Satellite Subsystems

Communication Systems
Lecture 6
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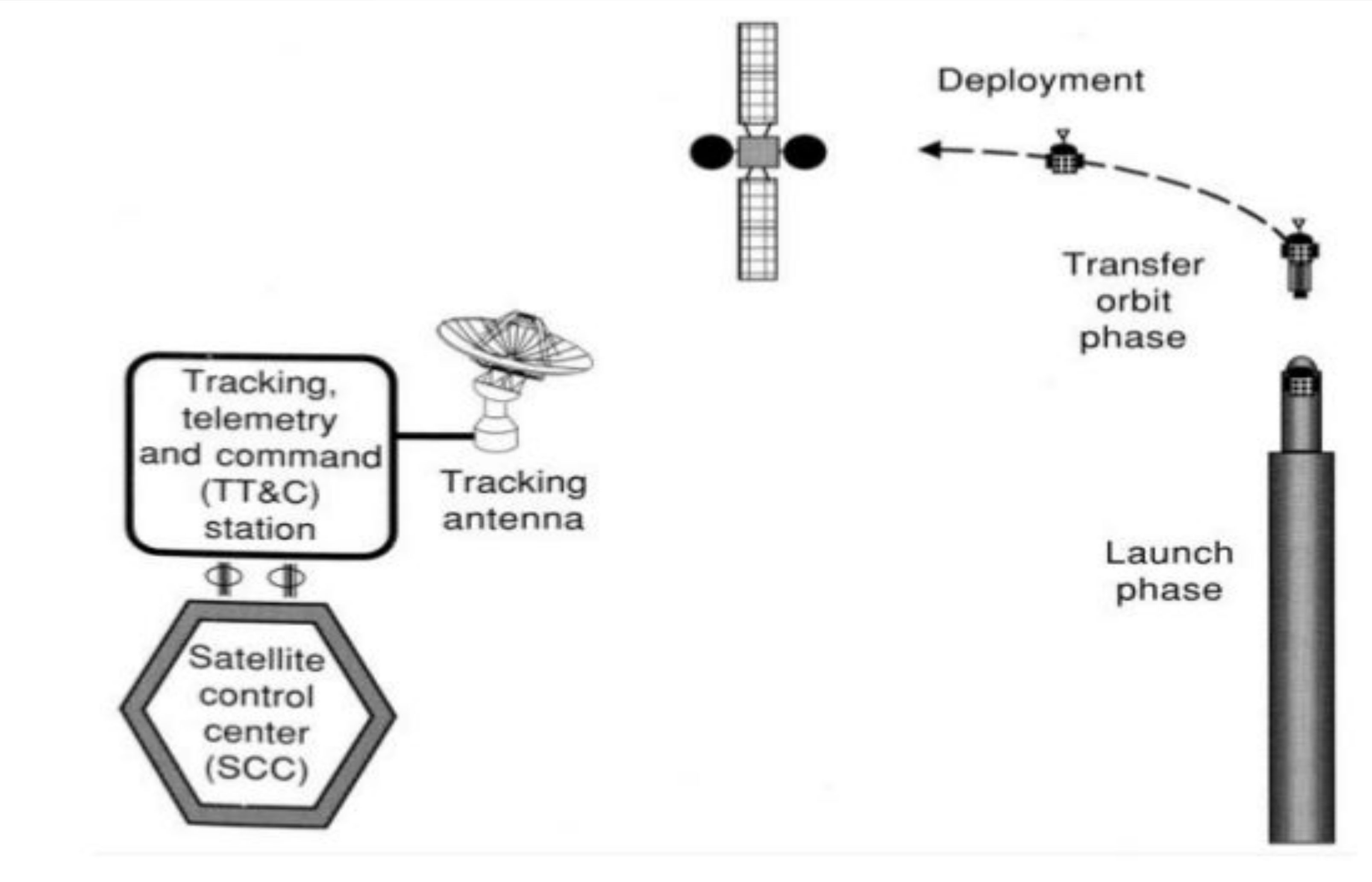
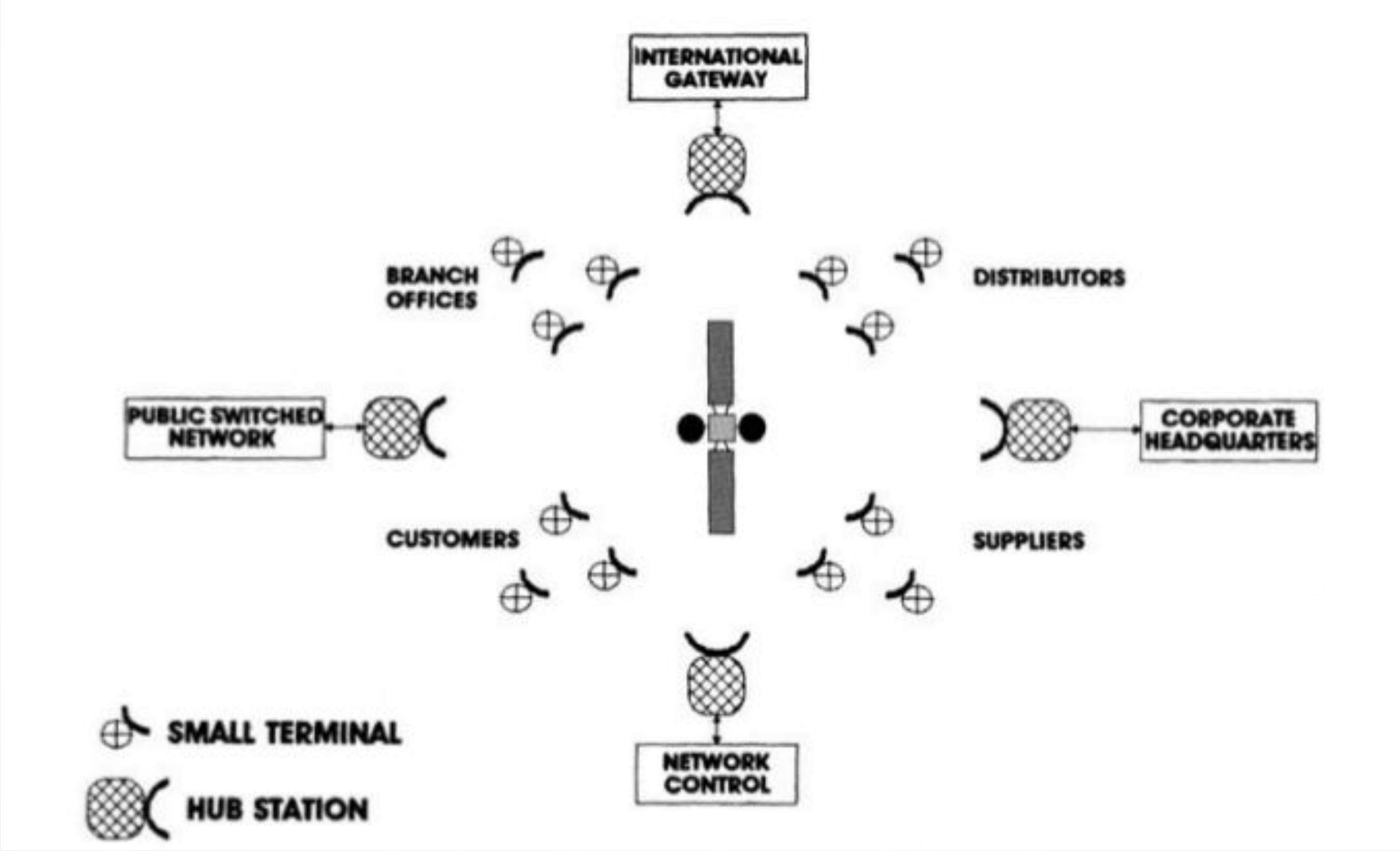
Space Segment



