Jet Propulsion Laboratory's Space Explorations

Part 3: Basics of Space Flight

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Jet Propulsion Laboratory
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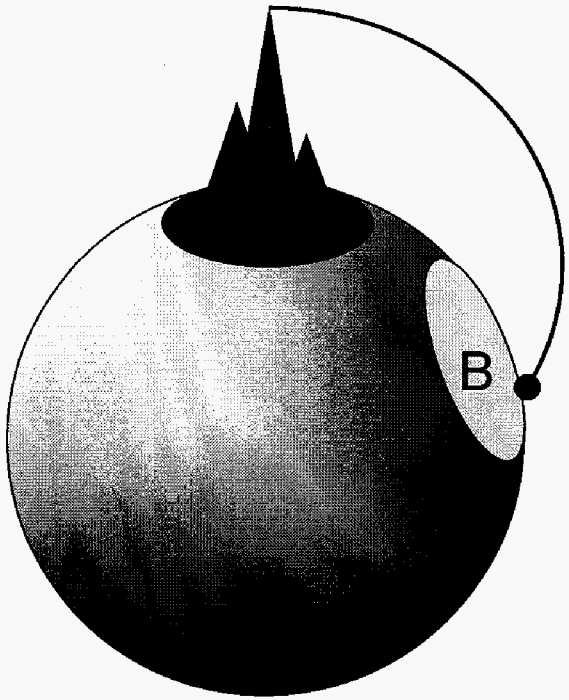
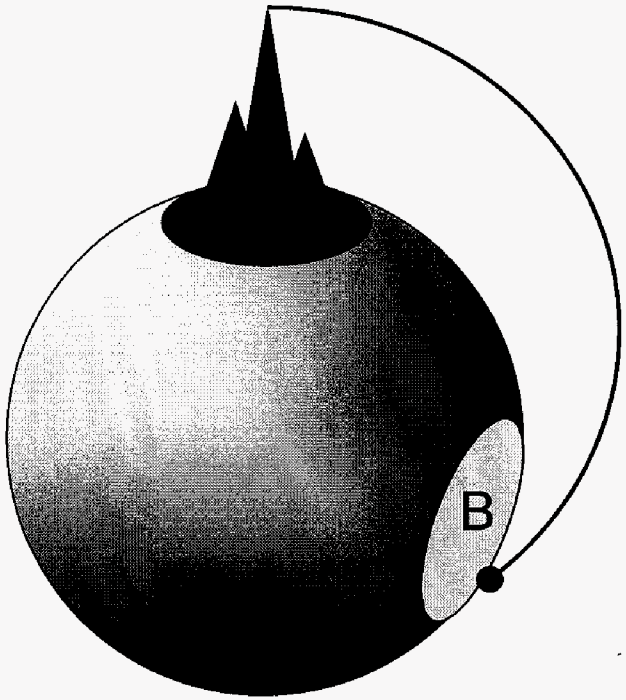
How Orbits Work

Imagine on a strange planet, two countries are having a war:



