INSTITUT SUPÉRIEUR DE L'AÉRONAUTIQUE ET DE L'ESPACE – ISAE
ÉCOLE NATIONALE SUPÉRIEURE DE L'AÉRONAUTIQUE ET DE L'ESPACE

Mechanical Noise Caracterization of the InSight Mission

Département Conception et Conduite des véhicules Aéronautiques et Spatiaux (DCAS)
Département Electronique, Optronique et Signal (DEOS)
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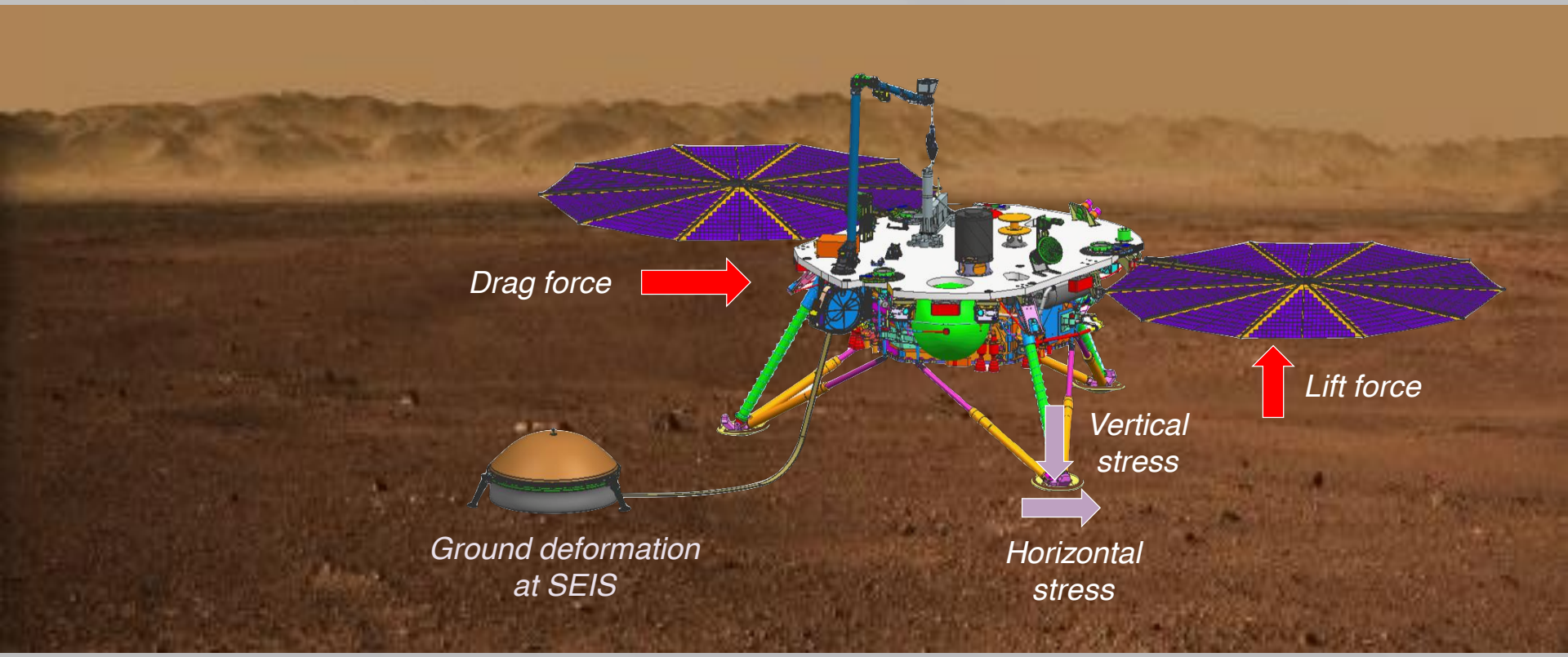
Toulouse, 29th June, 2016

- **1 - Introduction**
- **2 - Wind modeling**
- **3 - Transmission of effort by flexible body model**
  - 3.1 - Inverse dynamic model
  - 3.2 - Regolith properties on Mars
- **4 – Ground deformation**
- **5 – Discussion**
  - 5.1 - Variation of wind parameters
  - 5.2 - Variation of ground properties
  - 5.3 - Variation of distance between SEIS and lander center
  - 5.4 - Model application in a real case
- **6 - Conclusions**

1 – Introduction: Overview



- Lift and drag forces acting on the lander
- Induce horizontal and vertical stresses on the ground
- Seismometer feels the mechanical noise

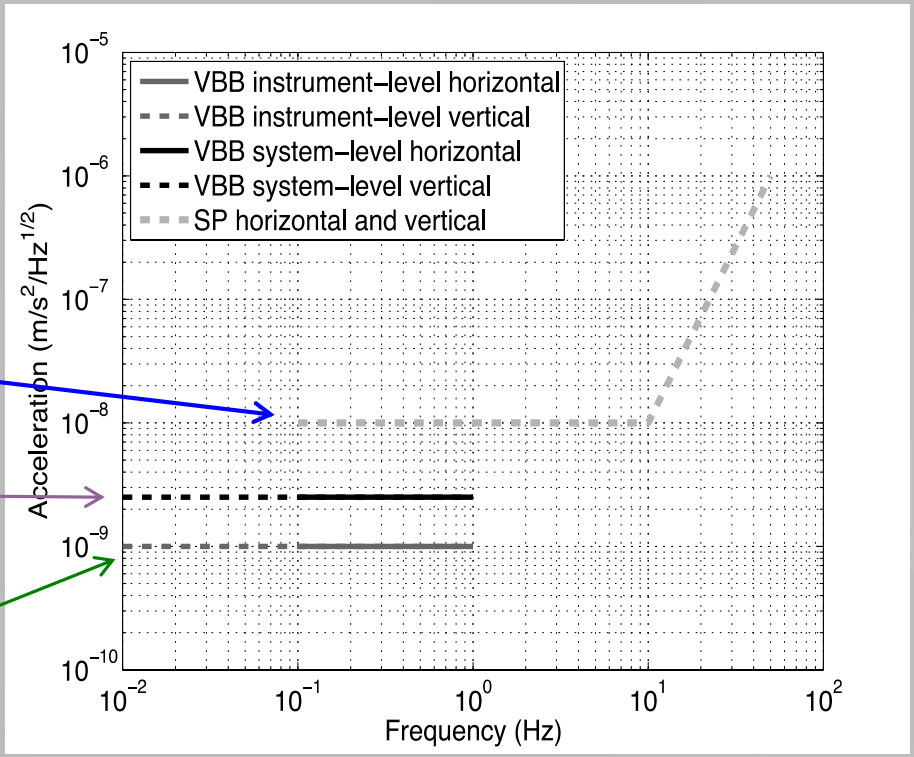
1 – Introduction: noise requirements

To achieve the InSight mission goals, the seismometers must meet **the noise requirements**

SP noise requirement

InSight system-level noise requirement (L3)

VBB instrument-level noise requirement (L4)



(Naomi, 2016)

2 - Wind modeling

- Calculation method from (Naomi Murdoch, 2016)
- We assumed $U_x(z_r)^2 = 125\, m^2 s^{-2} Hz^{-1/2}$, for $f < 15\, mHz$
- For a horizontal wind direction: 45° from the N-W
- For a vertical wind direction: 15° (Critical case)
- Lift and drag forces exerced on the lander CoP

$$F_l = PS_{lift}C_l$$

$$F_d = PS_{drag}C_d$$

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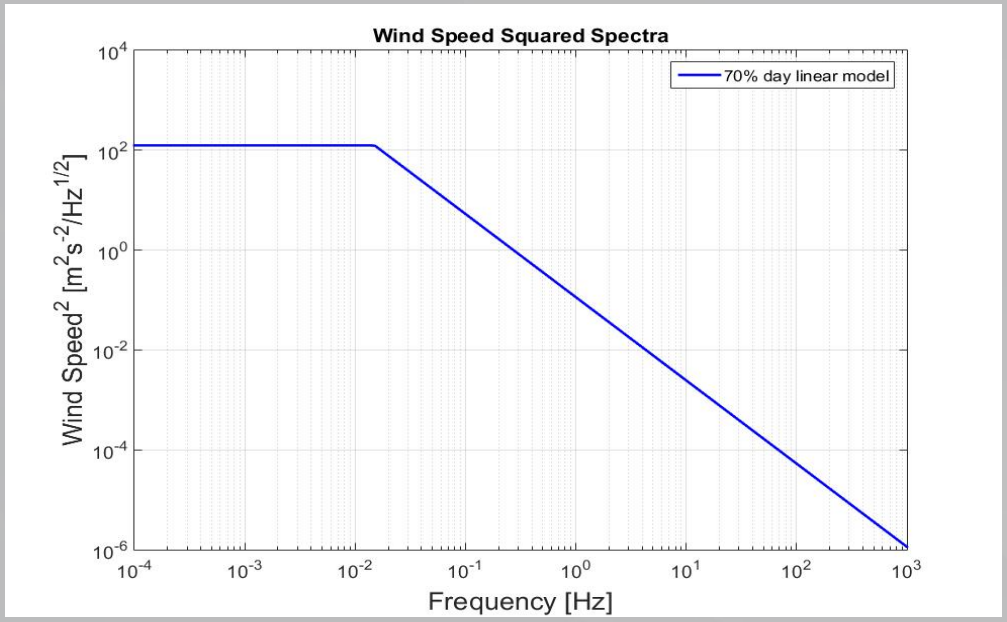


$$f \geq f_{cut} : U_x(z_r)^2 = B \left(\frac{f}{f_{cut}} \right)^{-\frac{5}{3}} \; m^2 s^{-2} Hz^{-1/2}$$

3 - Transmission of effort by flexible body model
3.1 – Inverse dynamic model

- Based on Newton-Euler equations (Alazard and Cumer, 2014)
- Addition of modal effective mass, CG coordinates, masses and moments of inertia
- **Inputs**: 3 components of external forces and 3 components of external torques
- **Outputs**: 3 linear accelarations and 3 angular accelerations

