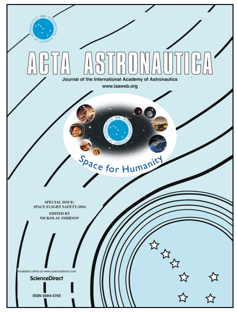


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# Effects of a High Fidelity Filter on the Attitude Stabilization of a Flexible Spacecraft

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**Abstract**

The problem of stabilizing the time delayed control of a flexible space structure is analyzed in this paper. A free floating platform is used to investigate the space multibody dynamics and control. A first necessary step to develop stabilizing techniques is considered the availability of a set of measurements as complete as possible: in particular measurements of the elastic vibrations are necessary in addition to classic attitude measurements. At the scope, a net of PZT sensors have been designed and manufactured on a composite material panel, purposely built to resemble a space structure. A combined use of the PZT/optical sensor is proposed, where the role of the camera is to estimate the PZT parameters that can be changed after the manufacturing or for environmental aging. When this calibration process is performed, PZT can be used as standalone sensors for measuring also the elastic displacement of the structure. Once these measurements of attitude and elastic displacement are obtained, two stabilizing techniques have been developed, the Finite Spectrum Analysis, already known in literature, and the newly developed High Fidelity Filter approach, based on the design of a Kalman filter with large confidence on the process dynamics. It is shown that both techniques manage to increase the delay margin of the system, thus obtaining a stable maneuver, but the second approach reach this goal with very low residual vibrations and a remarkable fuel saving.

**Keywords:** flexible space multibody; dual PZT/camera use; vibration sensing and control; attitude control.

## 1. Introduction

Space structures are usually characterized by the presence of large and light bodies e.g. solar arrays or antennas (see for example the classic space structure depicted in Fig. 1). The dynamics of the appendages interacts with the attitude dynamics of the system and vice versa, hence the control of large space structures can be seriously affected in terms of accuracy or even of stability, because of the high flexibility and the very low natural frequencies of the involved structures [1].

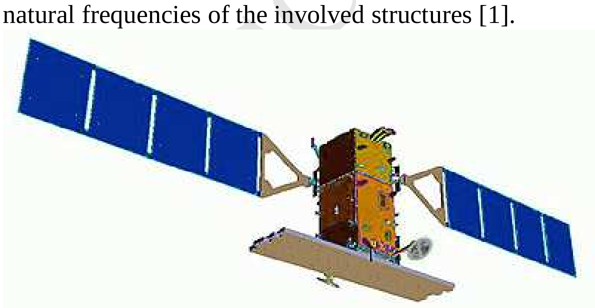

**Fig. 1 An example of a typical LEO satellite with large elastic appendages.**

This problem has received great attention in recent years, and different solutions have been proposed. From one side, attitude control strategies have been studied for the specific problem of large flexible satellites, such H-infinity controllers [2], robust controllers [3], and model-based controllers [4], just to cite some. A completely different approach consists in actively damp the elastic oscillations, so the attention is focused on the use of smart materials like lead zirconate titanate (PZT) to directly act on the flexible structure [5], [6], [7]. Finally, some other papers propose the combined use of attitude and smart material actuators [8].

In this paper the main focus is on possible remedies for unstable dynamics caused by a poor control design on a flexible system, in which the time delay affecting the Guidance, Navigation and Control (GNC) loop plays a crucial role. Two different strategies have been implemented in order to prevent an unstable behavior during the maneuver, without decreasing the control gains or slowing down the maneuver. In fact, it is shown that the (unavoidable) presence of a time delay in the GNC loop can produce instability, if the delay margins of the system are not sufficient.

The first strategy tested to solve this issue is usually called Finite Spectrum Assignment (FSA) [9], [10], and