Satellite Components & Systems

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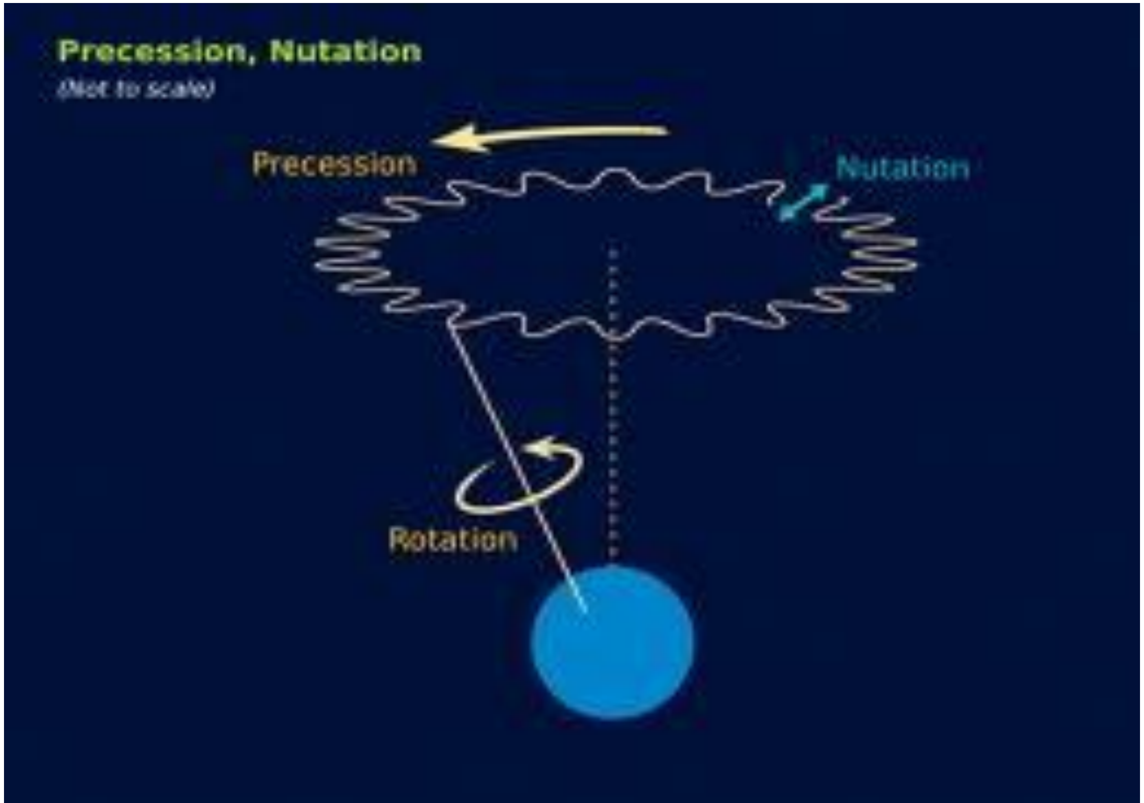
Definitions

- **Attitude**: The way the satellite is inclined toward Earth at a certain inclination angle with a certain face facing Earth.

Nutation & Precession

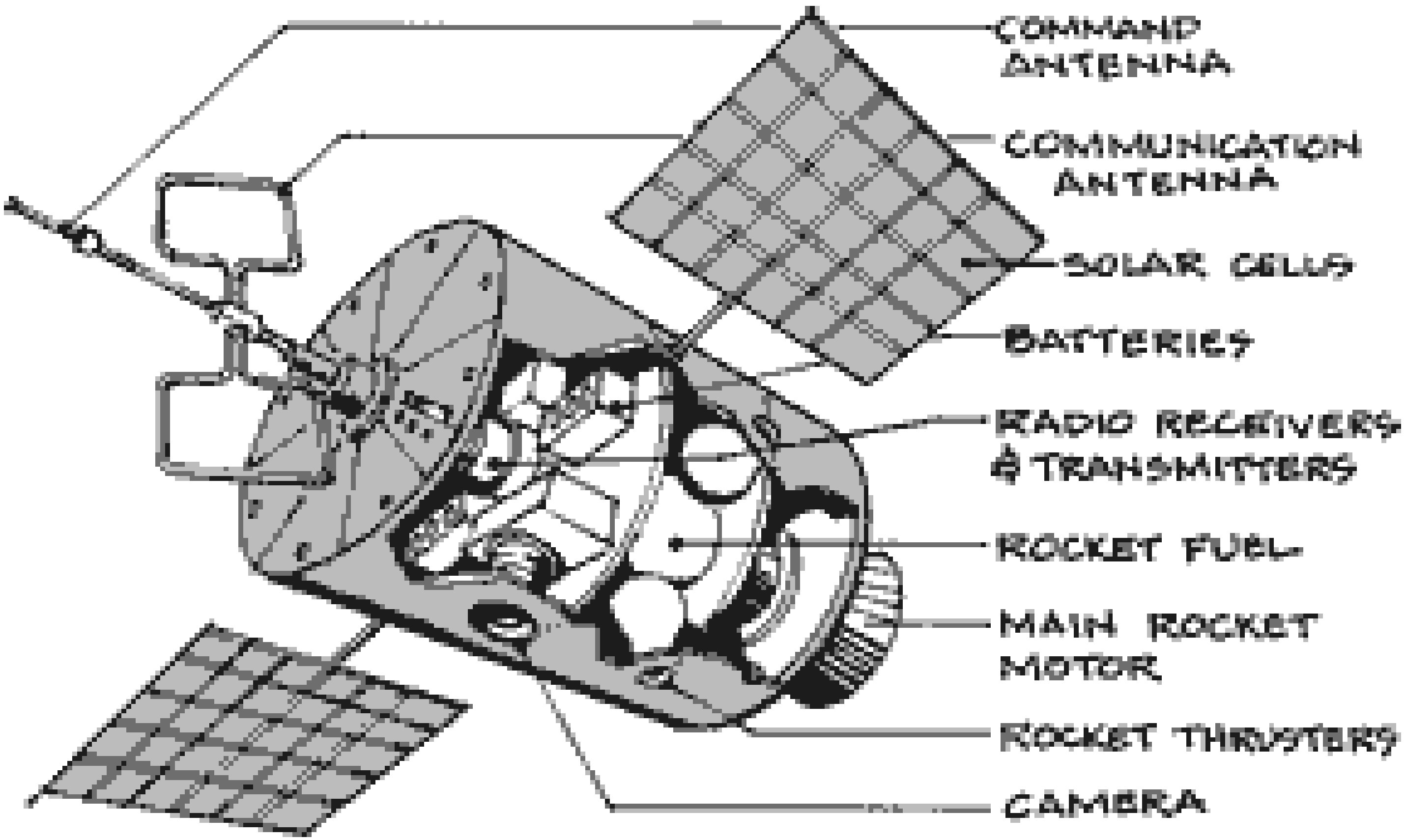
- **Nutation:** It is the wobbling of the satellite
- **Precession**: is a change in the orientation of the rotation axis of a rotating body



Components of Satellites

- Attitude and Orbit Control Systems
- Telemetry Tracking and Monitoring Systems
- Command Systems
- Cooling & Maintenance Systems
- Power Systems (Internal)
- External Solar Panels
- Communication Systems (Internal)
- Satellite Antennas (external)

