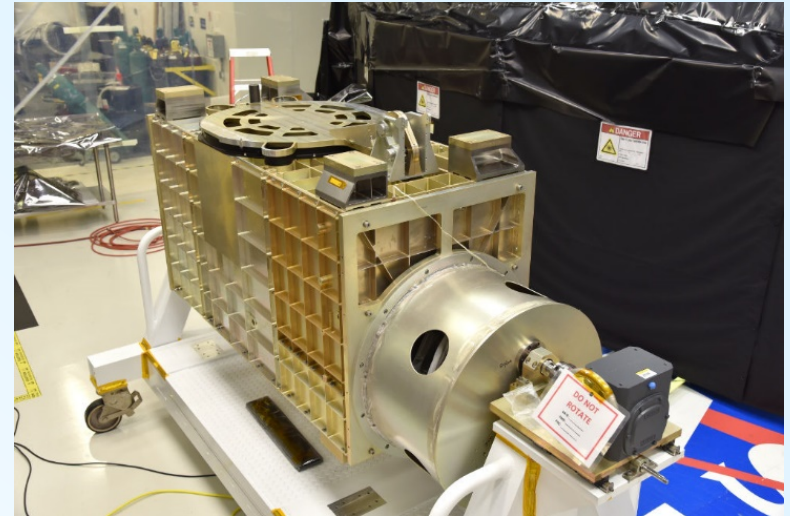


# Protoflight Instrument Vibe Test



## SVU Test Lessons Learned

- Served as dry run for test control and limiting approach
- Provided useful information for model correlation
- Gained insight into dynamic responses
- Protoflight instrumentation will nearly mimic SVU test



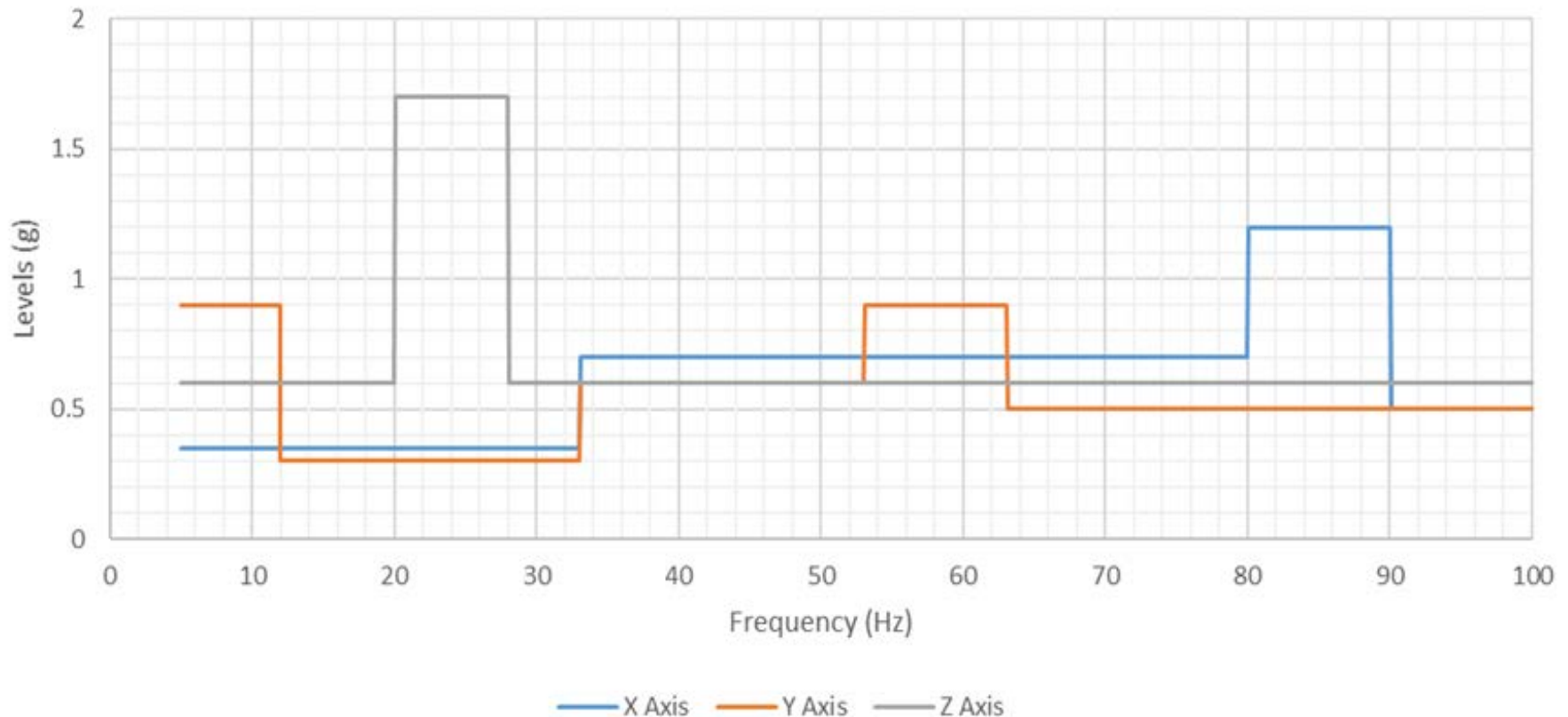


# Protoflight Instrument Sine Vibe Levels



- Loads derived by analysts from Coupled Loads Analysis (CLA), SVU testing to verify low frequency dynamic requirements

