Active Damping of Missile Bending Vibrations

Anatole Verhaegen

Supervisor – R. Zbikowski
Industrial Supervisor – G. Wallis

Introduction

Defense missiles with extreme slender shapes have issues with bending oscillations. This type of structural deformations is easily excited during the flight. It is a source of noise for the seeker and creates parasitic actuations as shown in Figure 1. Structural filters are generally used to avoid the propagation of bending noise through the system. However they create a significant phase loss at low frequency and they do not suppress the oscillation. The thesis investigates active damping of these bending vibrations on ASTER-30, an MBDA surface-to-air missile.

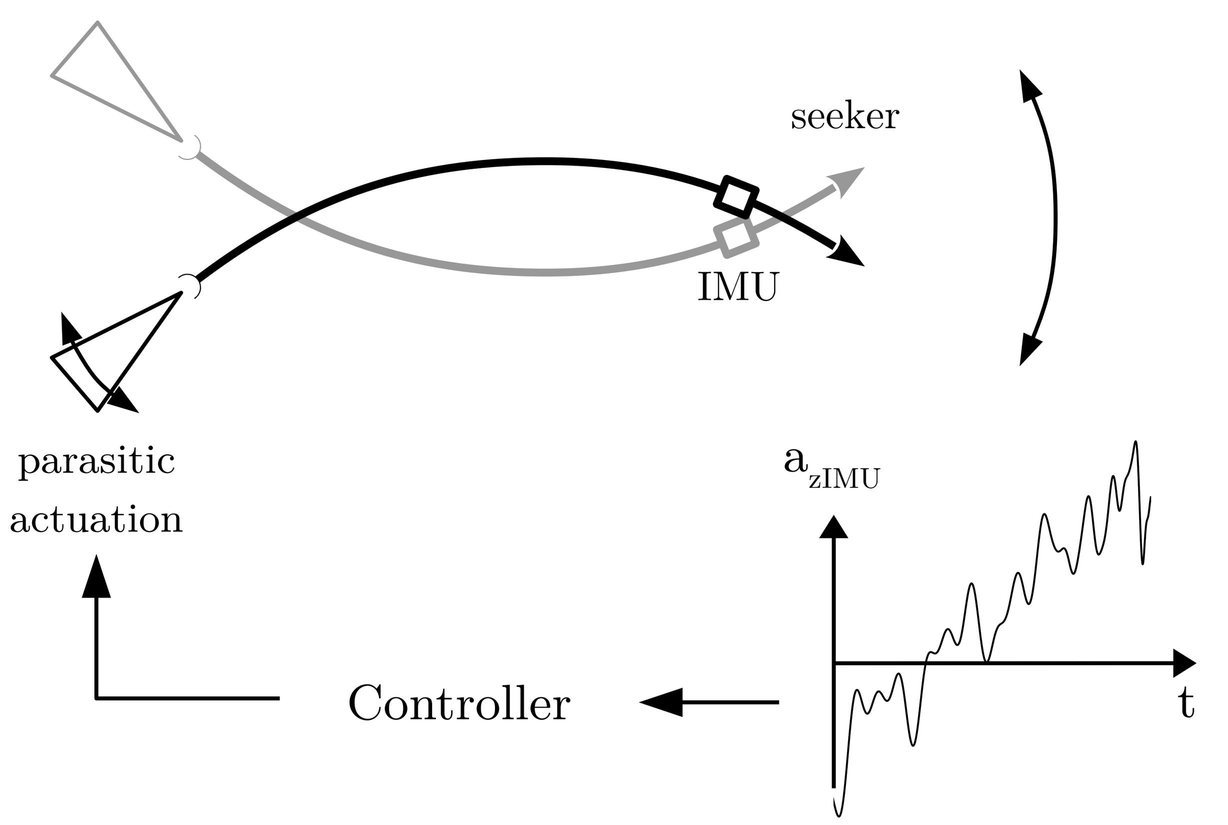


Figure 1 - Bending Oscillations

Problem Approach

The process for the design of an active damping system has been divided in three steps. The first step was to model the flexible missile. A longitudinal servo-aeroelastic model has been derived using linear flight dynamics and a Euler-Bernoulli beam representation of the structure. The second step was to add sensors on the airframe to measure the flexure. The H_∞-norm of the MIMO system is used to find the best locations to place a strain gauge, gyroscopes and accelerometers shown on Figure 2. The last step consisted in the design of 3 active damping and lateral acceleration controllers. They were optimally tuned and compared with the conventional controller featured with a structural filter.

