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PDV Transfer Function Sensitivity Study
Effect of Rover Mass Variations

Ramses Mourhatch
Reza Nayeri

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mechanical Systems Engineering, Fabrication and Test Division
June 21–23, 2016

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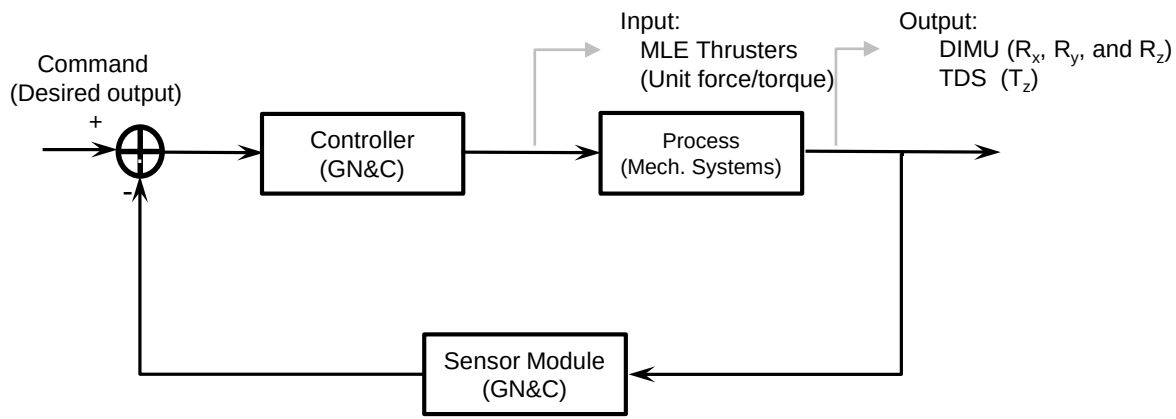
Background

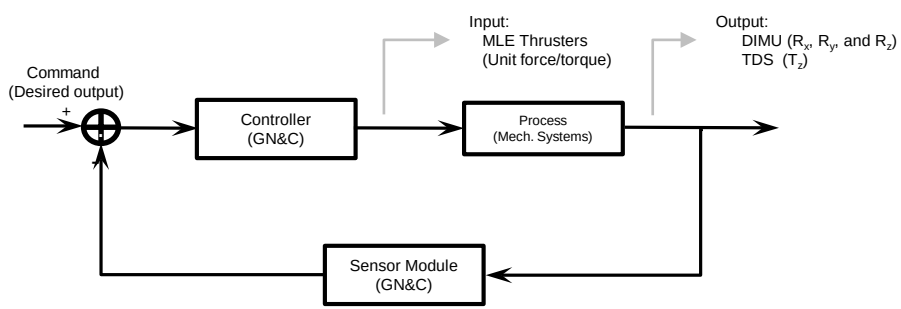
- Mechanical Systems Should Satisfy GN&C requirements for Powered Descent Stage (PDV) and Entry Vehicle (EV)

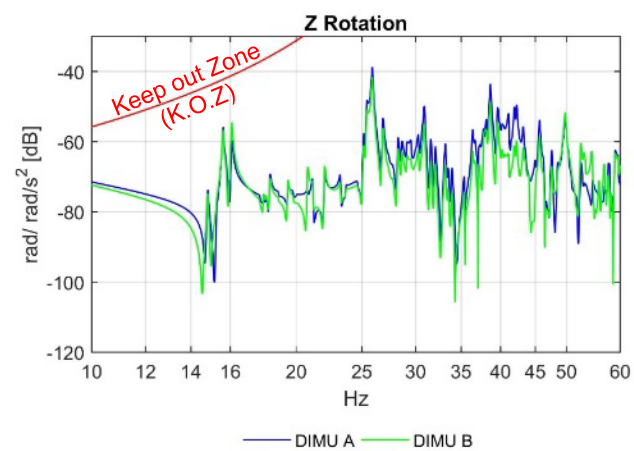


- Requirements:
  - *MECH-126: "The <u>Mechanical System</u> shall ensure that the gain of the <u>open loop transfer</u> functions between MLEs and both DIMU-A and DIMU-B satisfies the bounds specified in D-79409, for all fuel levels."*

Background

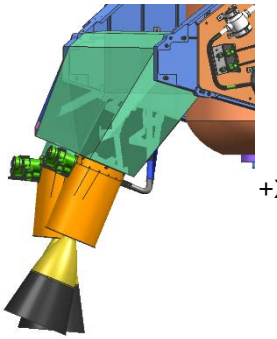
- Transfer Function
  - *Input:*
    - 8 MLE Thrusters : Mars Landing Engines
  - *Output*
    - 2 DIMUs : Descent Inertial Measurement Units – Measure the angular rates
    - 1 TDS: Radar/Terminal Descent Sensor – Measures Z translations during the descent