GEDI Protoflight Qualification Test Inputs





# Protoflight Instrument Vibe Test Plan



- 27 limit channels including force, moment, and acceleration signals will be used to mitigate risk of over-test

Response Channel	Test Axis		
	X	Y	Z
Net IF Force Sum (FS) X	4000 lb	NA	NA
Net IF Force Sum (FS) Y	NA	4000 lb	NA
Net IF Force Sum (FS) Z	NA	NA	9000 lb
Net IF Moment Sum (FS) X	NA	1.25E5 in-lb	NA
Net IF Moment Sum (FS) Y	1.25E5 in-lb	NA	NA
PIU (A1) X	10 g	10 g	10 g
PIU (A1) Y	10 g	10 g	10 g
PIU (A1) Z	10 g	10 g	10 g
Fiber Tray (A22) X	25 g	25 g	25 g
Fiber Tray (A22) Y	25 g	25 g	25 g
Fiber Tray (A22) Z	25 g	25 g	25 g
GPS Bracket (A3) X	23 g	23 g	23 g
GPS Bracket (A3) Y	23 g	23 g	23 g
GPS Bracket (A3) Z	23 g	23 g	23 g
IOB (A23) X	13 g	13 g	13 g
IOB (A23) Y	13 g	13 g	13 g
IOB (A23) Z	13 g	13 g	13 g
IOB (A24) X	13 g	13 g	13 g
IOB (A24) Y	13 g	13 g	13 g
IOB (A24) Z	13 g	13 g	13 g
Laser 3 Cold Plate (A20) X	30 g	30 g	30 g
Laser 3 Cold Plate (A20) Y	30 g	30 g	30 g
Laser 3 Cold Plate (A20) Z	30 g	30 g	30 g
ST #1 (A4) X	72 g	72 g	72 g
ST #1 (A4) Y	72 g	72 g	72 g
ST #3 (A6) X	72 g	72 g	72 g
ST #3 (A6) Y	72 g	72 g	72 g

