Control of Flexible Spacecraft with Structural Feedback

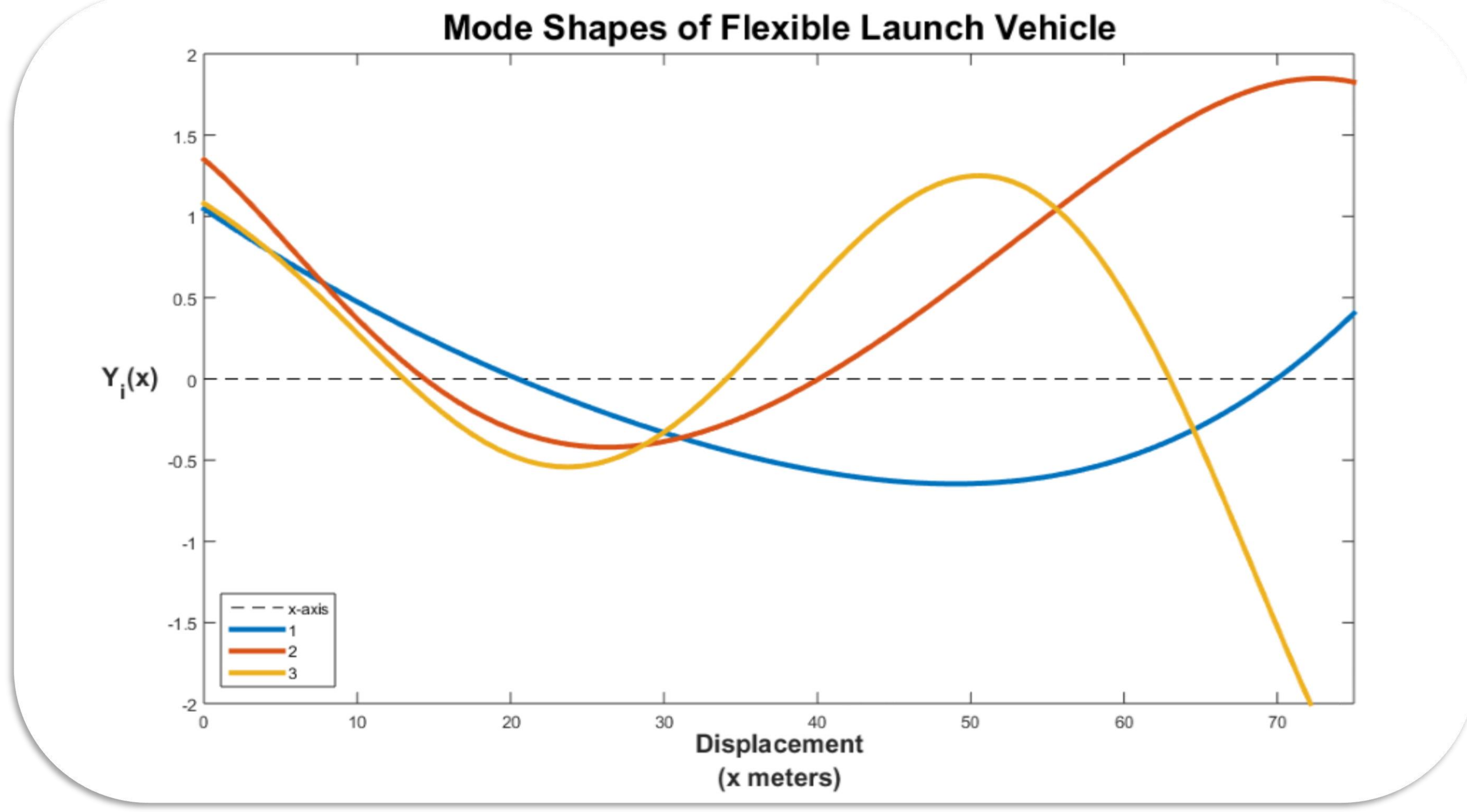
Matthew McGillick – Massachusetts Institute of Technology, Aerospace Engineering
Code 530 – Dynamics and Controls | Mentor – Matt Boucher
Armstrong Flight Research Center

Context: X-56 and FOSS

The application of feedback control to flexible aircraft has been a research topic for decades, but particularly so in the past few years at the National Aeronautics and Space Administration's (NASA) Armstrong Flight Research Center (AFRC). The Center's recent work with the X-56A airframe has shown that the use of feedback control can combat the development of flutter in a flexible wing. AFRC also utilized a novel instrument: the Fiber Optic Sensing System (FOSS). FOSS is comprised primarily of a fiber-optic cable that is ran along the length of an aircraft's wing. As the wing is deflected due to aerodynamic forces, the light traveling through the fiber-optic is diffracted away from its normal path. The strain the wing experiences can be extrapolated from this diffraction, providing additional information into the state of the aircraft.