Ground Segment



Space Segment

- Placement in orbit is accomplished by contracting with a **spacecraft manufacturer and a launch agency** and allowing them about three years to design, construct, and launch the satellite.

-After the spacecraft is placed in the proper orbit, it becomes the responsibility of a **satellite operator to control the satellite for the duration** of its mission (its lifetime in orbit)

Introduction to Subsystems

- The typical satellite consists of the communication payload and the network of supporting subsystems.
- The major subsystems required on the communications satellite are:

1.
2. **Altitude and orbit control system(AOCS):**

It consists of rocket motors that are used to move the satellite back to the correct orbit when external forces causes it to drift.

Introduction to Subsystems

1. **Altitude and orbit control system(AOCS):**

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2. **Telemetry, Tracking, Command and Monitoring (TTC & M):**

This is partly on the satellite and partly on the controlling earth station. A dedicated earth station is used for this purpose. Used for launch sequence deployment, monitoring of command actions, report spacecraft health, control of thrusters and payload etc.

3. **Power Systems: Mainly solar cells**
4.
5. **Communications Subsystem:**
6. These are major components (represent small part of volume, weight and cost of sat in orbit) of a communication satellite. Includes transponders and antennas
7. **Satellite Antennas:**
8. Type depends on functionality and coverage

Attitude and Orbital Control

- AOC system keeps the satellite pointed towards the desired location on the earth.
- Altitude control means controlling the angular orientation.
- Several factors make the space craft tend to rotate and wobble(nutation) and change orbit (ex. gravitational forces from sun, moon ,solar pressure, variations in earth’s magnetic field) for which orbit maintenance is required.
- Different forms of stabilization for fine pointing are used depending upon type of the satellite.