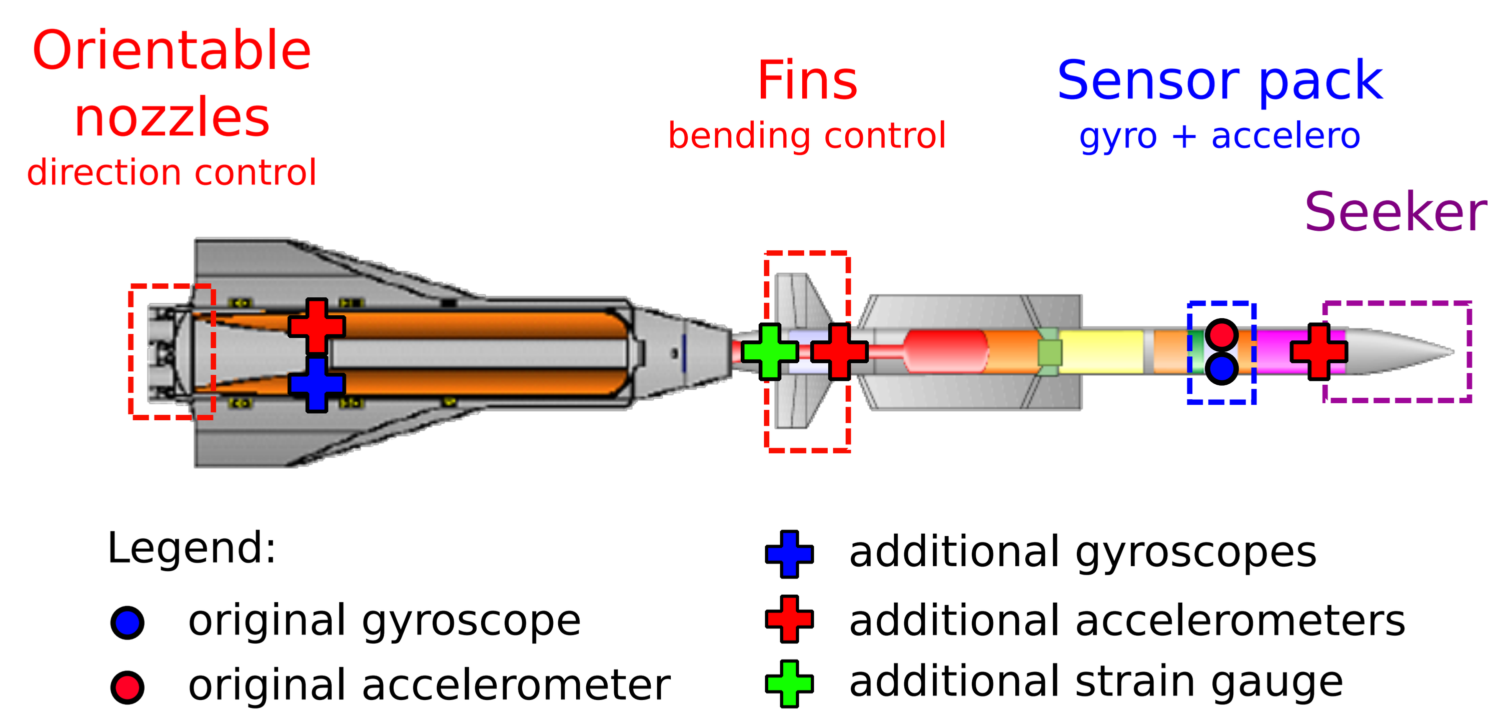
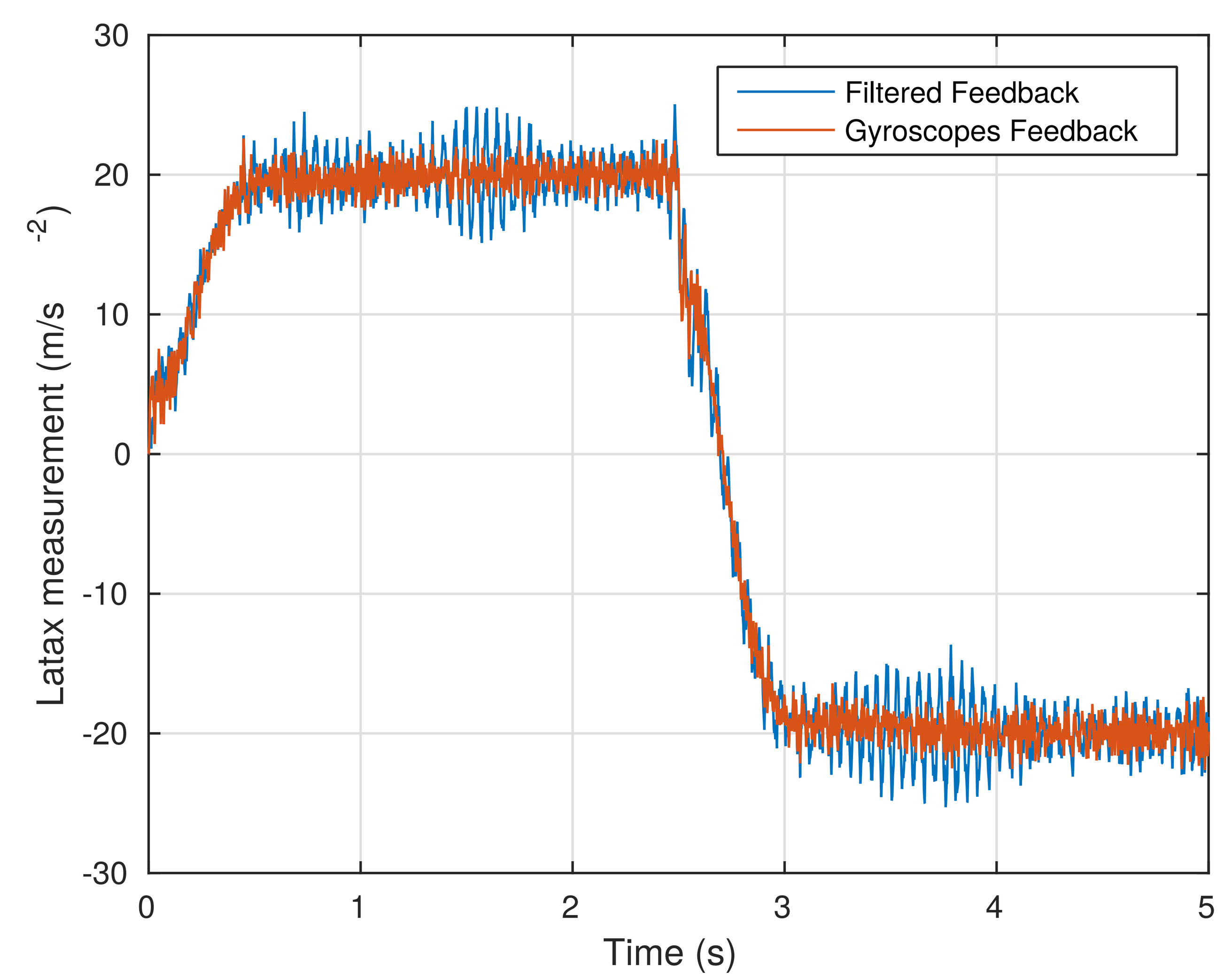