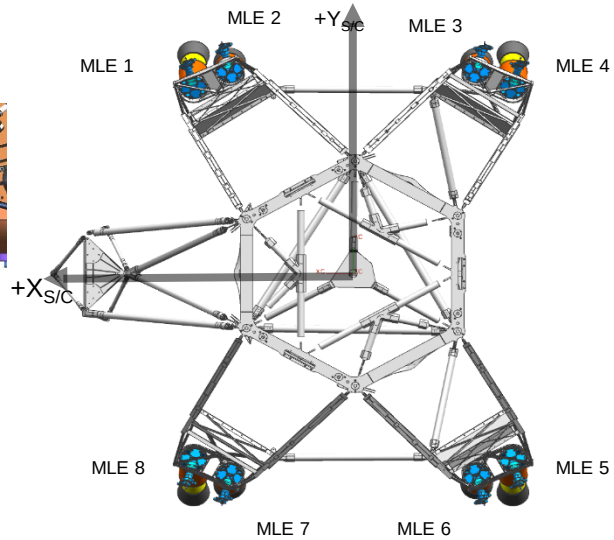




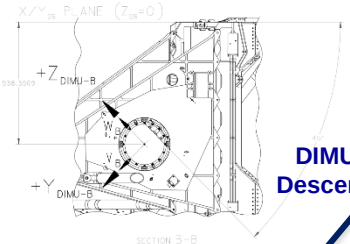
Background

MLEs



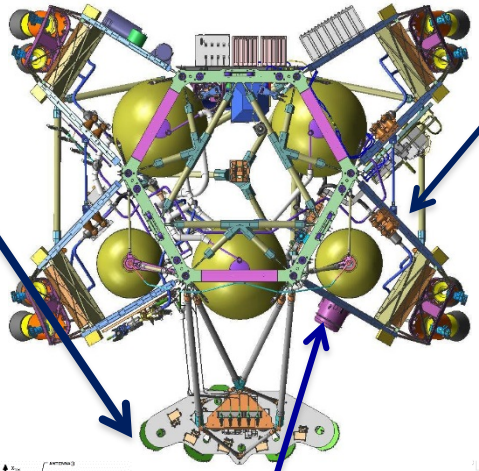


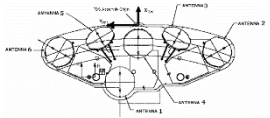
DIMUs and TDS



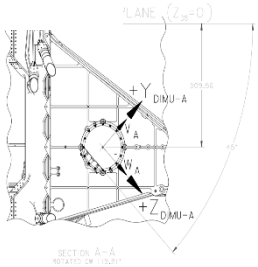
TDS

DIMU_B on Descent Stage





DIMU_A on Descent Stage



Background

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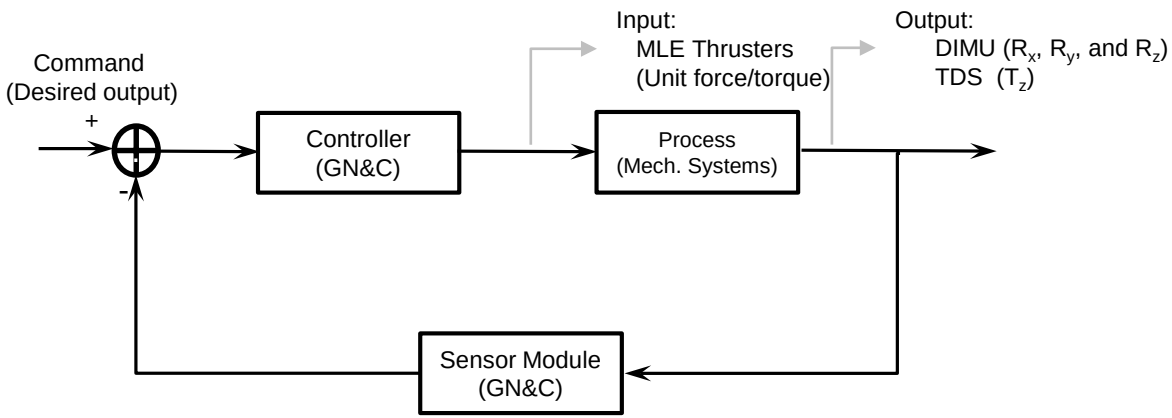
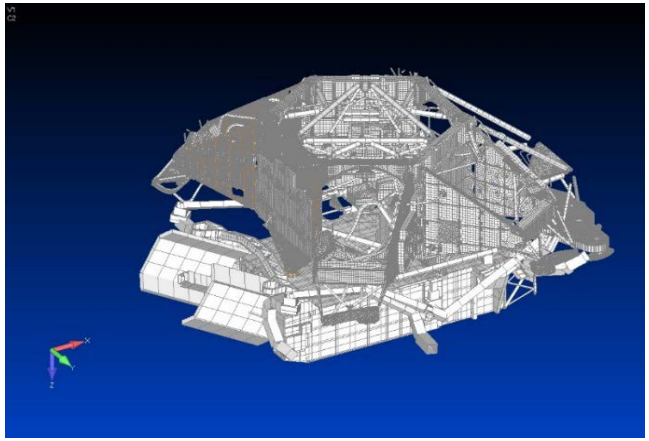


- Requirements:
  - *MECH-126: "The <u>Mechanical System</u> shall ensure that the gain of the <u>open loop transfer</u> functions between MLEs and both DIMU-A and DIMU-B satisfies the bounds specified in D-79409, for all fuel levels."*

PDV Model

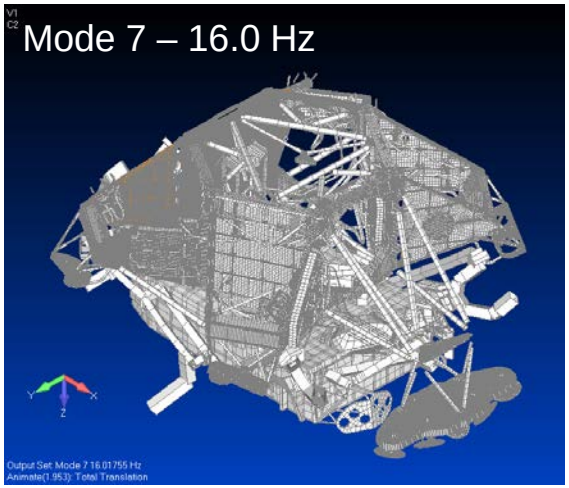
Current PDV model details

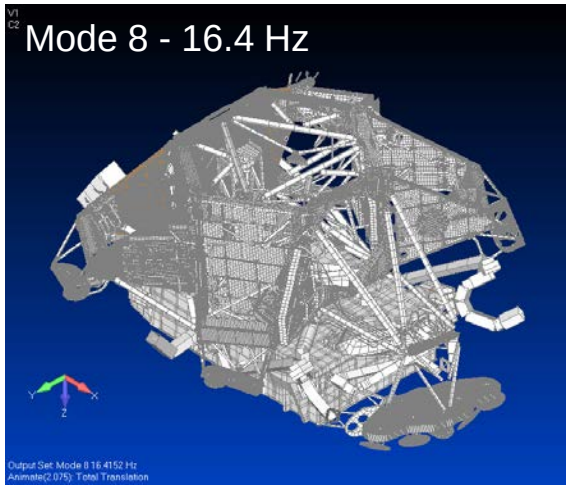
- Descent Stage
  - *Mass:* ***929.3 kg***
    - Dry Mass: ***676 kg***
    - Propellant: ***253.2 kg*** (70 % Fill Ratio)
- Rover
  - *Mass:* ***1050.1 kg*** *(July 15 Freeze: 1052.0 kg)*
  - *Based on Dec 9, 2015 configuration (Rev. 12)*
- PDV
  - *Mass:* ***1979.4 kg*** *(July 15 Freeze: 1981.3 Kg)*

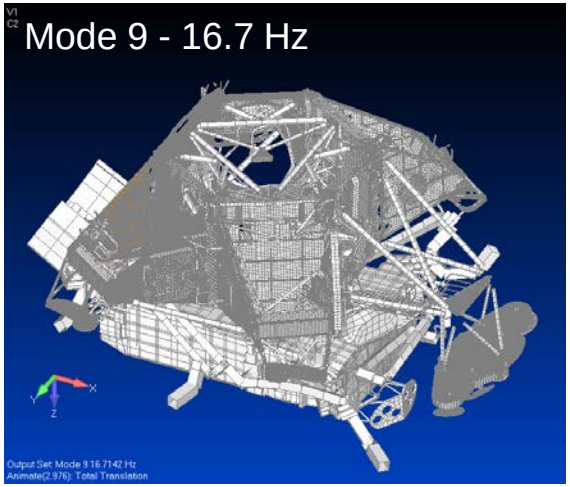


Mode No	Frequency (Hz)
1-6	0
7	16.0
8	16.4
9	16.7
10	17.4
11	18.2
12	18.4
13	19.1
14	19.2
15	19.3