Few Basic Definitions

ROLL AXIS

- Rotates around the axis tangent to the orbital plane (***N-S*** on the earth)

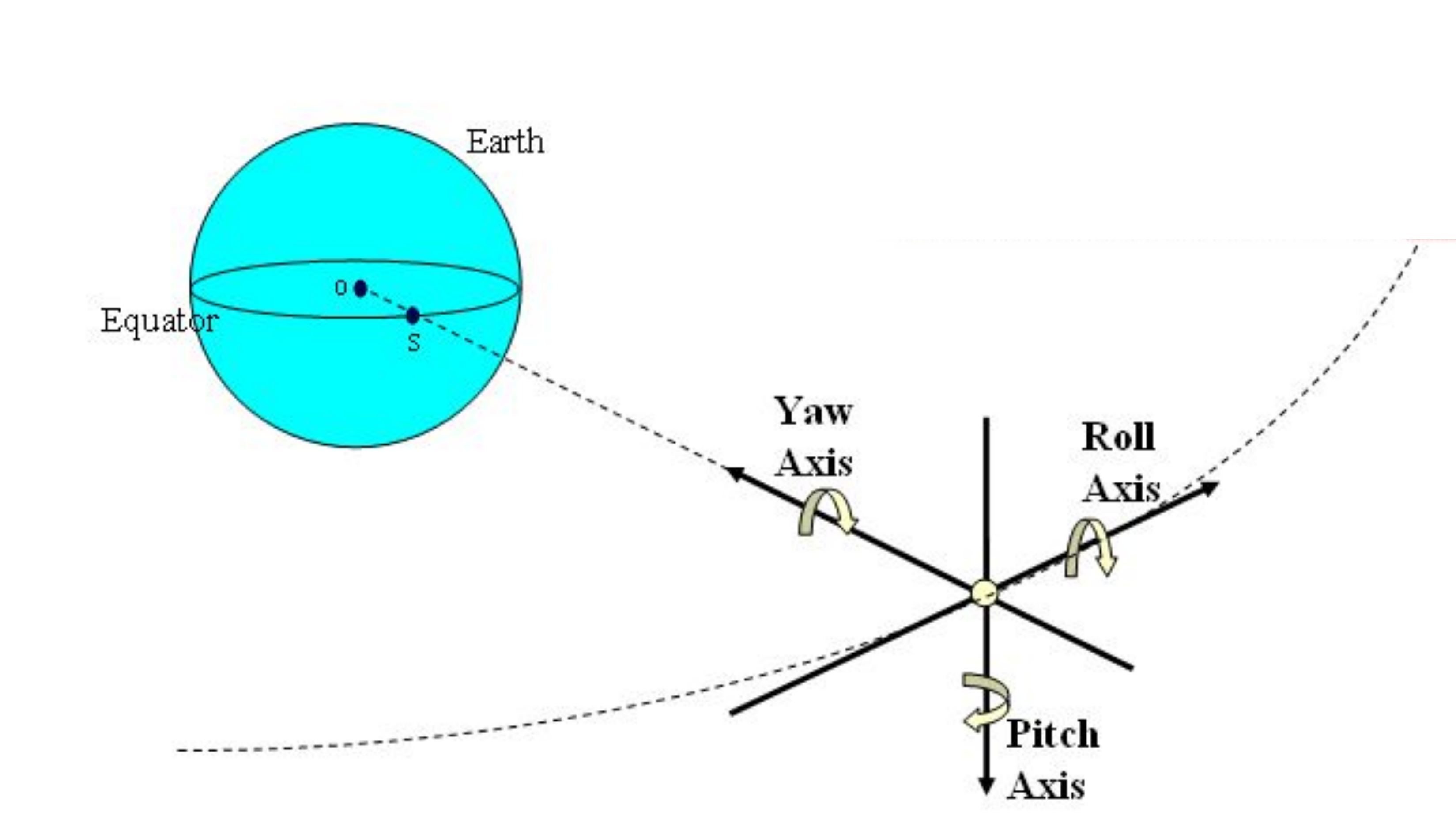
PITCH AXIS

- Moves around the axis perpendicular to the orbital plane (***E-W*** on the earth)

