# SESA2024 Astronautics

## Section 6: Attitude Control System (ACS) – Exercises

1. Describe the primary functions of the ACS.

2. Explain, with the aid of a sketch the closed-loop operation of a typical spacecraft ACS.

3. The distribution of mass in a spacecraft is quantified by the inertia matrix **[I]**. Discuss the physical significance of the diagonal and off-diagonal terms in this matrix, and explain why **[I]** is an important engineering quantity.

4. Describe, with the aid of sketches, the characteristics of the four main generic types of attitude stabilisation.

5. Distinguish the characteristics of external torques from those of internal torques. Which of these appears on the RHS of Newton's $2^{nd}$ law of rotational motion?

6. Explain qualitatively, in terms of angular momentum conservation, how a reaction wheel works to produce large changes in spacecraft attitude. Give an example of a spacecraft which uses reaction wheels. Explain the process of (angular) momentum dumping from reaction wheels, and why it is necessary.

7. Describe the major system impacts of using type 1 and 2 (pure spin and dual-spin) stabilisation. Explain how some of these impacts/constraints are alleviated by the adoption of Type 3 and 4 attitude stabilisation.

8. Explain how rotating devices like reaction wheels can still be used to control type 4 (3-axis stabilised) spacecraft, given that these are meant to be zero-bias systems.

9. Explain the difference between passive and active attitude stabilisation, and give examples of each.

10. What general mass distribution must a spacecraft have to take advantage of gravity-gradient stabilisation?

11. Describe the ideal mass distribution, in terms of the inertia matrix **[I]**, for a pure spin stabilised spacecraft.

12. The proposed configuration of an astronomical observatory spacecraft is shown in Figure 1. It is to be deployed in geostationary Earth orbit (GEO). During the transfer phase to acquire this mission orbit, the spacecraft is rotated rapidly (at ~ 60 rpm) to stabilise the attitude while the rocket motor firings are executed. When on mission orbit, the mission objectives require that the payload be pointed with an accuracy of the order of 1 arcsec for periods of up to 1 hour.

    By a qualitative analysis of the vehicle's ACS functions, address the following issues, giving your reasoning at each step:

i) explain briefly the engineering implications of the rotation phase during the transfer
ii) suggest an appropriate mission-orbit stabilisation type
iii) what internal torquers would you use?
iv) what external torquers would you use, and what would be their principal function? – remember, there may be issues of contamination of the payload optical elements.
v) what ACS sensors would you use?

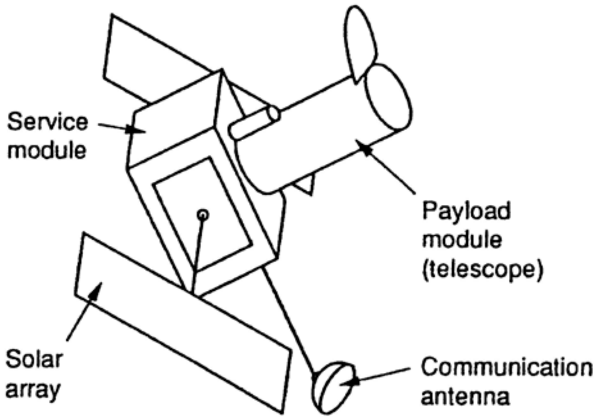


**Figure 1.** Schematic of space observatory configuration.