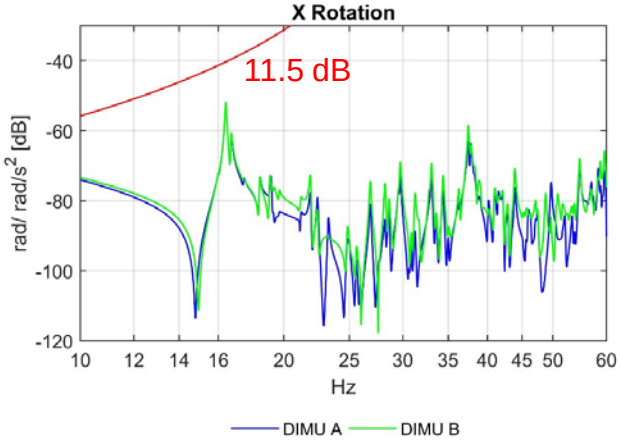
PDV Modes

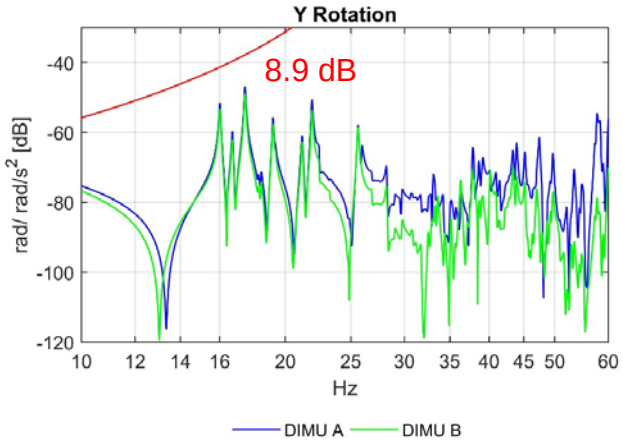

Mode 7 – 16.0 Hz
Output Set: Mode 7 16.01755 Hz
Animate(1.953): Total Translation

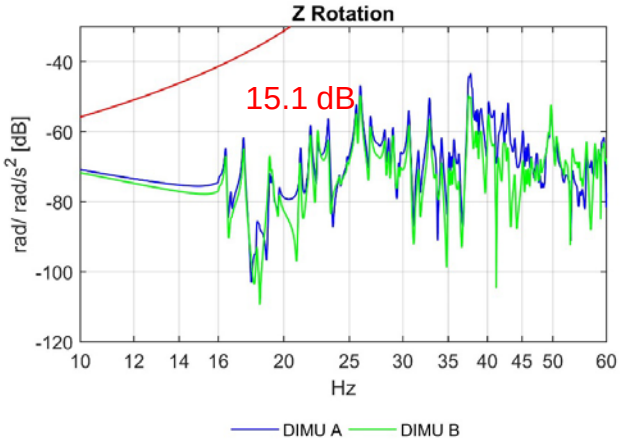

Mode 8 - 16.4 Hz
Output Set: Mode 8 16.4152 Hz
Animate(2.075): Total Translation

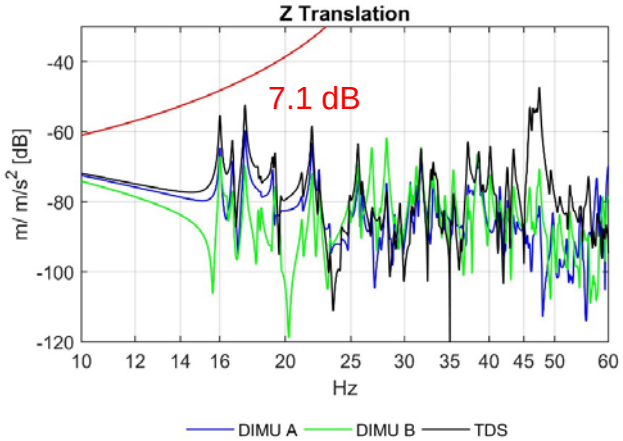

Mode 9 - 16.7 Hz
Output Set: Mode 9 16.7142 Hz
Animate(2.976): Total Translation

PDV TFs


X Rotation
11.5 dB
rad/ rad/s^2 [dB]
Hz
DIMU A
DIMU B


Y Rotation
8.9 dB
rad/ rad/s^2 [dB]
Hz
DIMU A
DIMU B


Z Rotation
15.1 dB
rad/ rad/s^2 [dB]
Hz
DIMU A
DIMU B


Z Translation
7.1 dB
m/ m/s^2 [dB]
Hz
DIMU A
DIMU B
TDS

PDV Transfer Function Sensitivity Study

Effect of Rover Mass Variations

Sensitivity Study : Mass growth impact on the PDV and TF margin

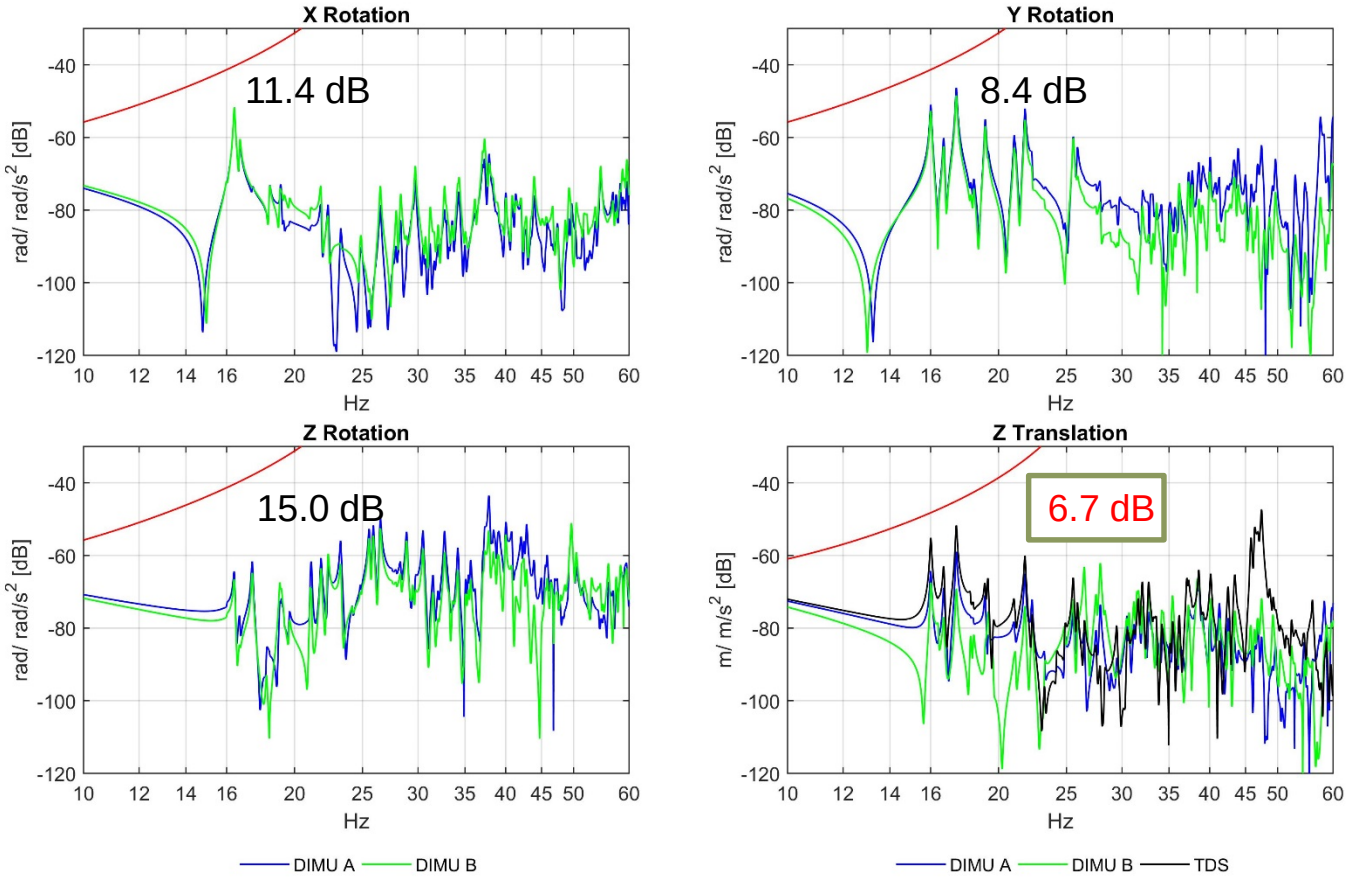
- *Case 1: SCS Arm and Turret up by 10% from PBE*
- *Case 2: SCS Arm and Turret up by 20% from PBE*
- *Case 3: SCS Arm and Turret down by 10% from PBE*
- *Case 4: SCS Arm and Turret up by 20% from PBE + 20 kg BM to AFT*
- *Case 5: Wheels (X 6) down by 10% (Assuming Ti wheel)*