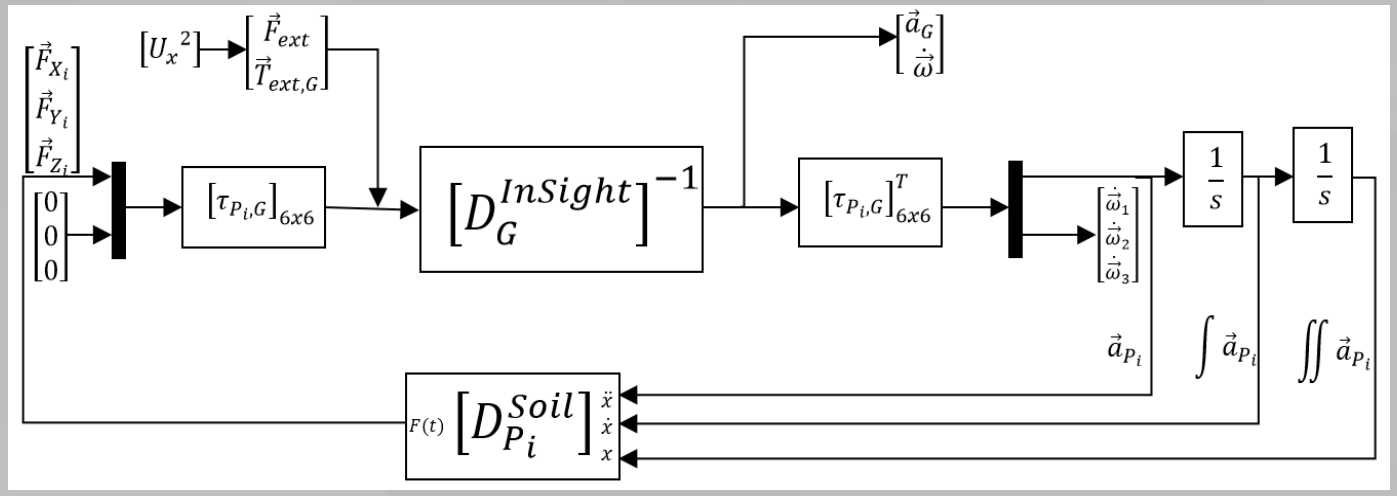
Representation of the inverse dynamic model

3 - Transmission of effort by flexible body model

3.2 – Regolith properties on Mars

- Calculating of ground stiffness Ks - method presented in (Naomi, 2016)
- Calculations made from extrapolating of results found in laboratory
- Three-dimensional soil-structure-interaction model represented by:

$$M\ddot{x} + C\dot{x} + Kx = F(t)$$



Complete Model

4 - Ground Deformation

- Deformation of the ground under SEIS feet
- Ground Model: Elastic half-space
- Boussinesq point load solution

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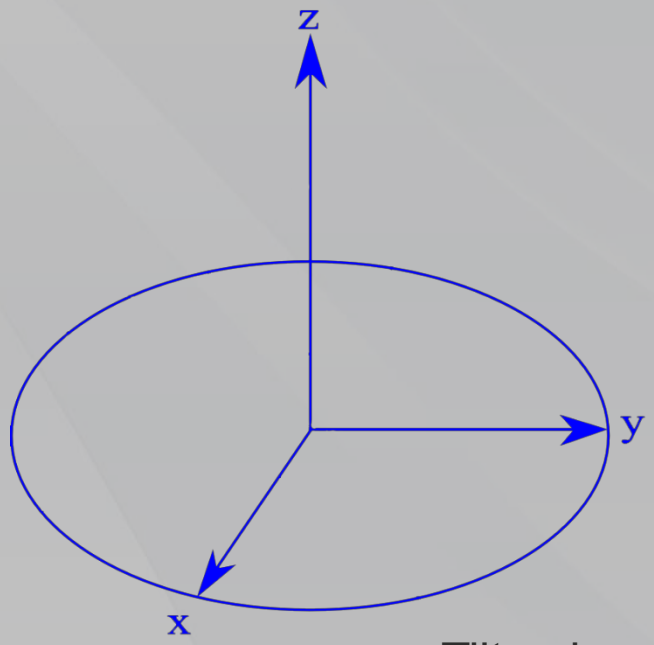

Tilt noise shematic

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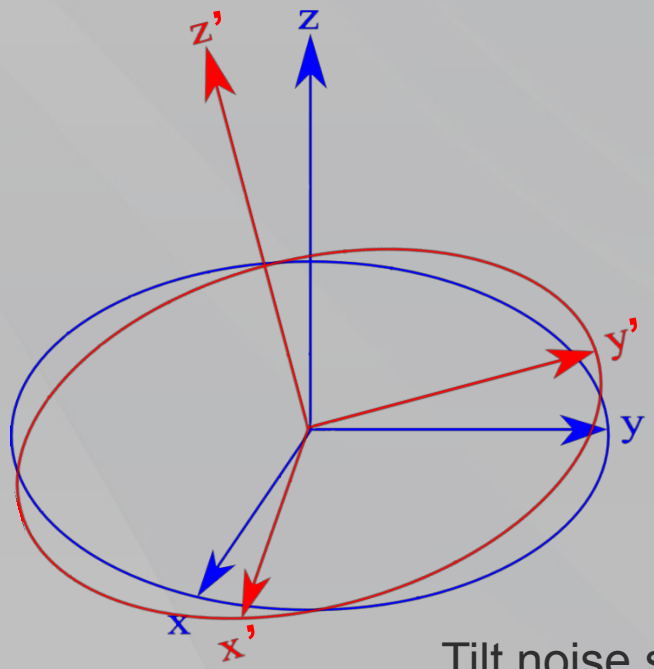
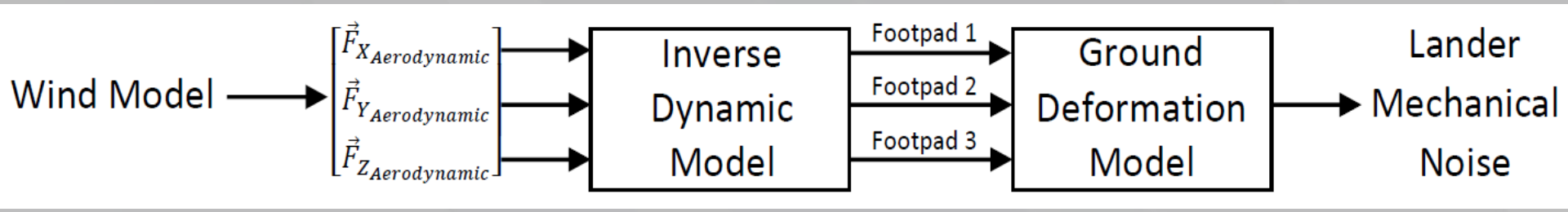


Tilt noise shematic

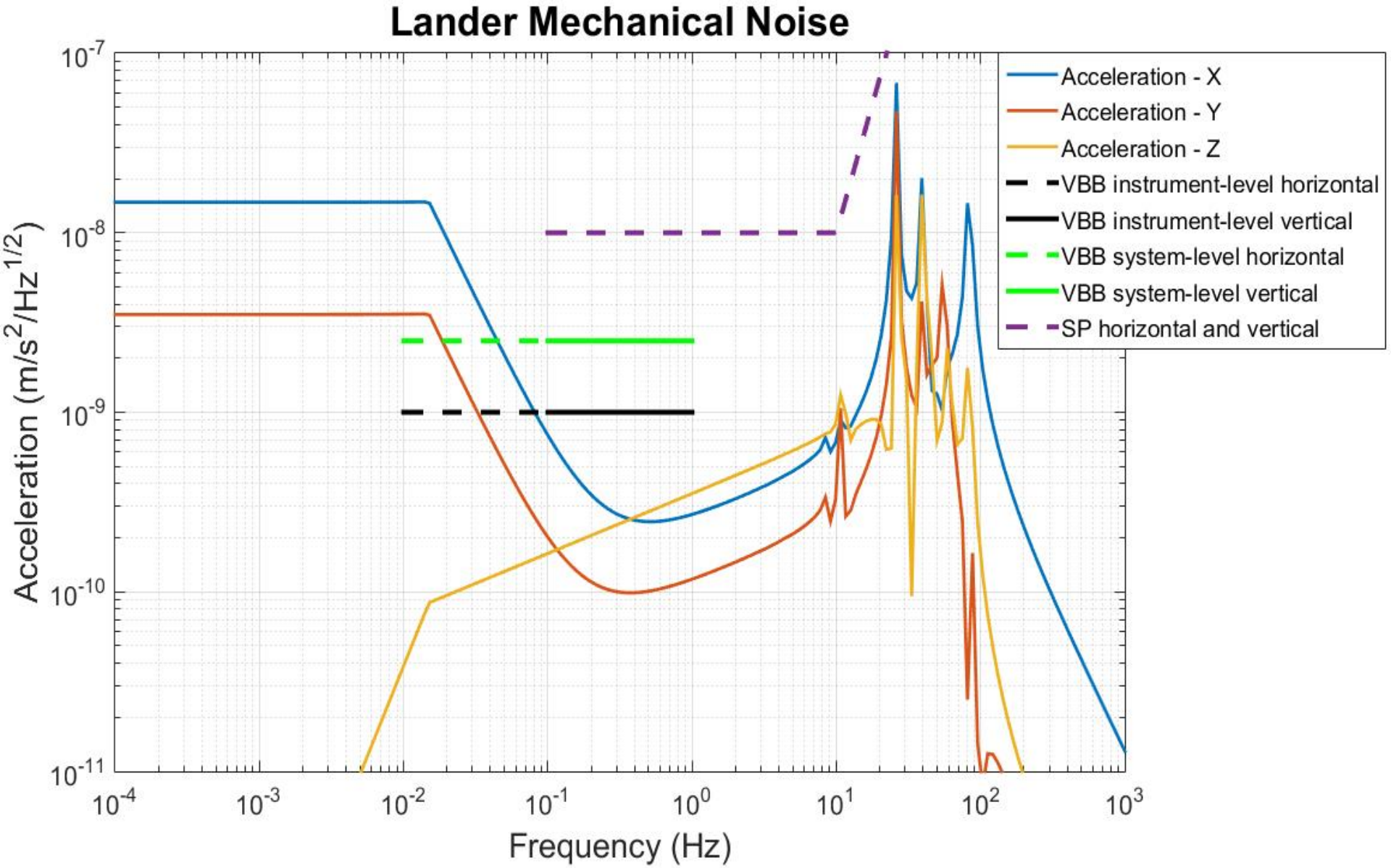
4 - Ground Deformation

- Final Model
  1. Input: Wind Model
  2. Calculation of aerodynamic forces
  3. Calculation of forces at lander footpads
  4. Output: Lander Mechanical Noise