Satellite Representation

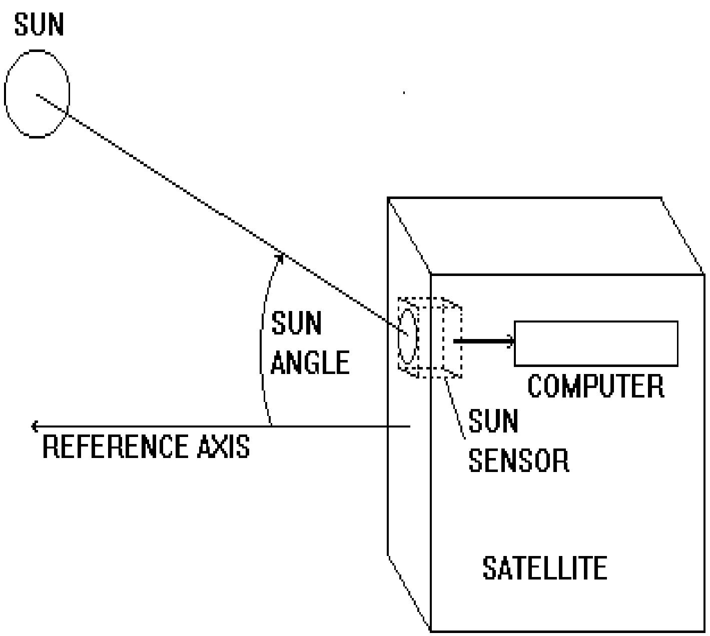


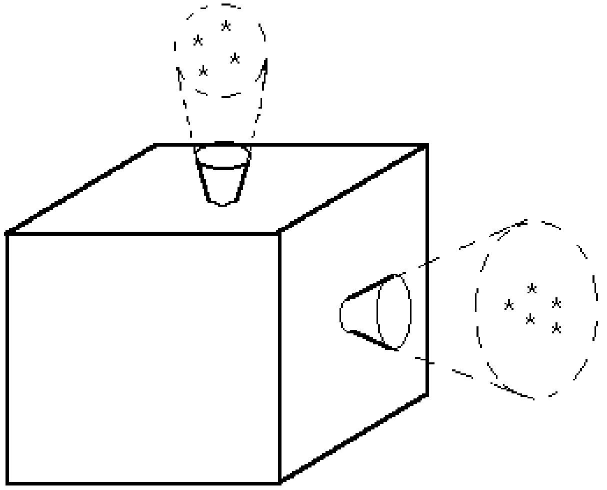
Attitude & Orbit Control Systems

- The attitude and the orbit of a satellite must be under control at all times, so that the satellite’s antennas always point toward the Earth and so that the user can look for the satellite in the right place.
- Especially for a GEO satellite, it is essential since even a change of 1 degree will cause the signal to be lost or attenuated beyond retrieval.

Sensors for Attitude Adjustment

- **sun sensor** -- measures angle between "sun line" and a reference axis in the s/c -- onboard computer uses this angle to help determine overall orientation of s/c
- **star sensor** -- cameras looking in different directions see different star patterns -- onboard computer compares camera images with stored star catalog to determine which way the s/c is oriented



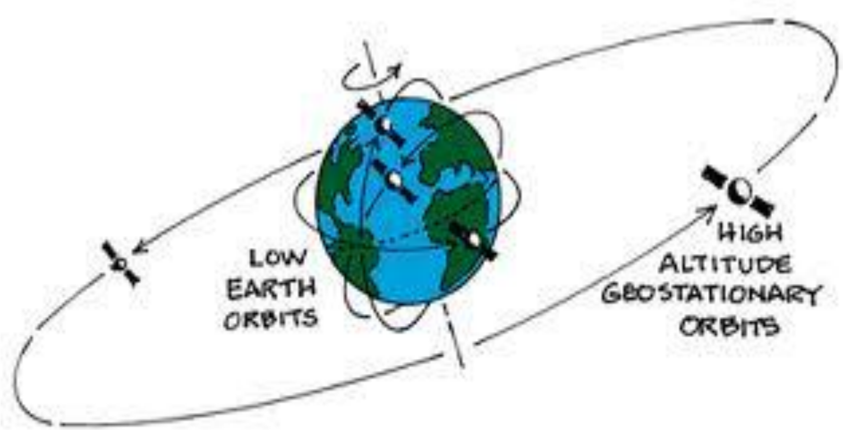


Effects on the Attitude & Orbit

- Some forces that effect the orbit and the attitude of a satellite are:
- Gravitational Field of the Sun and the Moon
- Irregularities in the Earth’s Gravitational Field
- Variation’s of the Earth’s Magnetic Field
- Solar Pressure from the Sun (Solar Winds / Ejections)

Effect on GEO Satellites

- The presence of gravitational fields from the sun and the moon cause the orbit of a GEO satellite to change with time.
- At GEO orbit altitude, the moon's gravitational force is twice as strong as the sun's.
- The various interacting forces cause the satellite's orbit to be changed by 0.86 degrees per year. This needs to be rectified by Attitude adjustment systems.



Effect on LEO Satellites

- LEO satellites are less effected by the sun's and the moon's gravitational field, due to the fact that they are much closer to the Earth and as a result, they would be under Earth's direct influence.
- However, magnetic flux and solar wind pressure can still have some effect which needs to be adjusted.