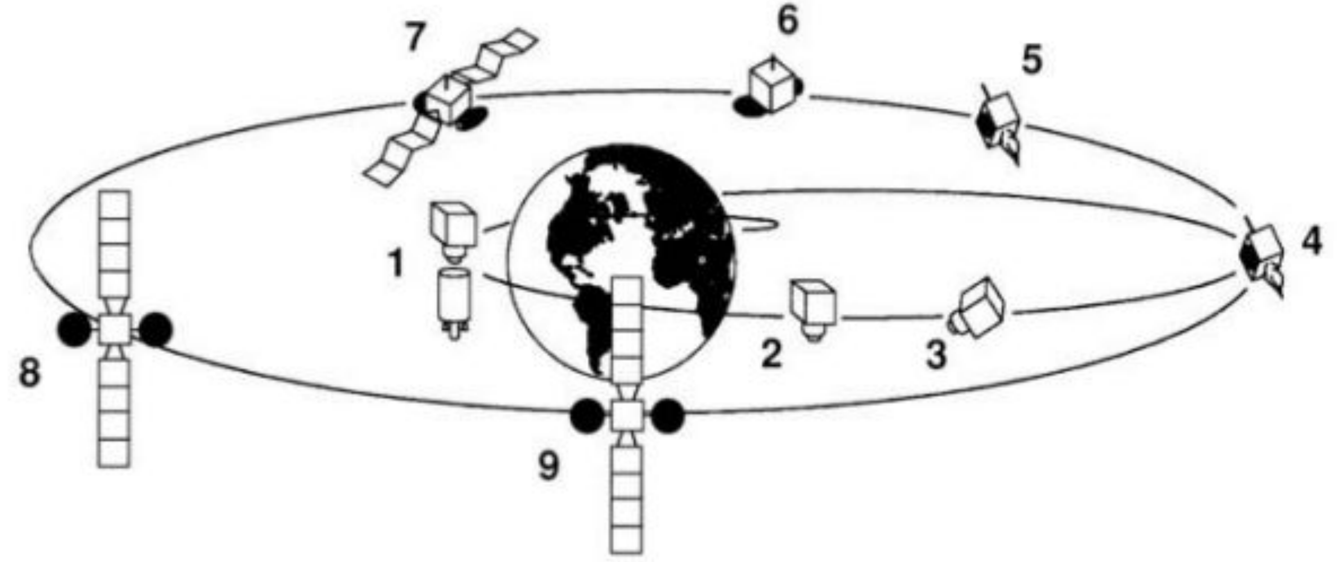
YAW AXIS

- Moves around the axis of the subsatellite point

ROLL, PITCH and YAW



A typical GEO mission sequence for a three-axis spacecraft



1 Separation from Launch Vehicle
2 Reorient to sun-normal
3 Reorient for apogee injection attitude
4 Apogee injection boost
5 Reorient for deployments
6 Deploy reflectors and spin down
7 Deploy solar panels
8 Sun acquisition and bus testing
9 Earth acquisition and start of operations

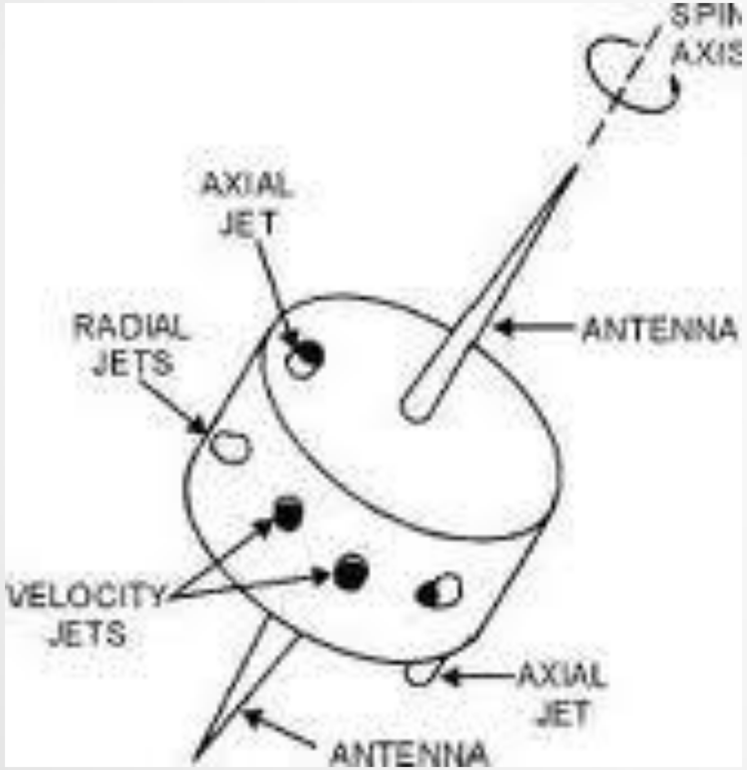
Structural Arrangement of a Satellite

- The box structure is used for many three-axis satellites because it facilitates the attachment of solar panels and antennas.
- A monocoque cylindrical can be placed at the center to handle launch loads, although flat panels and structures may be preferable to maximize mounting area and volume.