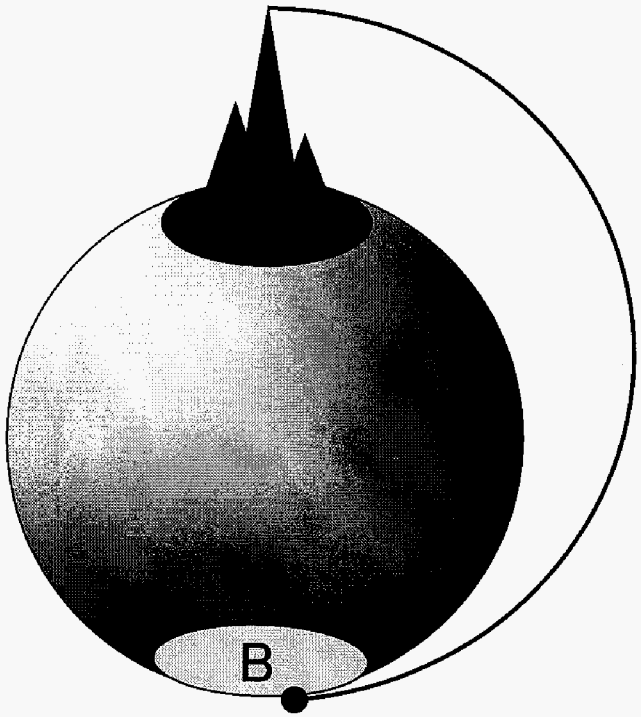
How Orbits Work

If County B is further apart



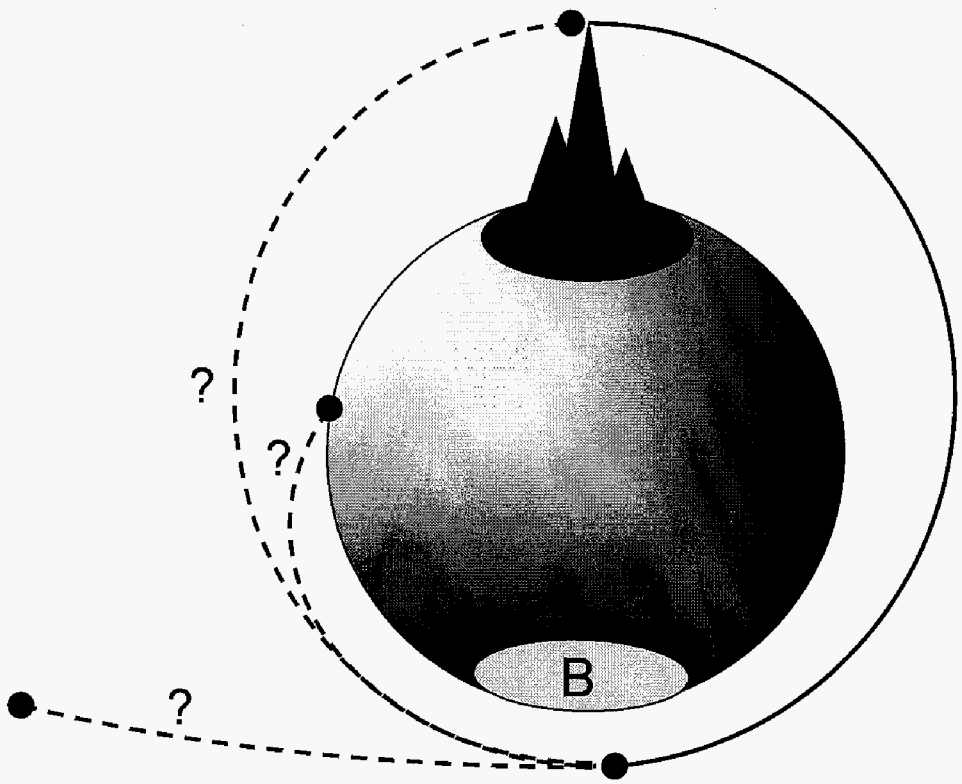
How Orbits Work

If Country B is on the other side of the planet



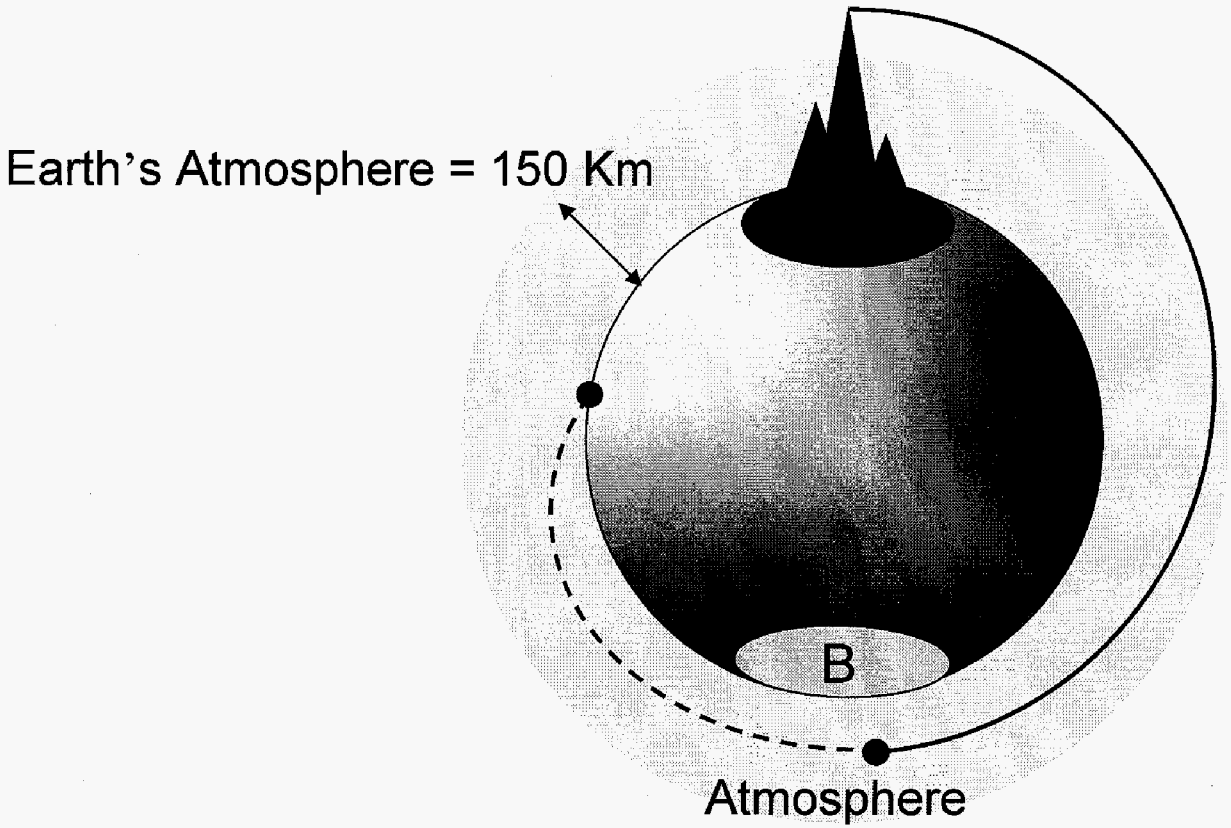
How Orbits Work

What if the cannon ball is aimed too high?