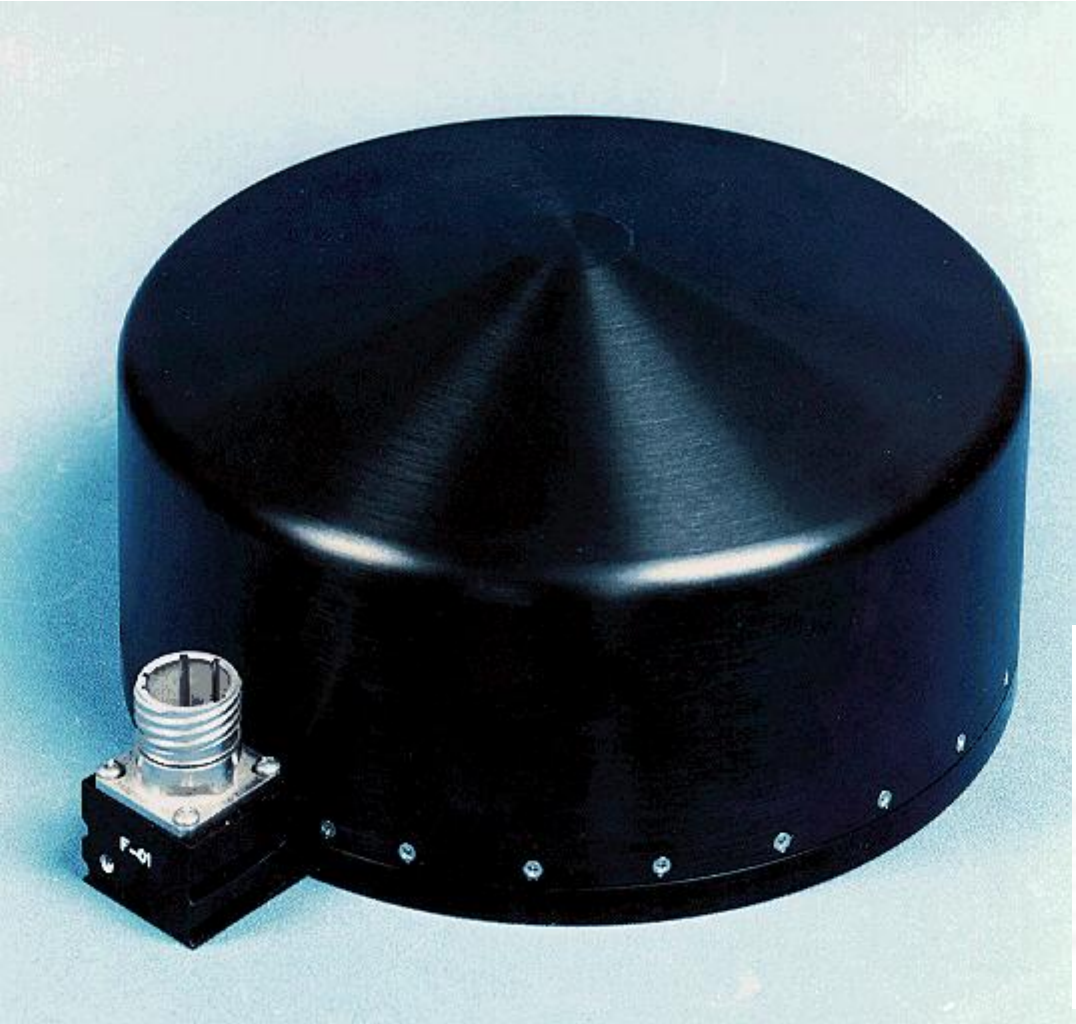
Attitude Stability of a Satellite

- Especially for communications satellites, it is essential to keep them pointing in the same direction.
- Hence, a satellite may be in a correct orbit, but it may not be in the correct attitude towards the Earth.
- Thus, it is essential to change the attitude of the satellite towards Earth without changing its orbit.

Attitude Stability

- The first way to maintain stability of a satellite is by rotating it between 30 to 100 rpm, in order to create a gyroscopic force that provides stability in the spin axis and keeps it pointing in the same direction.
- The second way would be to rotate a momentum wheel (which is a metal disk) and increasing the speed will cause the satellite to precess in the opposite direction according to the principle of conservation of momentum

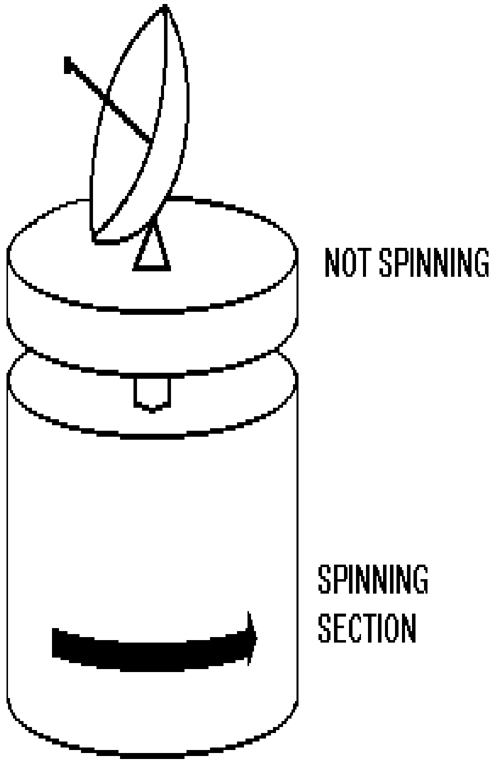
Momentum Wheels

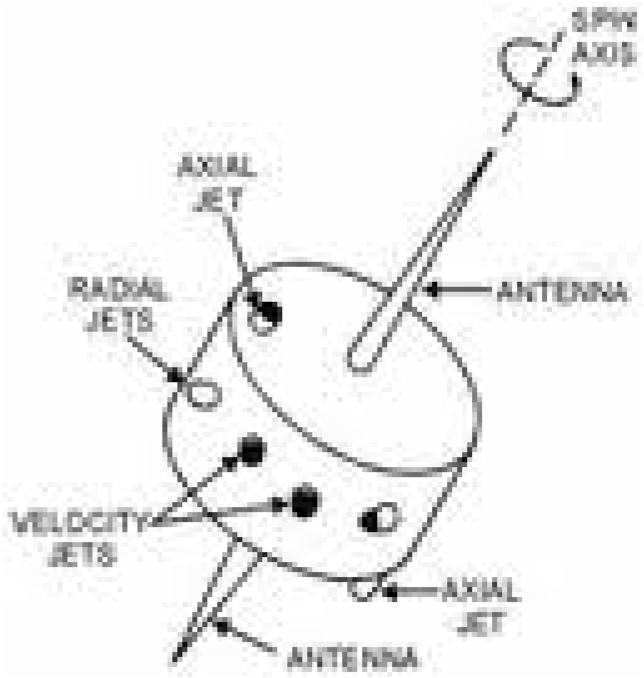


Spinners

- If a satellite is rotated much like a gyroscope, then it is called a **spinner** satellite.
- The communication system is mounted on the top of the drum and it is driven by an electric motor in the opposite direction to the rotation of the satellite body in order to keep the antennas pointing toward Earth.
- Such satellites are called **despun**.