• NA - location will not be needed for limiting in that axis of testing





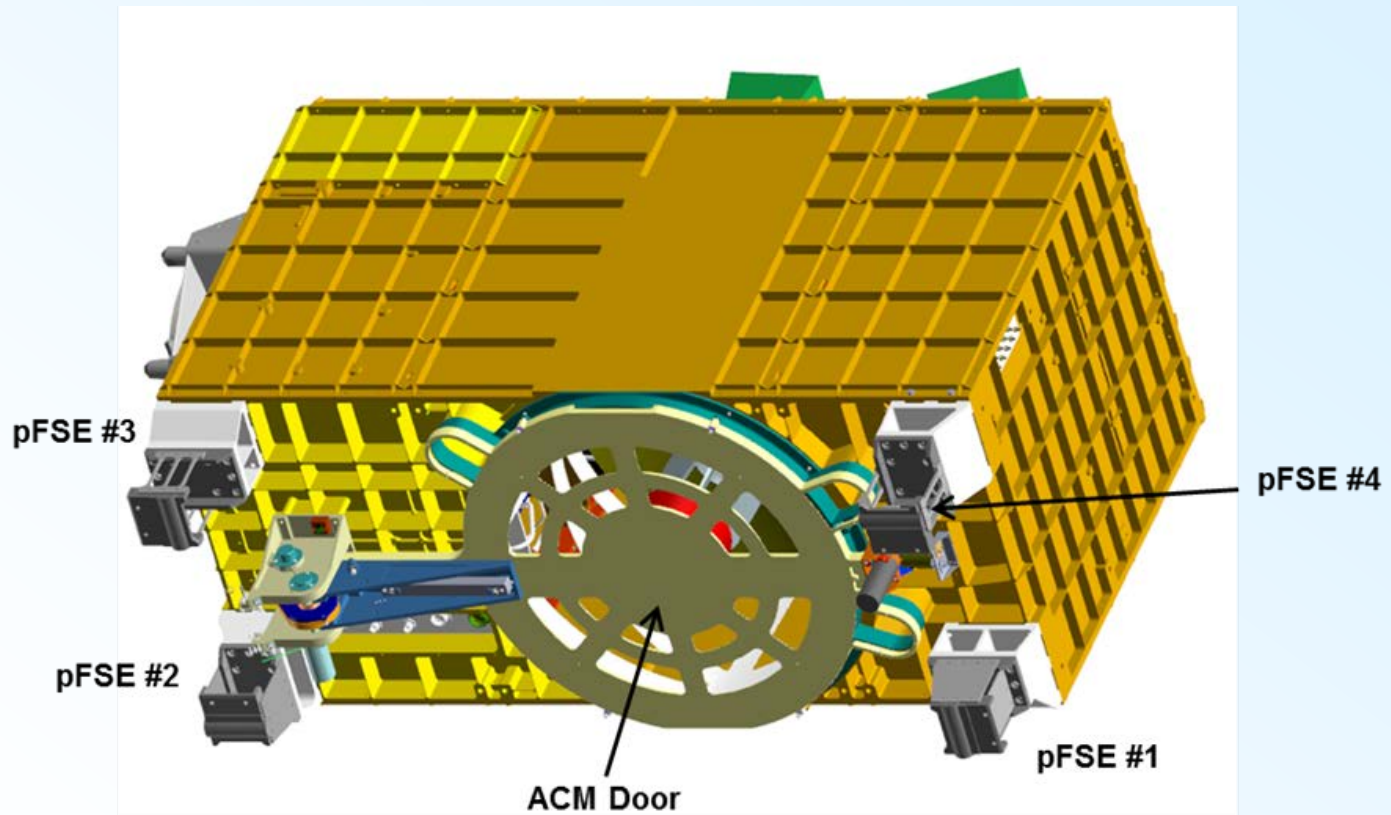


# Questions



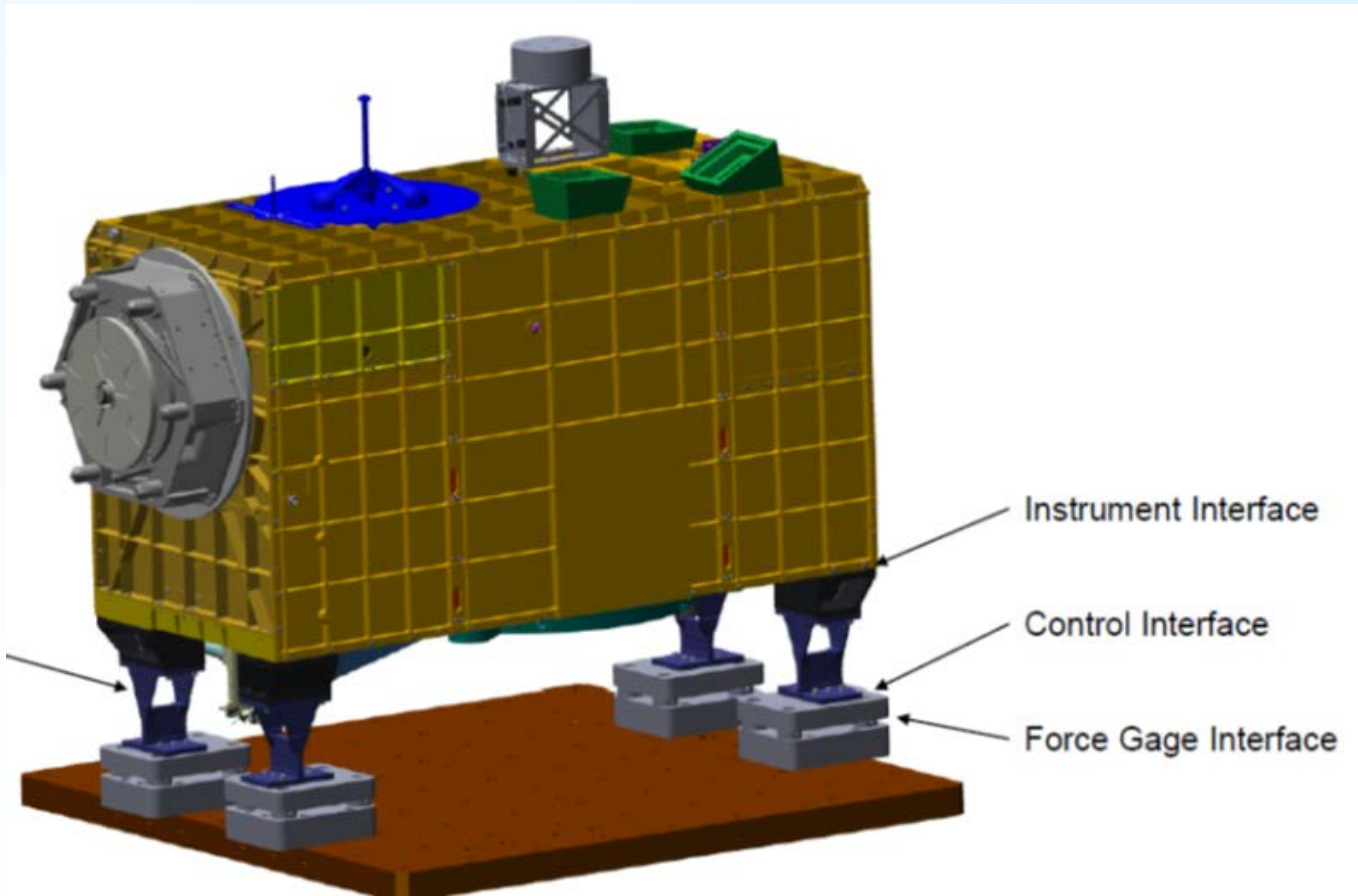


# Backup Slides



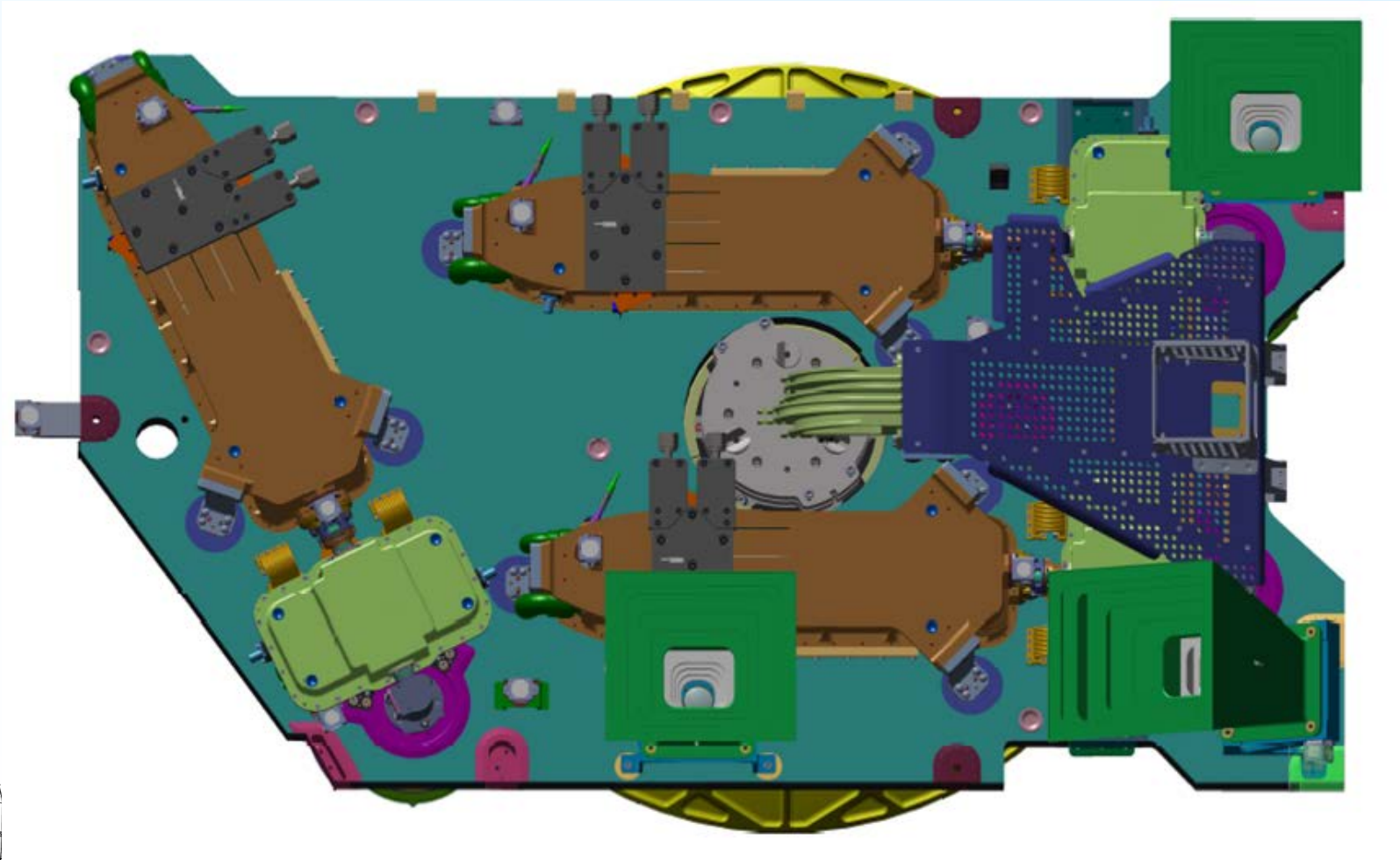


# Backup Slides





# Backup Slides



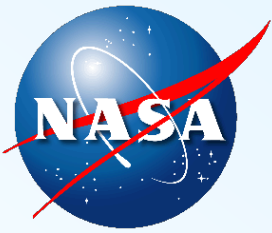


# Backup Slides



Accel/ Force Gage/ Force Sum	Type	Channel Count	Description
<b>Control Accelerometers (Vibration Only)</b>			
C1	Tri-Axial	3	Control on Upper Force Block at interface #1
C2	Tri-Axial	3	Control on Upper Force Block at interface #2
C3	Tri-Axial	3	Control on Upper Force Block at interface #3
C4	Tri-Axial	3	Control on Upper Force Block at interface #4
<b>External Response Accelerometers (Vibration and Acoustic)</b>			
A1	Tri-Axial	3	PIU Outer Center
A2	Tri-Axial	3	ACM Door Center
A3	Tri-Axial	3	GPS Bracket @ Antenna IF
A4	Tri-Axial	3	ST 1 Baffle
A5	Tri-Axial	3	ST 2 Baffle
A6	Tri-Axial	3	ST 3 Baffle
A7	Tri-Axial	3	+Y Panel Near Center of Cold Plate IF
A8	Tri-Axial	3	-Y Panel Near Center of Cold Plate IF
A9	Tri-Axial	3	+X Panel Near Center of Cold Plate IF
A10	-	-	Reserved
A11	Tri-Axial	3	pFSE Standoff Base Interface #1