Final Model

4 - Ground Deformation



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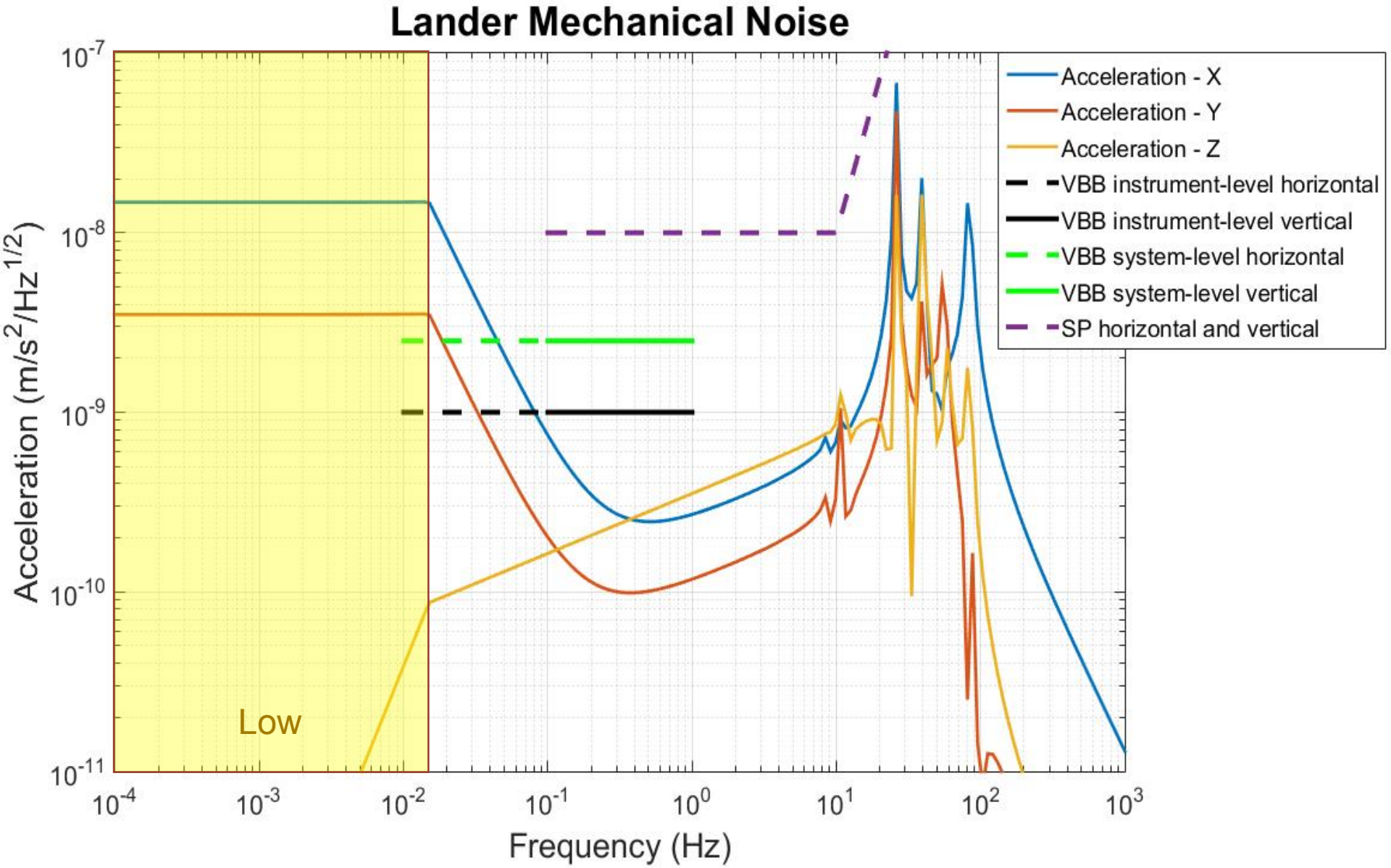

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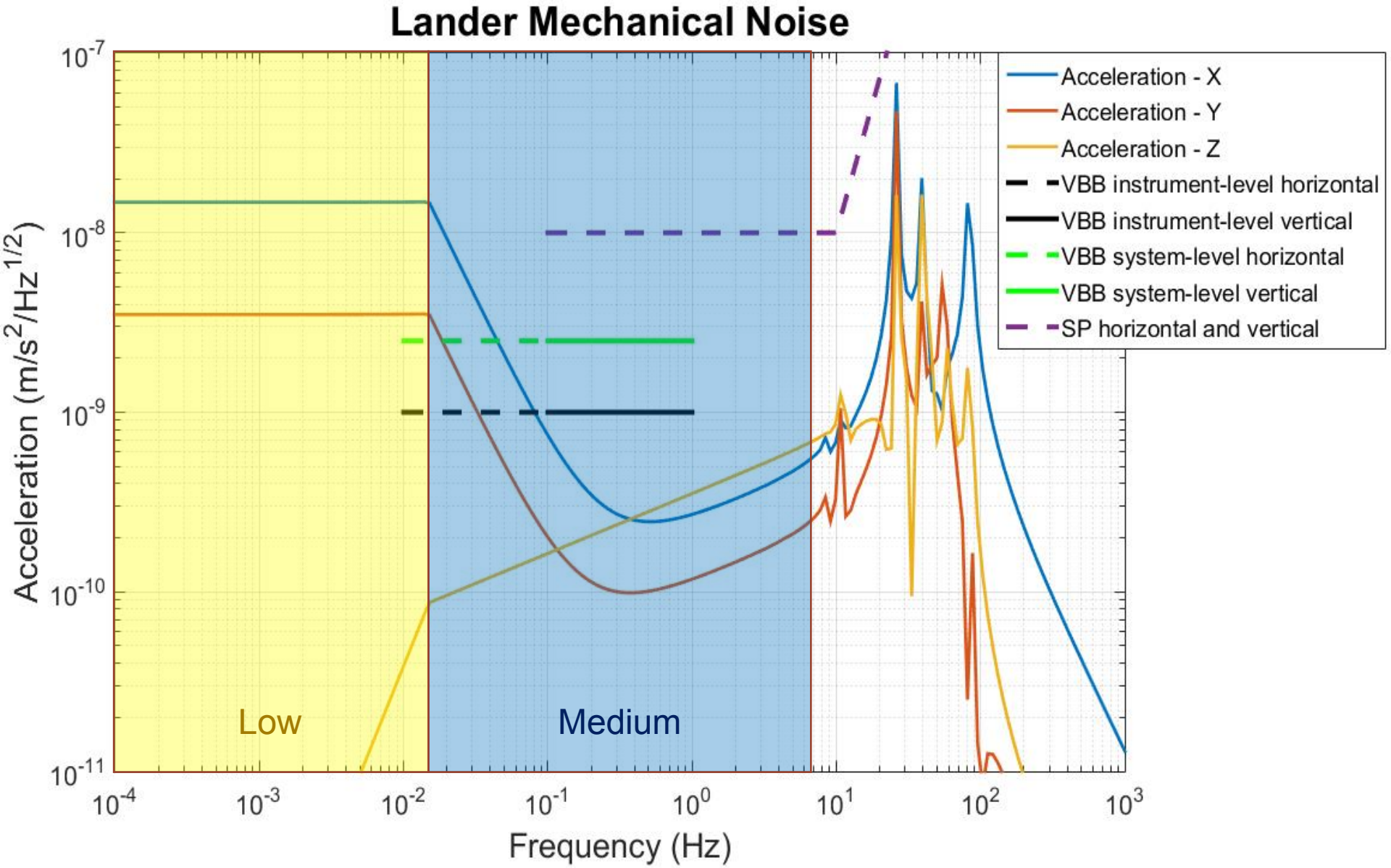

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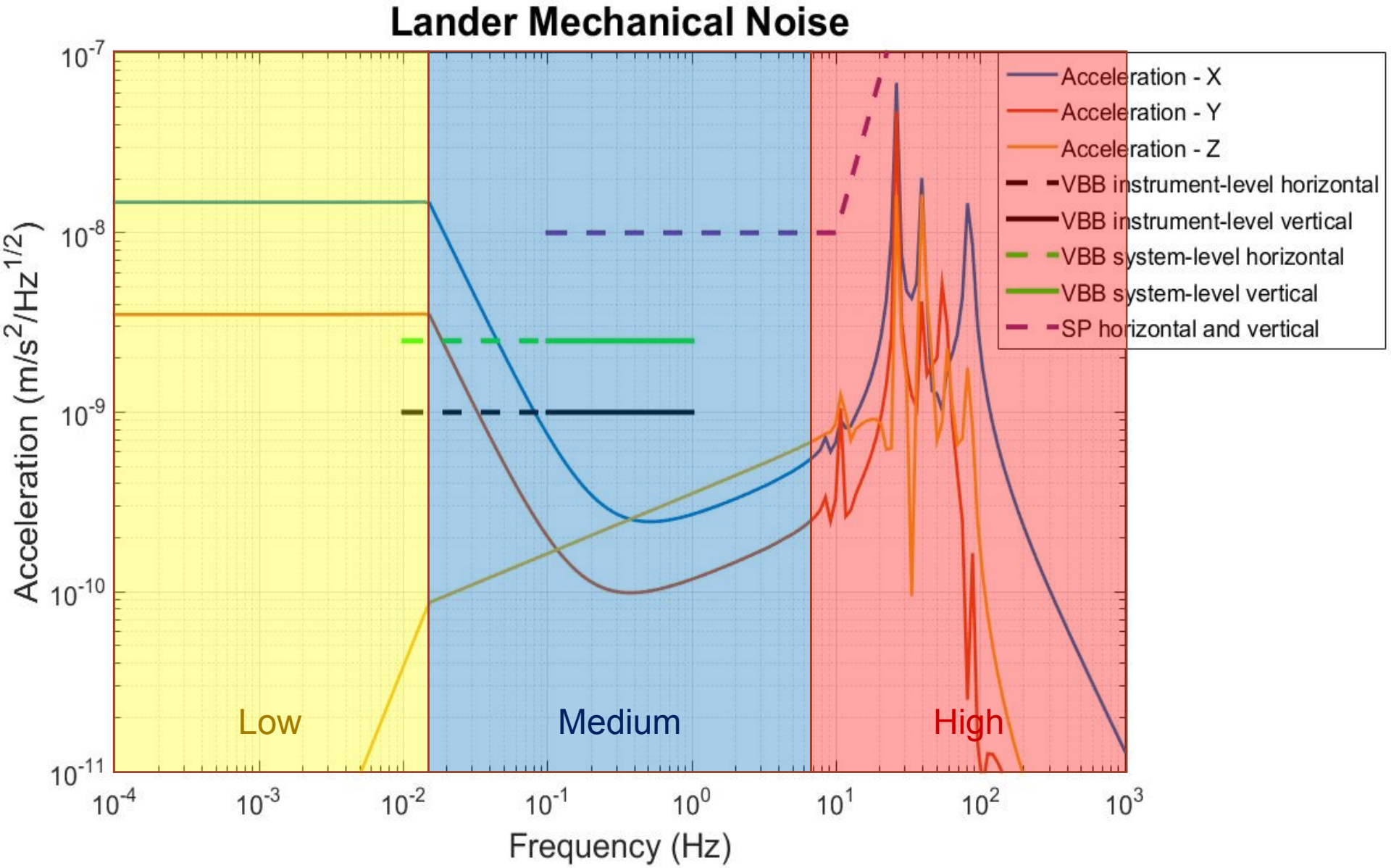