Satellite Spinners





Satellite Propulsion Jets

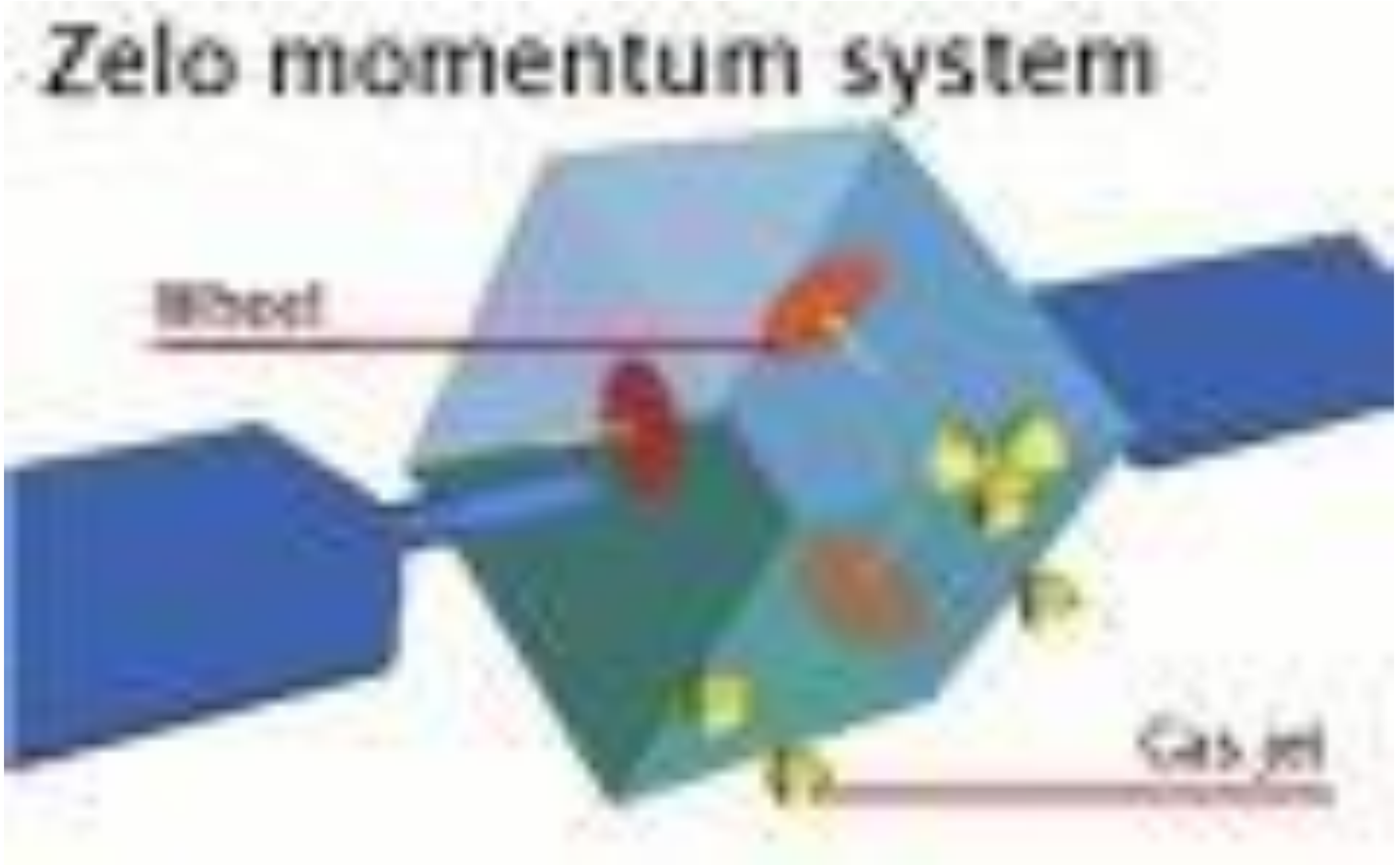
- In order to spin up the satellite, small radial gas jets are used
- The most common propellant is hydrazine, which is N_2H_4 as it is liquefied under pressure, but decomposes after passing a catalyst.
- By adjusting the flow of the propellants, pulses of thrust can be maintained for the required time and the required direction.

Gas Jets

- Most satellites will have three axis gas jets in order to maintain the proper orientation in the orbit.
- Some gas jets will burn in the Y direction to maintain the attitude of the satellite
- Some gas jets will work on the X axis to accelerate or decelerate the satellite
- If the satellite has lost altitude, it will fire up its Z axis gas jets

Combined Systems

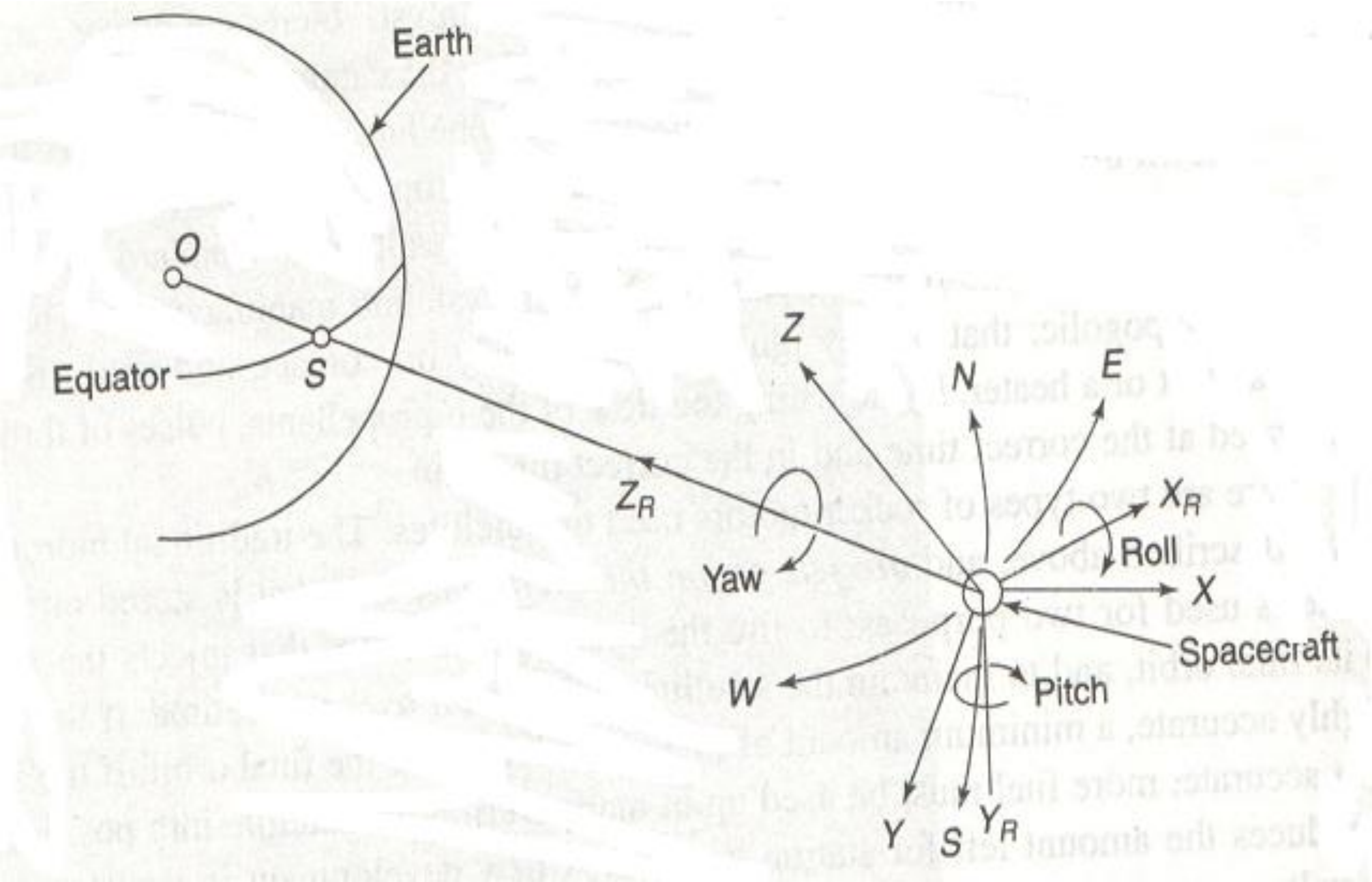
- In some cases, both spinners as well as momentum wheels may be used for attitude & orbit adjustment