Spin Stabilization

- Most commonly used method.
- The entire space craft rotates at 30 to 100 rotation per minute.
- This spin provides powerful gyroscopic action to maintain the spin axis in the correct direction.
- These satellite consists of cylindrical drum covered by solar cells and the rocket motors.
- The transponder is mounted on the top of the drum.

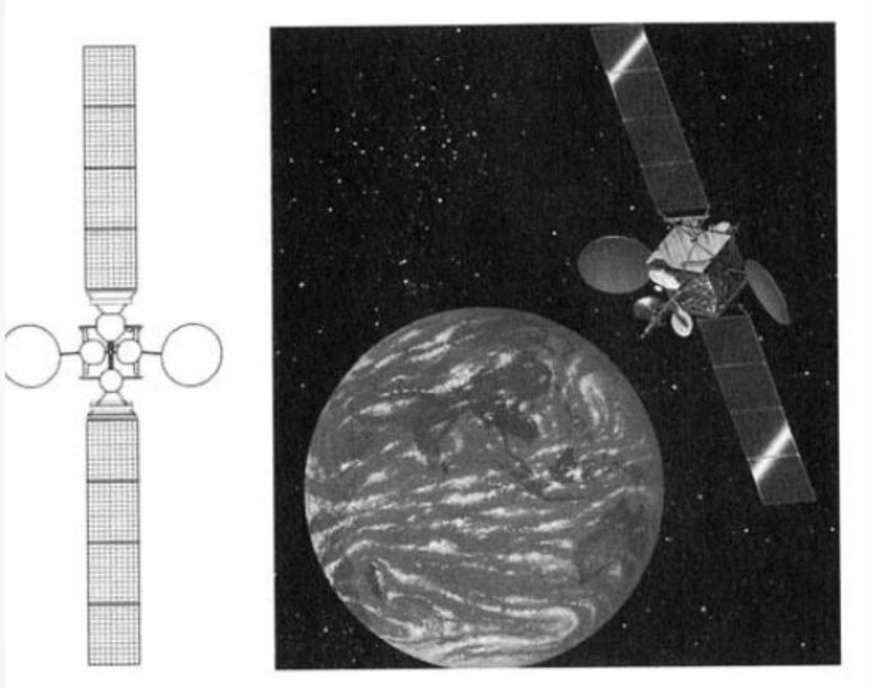
Spin Stabilization



Different forms of stabilization are used e.g. entire craft is rotated at 30-100 RPM to provide gyroscopic action by using spinners.

Three axis body stabilization

- 3- axis stabilization using 3 momentum wheels mounted on 3 orthogonal axes.
- Typically, the body is box-shaped with one side pointing toward the Earth at all times.
- Antennas are mounted on the Earth-facing side and the lateral sides adjacent to it.
- The solar panels are flat and deployed above and below the body, with orientation mechanisms provided to keep the panels pointed toward the sun as the satellite revolves around the Earth.