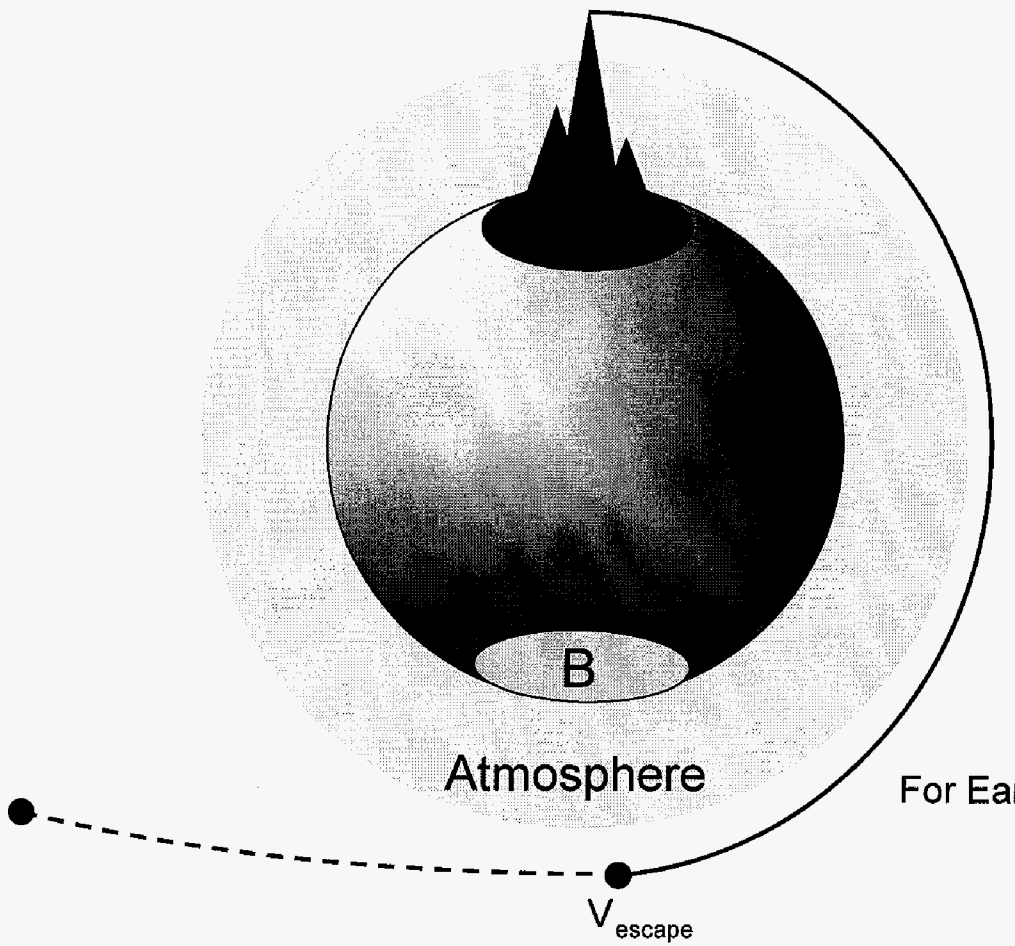
How Orbits Work

If the cannon ball is lower than the atmosphere or too slow



How Orbits Work

If the cannon ball is above atmosphere and too fast



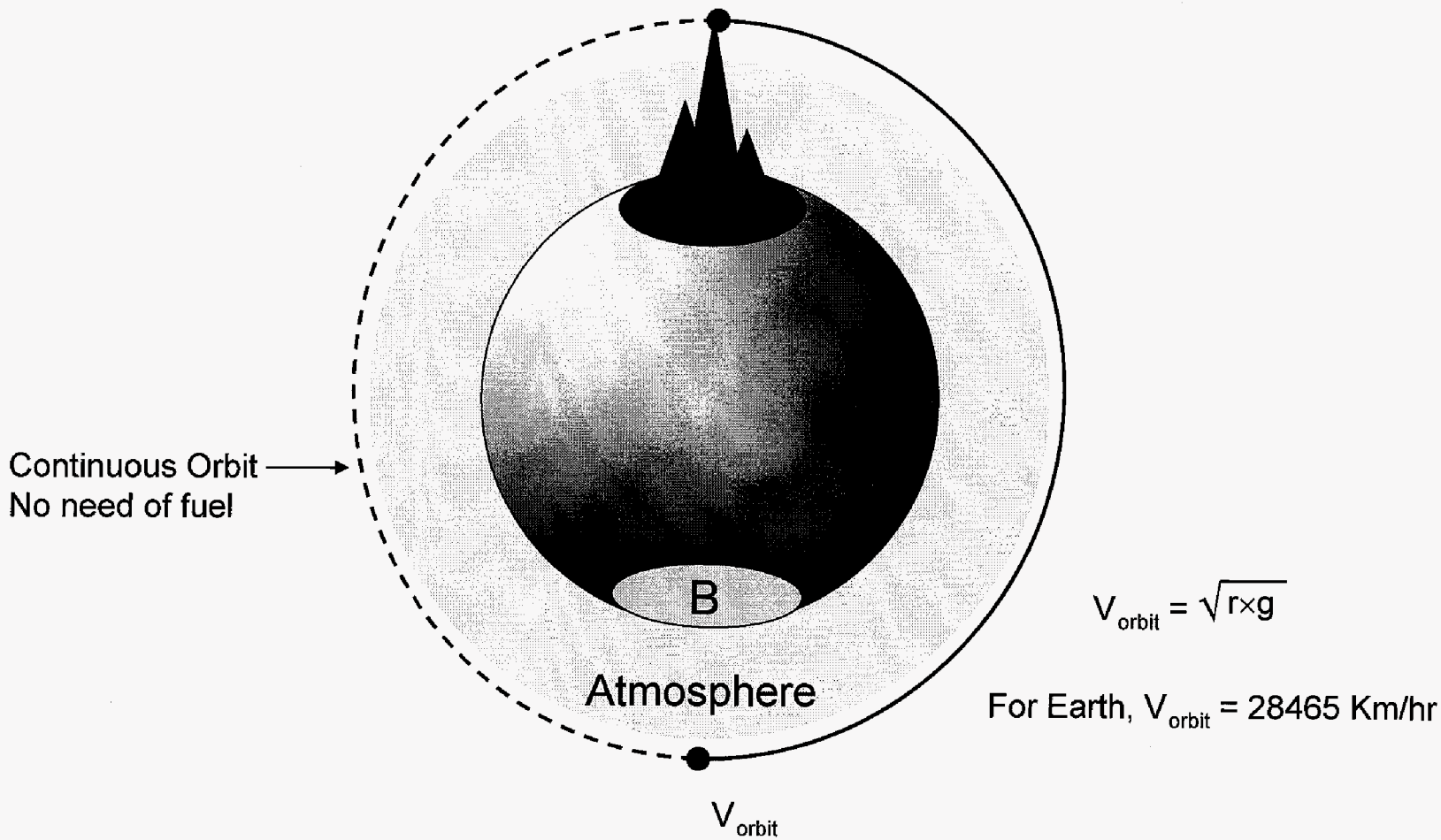
$$\frac{1}{2}mv^2 = \frac{GMm}{r^2} \times r$$