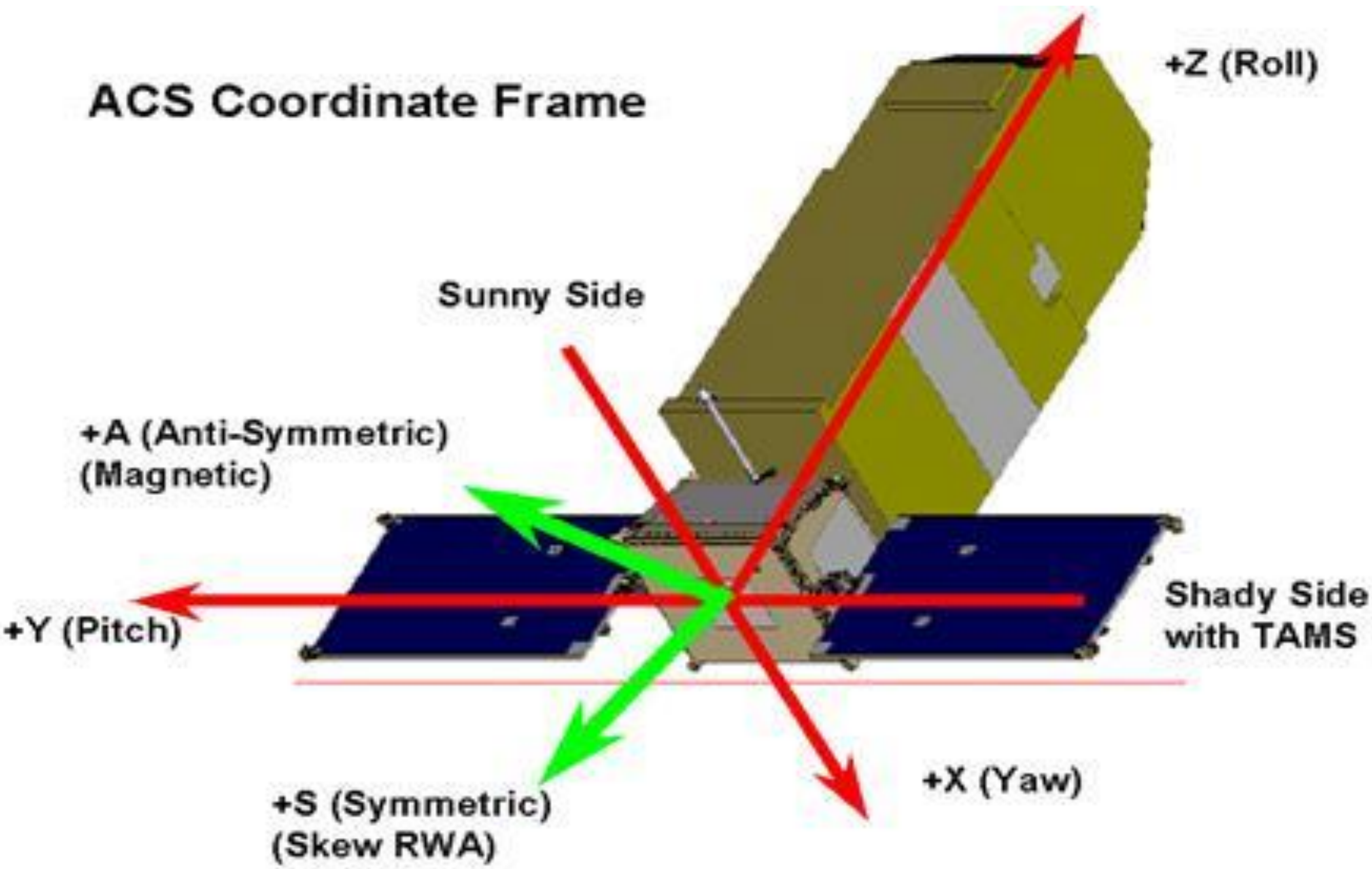
Orbit Control System

- Momentum wheels and spinners are used to adjust the satellite to the correct orientation, but they can not be used to adjust the orbit
- For orbit adjustment, linear acceleration will be required
- The satellite will spin on its Y axis, the change in the linear orbit will require acceleration or deceleration in the X axis and altitude adjustments are done in the Z axis
- Gas jets are the best way for orbit control system

Satellite Spinning Terms



Stability


ACS Coordinate Frame
+Z (Roll)
Sunny Side
+A (Anti-Symmetric)
(Magnetic)
+Y (Pitch)
Shady Side
with TAMS
+S (Symmetric)
(Skew RWA)
+X (Yaw)

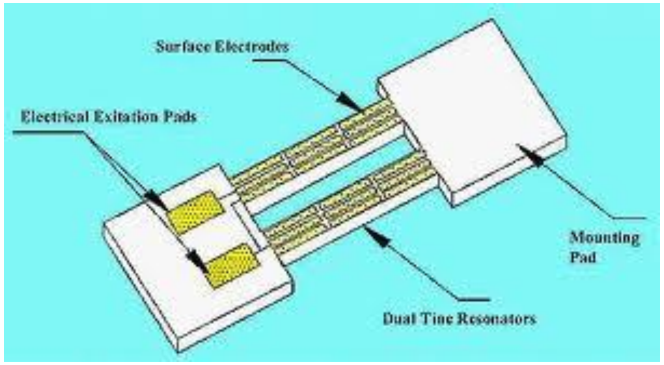
Station Keeping in GEO

- Most GEO satellites are required to remain within a box of +/- 0.05 degrees, so that it can be kept within operational parameters.
- Usually with an interval of two weeks, first

  E-W corrections are made and then after another two weeks N-S corrections are made. Hence, this is repeated monthly to station keep the satellite.

Fuel Considerations in Station Keeping

- Correcting the inclination of a satellite requires more fuel to be expanded then any other orbital correction. This places a weight penalty on satellites that require very accurate station keeping and thus as a consequence, the communications payload must decrease
- This is why most GEO have a life span of 15 years.

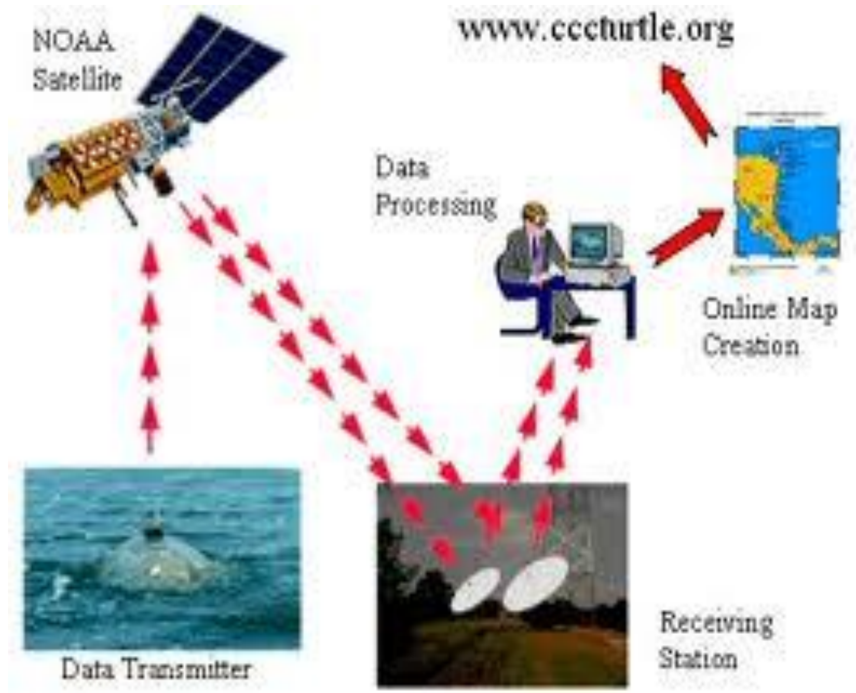


Gravity Boom

- For small nanosatellites as well as for satellites in LEO, the gravitational force of the Earth is stronger and thus a simple gas jet will not suffice.
- In these cases, attitude stabilization is accomplished by using gravity gradient boom.
- This is a long pole that points toward the center of the earth, providing damping of oscillations about the satellite’s z axis by virtue of the difference in the gravitational field at the top of the pole and the bottom

Telemetry and Monitoring Systems

- Monitoring system collects data from many sensors within the satellite.
- The telemetry system sends data derived from the sensors on the satellite which monitors the satellite's health via telemetry link to the controlling Earth station
- Telemetry and monitoring systems are essential for a satellite's long life term.