Sensitivity Study:
Mass Growth on the PDV and TF margin

Increasing mass →→		Case 3 SCS ARM/Turret - 10 %	Case 5 6 Wheel Masses - 10 %	Current FEM 0 %	Case 1 SCS ARM/Turret + 10 %	Case 2 SCS ARM/Turret +20 %	Case 4 SCS ARM/Turret +20 % + 20 kg Aft
Mass (kg)	**Rover**	1038.8	1044.6	**1050.1**	1061.3	1072.6	1092.6
	PDV	1968.1	1973.9	**1981.3**	1990.6	2001.9	2021.9
Rover Frequency (Hz)	**Mode 1**	15.5	15.9	**15.5**	15.4	15.4	15.3
	Mode 2	15.7	16.2	**15.7**	15.7	15.7	15.7
	Mode 3	16.1	16.6	**16.1**	16.1	16.1	16.1
PDV Frequency (Hz)	**Mode 1**	16.02	16.48	**16.02**	16.01	16.00	15.99
	Mode 2	16.42	16.85	**16.42**	16.41	16.40	16.40
	Mode 3	16.72	17.19	**16.71**	16.71	16.70	16.69
Min Margin (dB)	**X-Rot.**	11.5	12.1	**11.5**	11.4	11.2	11.1
	Y-Rot.	9.4	9.4	**8.9**	8.4	7.9	7.5
	Z-Rot.	15.1	15.0	**15.1**	15.0	15.0	15.1
	Z-Trans.	7.3	7.4	**7.1**	6.7	6.0	6.2

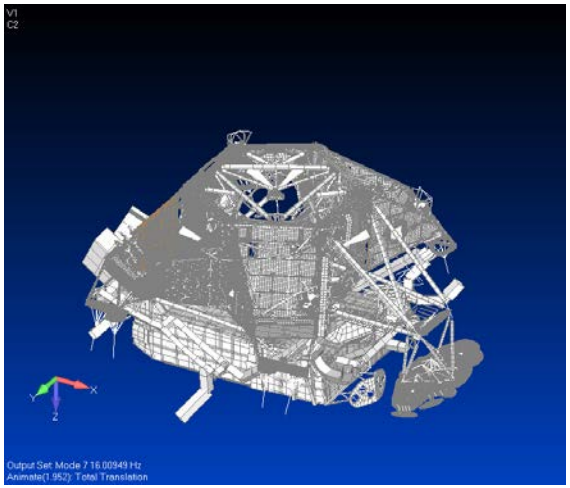
- Mass increase decreases the margin for Z-translation and reduces the margin on Y-rotation
- Reducing the mass of wheels increases the PDV frequencies significantly relative to the reduced mass. However, it doesn't effect the transfer functions as much and the mode shapes remain the same.
- In all cases the margin remains above 6 dB