A12	Tri-Axial	3	pFSE Standoff Base Interface #2
A13	Tri-Axial	3	pFSE Standoff Base Interface #3
A14	Tri-Axial	3	pFSE Standoff Base Interface #4
<b>Internal Response Accelerometers (Vibration and Acoustic)</b>			
A20	Tri-Axial	3	Laser 3 Cold Plate
A21	Tri-Axial	3	Laser 2 Housing Aperture End (align to Laser axis)
A22	Tri-Axial	3	Fiber Tray (underside) @ Tall Stand
A23	Tri-Axial	3	IOB +X/+Y Lift Fitting
A24	Tri-Axial	3	IOB -X Lift Fitting
A25	Tri-Axial	3	BDU #2 Housing
<b>Interface Force Gages (Vibration Only)</b>			
F11-F14	Force Gages	12	Interface #1 – Clockwise beginning with +X+Y gage
F21-F24	Force Gages	12	Interface #2 – Clockwise beginning with +X+Y gage
F31-F34	Force Gages	12	Interface #3 – Clockwise beginning with +X+Y gage
F41-F44	Force Gages	12	Interface #4 – Clockwise beginning with +X+Y gage
<b>Calculated Responses for Force and Moment Summing (Vibration Only)</b>			
FS	Force/Mom Sums	6	Total Force and Moment Summing
FS1	Force/Mom Sums	6	Interface #1 Force and Moment Summing
FS2	Force/Mom Sums	6	Interface #2 Force and Moment Summing
FS3	Force/Mom Sums	6	Interface #3 Force and Moment Summing
FS4	Force/Mom Sums	6	Interface #4 Force and Moment Summing