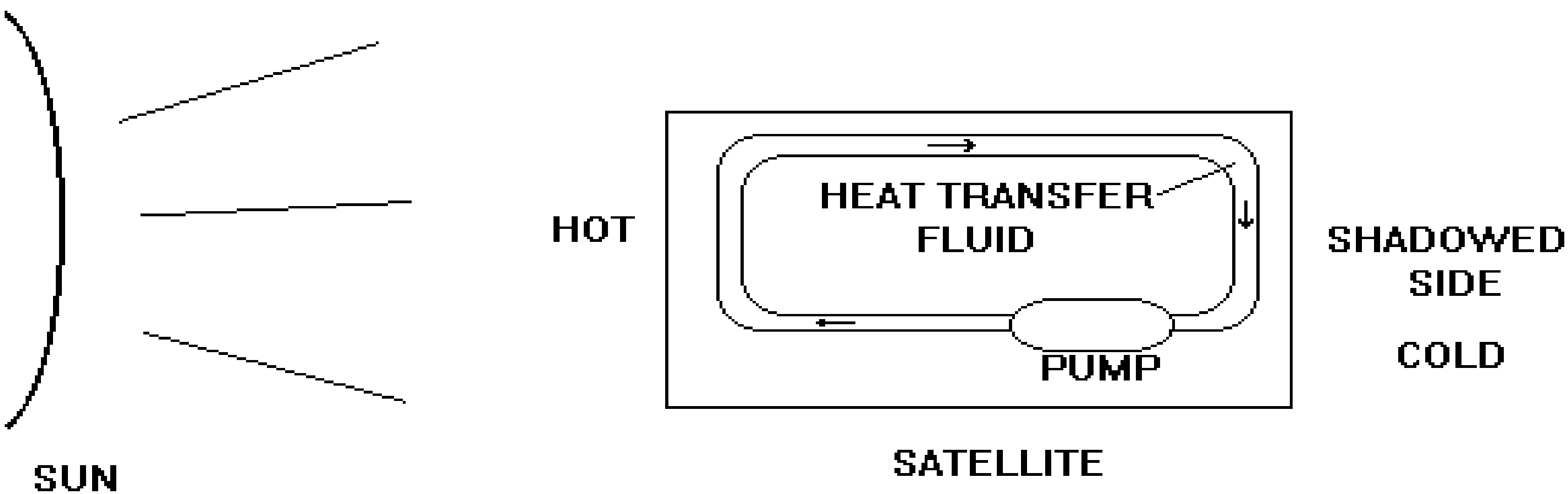
Monitoring System

- Some of the sensors located on the satellite include pressure in the fuel tanks, voltage and current in the power conditioning unit as well as critical voltages in the communications electronics.
- Temperature sensors are also very important part of the monitoring system as the satellite will be subjected to adverse pressure gradients
- Attitude sensors help to keep the attitude aligned in the correct manner

Cooling Systems

– Heating coils (like in a toaster) to warm up cold parts (some propellants freeze easily)

– Use special cooling systems on hot parts



Power Systems

- Power systems are a very important part of satellites as power systems help feed the navigational systems, propulsion systems, communication systems etc.
- Power is mainly used for the transmitters as they require the most power.
- The second usage is for housekeeping to keep the satellite functioning.

Solar Power in Communication Satellites

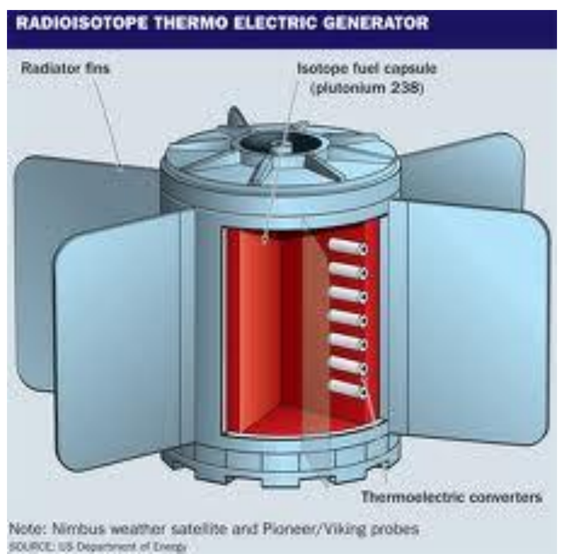
- A spin sized satellites have a cylindrical body covered with solar cells.
- Large communication satellites can generate up to 6 kW from solar power
- In a spinning satellite about half will operate, while the other half will be on the cold side.
- Micrometeorite damage can also cause the efficiency of the solar cells to go down
- Solar cells will work better when they are colder.

Solar Sails

- For large communications satellites, it may be a better idea to put a retractable solar sail.
- However, a three axis stability satellite needs to be there for solar sails to work without losing stability of the satellite.
- You can create up to 10 kW with solar arrays

RTG

- Radioisotope Thermoelectric Generators -- convert heat from decaying radioisotope (usually plutonium) directly into electrical power -- only about 7% efficient, so 93% of the heat is lost
- \- RTG's used for s/c moving *away* from the Sun (Mars close enough to use solar cells, but RTG's need for Jupiter and beyond)



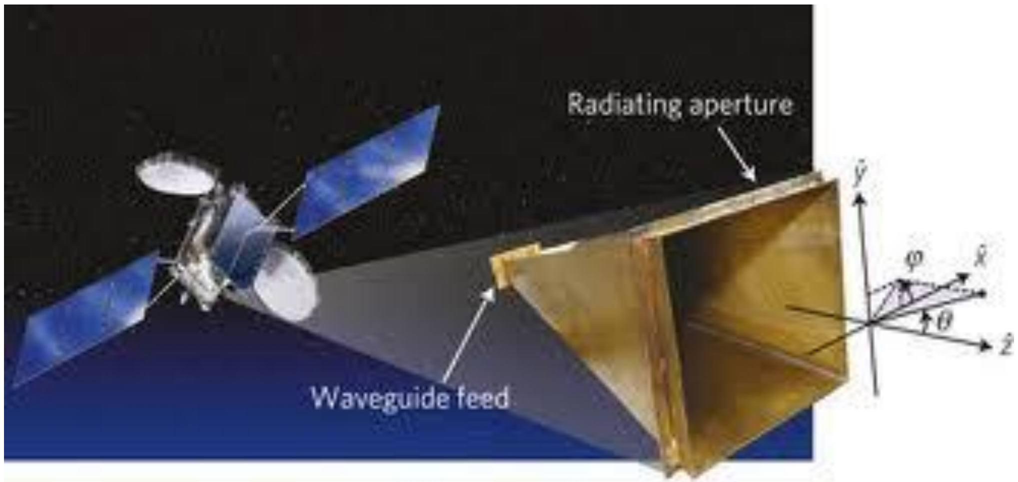
Communication Systems

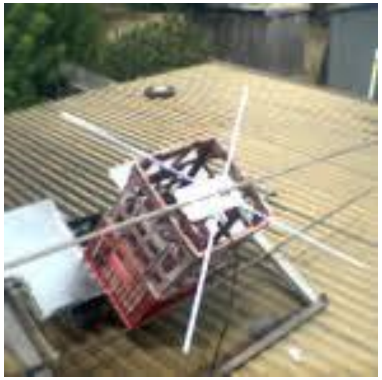
- The communications subsystem is the important part of the satellite as it serves the most important purpose.
- The communications system is composed of satellite antennas as well as transponders
- Transponders are responsible for sending the signals to Earth as well as for receiving. Usually with communication satellites, there will be many transponders.