Figure 2 -Sensor-rich ASTER-30

Summary of Results

Three active damping architectures were designed. The respectively use the measurements of the strain gauge, the gyroscopes and the accelerometers. Compared with a conventional notch filtered controller, these architectures were assessed with several criterion.
All the controllers present similar lateral acceleration tracking and noise rejection performance. However the active damping closed-loop succeed in removing bending vibrations thus the seeker and the sensor pack are less noisy. The other advantage is the reduction of dynamic strain in the link between the booster and the dart. Figure 3 shows the measurement of the sensor pack accelerometer and demonstrates the reduction of noise.

between the booster and the dart. Figure 3 shows the measurement of the sensor pack accelerometer and demonstrates the reduction of noise.
The feedback using the gyroscopes is the more appropriated since it requires only one additional sensor, its fins actuation demand is low and the signal processing is simple compared to the use of accelerometers.



Conclusions

The study demonstrated the feasibility of active damping for ASTER-30 using additional sensors and the fins. The suppression of the bending oscillations allows an alleviation of the structure constraints, the removal of structural filters and thus an increased reactivity of the defense missile.
The method presented could be implemented on all types of slender bodies as defense missiles but also space launchers.

September 2015

MSc Autonomous Vehicle Dynamics and Control
School of Aerospace, Transport and Manufacturing