Master's Thesis Mechanical Engineering

Control Co-Design of a Beam Pointing Mechanism

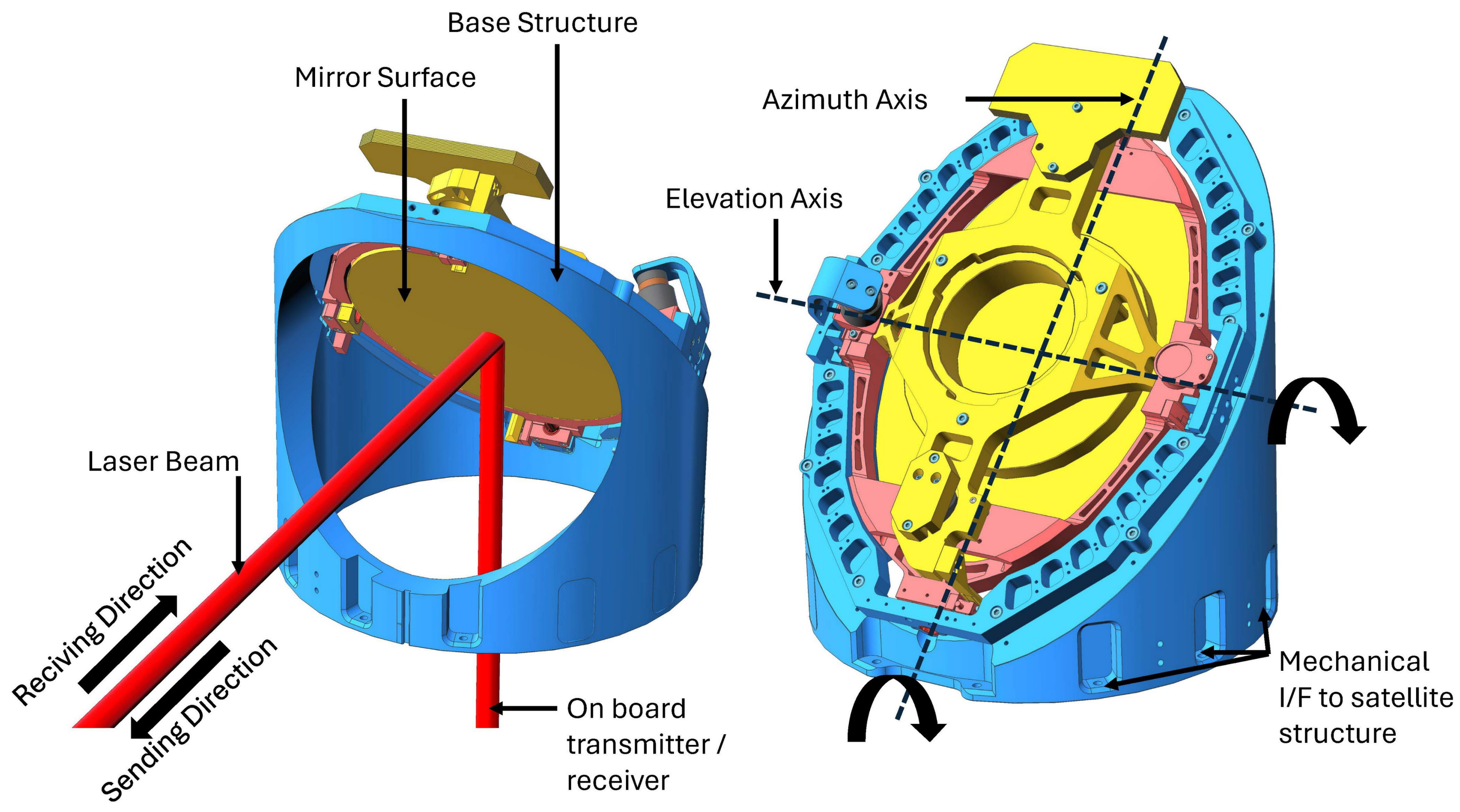

Figure 1: Beam steering assembly - Overview

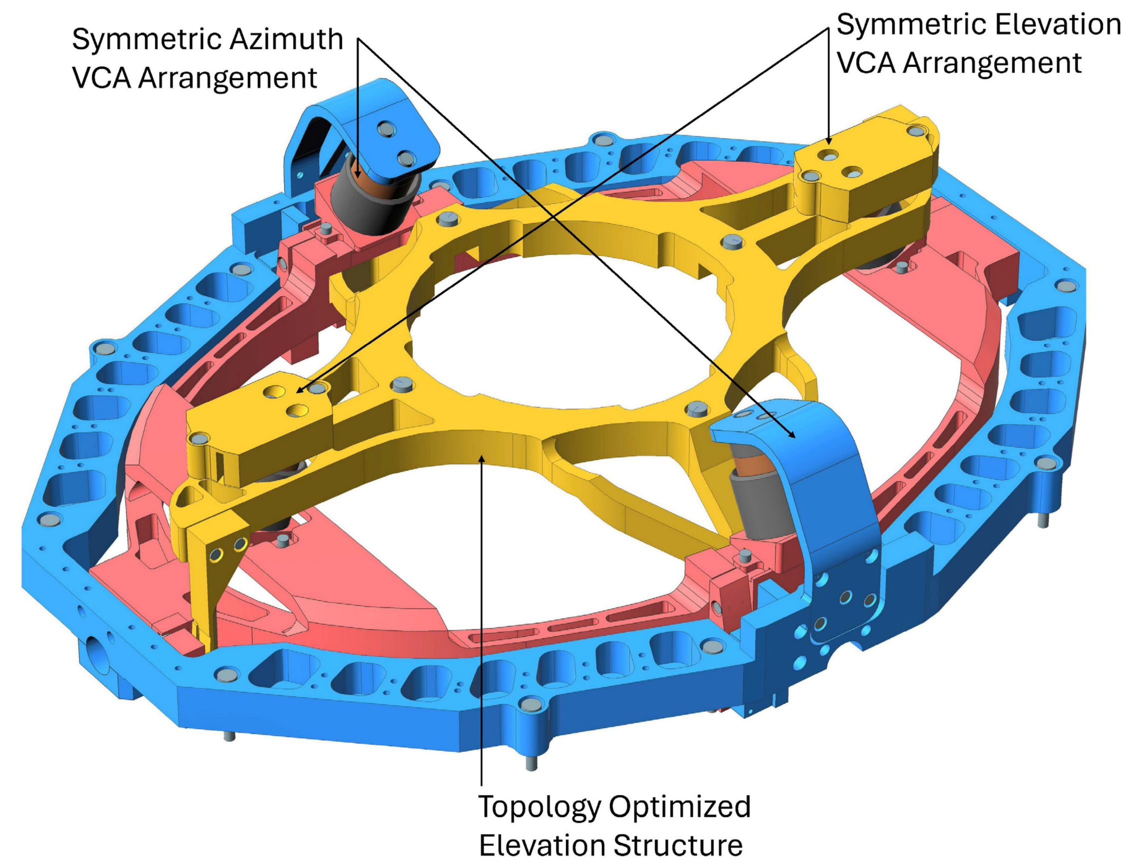

Figure 2: Optimized Cardanic Mechanism

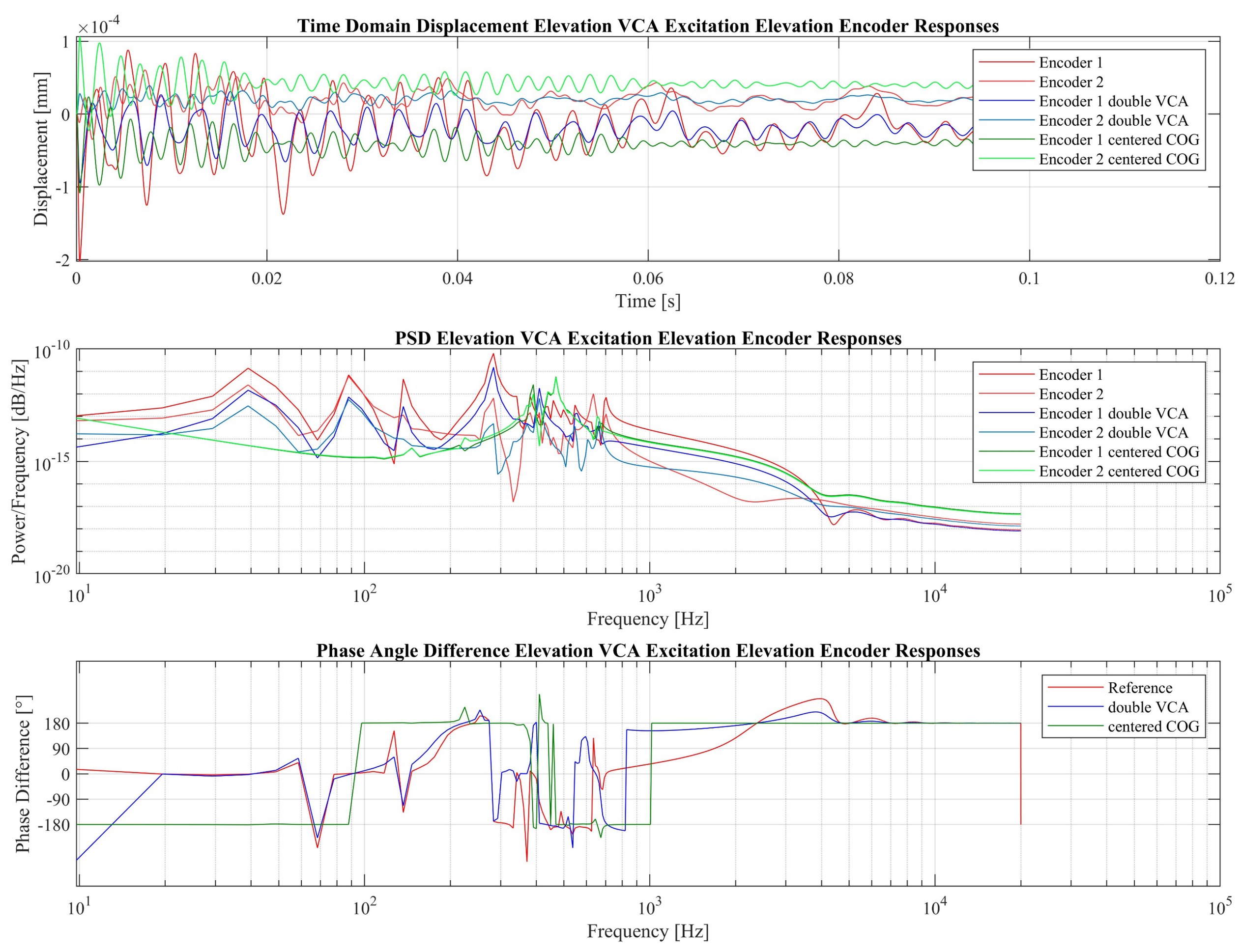

Figure 3: Dynamic Analysis and Design Comparison

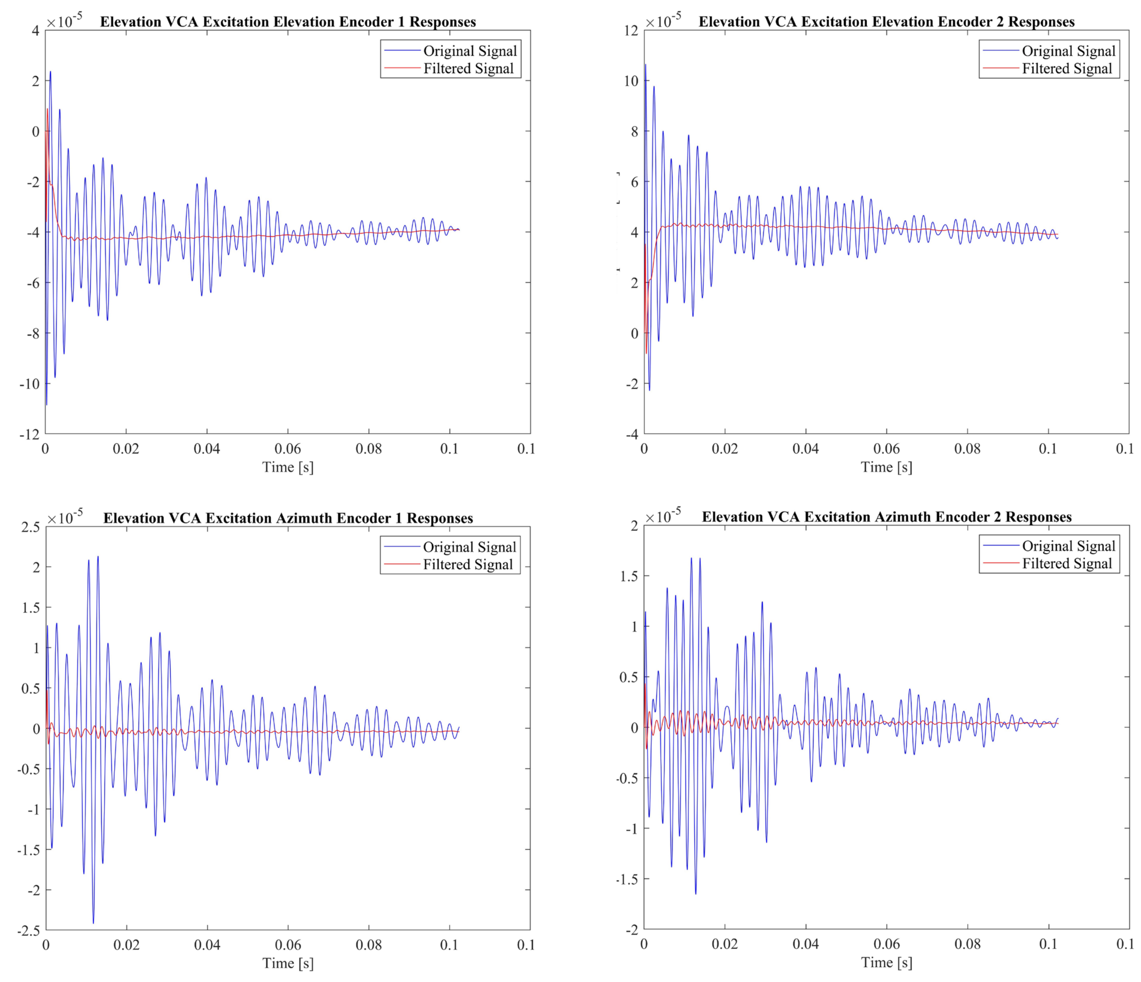

Figure 4: Encoder Signals after Signal Processing

Introduction

General Atomics Synopta GmbH offers development and production of complex opto-electronic instrumentation for space and industrial applications. They focus on systems enabling laser communication between earth-orbiting satellites and ground stations. They