$$V_{escape} = \sqrt{\frac{2GM}{r}}$$

For Earth, V_{escape} = 40265 Km/hr

How Orbits Work

If the cannon ball is above atmosphere and not too fast

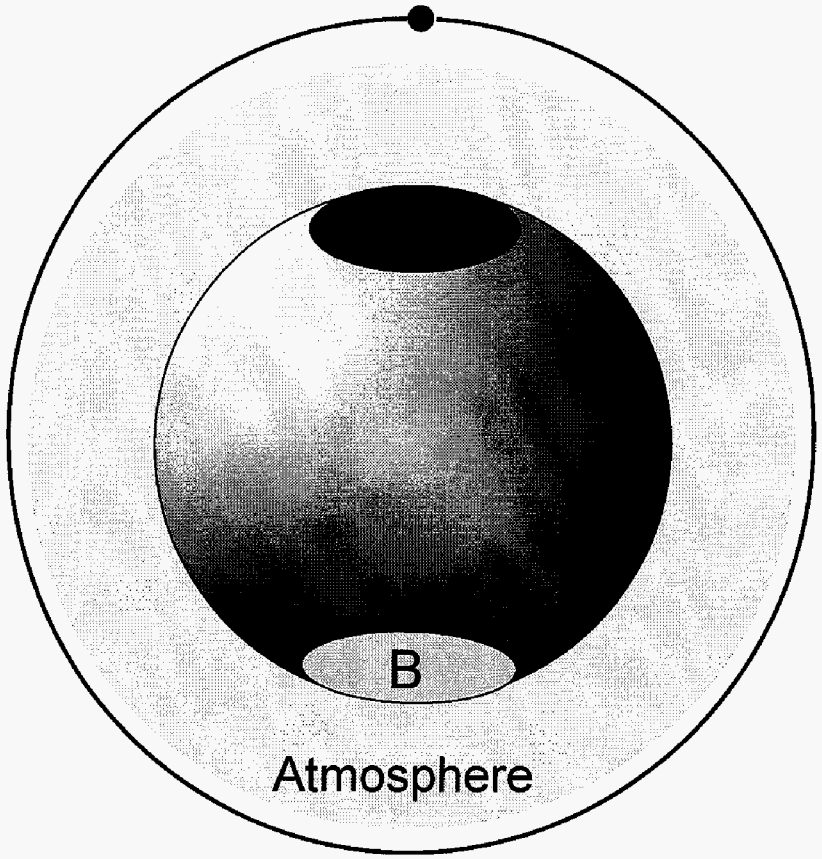


$V_{orbit} = \sqrt{r \times g}$

For Earth, V_{orbit} = 28465 Km/hr

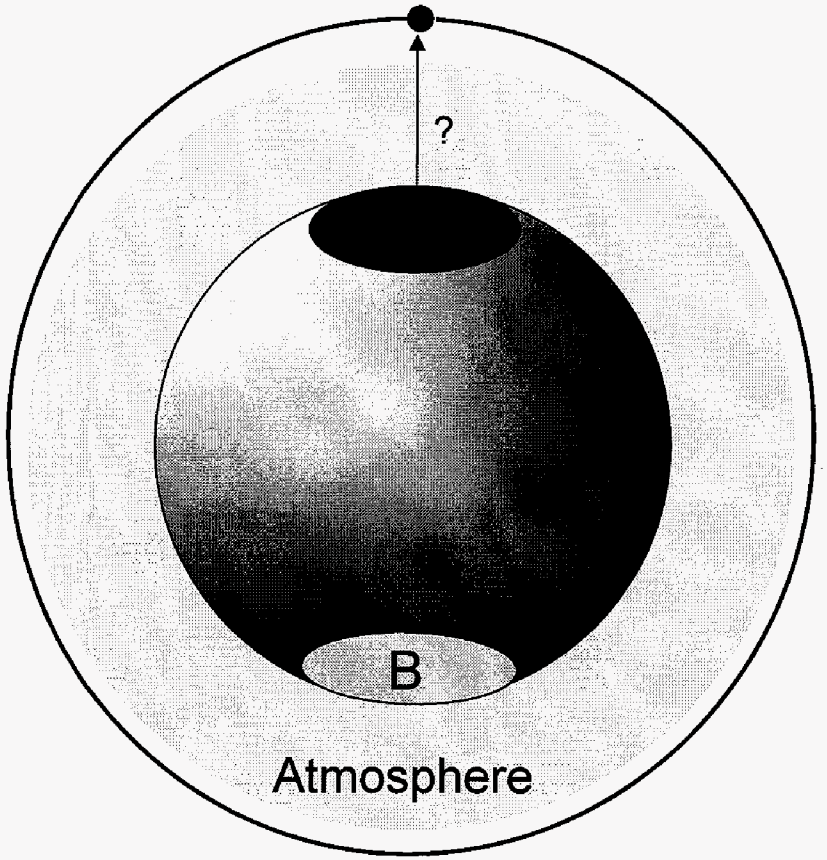
How Orbits Work

The orbit is actually elliptical (Kepler's 1st law). All stars, planets, satellites have similar orbits (they are falling on us all the time!)



