Krishna Dev Kumar, J Appl Mech Eng 2013, 2:3
http://dx.doi.org/10.4172/2168-9873.S1.004

OMICS Group Conferences
Accelerating Scientific Discovery

International Conference and Exhibition on
Mechanical & Aerospace Engineering
September 30-October 02, 2013 Hilton San Antonio Airport, TX, USA

Spacecraft dynamics and control: Evolution and current challenges

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The paper reviews the evolution of dynamics and control of spacecraft since the space era began with the launch of Sputnik in 1957. Early satellites typically weighted in the range of 100 kg had simple functionalities resulting in simple on-board control systems. In the 80's and 90's, the trend moved towards larger and more complex spacecraft weighing 1,000 kg to 10,000 kg with advanced on-board control systems. In the last two decades, with advances in miniaturization, small satellites such as nano satellites, picosatellites and femtosatellites have been designed and some of them using simple to advanced control systems have been launched as well. In addition, spacecraft formation flying has been considered as an enabling technology for future space missions. Several propellant-free or passive methods and active methods for spacecraft control and maneuvering have been proposed in the literature; in the case of spacecraft orbital maneuvering, these methods are mainly based on thrusters, aerodynamic forces, solar radiation pressure, magnetic forces, and tethers. On the other hand, the methods for spacecraft attitude control and maneuver include reaction wheels/control moment gyros, thrusters, fluid rings, solar radiation pressure, aerodynamic forces, magnetic Torquers, tethers, manipulators, MEMS devices, and movable masses. The controllers for spacecraft orbit and attitude maneuvering have been designed using linear control techniques as well as nonlinear control techniques such as linear quadratic regulator, Lyapunov-based control, feedback linearization control, sliding mode control or variable structure control, adaptive control, intelligent control (includes neural networks, fuzzy logic, and genetic programming), and combination of these. In addition to the fully actuated spacecraft, partial or intermittent failures of actuators as well as complete failures of some actuators i.e., the under actuated systems have also been examined. The feasibility of all these methods/techniques is established, in general, using stability analysis based on Lyapunov theory, numerical simulations, hardware-in-loop (HIL) simulations, and flight demonstrations. The evolution of all these methods, their current status and challenges associated with them are briefly described in the present paper along with future direction of research on spacecraft dynamics and control.

Biography

Krishna Dev Kumar is a Professor and Canada Research Chair in Space Systems, and Director of Space Systems Dynamics and Control Laboratory in the Department of Aerospace Engineering at Ryerson University, Toronto, Canada. His research interests include spacecraft dynamics and control, micro/nano-sensors and actuators, and intelligent control. His research has resulted in more than 150 publications (64 journal papers, 90 conference papers, five books, and two patents) and several awards including Canada Research Chair, Ontario Early Researcher Award, NSERC Discovery Award, Japan Society for the Promotion of Science Fellowship, Science and Technology Agency Fellowship, Associate Fellow of AIAA, and Senior Member of IEEE.

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