Case 1
SCS Arm and Turret Mass +10%

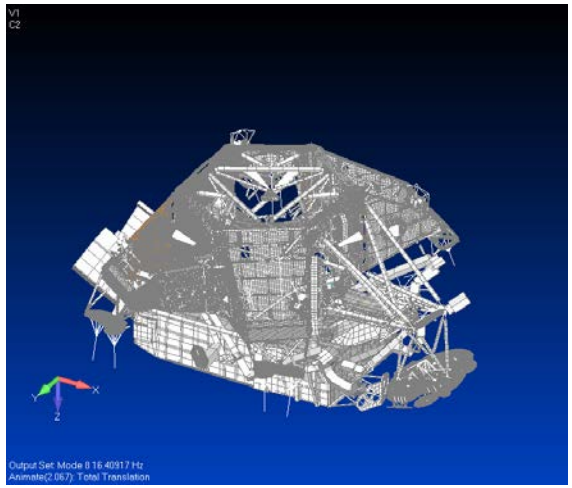


Case 1
SCS Arm and Turret Mass +10%

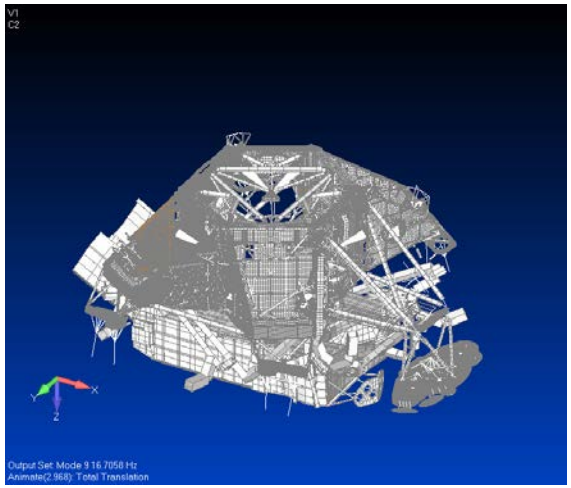
Mode 1 : 16.01 Hz



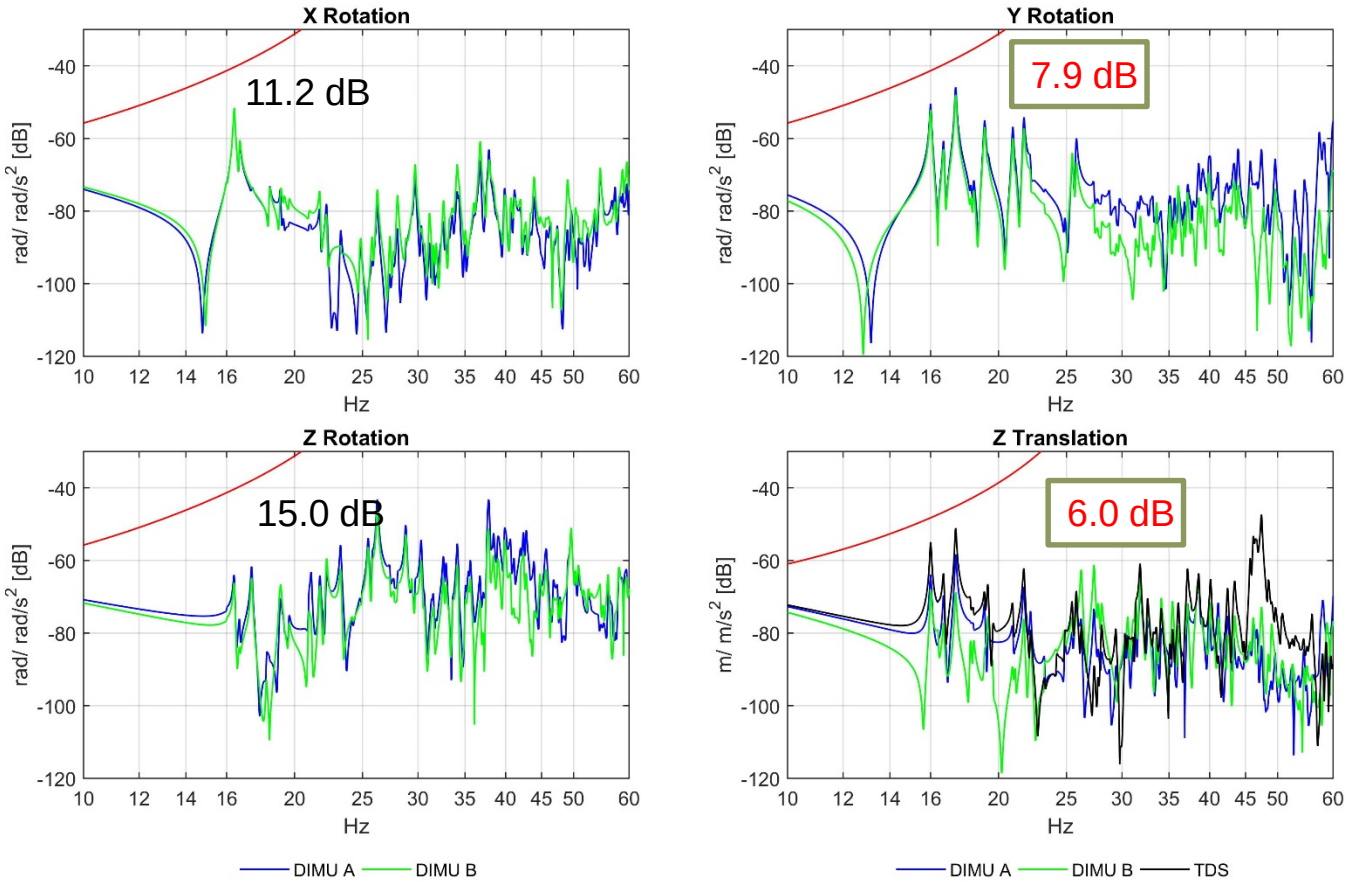
Mode 2 : 16.41 Hz



Mode 3 : 16.71 Hz

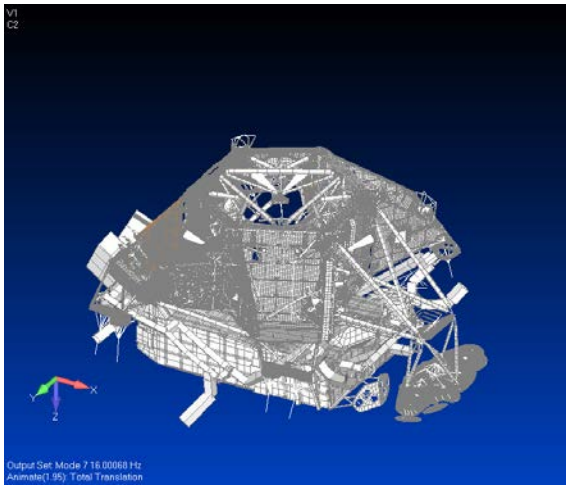


Case 2
SCS Arm and Turret Mass +20%

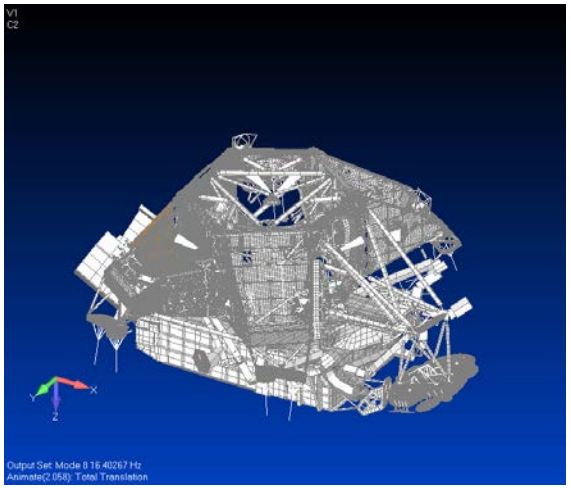


Case 2
SCS Arm and Turret Mass +20%

Mode 1 : 16.00 Hz

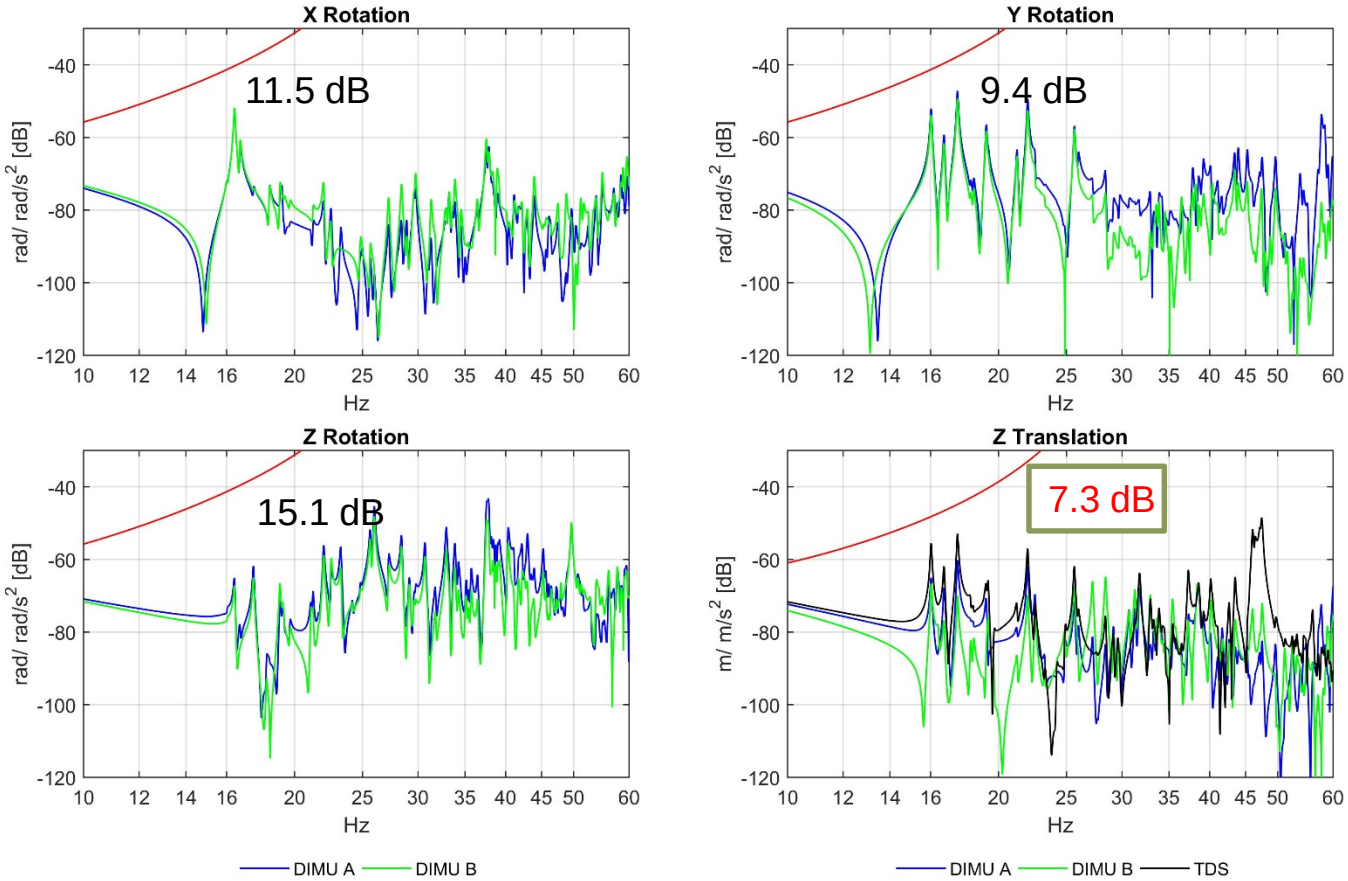


Mode 2 : 16.40 Hz



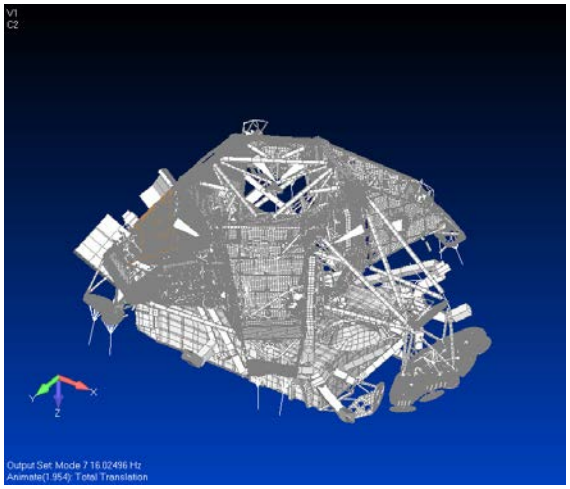