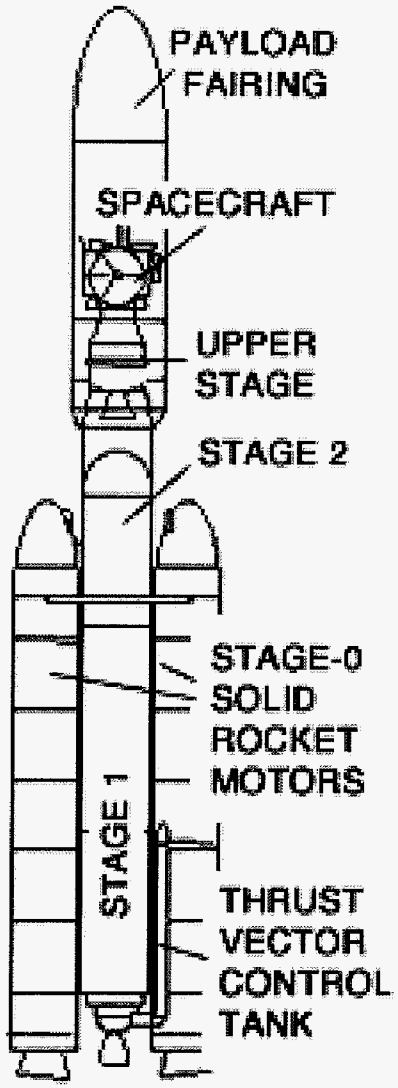
How Orbits Work

Question: There is no such high mountain on Earth,
How can we send the object to the high orbit?