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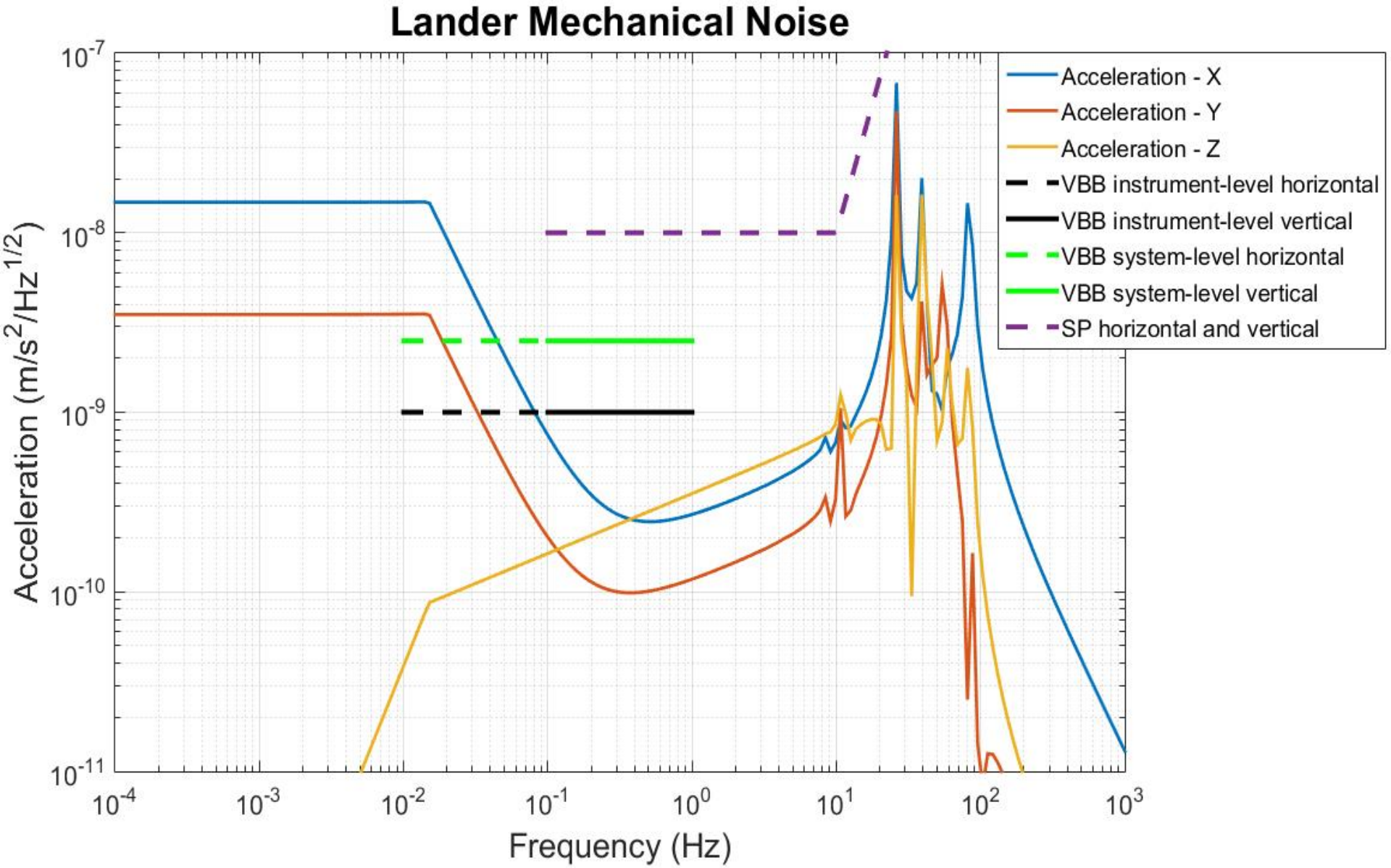

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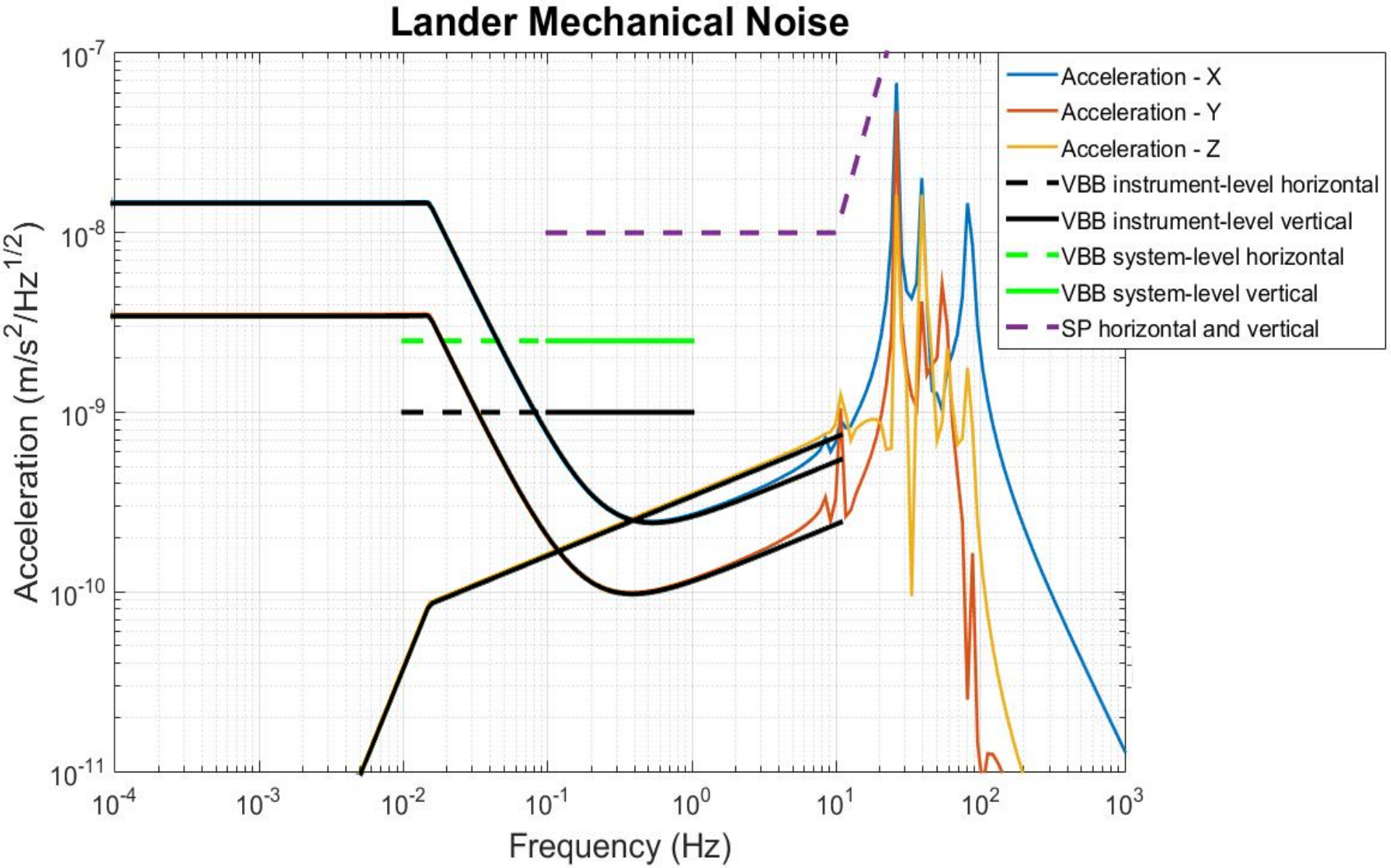

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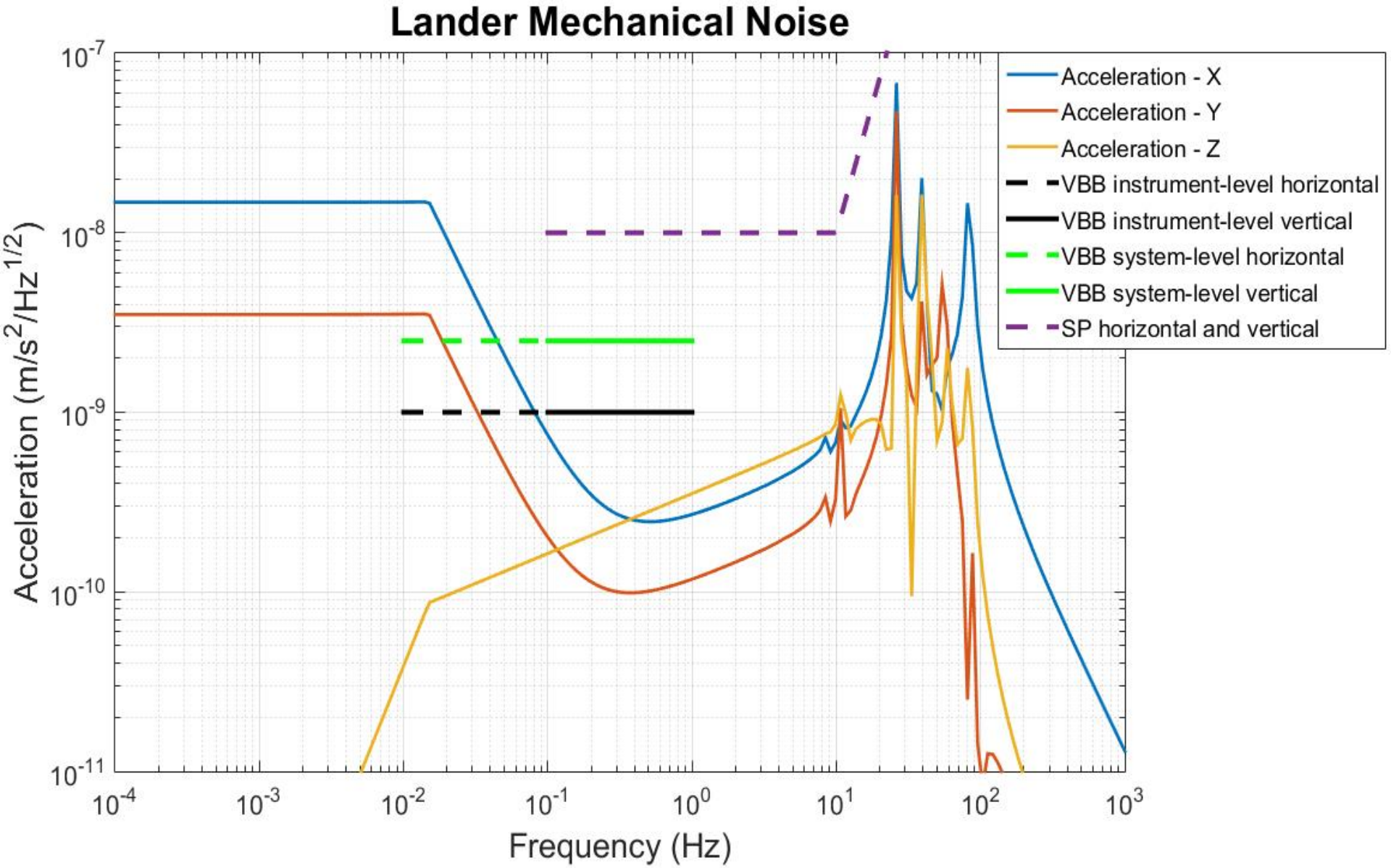

