Spring 2022

The Effect of Store-to-store Energy Transfers On the Global Dynamics of Aircraft

Guilherme Mainieri Eymael
University of Nebraska-Lincoln

Keegan J. Moore
University of Nebraska-Lincoln

The Effect of Store-to-store Energy Transfers On the Global Dynamics of Aircraft

Guilherme M. Eymael, Keegan J. Moore

Department of Mechanical and Materials Engineering, University of Nebraska-Lincoln

BACKGROUND

Wing Attachments (stores):

- Examples of stores are engines in an airplane and missiles in a fighter jet.
- The attachment of stores to the airplane's primary structure adds nonlinearity to the system.
- Such nonlinearity may cause serious structural damage to the airplane's structure by inducing self-sustaining vibrations [1].

Previous Studies:

- Pilots have reported that when stores are attached, there are unwanted lateral motions, which inhibits their ability to effectively use flight control mechanisms.
- Previous studies [2] indicated that wing-based stores can drastically alter the global dynamics of the aircraft when strong nonlinearities are present.
- It was found that the primary structure's dynamics changes depending on whether one or two stores are attached to it.

OBJECTIVE

- Investigate the energy transfer mechanisms that occur in different stores configurations and the possible cause for the change in dynamics.

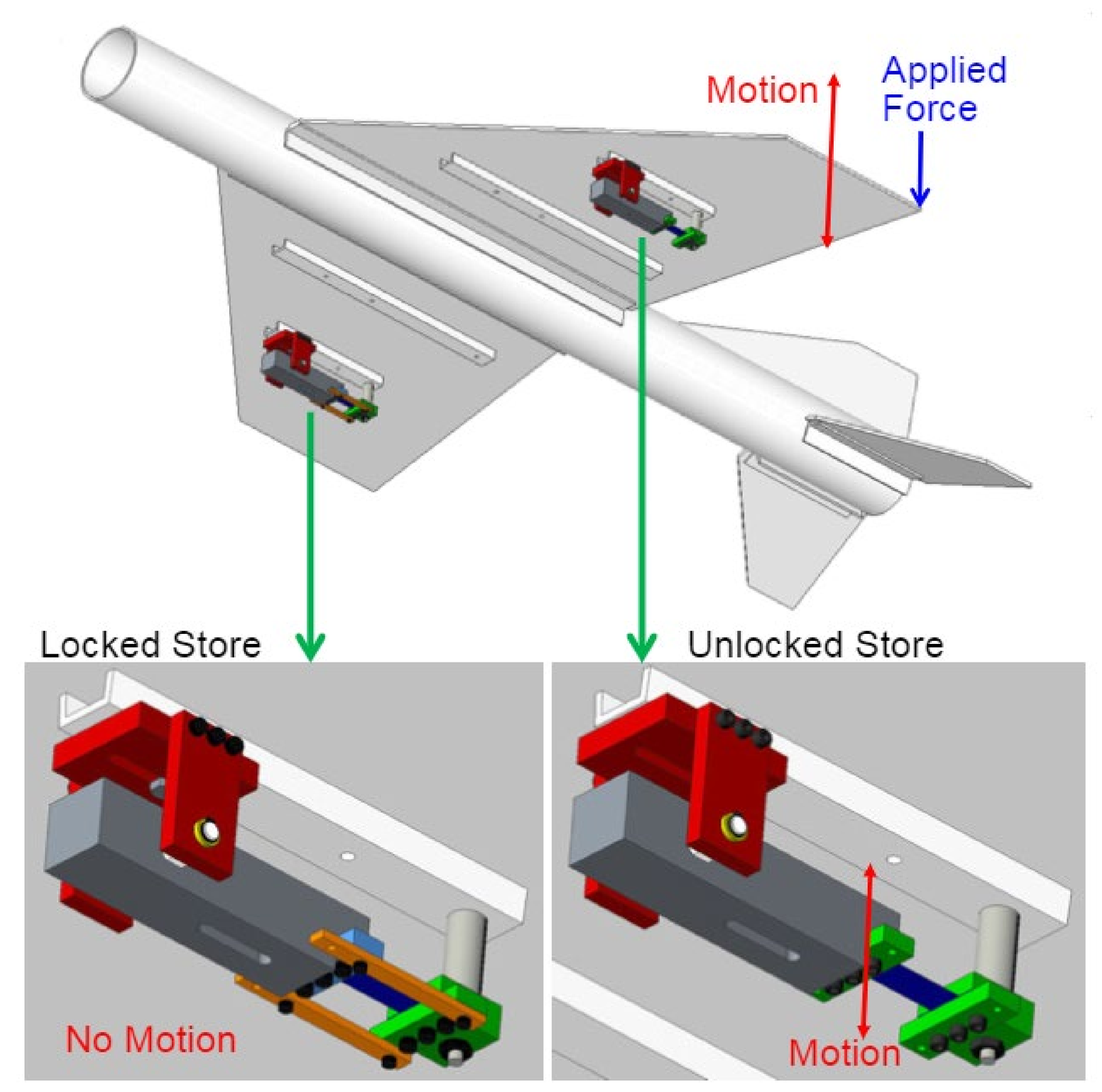
Hypothesis:

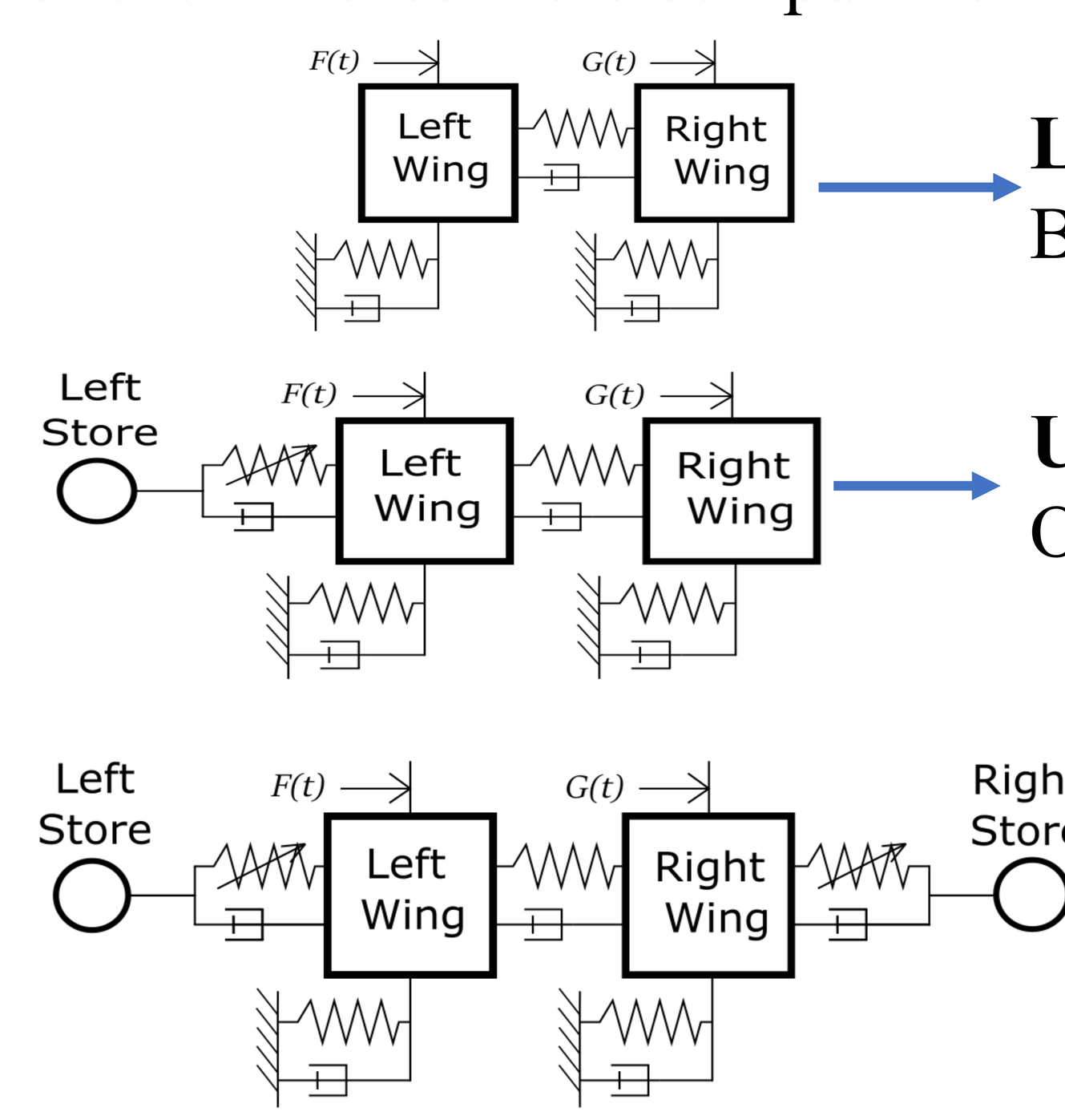
- We hypothesize that two stores interact with each other destructively, canceling out their effects.

