On-Earth Testbed for Implementation
of Attitude Control Laws

Hossein Karimpour [#1], Mojtaba Mahzoon [*2], Mehdi Keshmiri [#3]

Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran
[1]karimpour@me.iut.ac.ir
[3]mehdik@cc.iut.ac.ir
* *School of Mechanical Engineering, Shiraz University, Shiraz, Iran*
[2]mahzoon@shirazu.iut.ac.ir

Abstract - **The present attitude control testbed is intended to provide an experimental facility that, in certain senses, emulates the dynamics of in-orbit conditions and permits to evaluate path planning and feedback control algorithms for precise satellite manoeuvres in laboratory situ. This paper shows the feasibility of the approach and demonstrates how attitude control rules become compatible for both realms. Equations of motion for this internally and externally constrained nonholonomic system are studied in the modern setting of geometric mechanics.**

Index Terms — **Space Robots, Dynamics Analogy, Attitude Control, Reduction by Symmetry**

I. INTRODUCTION

In space robotic applications, the dynamically clean, weightless environment of space permits to plainly take advantage of conservative laws naturally arising, which in turn lead to governing equations of reduced-order facilitating the control design task. On the other hand, the lack of an on-orbit laboratory environment for testing hardware and validating system concepts is a fundamental difficulty in evaluating satellite attitude control technology. Consequently, development of new spacecraft attitude control technology has depended instead on extensive analysis and simulation of spacecraft rotational dynamics. Immersed encapsulated prototypes [1],[2] or models mounted on spherical air bearings [3]-[6] offer a nearly torque-free environment, meant to provide unconstrained rotational motion for ground-based research in spacecraft dynamics and control. But inconveniences exist such as drag forces, the burden of special equipments or the fact that the spatial angular cone swept is much less than a 4π steradian as the bearing limits the range of motion.

Motivated by the aforementioned issues and in order to compensate the omni-presence of gravity surrounding in-ground laboratories, an attitude control test-bed, shown in Fig. 1, has been developed to study concepts related to satellite attitude dynamics and control. This system is based upon a spherical platform constrained to roll on flat surfaces which allows experimenting manoeuvres involving continuous large angles, three-axis rotational motions.

The derivation approach discussed here is coordinate-free, based on the use of geometric tools specialized to deal with nonholonomic systems [6]. This approach allows one to make full profit of the system "symmetries" to reduce equations order and at the same time maintaining physical insight into their structure, without the notational overhead induced by the choice of a specific set of generalized coordinates [7]-[10].

Despite theoretical advances, demonstration of hardware reliability and algorithm performance in outer space conditions remains an issue. The analogy established here between the orbital and ground-based prototypes will permit to implement and verify control rules adapted for one system to the other, and vice-versa. Practical control implementation will require flexibility issues that may cause actual attitude drift in long term, to be explicitly addressed. Structural mode compensation approaches require the availability of accurate structural models, nonetheless distributed flexibility effects can still be adequately modelled using simple lumped approximations. It would be of interest to extend previous works on the stability of rigid and deformable bodies to rolling systems [11]. Such numerous potential applications describe the fact that much still remains to be learned from rigid body dynamics.
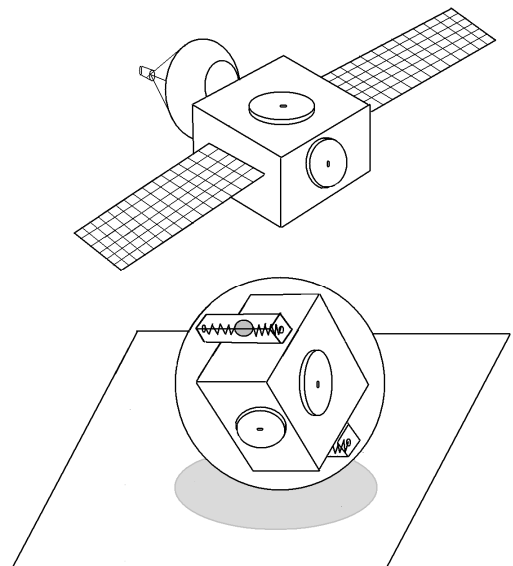

Fig.1 A satellite and its analogue imbedded into a rolling sphere, with flexible appendages replaced by oscillators