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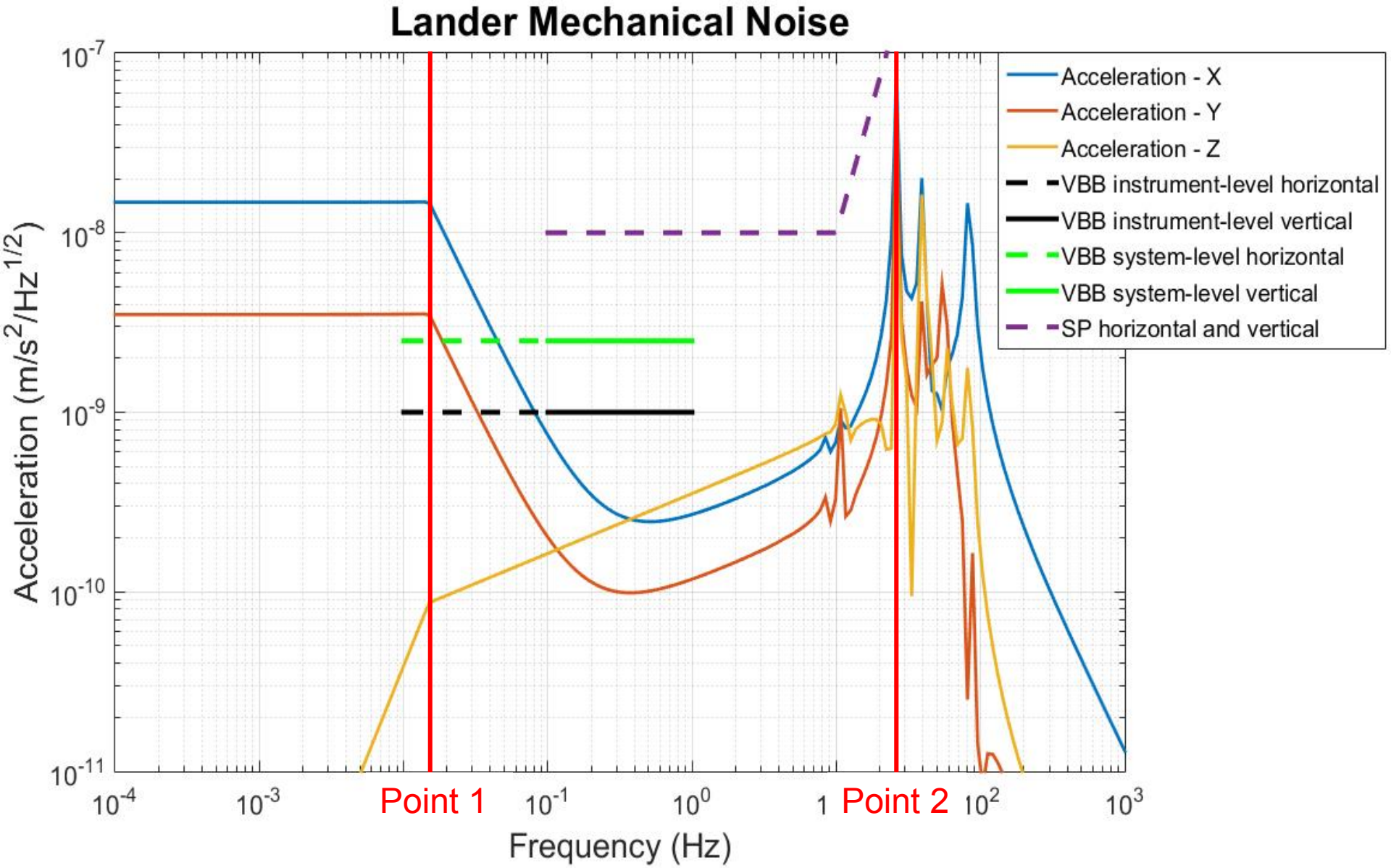
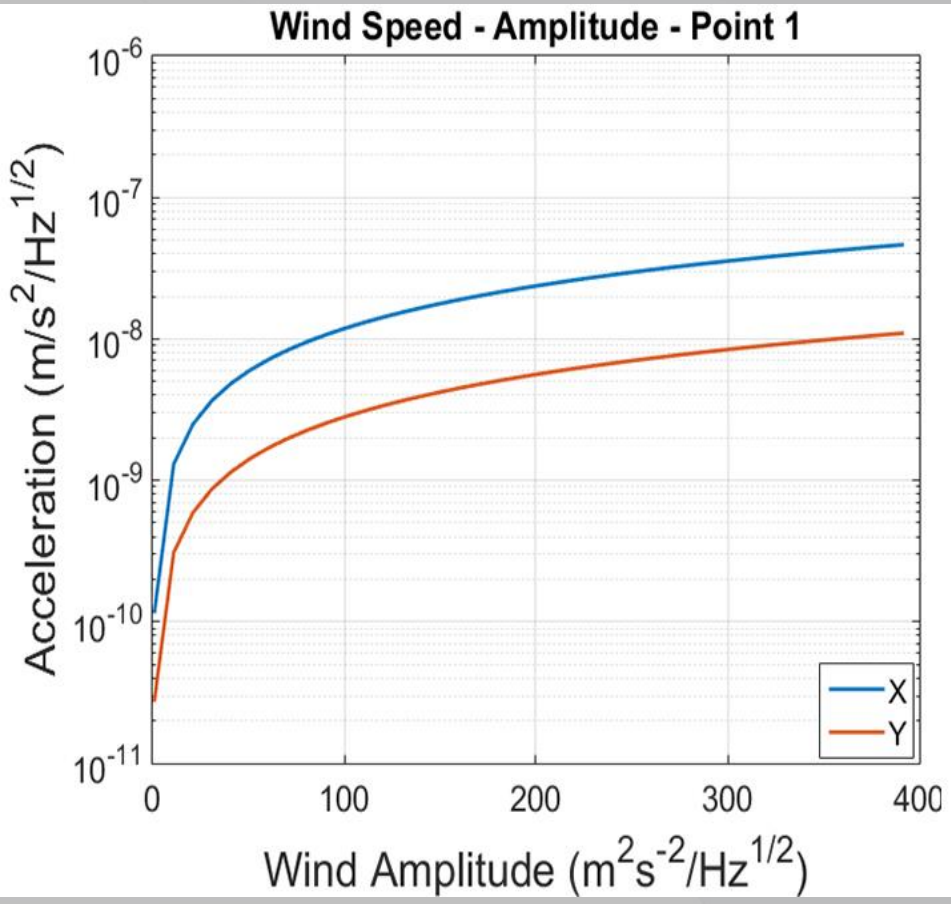
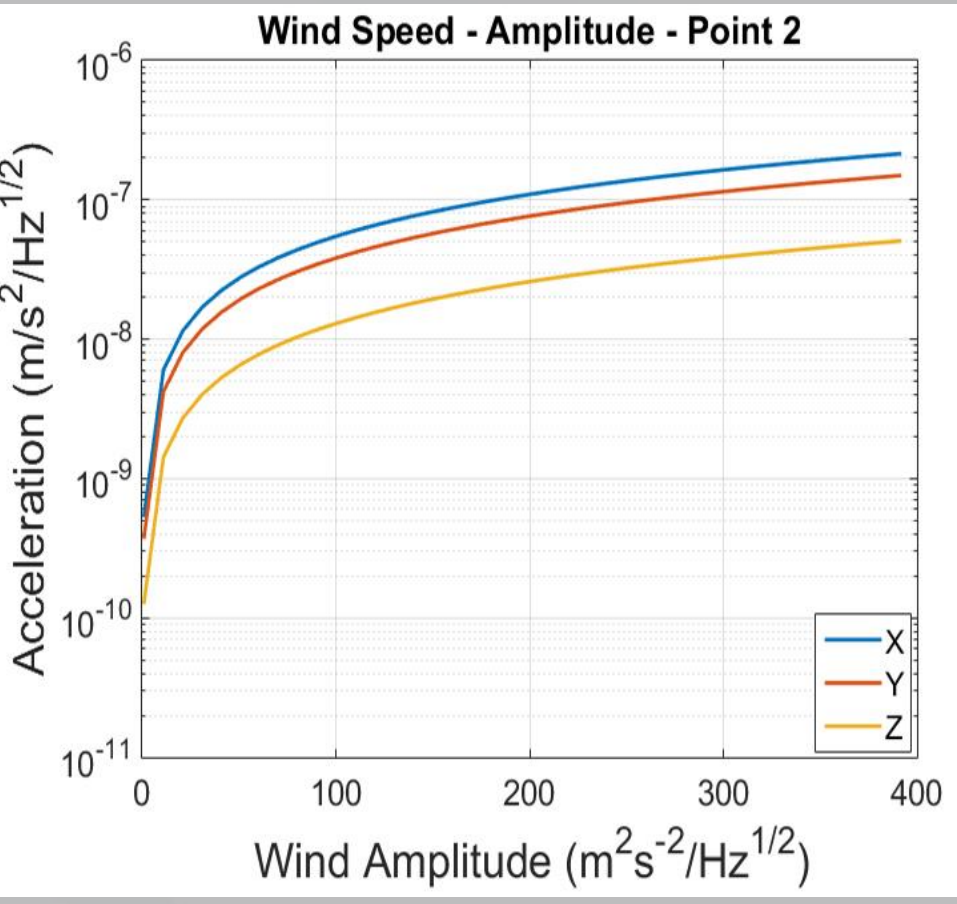