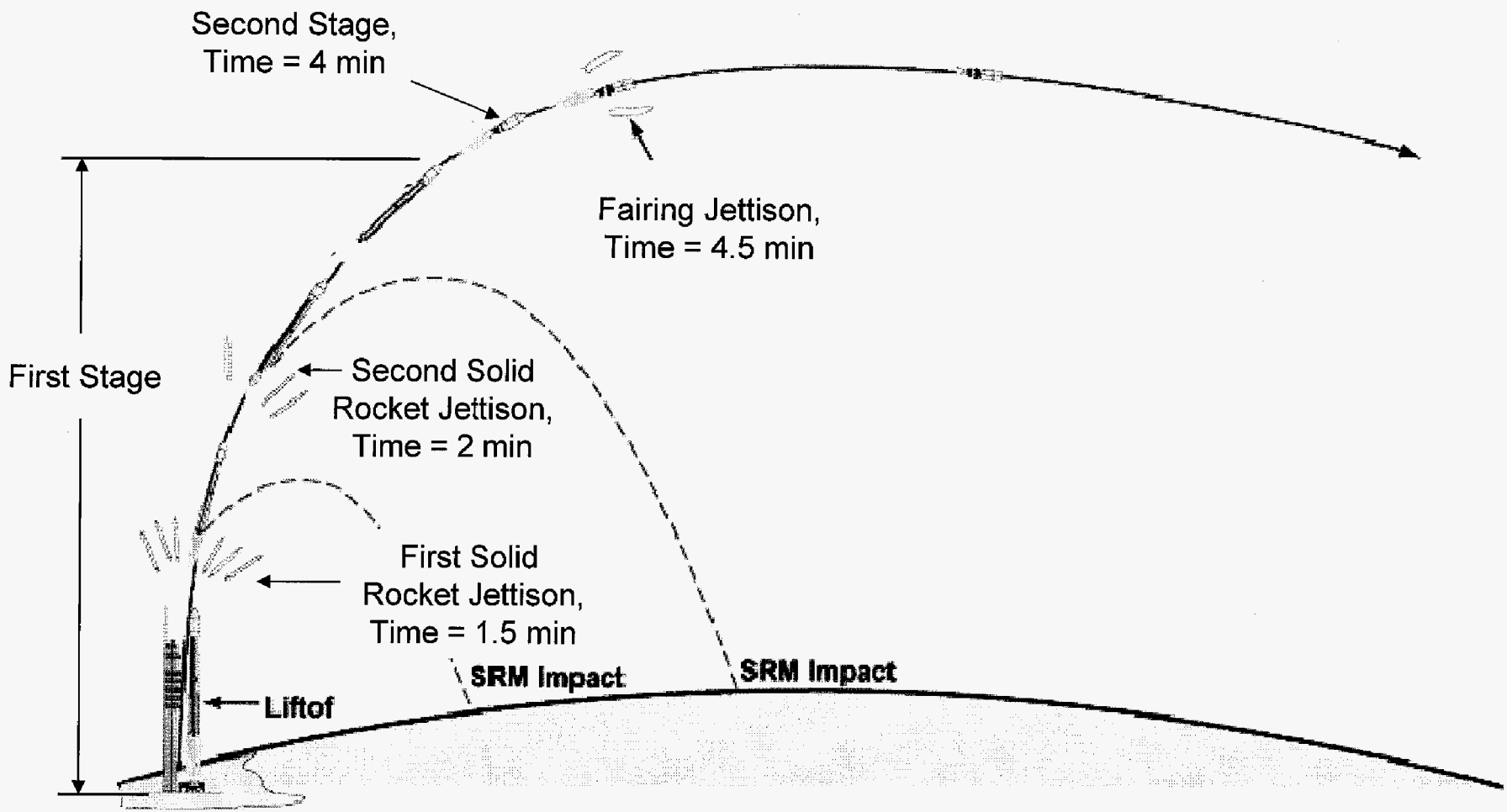


Answer: Use a rocket!