REDUCED-ORDER MODEL (ROM) SIMULATIONS

What are ROMs and why to use them?

- ROMs use a set of mathematical tools to simplify a complex system into a few equations by identifying its essential features and conserving its input-output characteristics.
- ROMs are used for fast simulations with reasonable computational power.



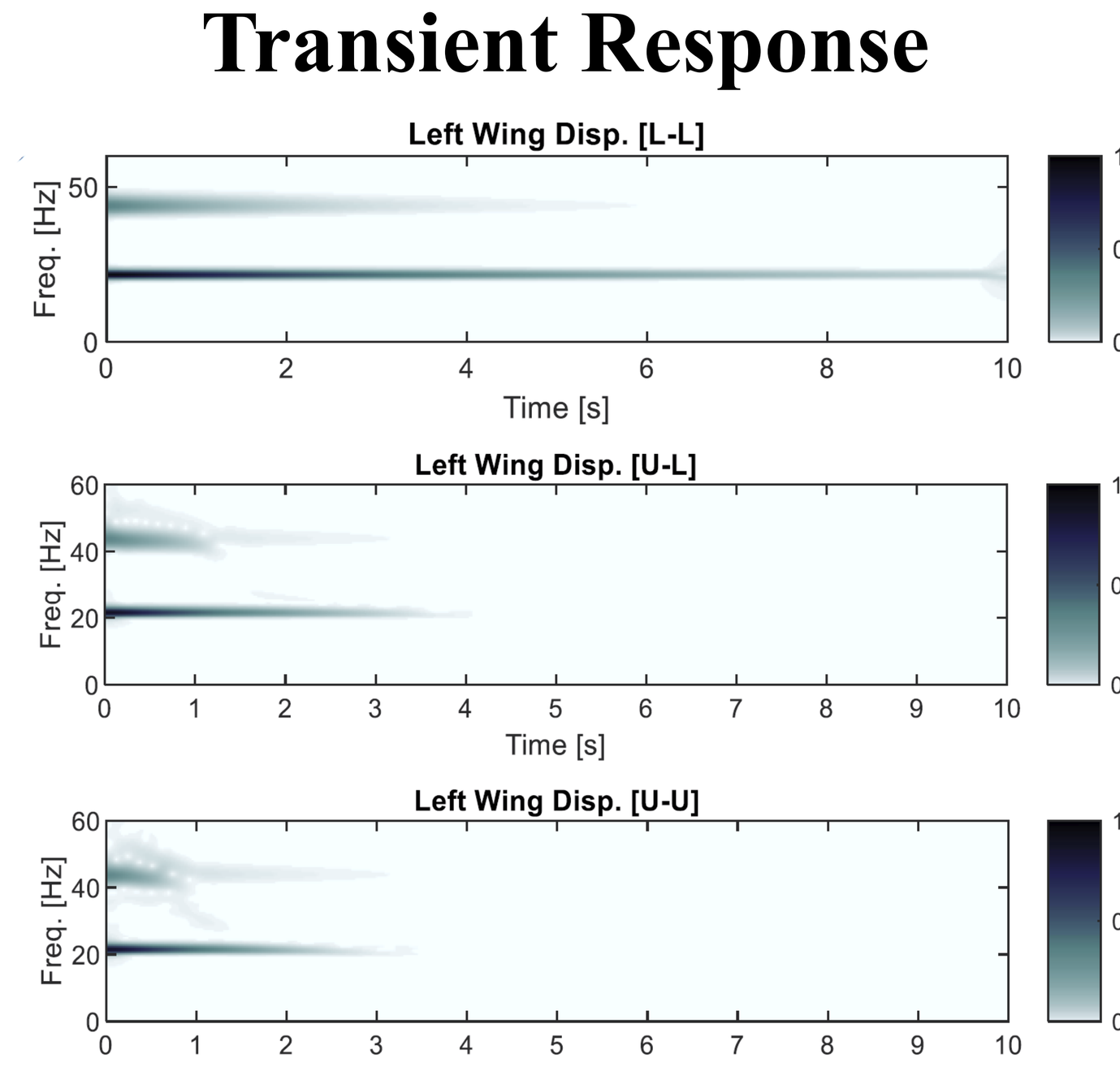


Locked-Locked configuration (LL):
Both stores are locked and act only as mass effect

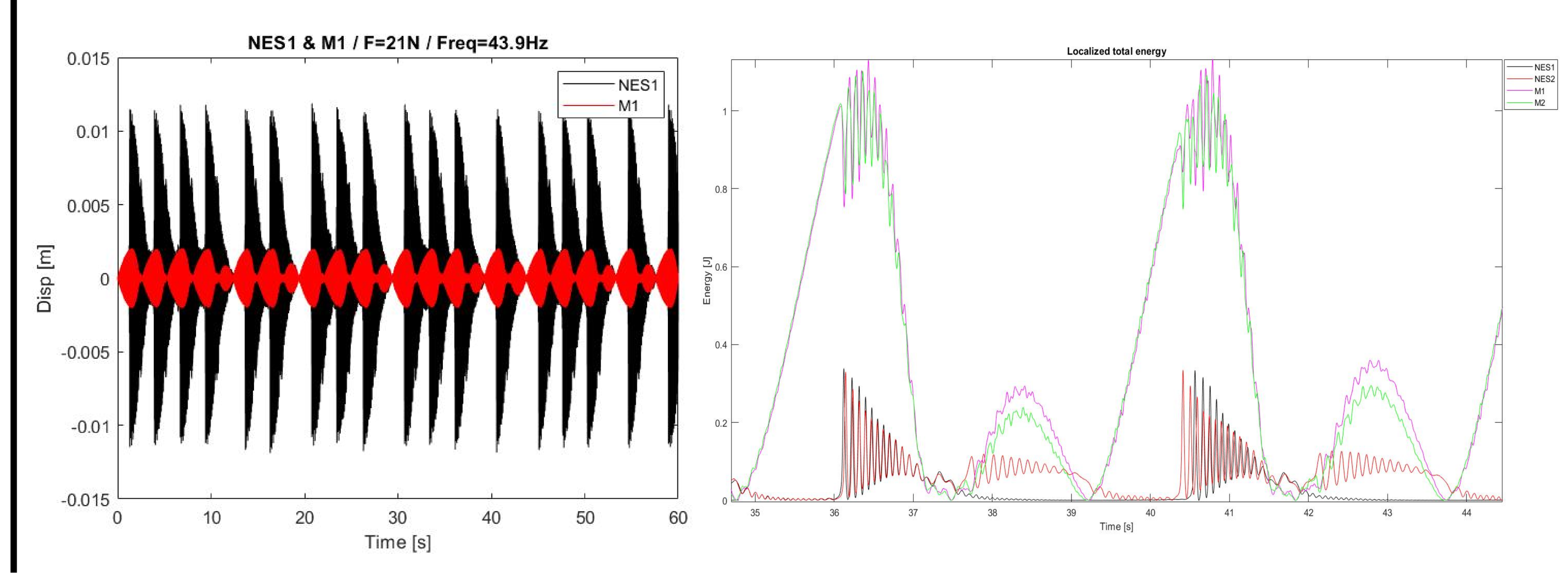
Unlocked-Locked configuration (UL):
One store is unlocked, adding nonlinearity to the system

