Spacecraft Attitude Motion and Control

Introduction

The present course aims to discuss the various aspects of modelling the attitude motion of a spacecraft, in the context of spacecraft mission objectives, and aims to provide the tools and procedures that help in arriving at the resulting attitude motion profiles. Further, the course aims to discuss the various strategies of attitude control that help us to achieve a desired attitude for the spacecraft during various phases of its life cycle.

Motivation for the Course

The problem of spacecraft attitude motion and control is an important problem in the domain of space missions, because of multiple requirements that spacecraft need to satisfy during their entire life cycle. This is due to the fact that spacecraft missions involve many tasks e.g. navigation, communication, surveillance etc., which require a specific inertial attitude to be achieved / maintained. In this regard we need to note that spacecraft contain many components e.g. solar arrays, sun / star sensors, antenna, etc., which need to be pointed in different directions at different times and for different durations. For example, sun-pointing is crucial for charging the on-board batteries, while Earth pointing is necessary to receive / transmit data / commands for its desired mission objective.

In addition, the task of achieving / maintaining the desired attitude is further complicated by the fact that spacecraft continuously moves on curvilinear paths, which have varying inertial orientations. In view of the above, determination and control of inertial attitude of spacecraft is a problem of great interest to space scientists.

Basic Problem of Attitude Motion and Control

Most of pointing exercises involve the following basic tasks i.e. Attitude Determination, Attitude Prediction and the quality of these tasks depends on the accuracy of models as well as solution algorithms. Further, attitude control is the process of orienting the spacecraft in the desired direction / holding a given attitude and typically involves two sub-tasks; stabilization and manoeuvre control. The present course aims to expose the participants to some of the fundamental aspects of attitude motion modelling and control in the context of practical spacecraft missions.

Course Objectives

To understand principles governing the attitude motion of spacecraft and applicable models.
To discuss various tools for attitude determination & prediction/ estimation.
To explore the various control options in the context of applicable sensors and actuators.

Course Contents

Module-1: Preliminaries - Review of basic rigid body dynamics and applicable space environment. (**6 Hours**)

Module-2: Attitude Kinematics - Angular velocity in rotating frames, direction cosines and quaternions-based models. (**6 Hours**).

Module-3: Basic Attitude Dynamics - Inertia matrix and principal inertia, Euler's equations. Single and three-axis attitude dynamics, single and dual-axis spin spacecraft models. (**8 Hours**).

Module-4: Attitude Determination - Single-axis/ three-axis attitude determination. Attitude estimation with TRIAD, QUEST. (**6 Hours**).

Module-5: Attitude Sensors/ Actuators - Gyros, Star trackers, sun sensors, horizon sensors. Reaction wheels, thrusters, magneto-torquers, CMGs etc. (**6 Hours**).

Module-6: Attitude Control - Single- & three-axis spin stabilization, attitude control strategies. In-orbit attitude control with precision pointing and tracking. (**6 Hours**).

Pre-requisites

Course does not have any formal pre-requisites. However, good familiarity with Newtonian mechanics and basic orbital mechanics is useful. Further, some understanding of elementary control concepts is desirable.

Text/References

Kaplan, 'Modern Spacecraft Dynamics & Control', Wiley India Edition, 1976.
Wertz (Ed.), 'Spacecraft Attitude Determination and Control', Kluver, 1978.
Hughes, 'Spacecraft Attitude Dynamics', John Wiley, 1986.
Rimrott, 'Introductory Attitude Dynamics', Springer-Verlag, 1989.
Sidi, 'Spacecraft Dynamics & Control', Cambridge, 1997
Markley & Crassidis, 'Fundamentals of Spacecraft Attitude Determination and Control', Springer, 2014.

Mode of Conduct and Delivery

The course is planned to be conducted fully in the on-line format, with two hours per week engagement. Further, it will be run in a module-wise sequence.