offer beam pointing mechanisms for satellites or ground stations to direct the communication laser beam. Such devices guarantee high pointing stability to enable laser communication links resistant to environmental disturbances like vibrations. One mechanism for an earth-orbiting satellite is the beam steering assembly (BSA) on which this thesis focuses. The mechanism features a mirror to redirect the laser beam, suspended by a cardanic structure allowing control of the mirror's angular position around the azimuth and elevation axis. During tests with the BSA ground demonstrator, control loop oscillations were observed, making precise positioning of the mirror difficult. In the context of this thesis the reasons for these oscillations are investigated. Based on the findings of these investigations the current design is optimized with the objective to minimize the oscillations and therefore improve the system's controllability.

Procedure

In a first project stage a finite element model of the mechanism is developed and correlated to provided test data. This process also involved stiffness testing of crucial components of the mechanism. In a second stage the dynamic behavior is investigated, using the simulation model. In the last stage the optimization is performed based on the analyses results.

Results

Dynamic analyses in the time and frequency domains show that precise control of the mirror is difficult for three main reasons. Firstly, the actuator excites modes that lead to oscillating control feedbacks. Secondly, the control feedbacks are out of phase, leading to misinterpretation of the feedback. And finally, there is cross-coupling between the azimuth and elevation structures, leading to additional oscillations. The implementation of conceptual changes towards a symmetrical design in conjunction with topology optimization and signal processing results in significantly reduced oscillations, thereby stabilizing the control system.

Samuel Tenisch

Advisor
Prof. Dr. Gerhard Stefan Székely

Expert
Tobias Waeber

Industry Partner
General Atomics Synopta GmbH

GENERAL ATOMICS SYNOPTA