Spin Stabilization – Background

Patrice Légaré

What is Spin Stabilization?

- Spacecraft is rotated about a principal axis
- Uses angular momentum to provide resistance to attitude changes
- Passive stabilization (natural equilibrium state)
- Reduces susceptibility to external disturbance torques

Spin Stabilization in CubeSats

- Attractive due to limited power and sensors
- Reduces need for reaction wheels
- Not ideal for precision pointing missions

Physical Principle

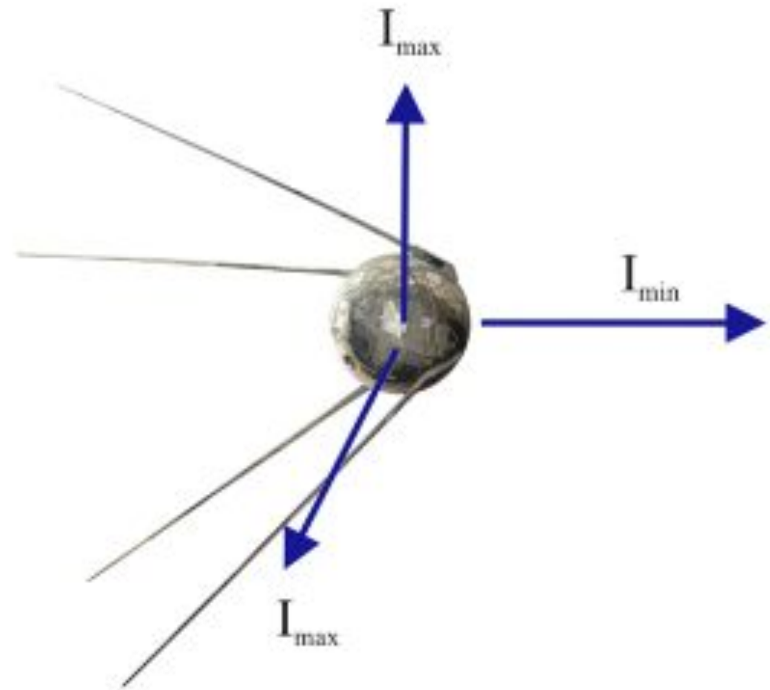
- Angular momentum: $H = I\omega$
- External torque: $\tau = dH/dt$
- Large angular momentum → smaller attitude change for given torque

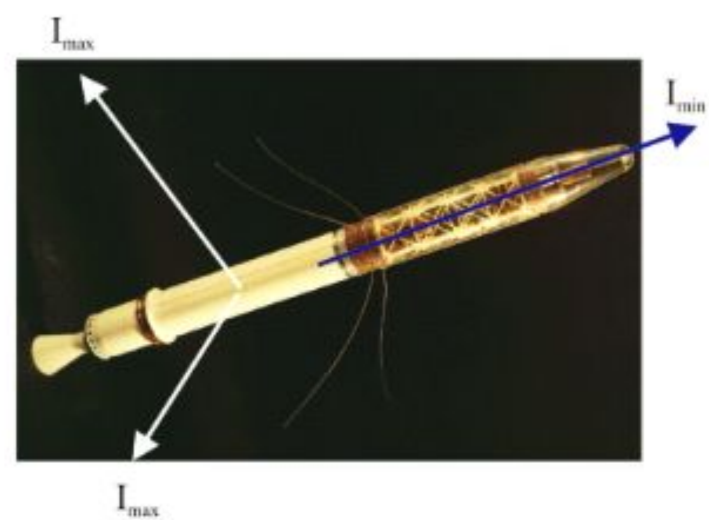
Precession and Nutation

- Disturbance torques cause precession rather than tipping
- Precession rate $\Omega \approx \tau / H$
- Nutation appears as wobbling motion after disturbances

Examples: Sputnik and Explorer-1

The long antennas are flexible and the satellites are semi-rigid and dissipating energy, therefore the only spin-stable axis is the maximum principle axis.



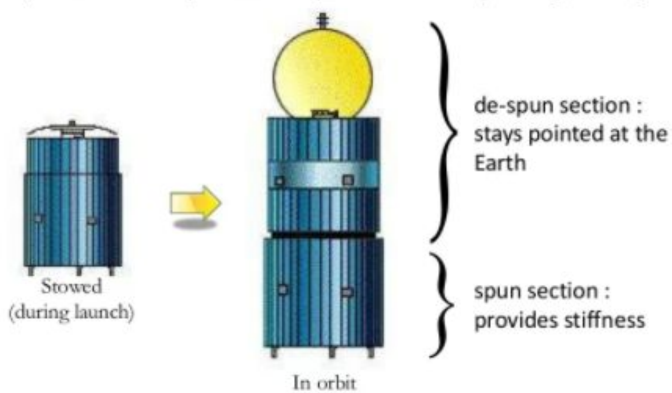


Types of Spin-Stabilized Systems

- Dual-spin: spinning part with despun payload
- Pure spinner: entire spacecraft spins

DUAL SPIN STABILIZED SATELLITE

- One way to avoid Earth-pointing limitations of spin stabilization is to use a dual-spin system. These systems consists of an inner cylinder called the 'de-spun' section, surrounded by an outer cylinder that is spinning at a high rate.



Pure Spinner

- Achieves gyroscopic stiffness by spinning the entire spacecraft

- Spacecraft must spin around its maximum principal axis

- Its limitation is that the entire spacecraft is spun which may be a problem if the mission requires accurate pointing

Dual-Spin

- One spinning platform coupled with a non-spinning platform that houses the communications payload
- Spinning wheel mounted with spin axis aligned with desired axis we wish to be inertially fixed

Advantages

- Don’t need to spin entire spacecraft
- Low power and mass requirements
- Good disturbance rejection
- Robust during early mission phases

Limitations

- Difficult continuous pointing
- Communication constraints
- Nutation must be damped
- Low agility for rapid maneuvers
- Limitations: Small available surface for power generation led to the demise of the design (not used anymore)

Disturbance Torques

- Gravity-gradient torque
- Aerodynamic torque (LEO)
- Solar radiation pressure
- Magnetic torque

Summary

- Spin stabilization provides passive attitude stability
- Best for missions with modest pointing needs
- Often replaced by 3-axis control for high-precision tasks

References

1) de Ruiter, A. H., Damaren, C., & Forbes, J. R. (2013). *Spacecraft dynamics and control: An introduction*. Wiley. ISBN 978-1-118-34236-7.