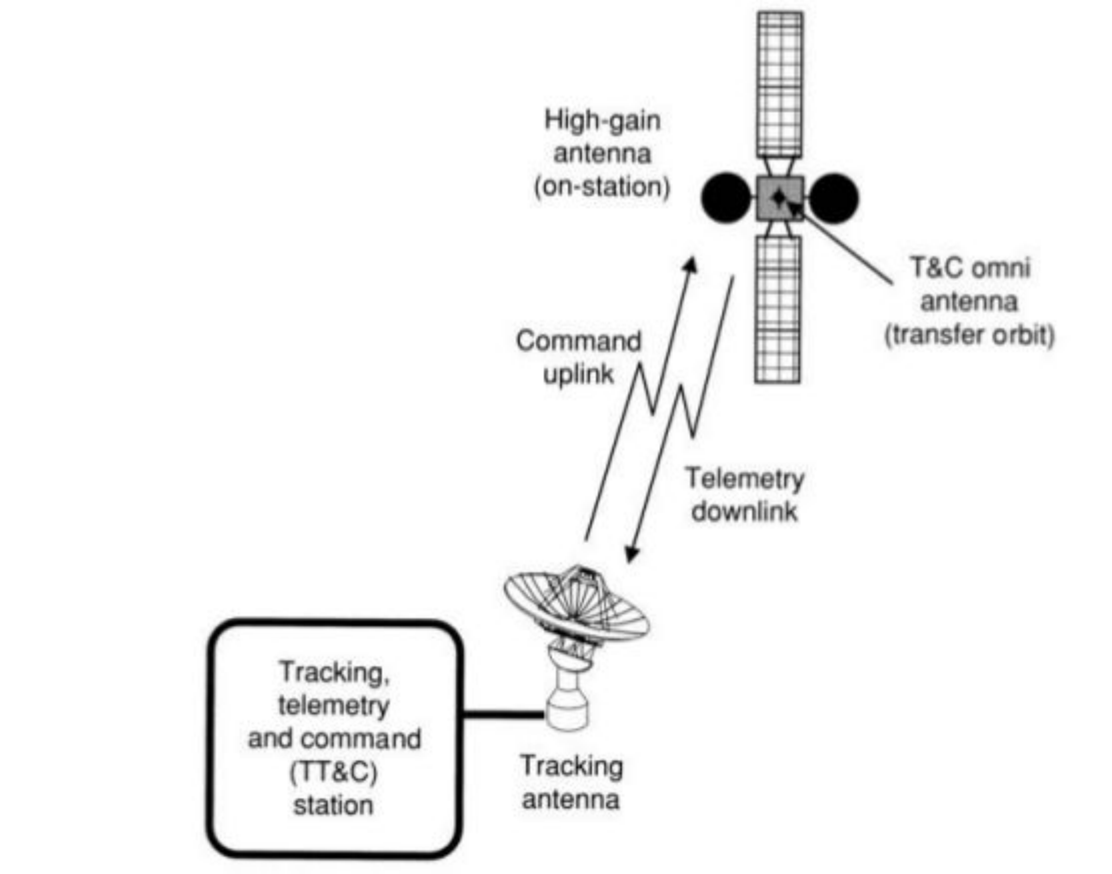


Three axis body stabilization

- Stability of the three-axis is ensured through an **active control system** that applies small forces to the body to correct for any undesired changes in spacecraft attitude.
- The most common three-axis attitude-control system (“biased momentum”) uses a **high-speed gyro called a momentum wheel** to provide some stiffness and to act as an inertial reference.
- A basic control technique is to either **speed up or slow down the wheel** to cause the body of the spacecraft to rotate in the direction opposite to the speed change, which produces precise east-west adjustment of the platform (depending on the type of mission and the orbit design).
- **The momentum wheel can sense transverse**
- **angular motion of the body (nutation), which causes a counterforce on its support**.
- The momentum wheel can be twisted by a gimbal (a motor-controlled pivot), placing a precise dynamic force on the spacecraft.
- There should be at least two momentum wheels to ensure reliability in case of a single failure and to provide additional attitude control options.

Satellite Telemetry, Tracking and Control Subsystems

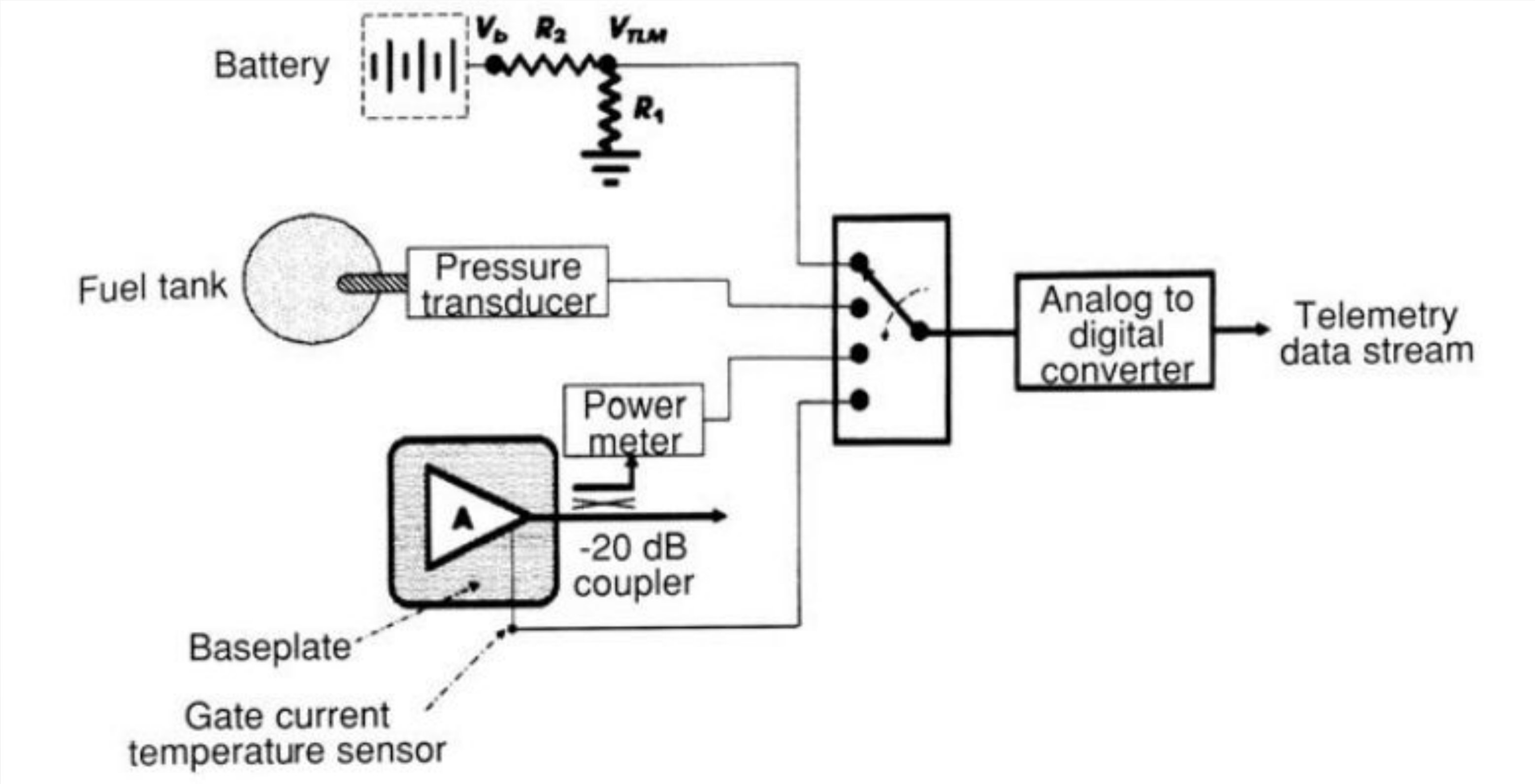
- The telemetry, tracking and control subsystem provides vital communication to and from the spacecraft.
- TT&C is the only way to observe and to control the spacecraft's functions and condition from the ground