# Backup Slides

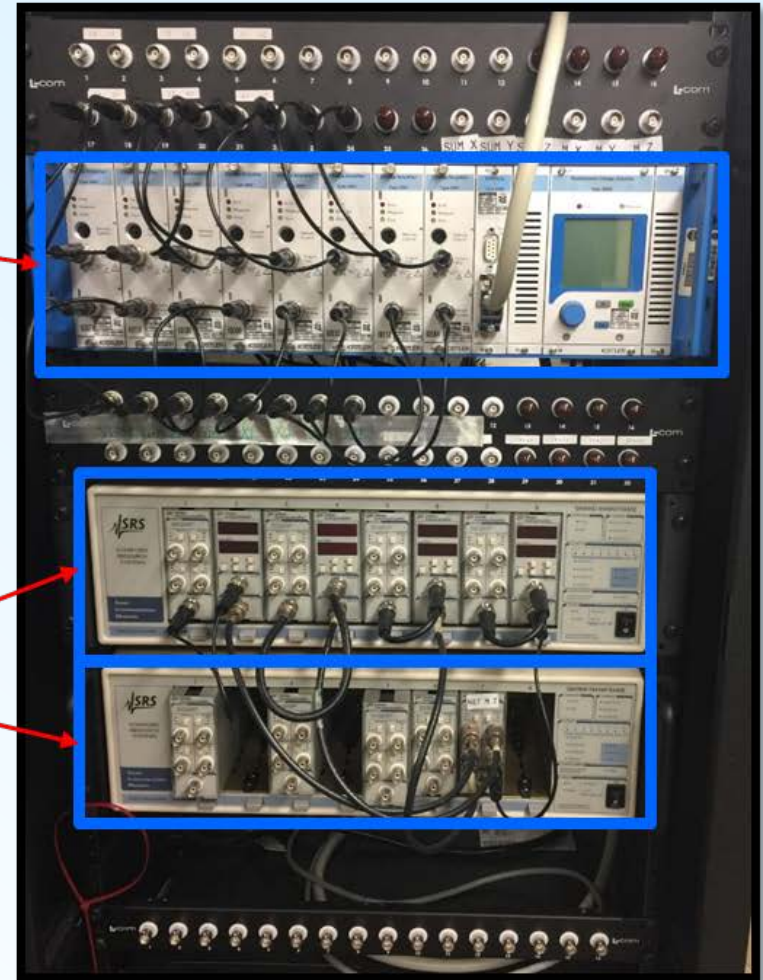


## Kistler 5080 Charge Amplifier

- Provides signal conditioning for force gauge signals
- Outputs force sums and net moments