5 - Discussion

5.1 - Variation of Wind Amplitude

- Acceleration

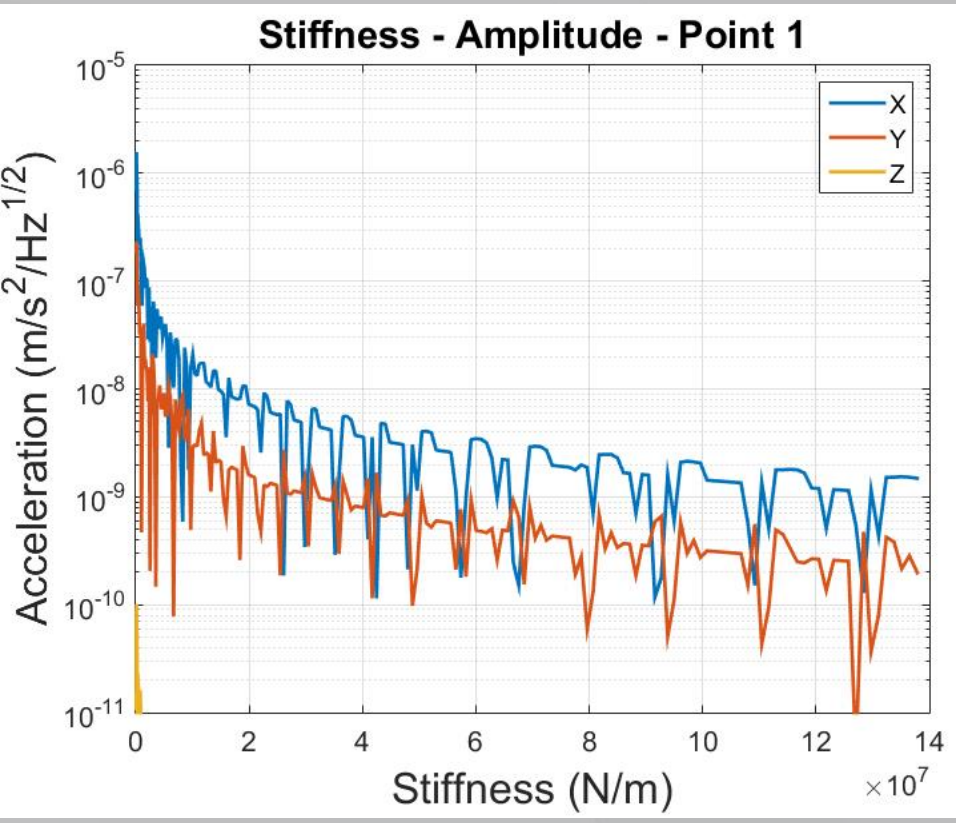


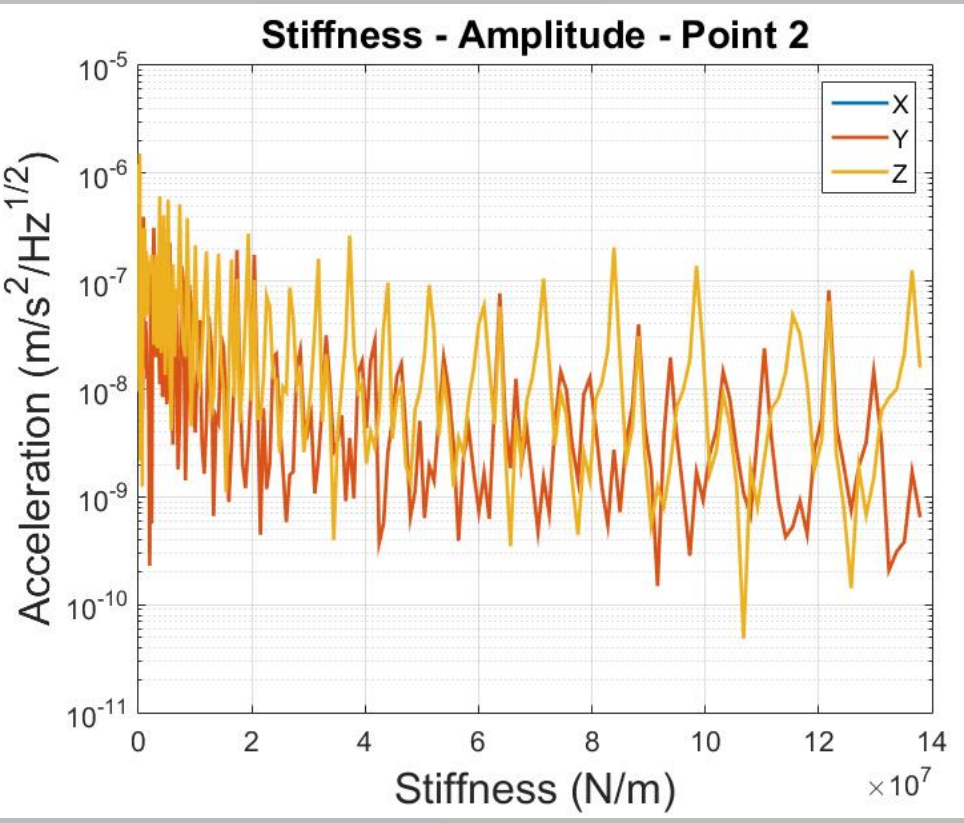


5 - Discussion

5.2 - Variation of Ground Properties

- Acceleration





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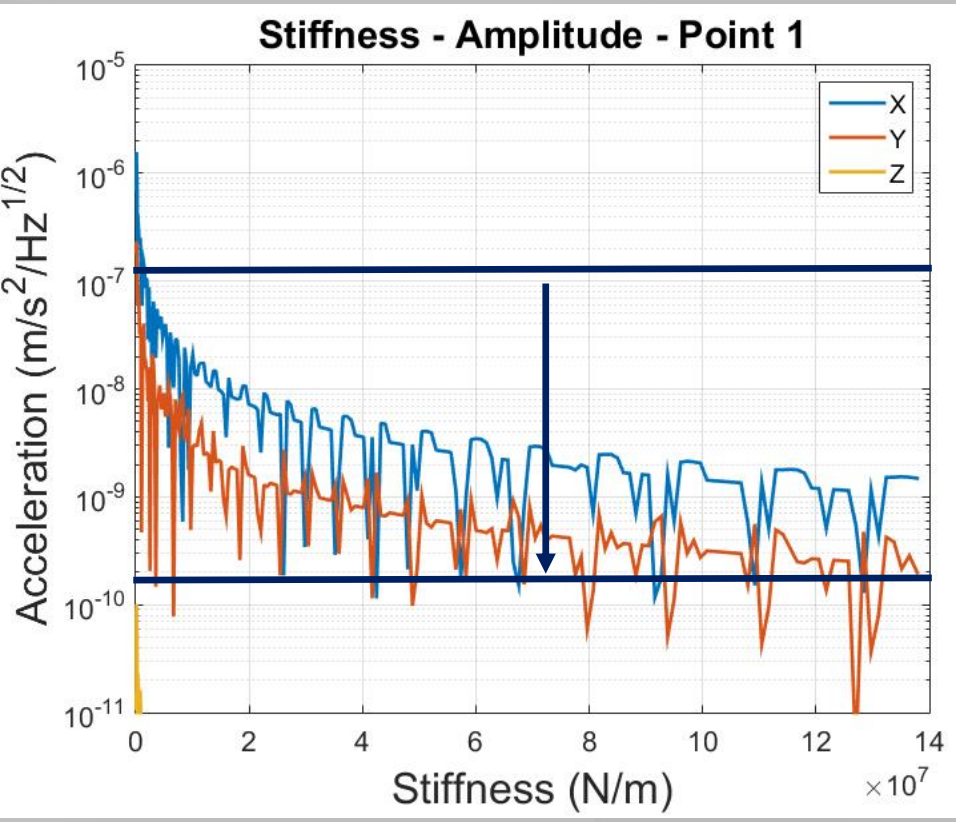
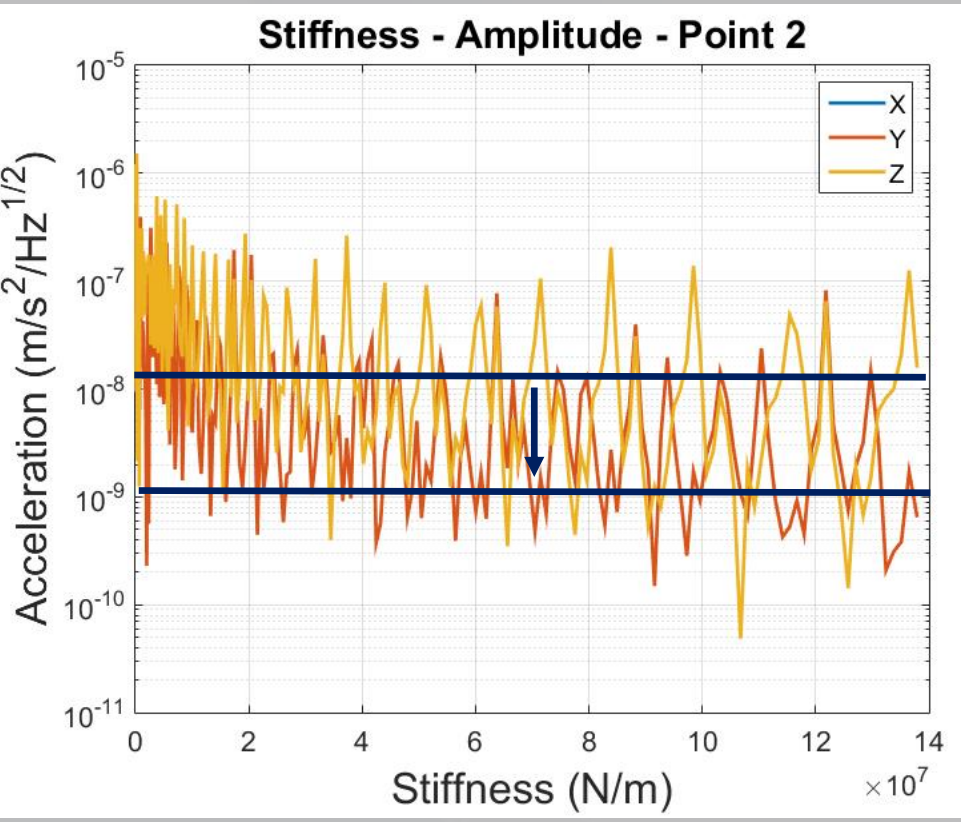
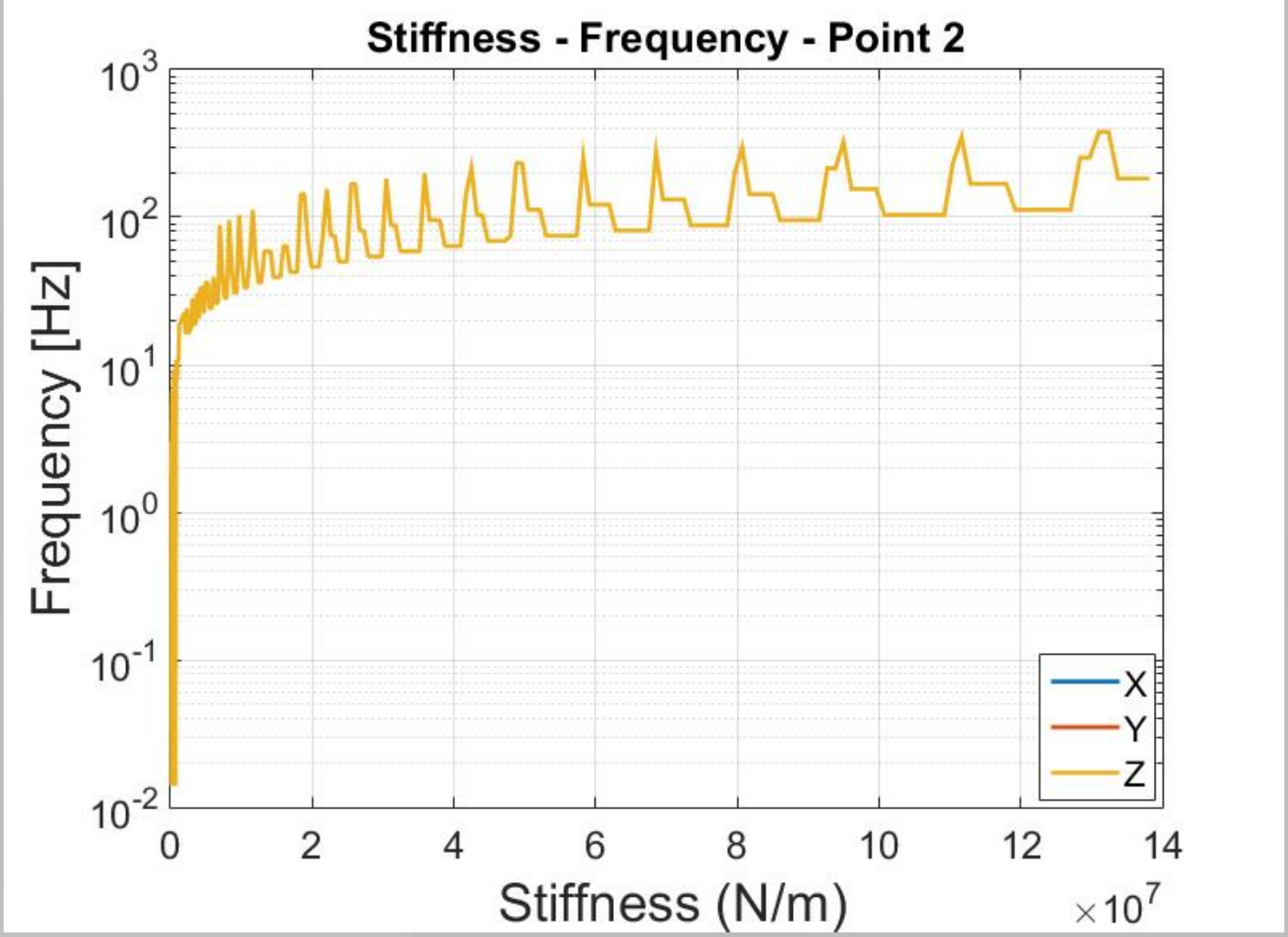