Telemetry System

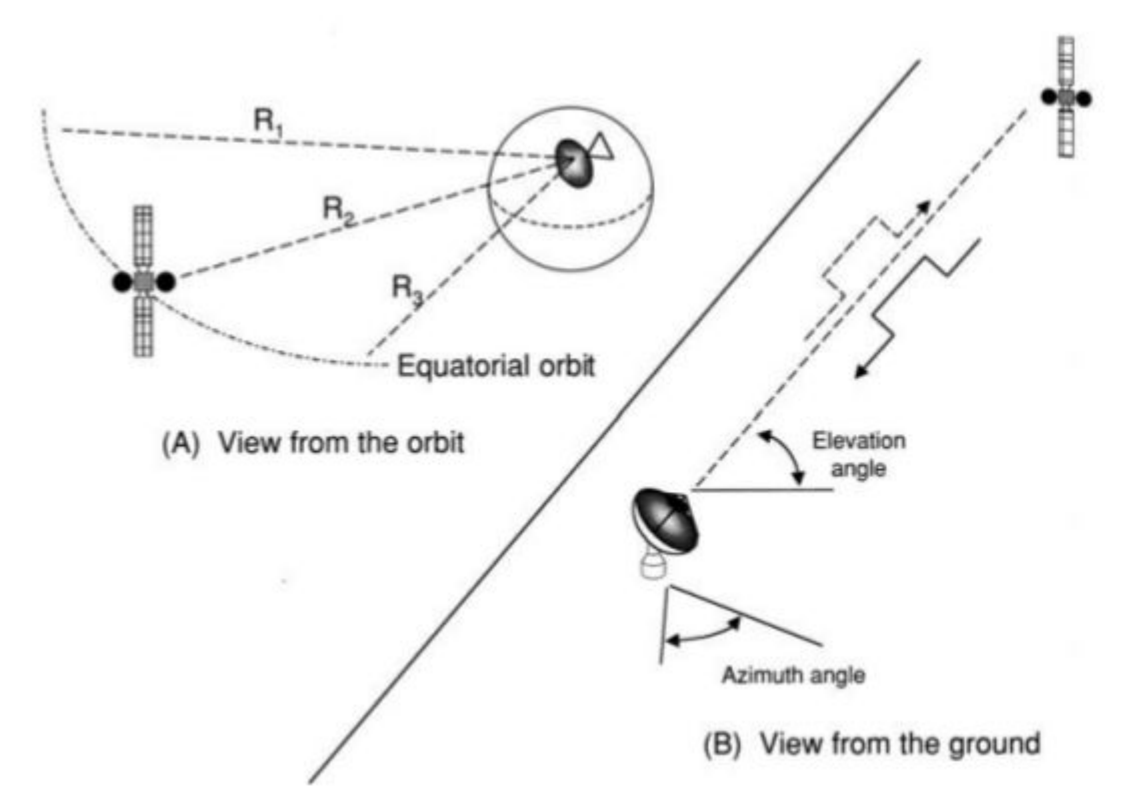
- Collects data from many sensors and sends them to the control earth station.
  - Pressure in fuel tanks.
  - Current drawn by each subsystem.
  - Critical voltages & currents.
  - Temperatures.
  - Status & positions of switches.
  - Sighting devices used to maintain attitude
- Low data rate is used to allow the receiver at the earth station to have narrow band-width and maintain high C/N ratio.