Unlocked-Unlocked configuration (UU):
Both stores are unlocked

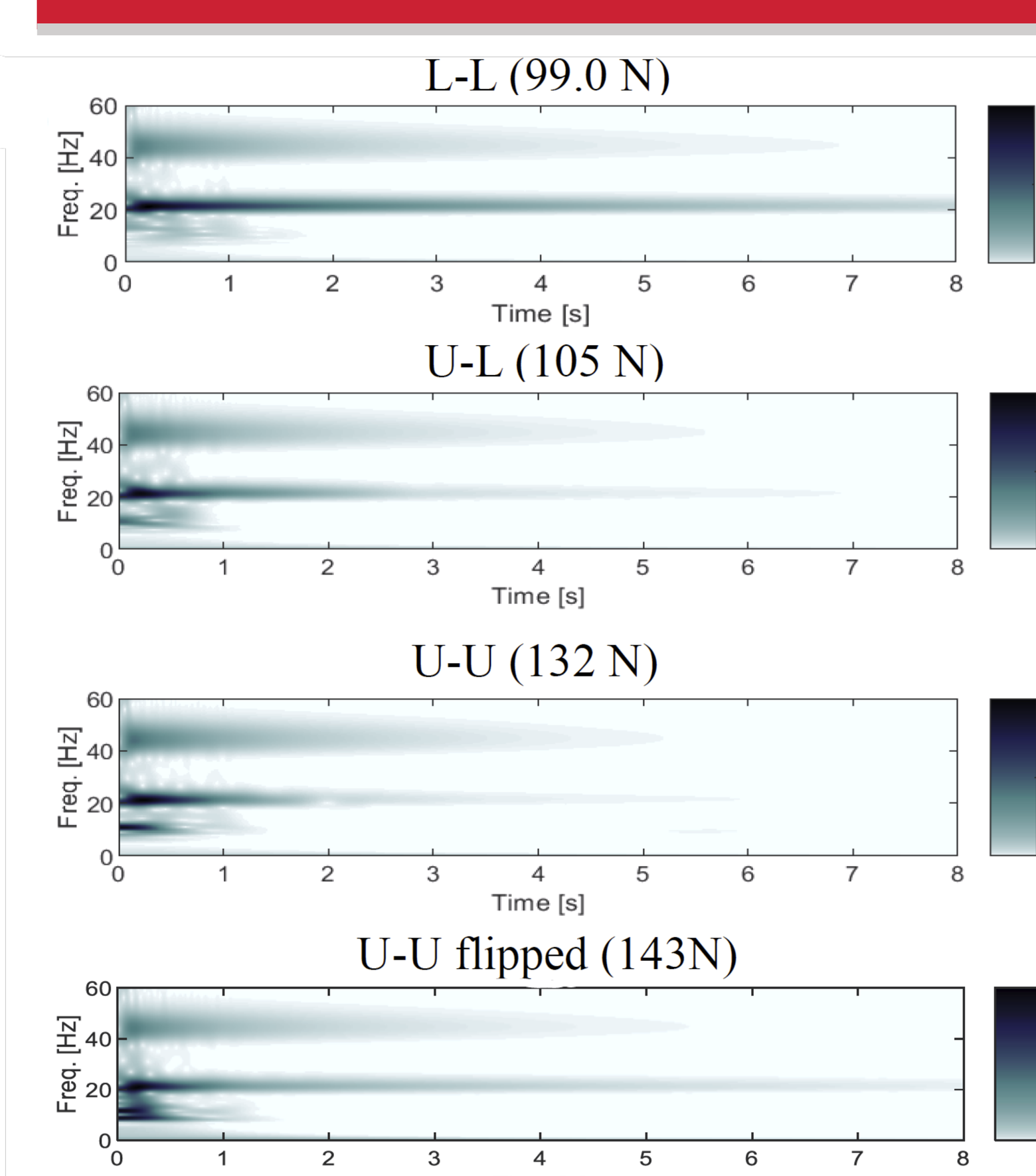
Transient Response

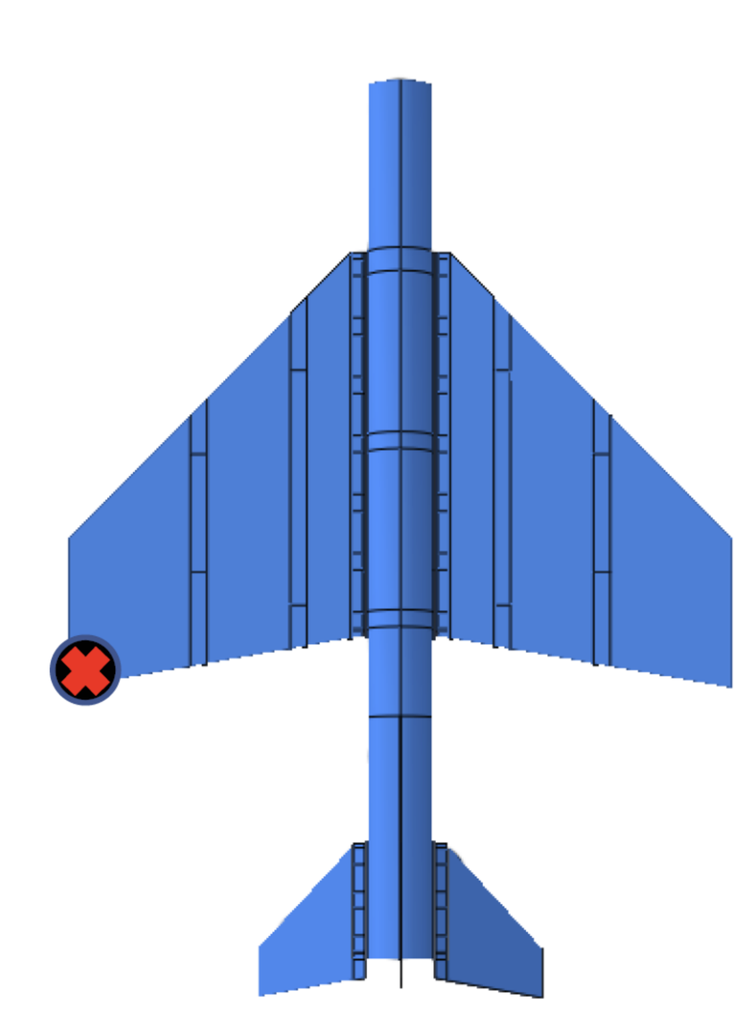


Periodic Forcing Response (UU)



EXPERIMENTAL RESULTS





✖ Impact Location

● Measurement Location

Why to perform experiments?

- The ROM failed to capture the expected results [2]
- Test the new hypothesis that the energy transfer mechanism depends on the geometry of the primary structure and how the NESs are attached.

Experiments Performed:

- Single hit with a modal hammer in the model airplane with different store configurations and multiple forcing amplitudes.

CONCLUSIONS

- The attachment of nonlinear stores in the ROM changes the global dynamics of the primary structure.
- Store-to-store interactions do not occur in the ROM.
- The attachment of nonlinear stores in the experimental model airplane changes the global dynamics of the primary structure; however, no store-to-store energy transfer was identified.
- The energy transfer mechanisms depend on the geometry of the system since the dynamics of the model airplane changes with the orientation of the stores.

FUTURE WORK

- To improve the consistency of experimental results, it is crucial to ensure the tension of the flexure stays the same through all experiments. This can be achieved by mounting the stores to a plate instead of directly to the airplane structure.
- Investigate how to target the energy transfer in different modes of vibration by positioning the stores according to each mode shape.

REFERENCES

1. Denegri, C. et al. (2005). In-flight wing deformation characteristics during limit cycle oscillations. Journal of Aircraft, 42(2), 500–508. https://doi.org/10.2514/1.1345
2. Moore, K.J., et al. (2019). Local nonlinear stores induce global dynamical effects in an experimental model plane. AIAA Journal, 57(11), 4953-4965.