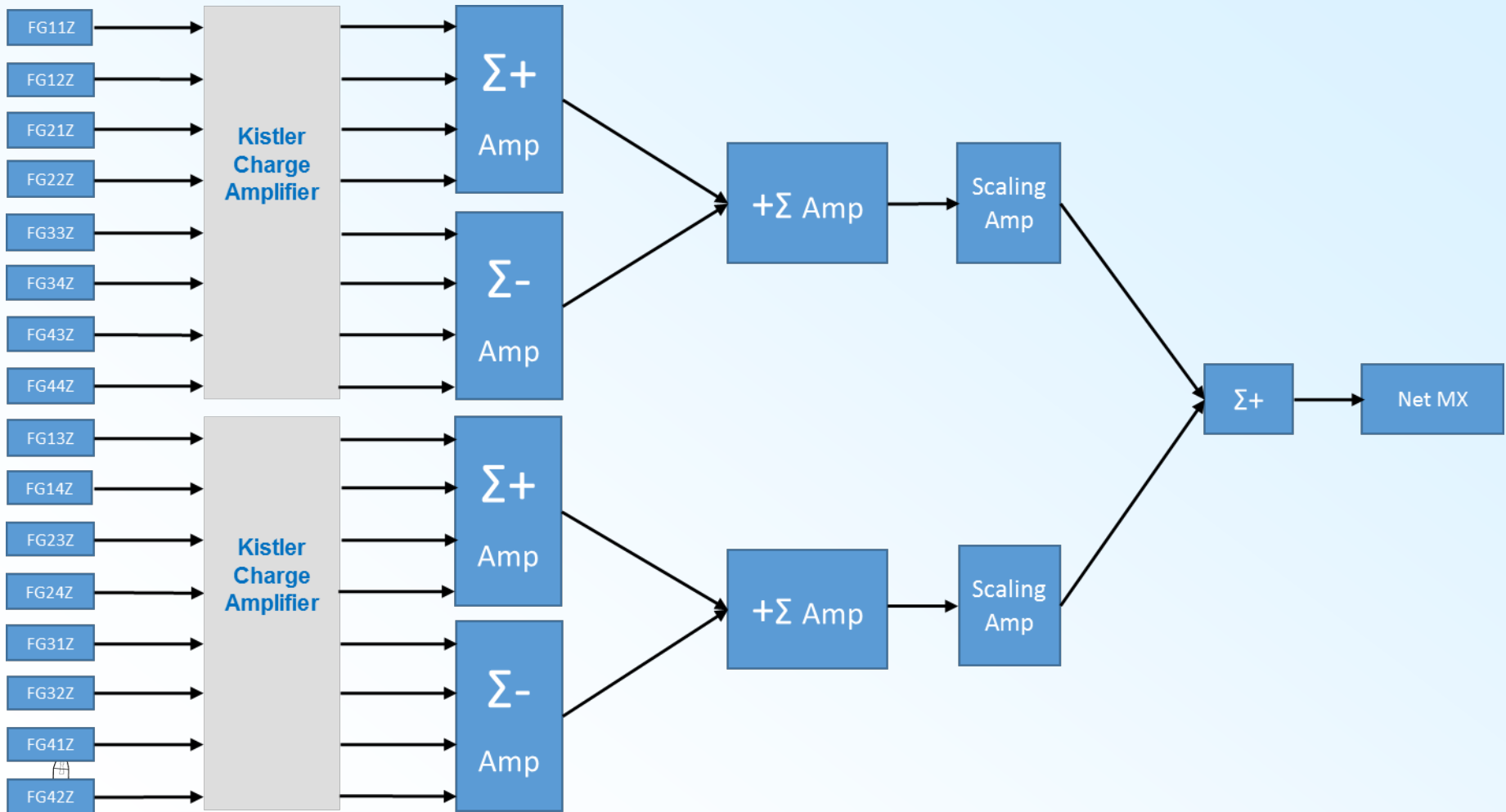
## Summing & Scaling Amps

- Combines appropriate signals and applies scale factor to calculate moment





# Backup Slides





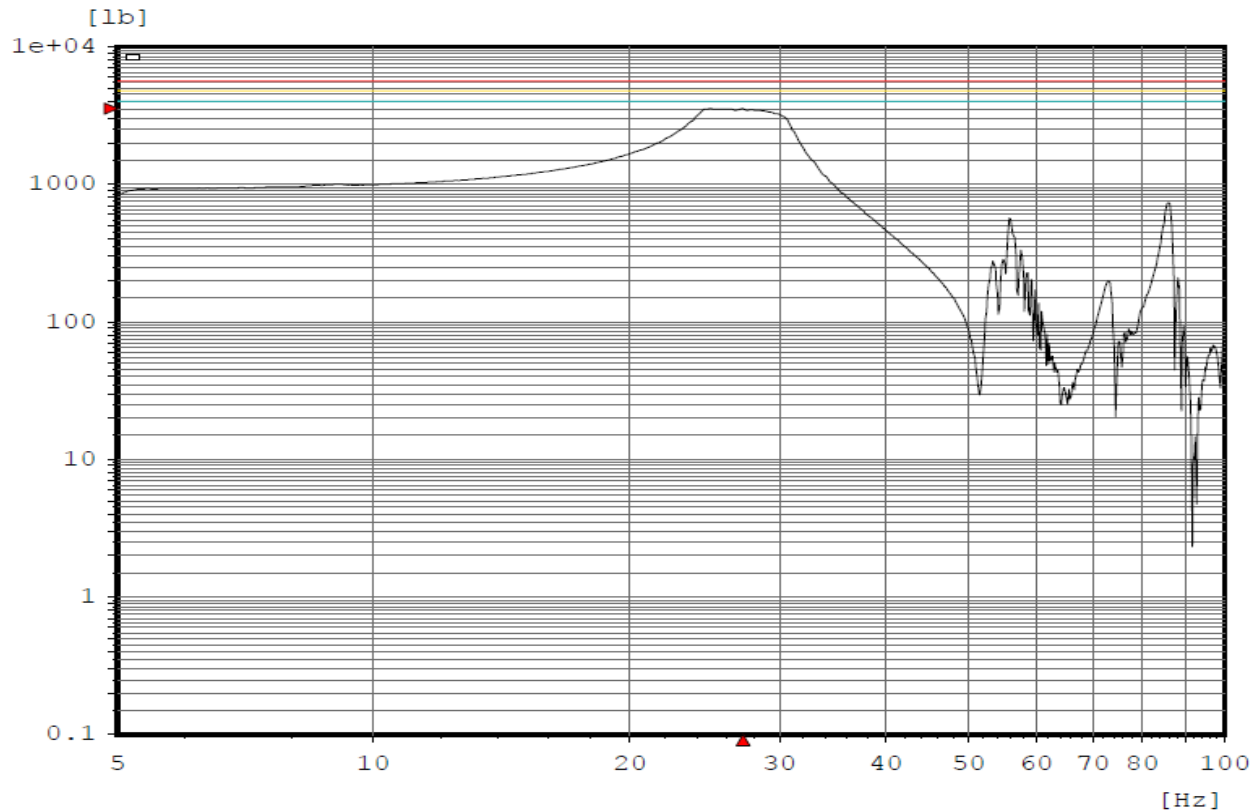
# Backup Slides



Max: 27.17 Hz 3541 lb

Sine  
Test ID: YSwp86

Net Sum Y



Chan. no: 30  
Chan. type: W Filtered  
Sweep type: logarithmic  
Sweeps done: 1  
Sweeps ref.: 1  
Sweep direct.: up  
Sweep rate: 4.00 Oct/min  
Contr. strat.: Maximum  