Satellite Antenna Types

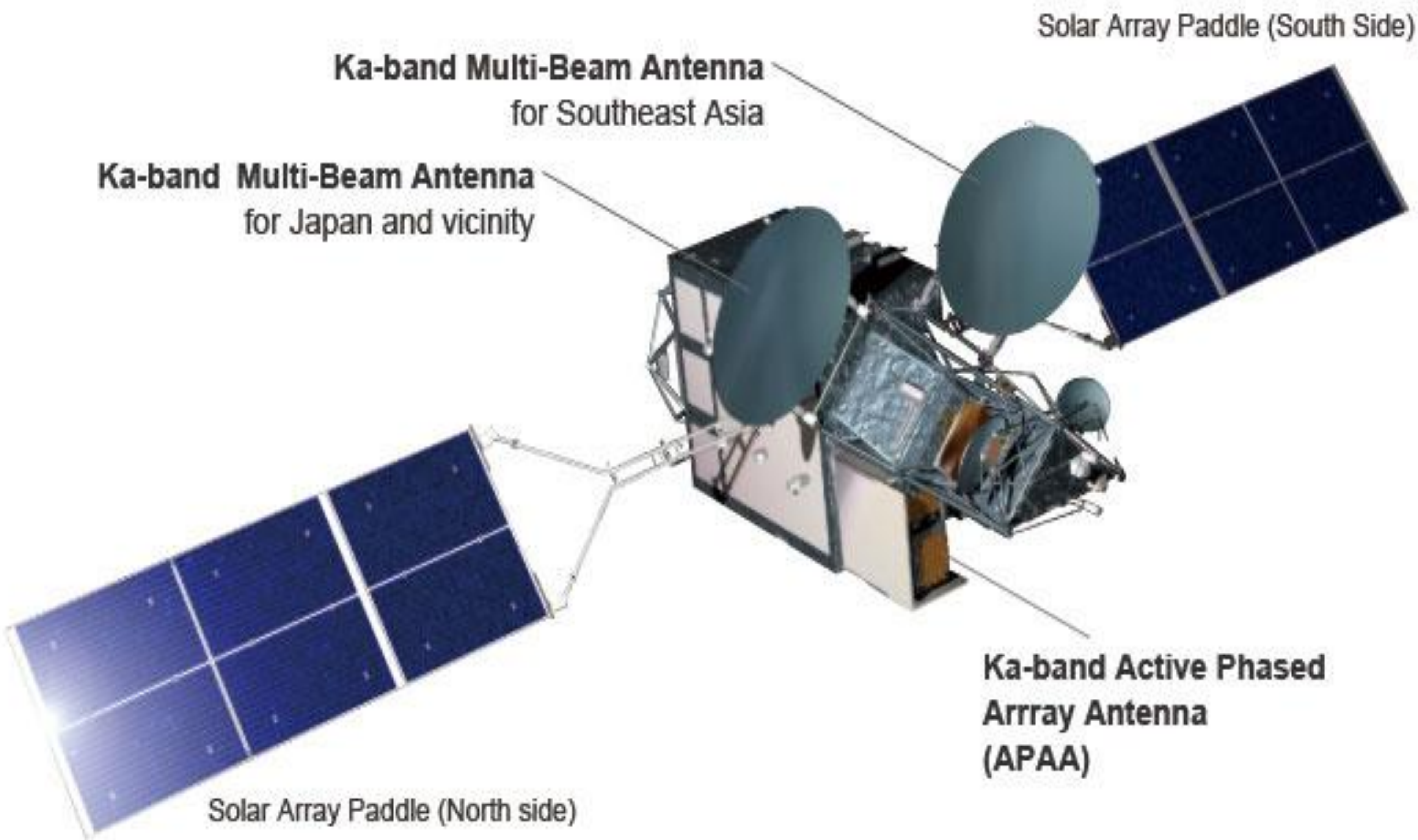
- There are 4 main types of antennas:
- 1) Wire antenna (monopole or dipole)
- 2) Horn antenna
- 3) Reflector Antenna
- 4) Array Antenna