Simplified Block Diagram of Telemetry System



Tracking

- Determines **the current orbit and position of the spacecraft.**
- **Velocity & acceleration sensors** are employed.
- The control earth station can observe the doppler shift of the telemetry carrier to determine the rate of change of the range.
- **Triangulation** can be used from measurements from several earth stations observing the satellite.



Command System

- Secure & effective command structure is vital for the successful launch and operation of a communication satellite.

- The command system is used for:

- Making changes in altitude & orbit correction.
- Controlling the communications system.
- Controlling the firing of the apogee boost motor.
- Spinning up a spinner spacecraft.
- Extending the solar sails of a 3-axis stabilized spacecraft

Command System

- **Safeguards against errors in received commands are built in command structure.**
  - Command originates at the control terminal by converting a control code into a command word which is sent in a TDM frame to the satellite.
  - Validity is checked and sent back via the telemetry link where it is checked again in the computer.
  - If the command word is received correctly, an execute instruction will be sent to the satellite.
  - The entire process takes 5-10 sec. And minimizes the risk of malfunctioning.

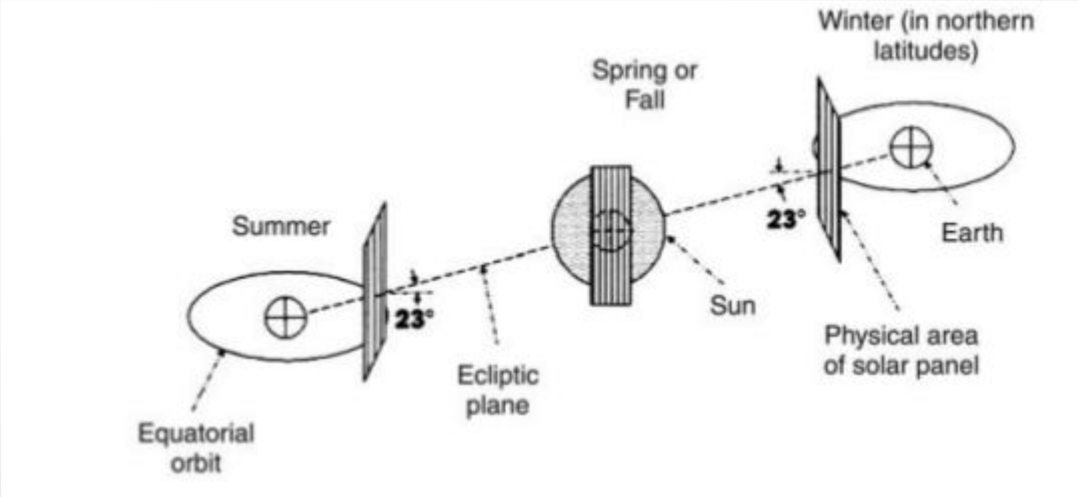
Power System

- All communication satellites obtain their power from solar cells.
- Solar radiation falling on a geostationary spacecraft has intensity of 1.39 kw/m2 (solar cell efficiency is 10-15%).
- Efficiency of solar cells falls with time due to aging and etching of the surface.
- Space crafts carry batteries to power the subsystems during launch and eclipses.

Solar Cells and Panels

- All Earth-orbiting communication satellites use panels of **solar cells to provide prime power.**
- The power output of a solar cell is proportional to the intensity of solar radiation reaching the cell.
- The **intensity is maximum with the rays arriving perpendicular** to the cell and **decreases with the cosine of the angle** of the ray with respect to the perpendicular.
- A condition of zero output occurs when the rays are parallel to the cell's surface.

- There is a seasonal variation that results from the angle between the ecliptic plane and the satellite's orbital plane.



Communication Sub System

- A communications satellite exists to provide a platform in the orbit for relaying of voice, video, and data.
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- Comm. Satellites are designed to provide the largest traffic capacity possible. (e.g. the INTELSAT system).
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- The INTELSAT example shows that successive satellites become larger, heavier, more expensive, and handles more traffic.

Result: lower cost per telephone circuit

Retirement of Satellite

- **Retirement of a GEO satellite** usually involves using a small reserve of propellant to **increase the velocity sufficiently to raise the orbit a few hundred kilometers**.
- The retired satellite will remain in orbit for eternity; with its repeater turned off, it cannot interfere or conflict with the operation of usable satellites in GEO.
- **Satellites in LEO** are subject to **atmospheric drag, which, if not corrected, causes the orbit to decay and the satellite to reenter the atmosphere and burn up**. This is, in fact, how LEO satellites may be removed from service.