Unit: lb  
Peak (curr.): 3541 lb  
Peak (ref.): 0 lb  
Contr. strat.: Closed loop

-- Testing time --  
elapsed: 000:01:04  
remaining: 000:00:00

Date: 08-21-17  
Time: 11:13:23  
Product version:

Project: GEDI  
Test Item: SVU  
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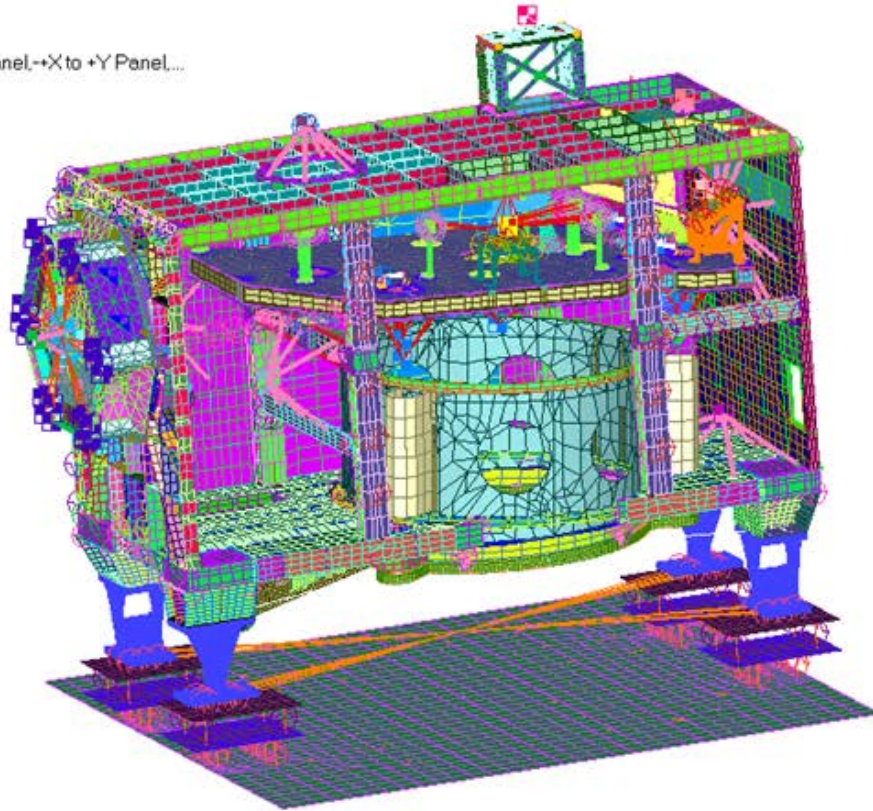




# Backup Slides



V: GEDI  
C: Test SPC and MPCs  
G: Full Model-GEDI Panel (+Y) Side,-X to +Y Panel,->X to +Y Panel...