Structure of a Rocket

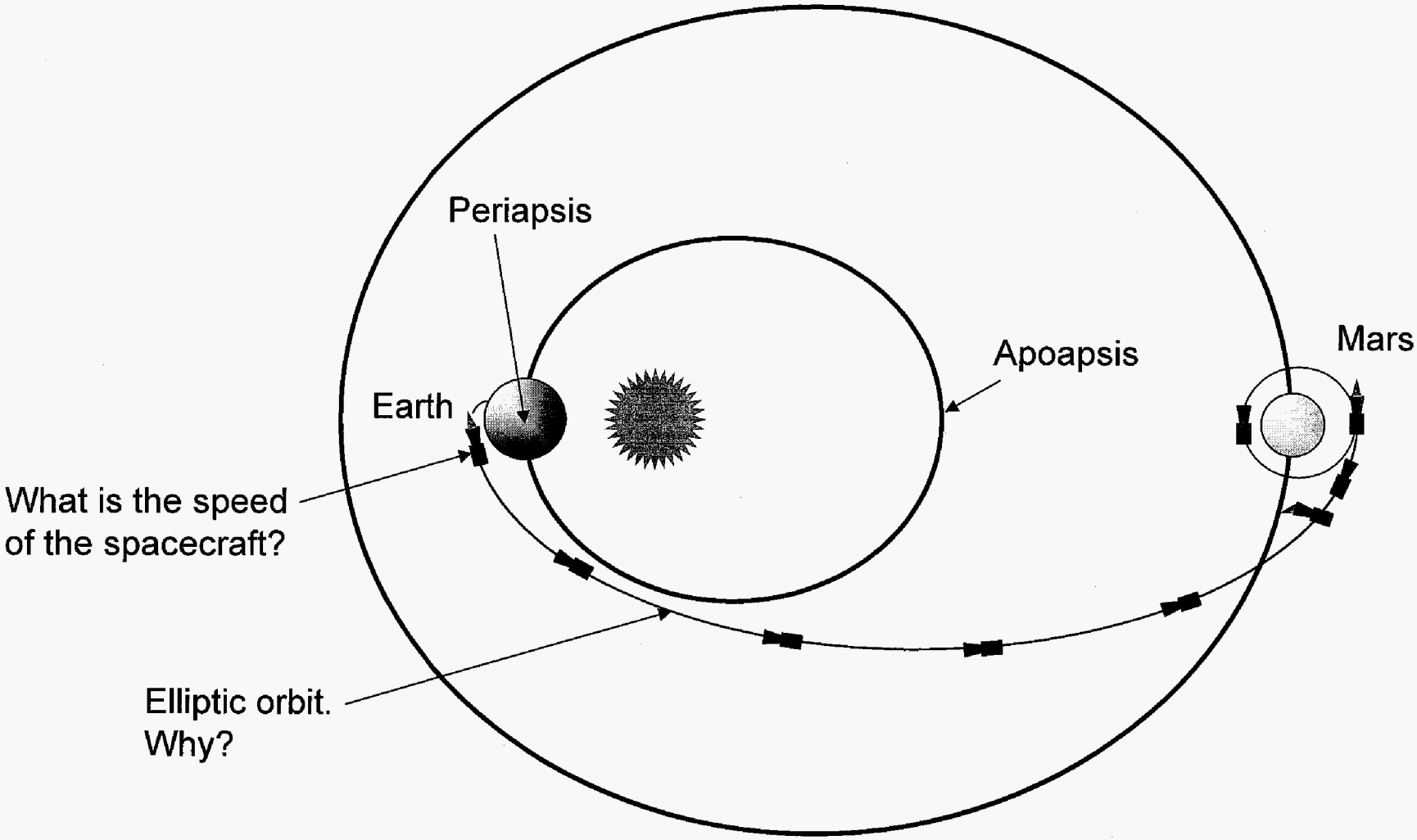


Typical Rocket Launch Profile