Mode 3 : 16.70 Hz

Case 3
SCS Arm and Turret Mass -10%

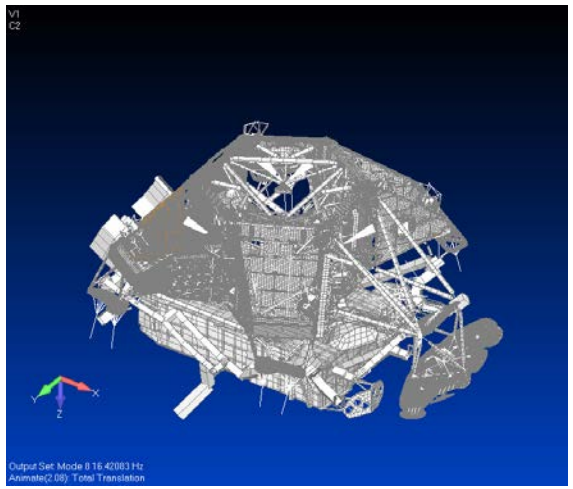


Case 3
SCS Arm and Turret Mass -10%

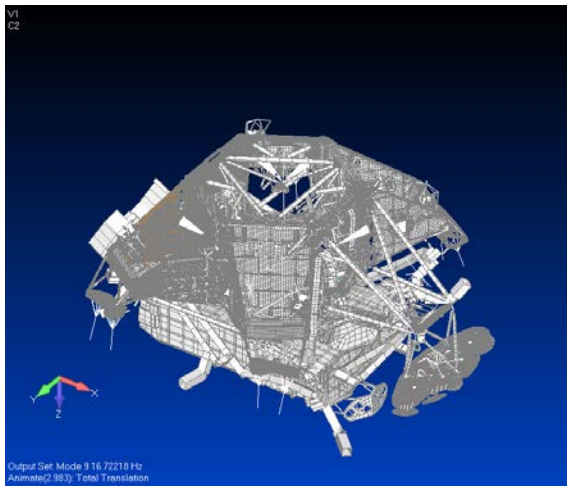
Mode 1 : 16.02 Hz



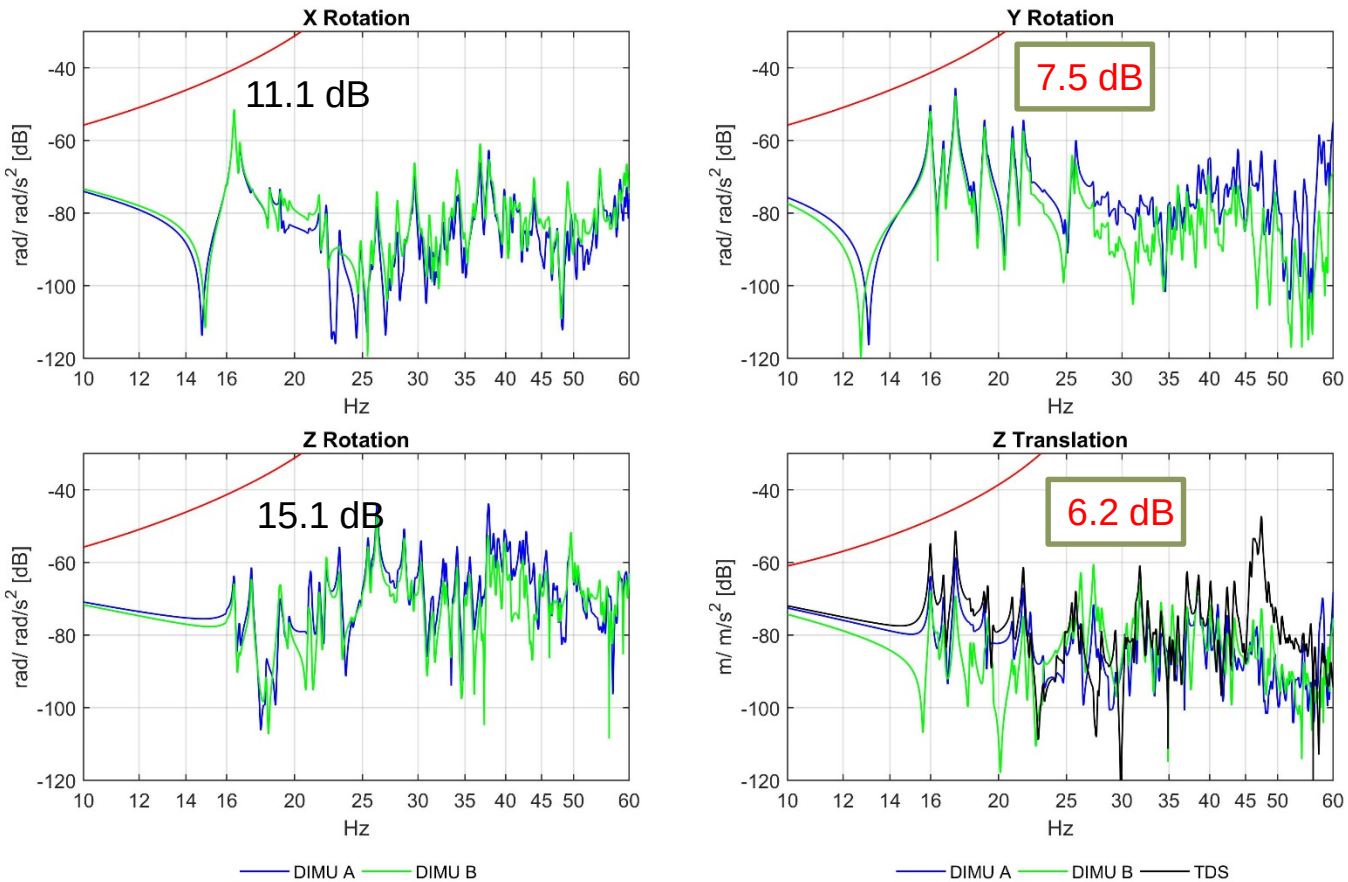
Mode 2 : 16.42 Hz



Mode 3 : 16.72 Hz

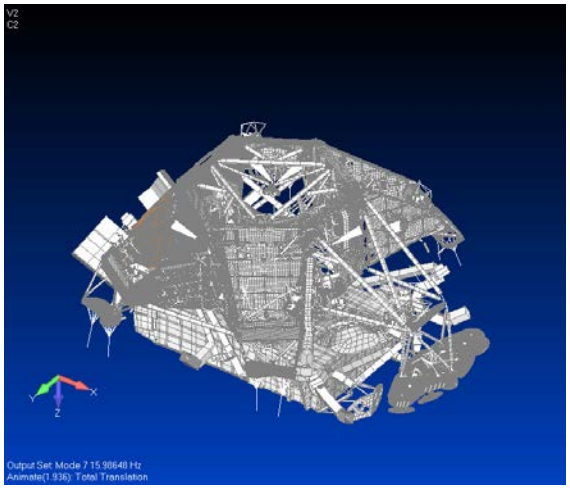


Case 4
SCS Arm Turret Mass +20% + 20 kg BM on Aft

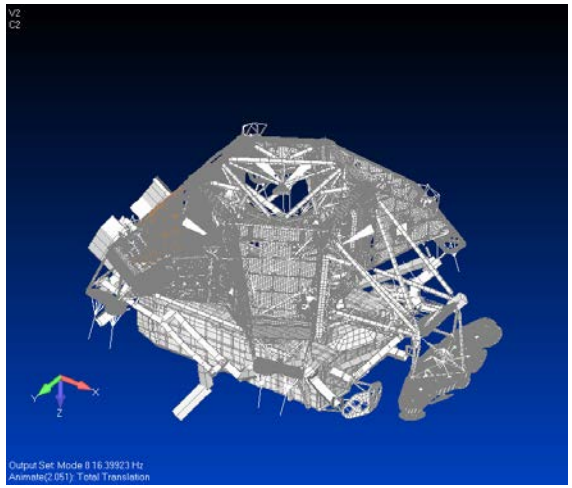


Case 4
SCS Arm Turret Mass +20% + 20 kg BM on Aft

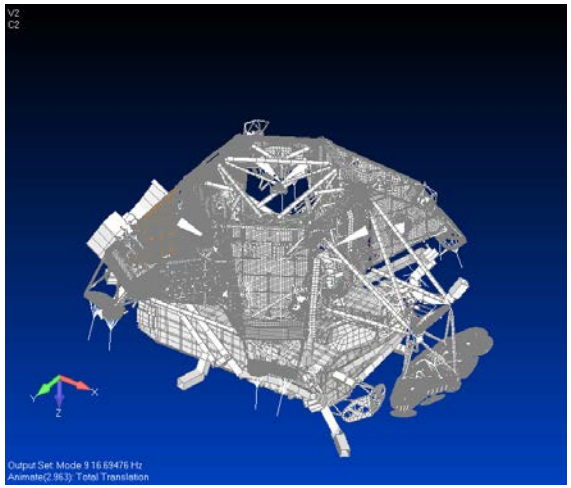
Mode 1 : 15.99 Hz