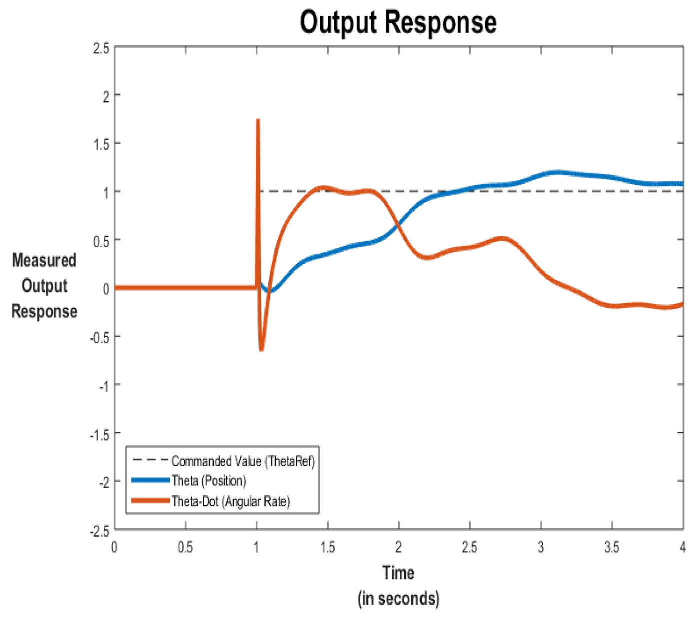
Motivation: Why Care about Flexible Spacecraft?

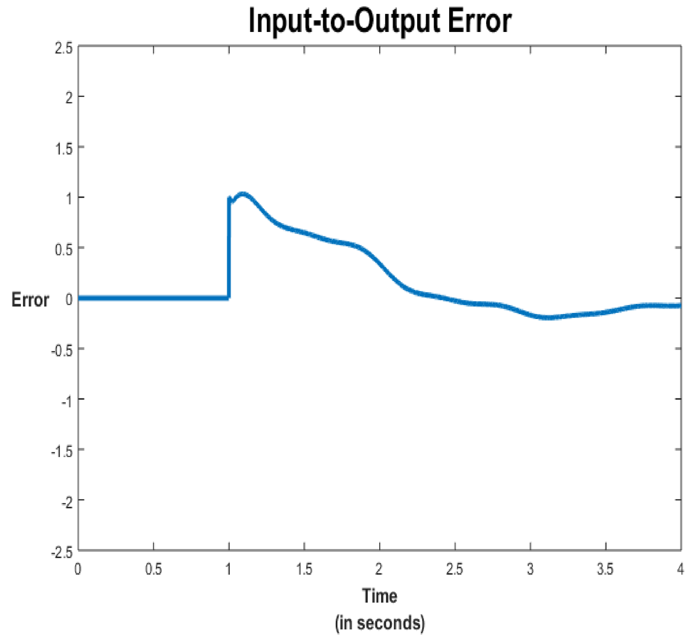
In most cases, flexibility in aircraft, spacecraft, and launch vehicles (LVs) is something to be avoided. The flexing – comprised of bending modes, or fundamental oscillations – of these vehicles can be amplified due to a variety of forces, leading to instability. However, as seen with the X-56A, actively controlling these bending modes can increase the flight envelope of an aircraft. The question remains: can the same be done with LVs and spacecraft? If so, this could lead to a slew of benefits – increased control of the vehicles, reduced payload costs, et cetera.



Approach: Modeling and Controlling Flexible Dynamics

Developing a strong foundation in control theory was necessary for the success of this project. This was achieved through an in-depth analysis of a flexible LV. The analysis included recreating the bending modes seen in the LV and designing a custom feedback control system for the LV, analyzing the LV's flight angle (theta) to a gimbal angle (thruster angle) input .





Looking Forward: Deliverables and Continuity

FOSS equations will be applied to various LV and spacecraft systems to assess potential benefits. The benefits will be catalogued, analyzed, and compiled into a position paper detailing these to NASA AFRC and NASA.

A special thanks to Matt Boucher, Oscar Murillo, Jack Button, Bahram Mobasher, and Xinnan Du for all their help.