Satellite Antennas



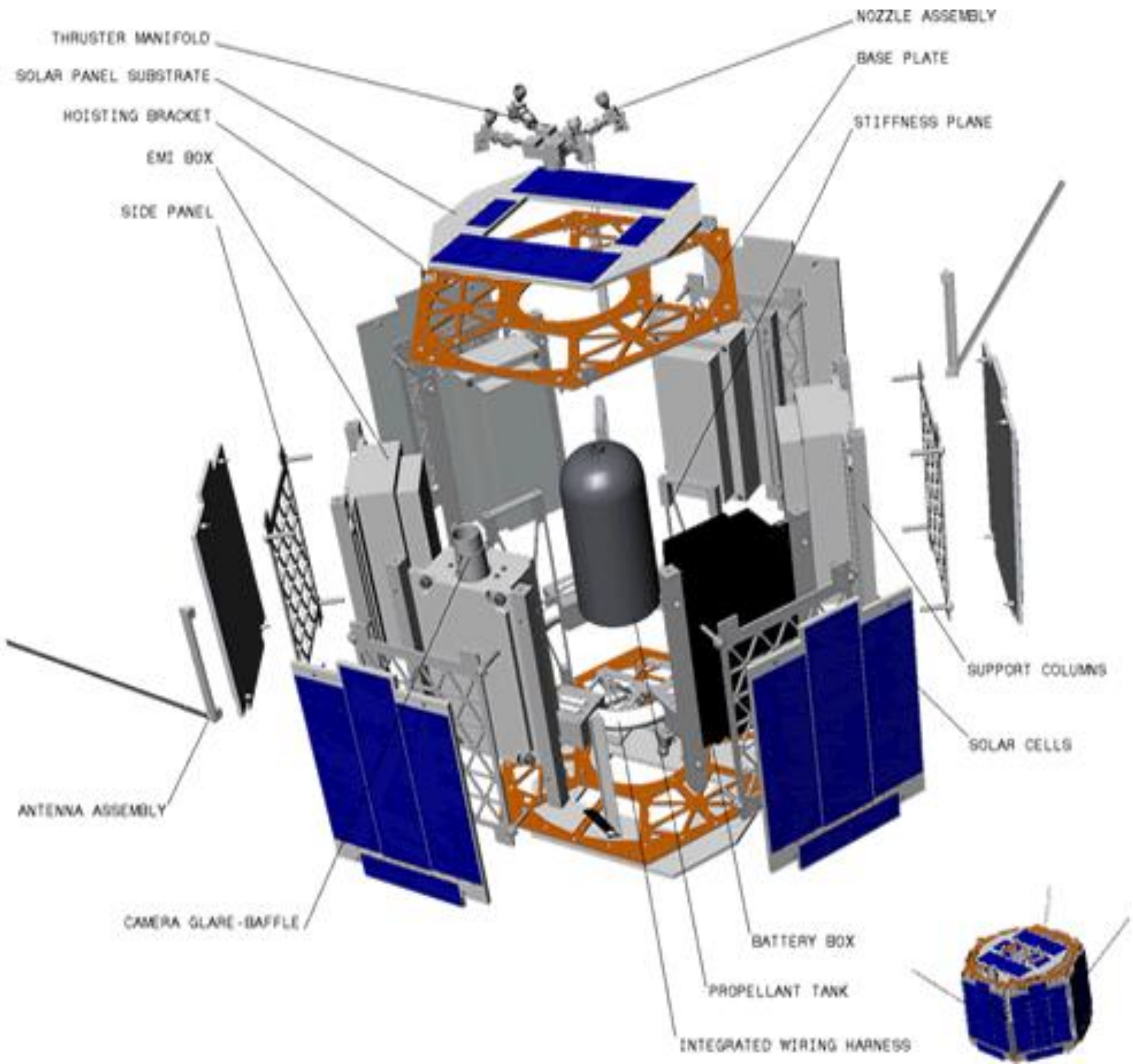


Communications Satellite

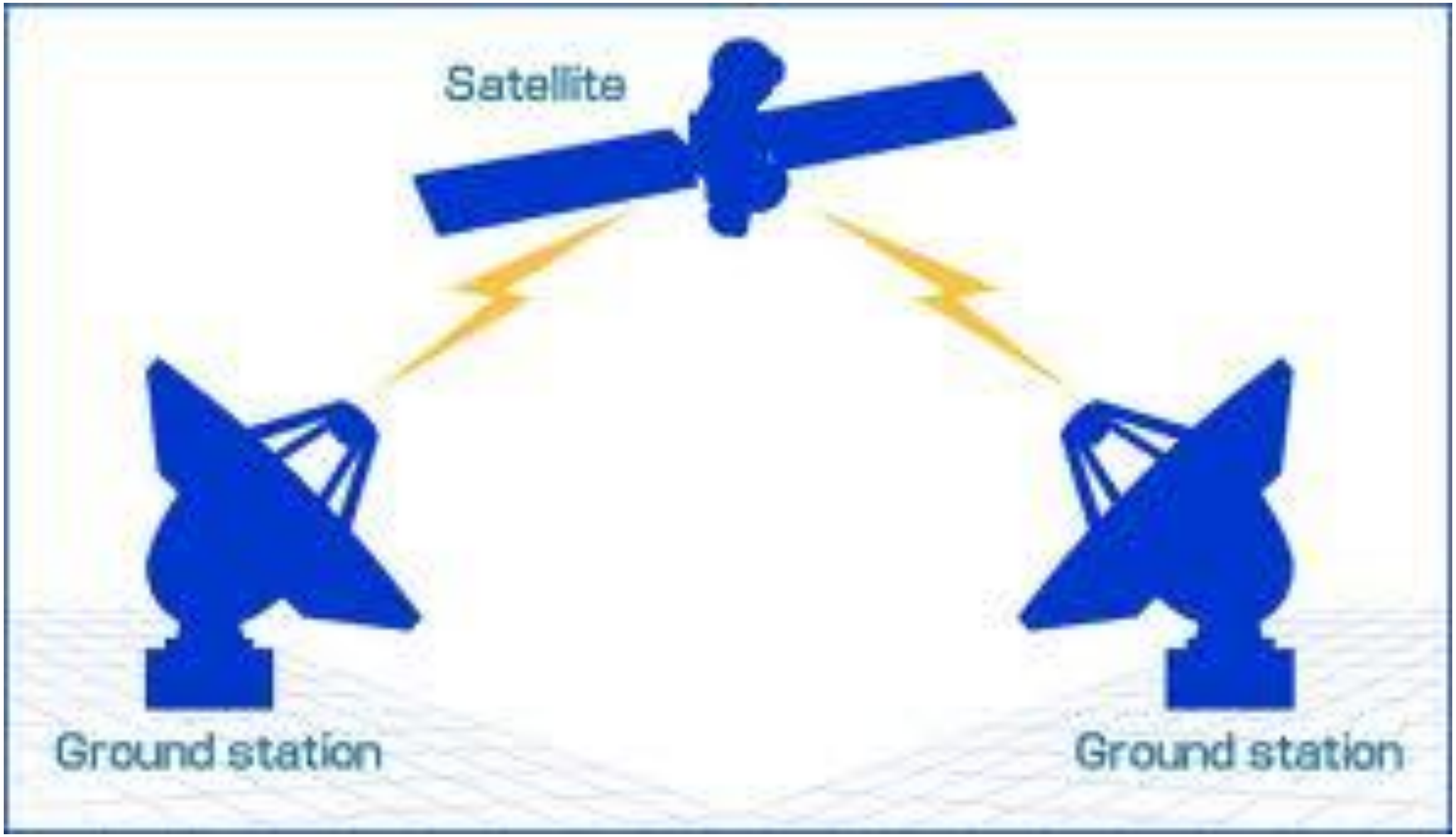


Nanosatellites

- Nanosatellites are satellites that are typically less then 5 kg

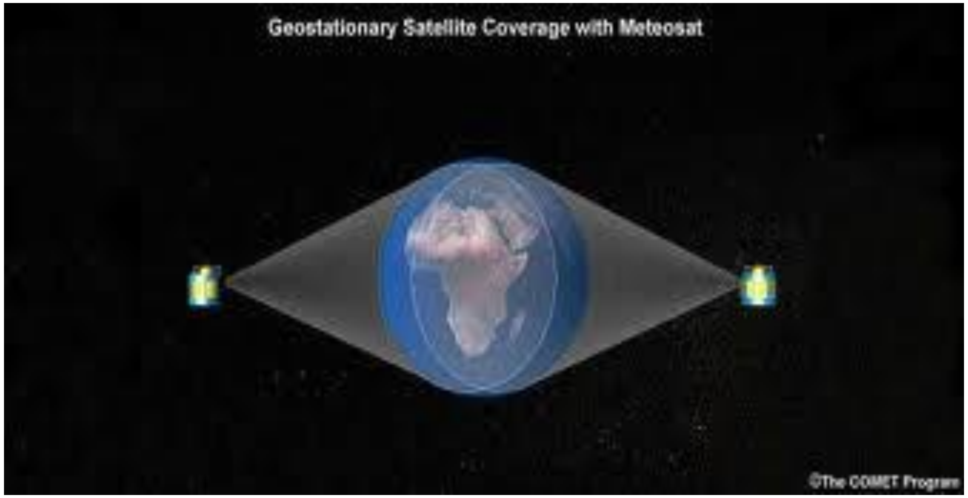


Satellite Communication Systems



Satellite Coverage

- A single GEO satellite can easily cover thousands of kilometers with proper positioning of the satellite.



Space Qualification of Satellites

- It is very important for all satellite components to be space qualified.
- All components need to be certified for microgravity as well as vacuum conditions
- Moreover, satellite components need to be resistant to large temperature gradients as well as magnetic gradients.
- Satellite components need to be shielded from micrometeorites as well as from high proton and particle flux.

THANK YOU

For further help consult Satellite Communications Textbook by Timothy Pratt

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