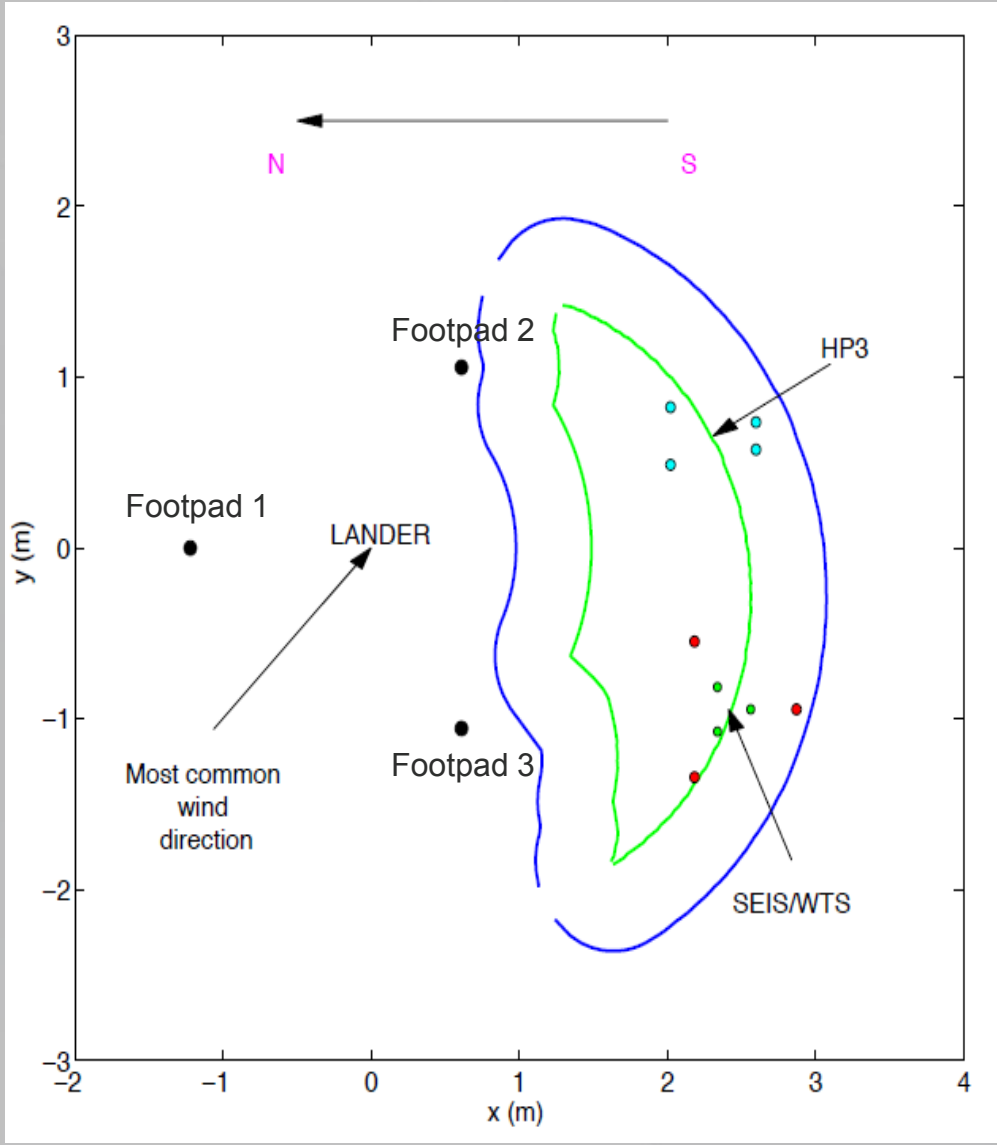
5 - Discussion

5.2 - Variation of Ground Properties

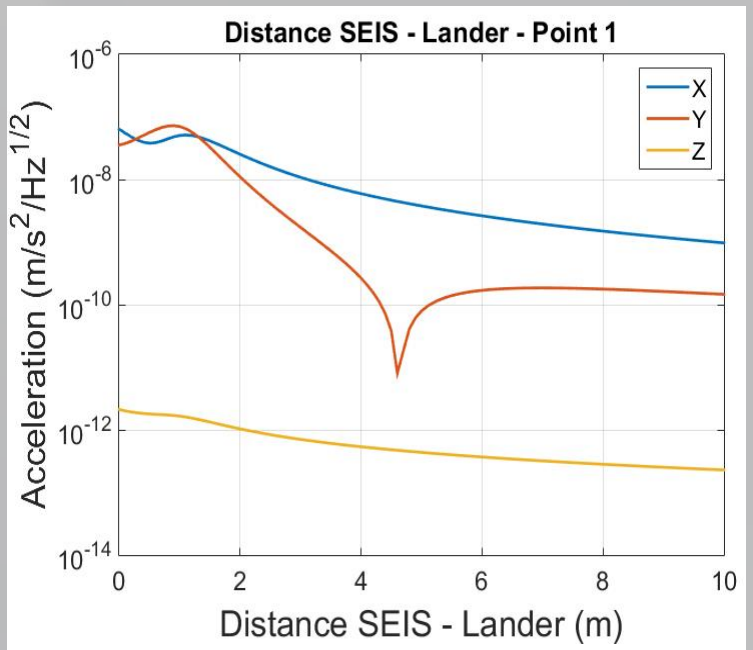
- Frequency

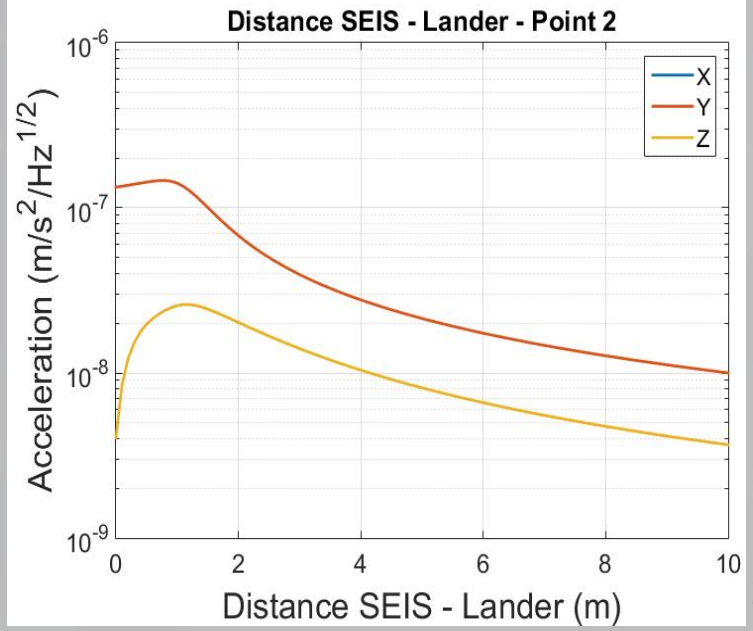


5.3 - Variation of distance between SEIS and lander center



InSight baseline deployment conguration





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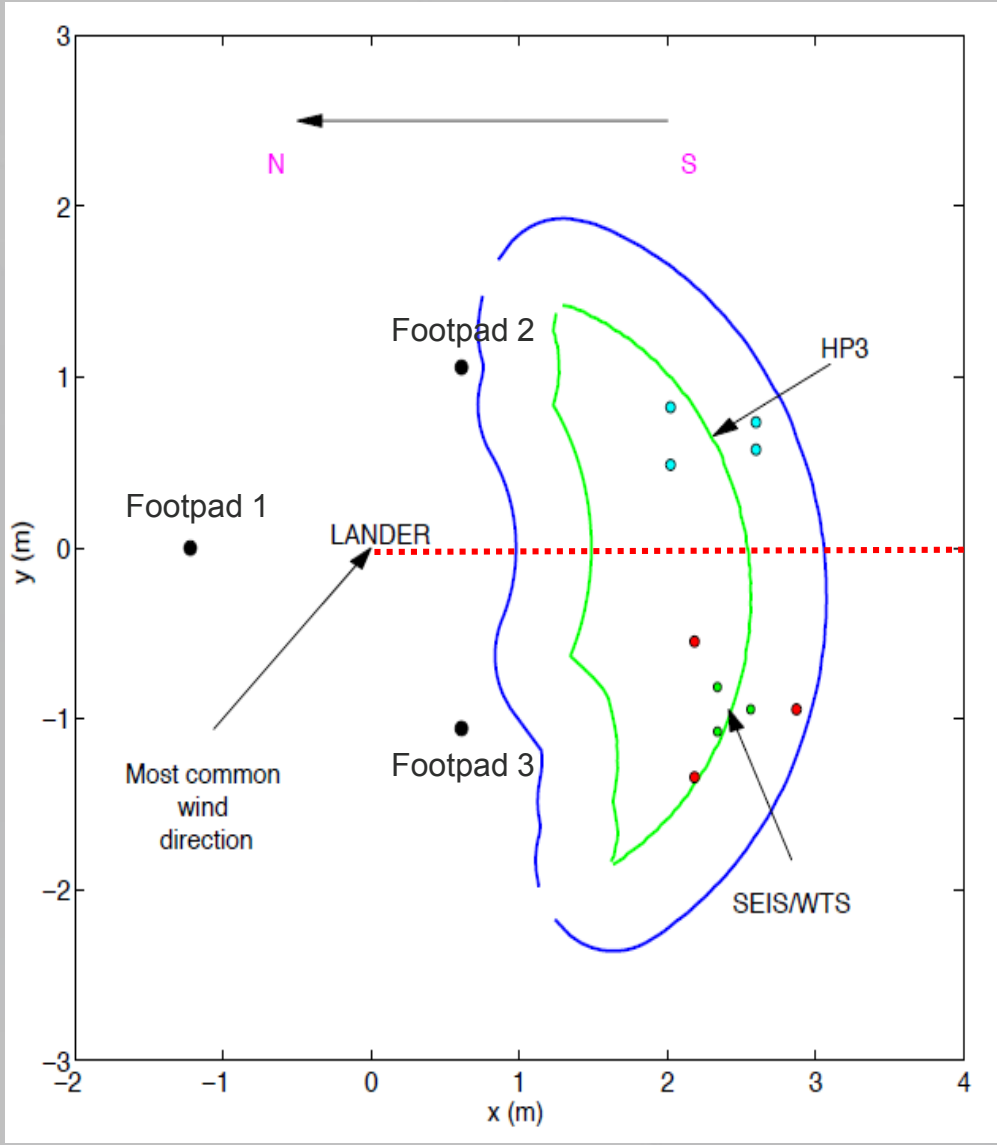

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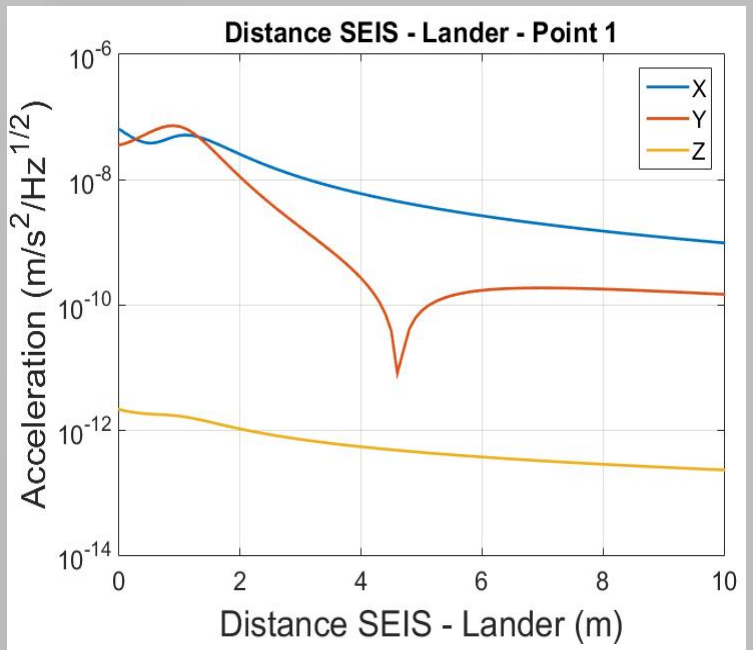
