

# Sensitivity analysis of a panel deployment maneuver of a satellite with pre-stressed components

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## Abstract

Sensitivity analysis is a powerful tool by its own on the assessment of the effects of manufacturing and assembling imperfections of practical dynamical systems, as well as the cornerstone of most popular optimization methods [1, 2]. On the other hand, three-dimensional mechanisms for space applications could be specially sensitive to these practical imperfections due to their high flexibility, caused typically by their slenderness and lightness. In particular, deployable devices are very common specially in satellites equipped with solar panels, being the deployment phase one of the most critical due to the complexity of the kinematics and the flexibility of the panels.

Within this context, this paper reports the results of a sensitivity analysis of the deployment maneuver of a four-panel satellite. The deployment is triggered by the release of four pre-stressed elements, that act as a rotational springs that free several beam-like structures that drive the overall movement. Both the pre-stressed elements and the panel frames are modeled with nonlinear beams capable of handling large displacements and strains, with a rotation-free formulation based on absolute coordinates that, combined with an implicit time-integration, provide a robust and accurate numerical model [3]. The sensitivities of the positions of several points of the satellite body and the panels respect to imperfections of the lengths of some of the beams (both rigid and flexible) are computed. Special attention is paid to the computation of the initial sensitivities, that largely impact the evolution of the aforementioned sensitivities in time [4]. A preliminar model with just two panels has been already developed and some preliminary sensitivities already computed. Some snapshots of the nominal movement are shown in Figure 1, and the preliminary sensitivities of the position  $(x, y, z)$  of one of the corners of one panel are shown in Figure 2. The definition of a more complex model composed by 4 panels is under development, and the results will be shown at the conference.

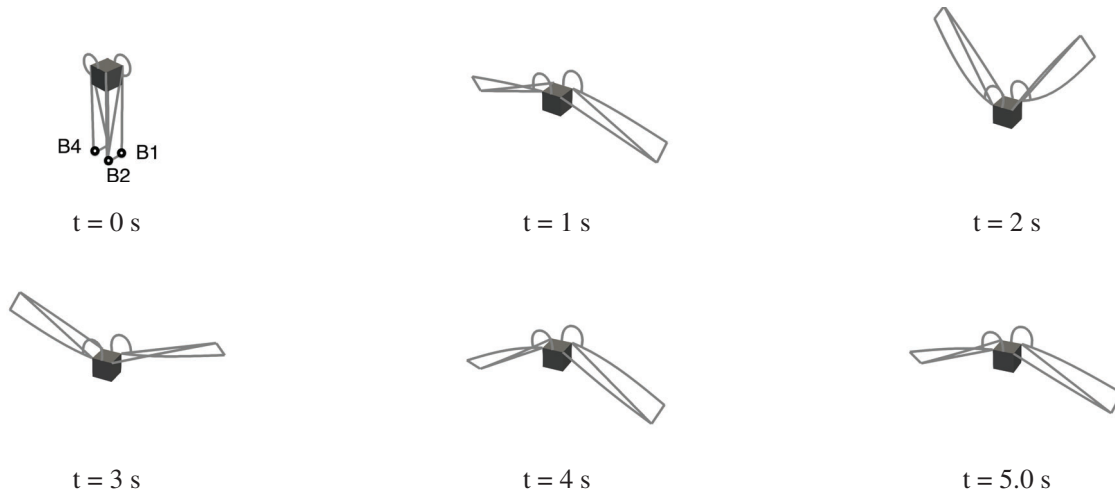


Figure 1: Deployment maneuver in a two-panel satellite: snapshots of the nominal movement

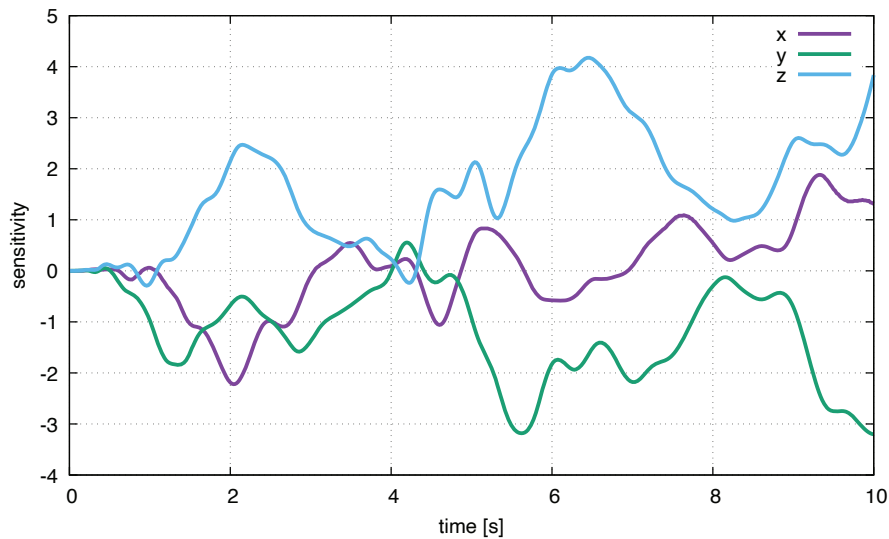


Figure 2: Sensitivity of the position of point  $B4$  respect the length of the rigid bar  $B1 - B2$  (see Figure 1,  $t = 0$  s)

### References

- [1] V. Gufler, E. Wehrle and A. Zwölfer: A review of flexible multibody dynamics for gradient-based design optimization. *Multibody System Dynamics* No. 53, pp. 379–409. DOI: 10.1007/s11044-021-09802-z. 2021
- [2] D. Dopico, Y. Zhu, A. Sandu and C. Sandu: Direct and adjoint sensitivity analysis of ordinary differential equation multibody formulations. *J. Comp. and Nonlinear Dynamics* No. 10. DOI: 10.1115/1.4026492. 2015.
- [3] J.C. García: A Simple Shear and Torsion-free Beam Model for Multibody Dynamics. *J. Comp. And Nonlinear Dynamics* No. 5, pp. 1-8. DOI: 10.1115/1.4036116. 2017
- [4] J.C. García, J.J. Arribas, A. López : Practical computation of initial sensitivities in dynamics of flexible multibody systems. *Computers & Structures*, under review. 2025