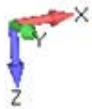
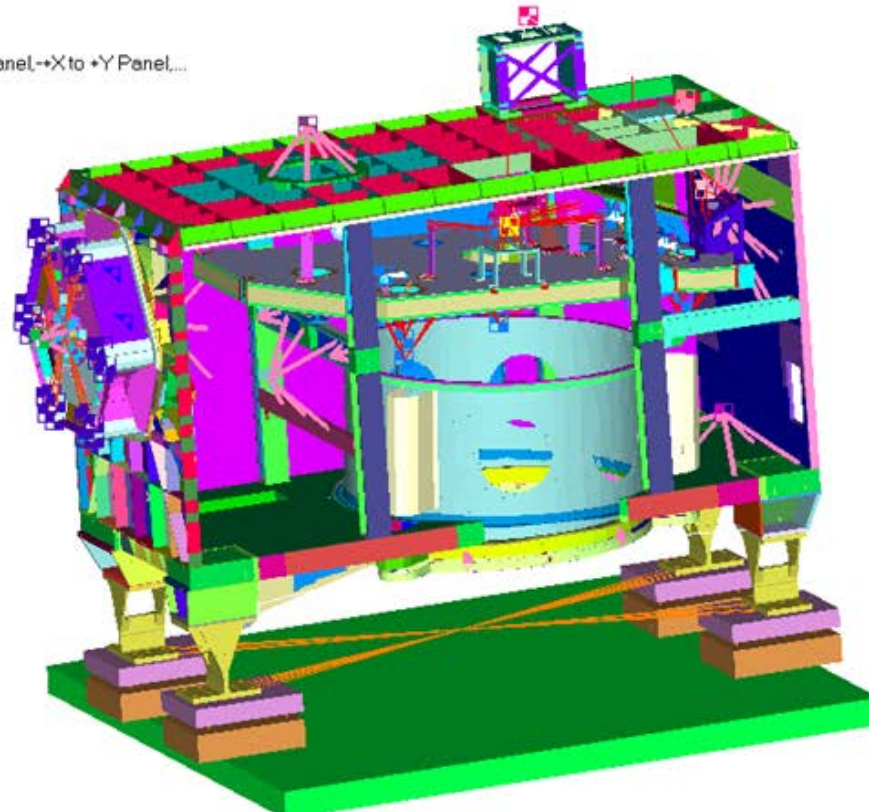




# Backup Slides



V: GEDI  
C: Test SPC and MPCs  
G: Full Model-GEDI Panel (+Y) Side,-X to +Y Panel,+X to +Y Panel,...

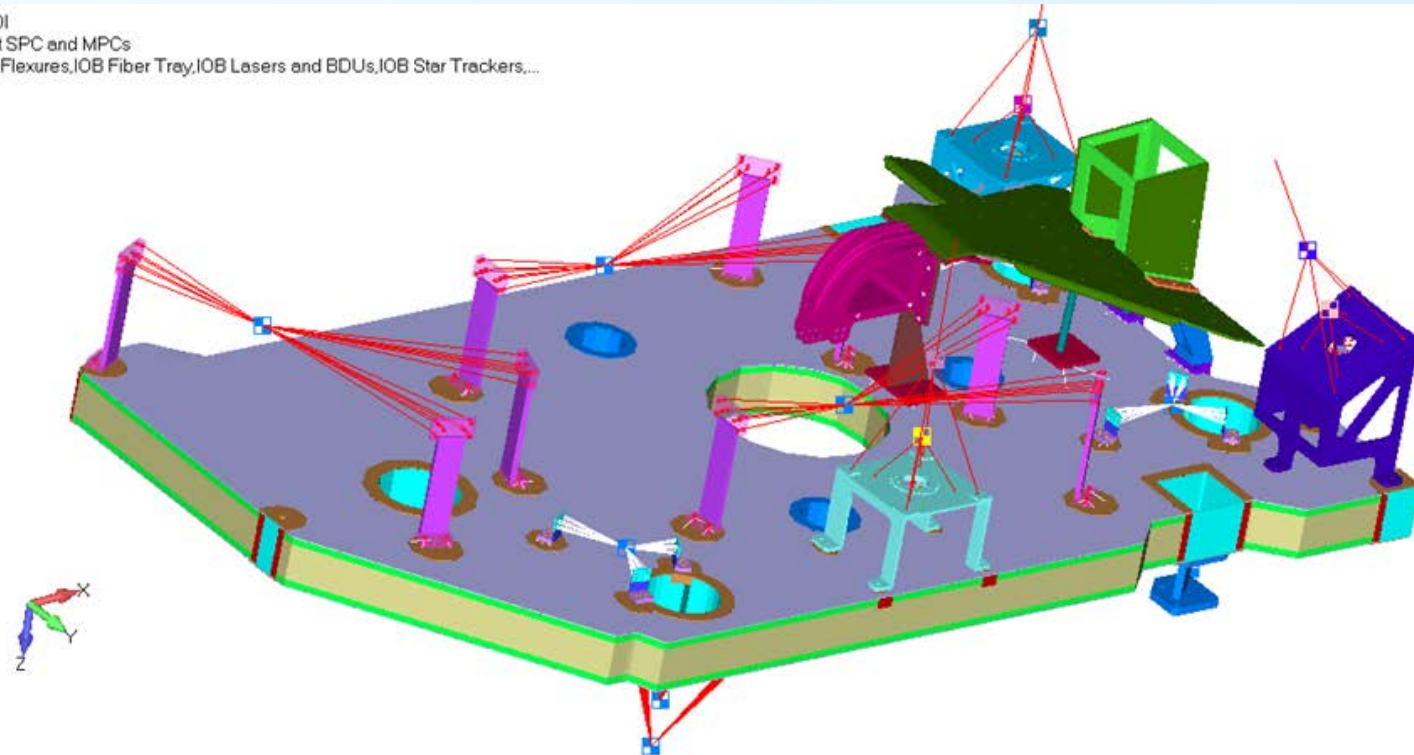




# Backup Slides



V: GEDI  
C: Test SPC and MPCs  
G: IOB Flexures, IOB Fiber Tray, IOB Lasers and BDUs, IOB Star Trackers,...





# Backup Slides



V: GEDI  
C: Test SPC and MPCs  
G: Fixture IF Elements and MPCs, Force Gage Plates, Table IF Plate, GSE pFES 4,...