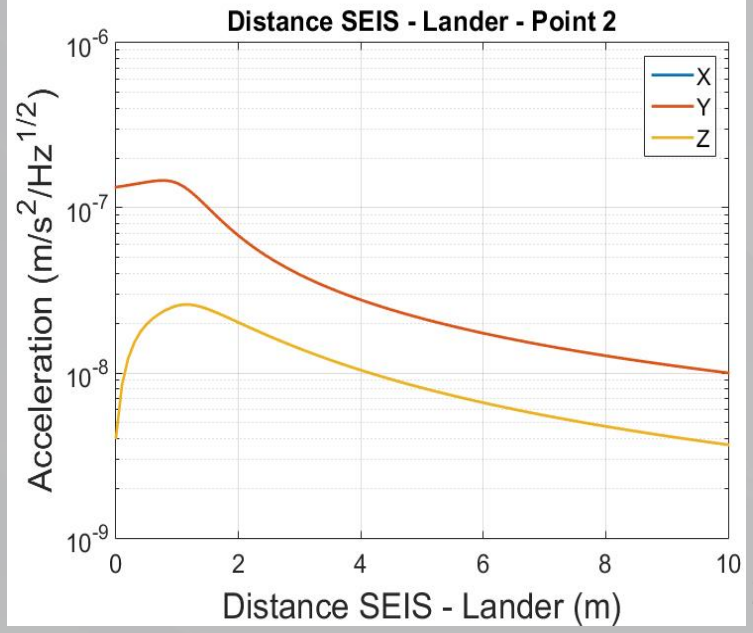
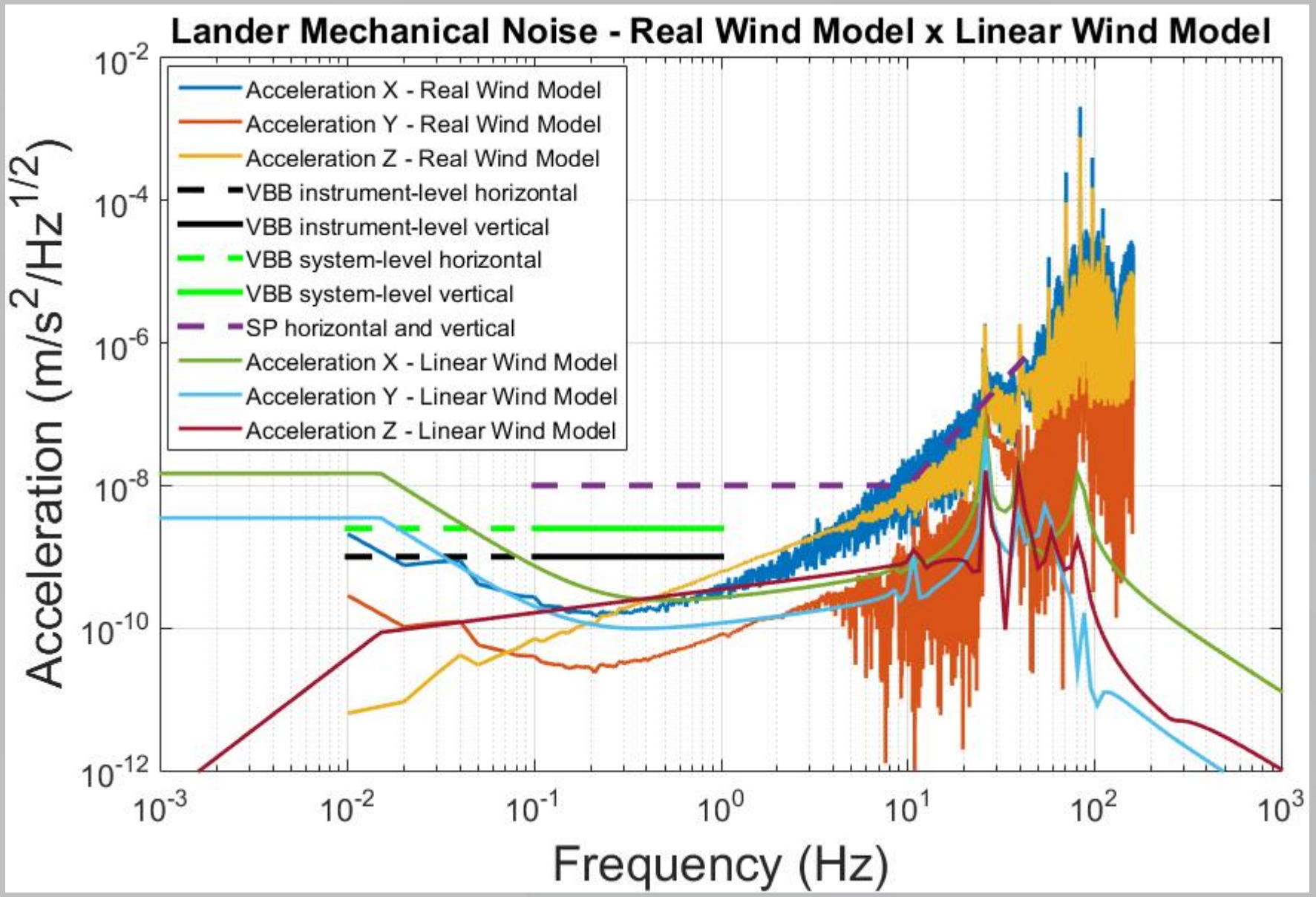




5 - Discussion

5.4 - Model Application in a Real Case

- Viking Lander 1 Data



6 - Conclusion

- Possible applications:
    1. Positioning of the seismometer
    2. Prediction and filtering of the lander mechanical noise
    3. Use of the lander mechanical noise as an active source of ground properties detection

Thank you for your attention!
Questions ?

InSight