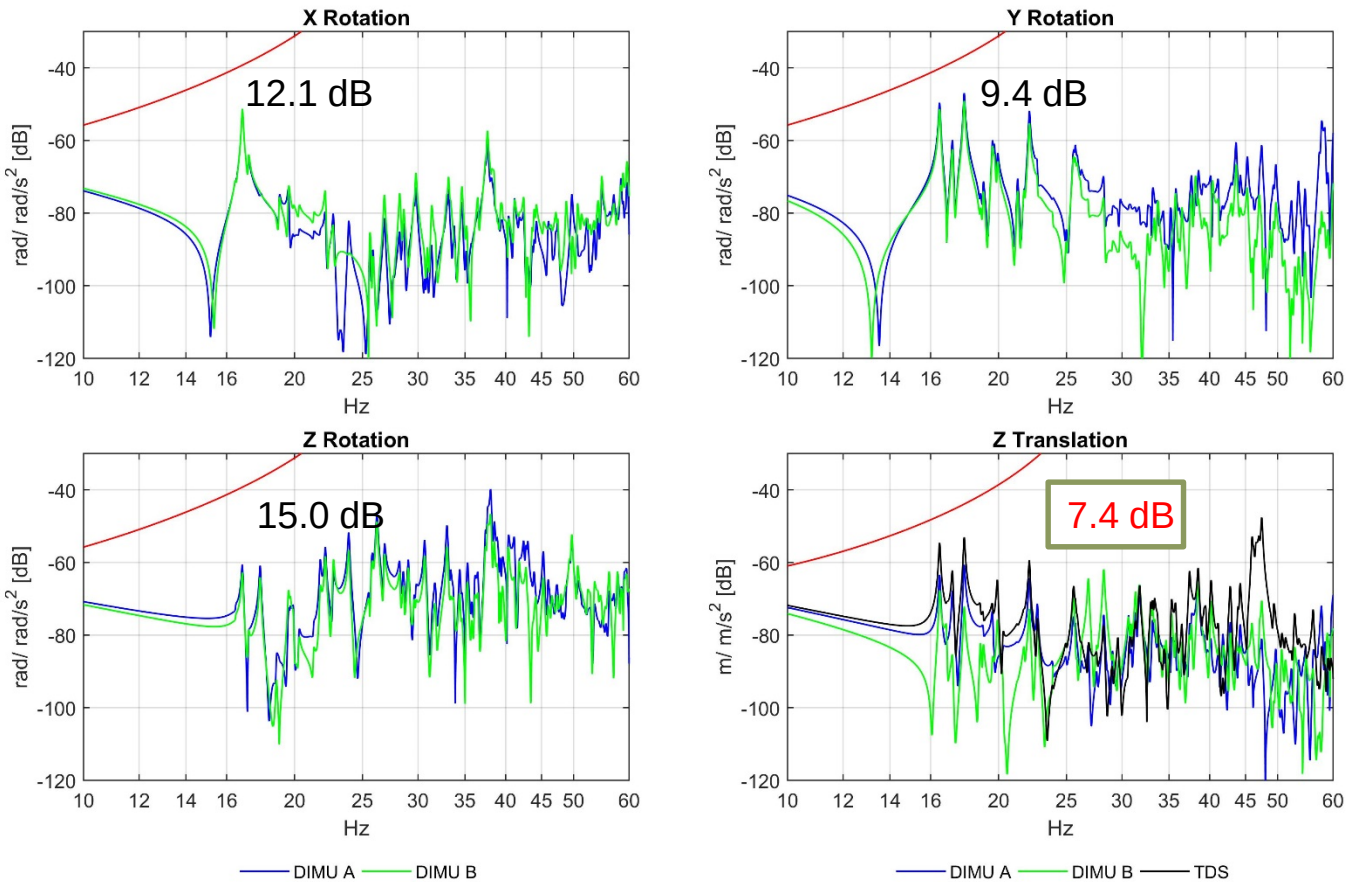
Mode 2 : 16.40 Hz



Mode 3 : 16.69 Hz



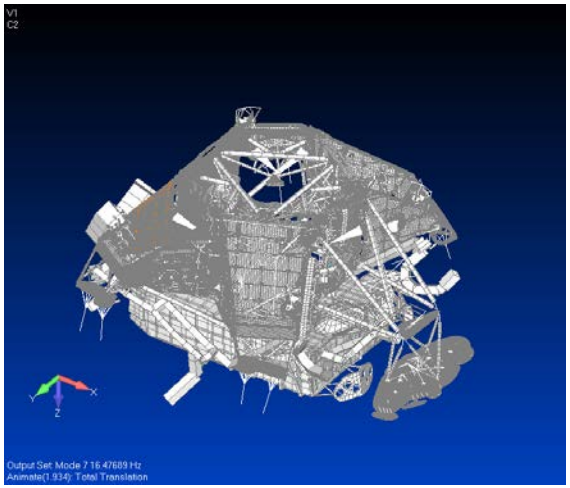
Case 5
All 6 Wheel mases -10%



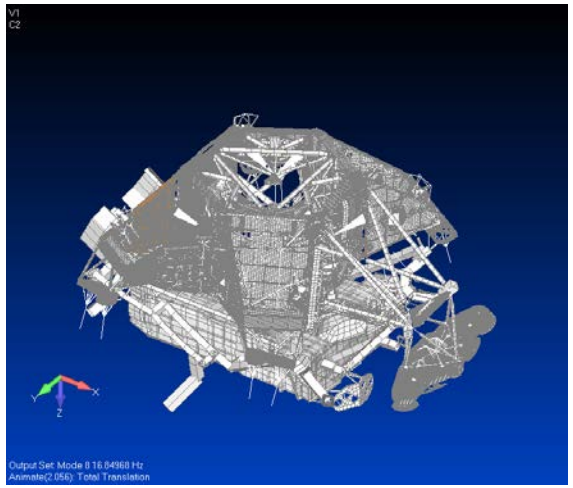
Case 5

All 6 Wheel mases -10%

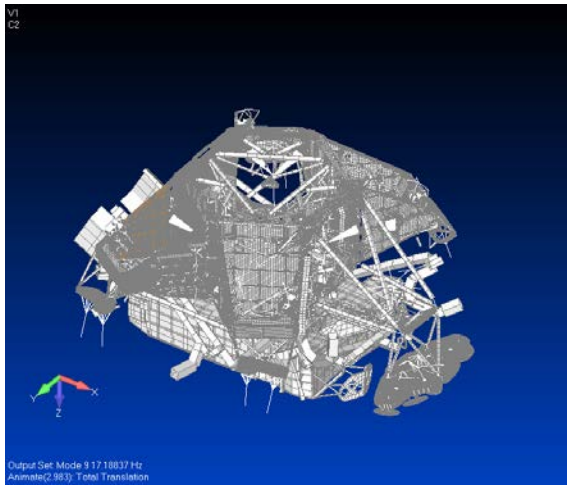
Mode 1 : 16.48 Hz



Mode 2 : 16.85 Hz



Mode 3 : 17.19 Hz



Summary

- The PDV with the current FEM shows a minimum of 7 dB margin against GNC keep-out-zone (KOZ) which already reserves 16 dB flex gain margin
- Conducted 5 cases of the mass sensitivity studies and
  - *Generally the SCS Arm/Turret mass growth up to 20 % did not notably impact the PDV first mode or the control TFs*
  - *The wheels mass reduction by 10% increased the PDV 1st modal frequency only by 0.5 Hz and it also increased the Ry control flex gain margin only by 0.5 dB*

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mechanical Systems Engineering, Fabrication and Test Division
June 21–23, 2016
Email: Ramses.Mourhatch@jpl.nasa.gov
Phone: 818-393-8159

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