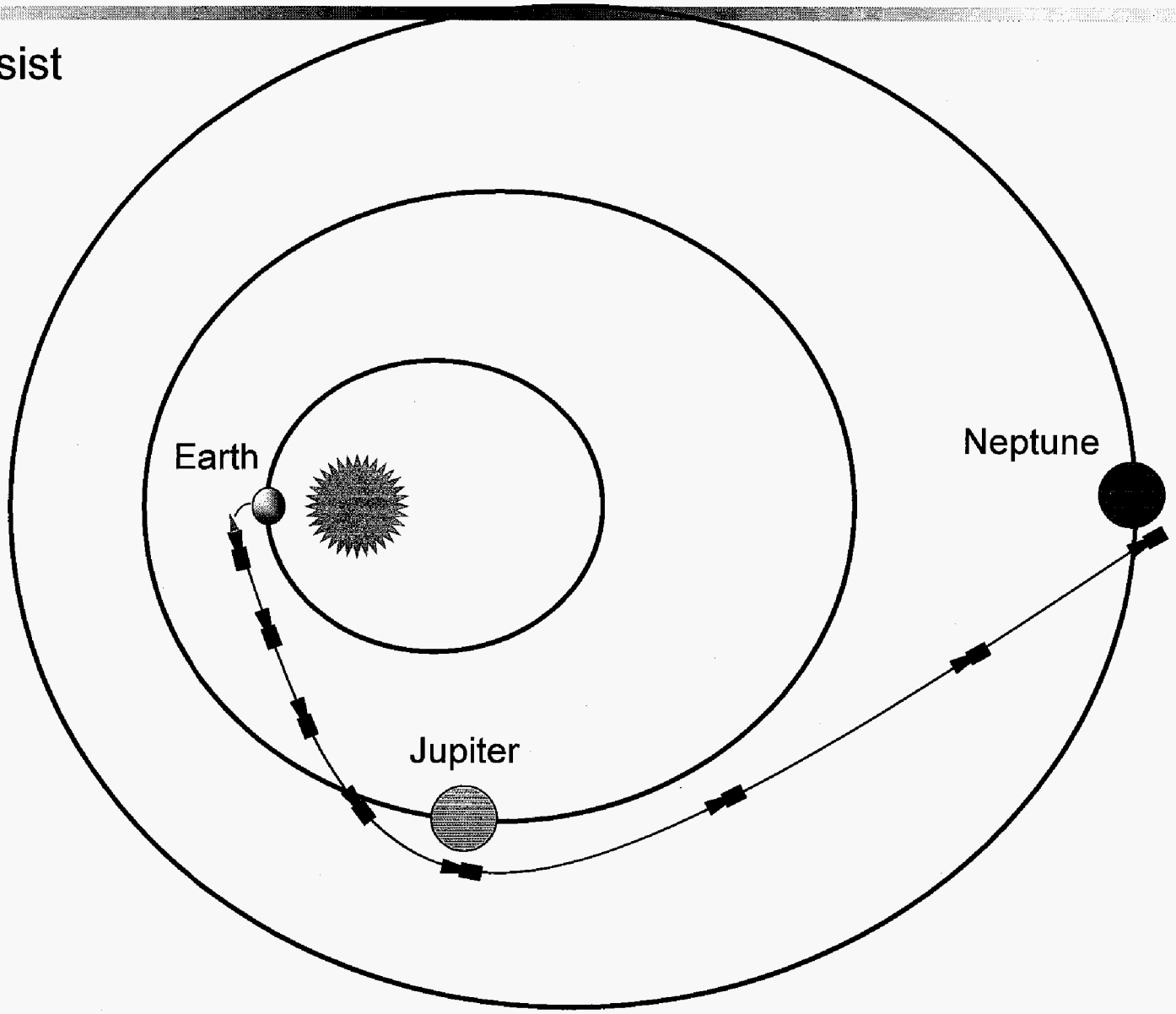
How to Go to Another Planet

Hohmann Transfer Orbit: requires least fuel



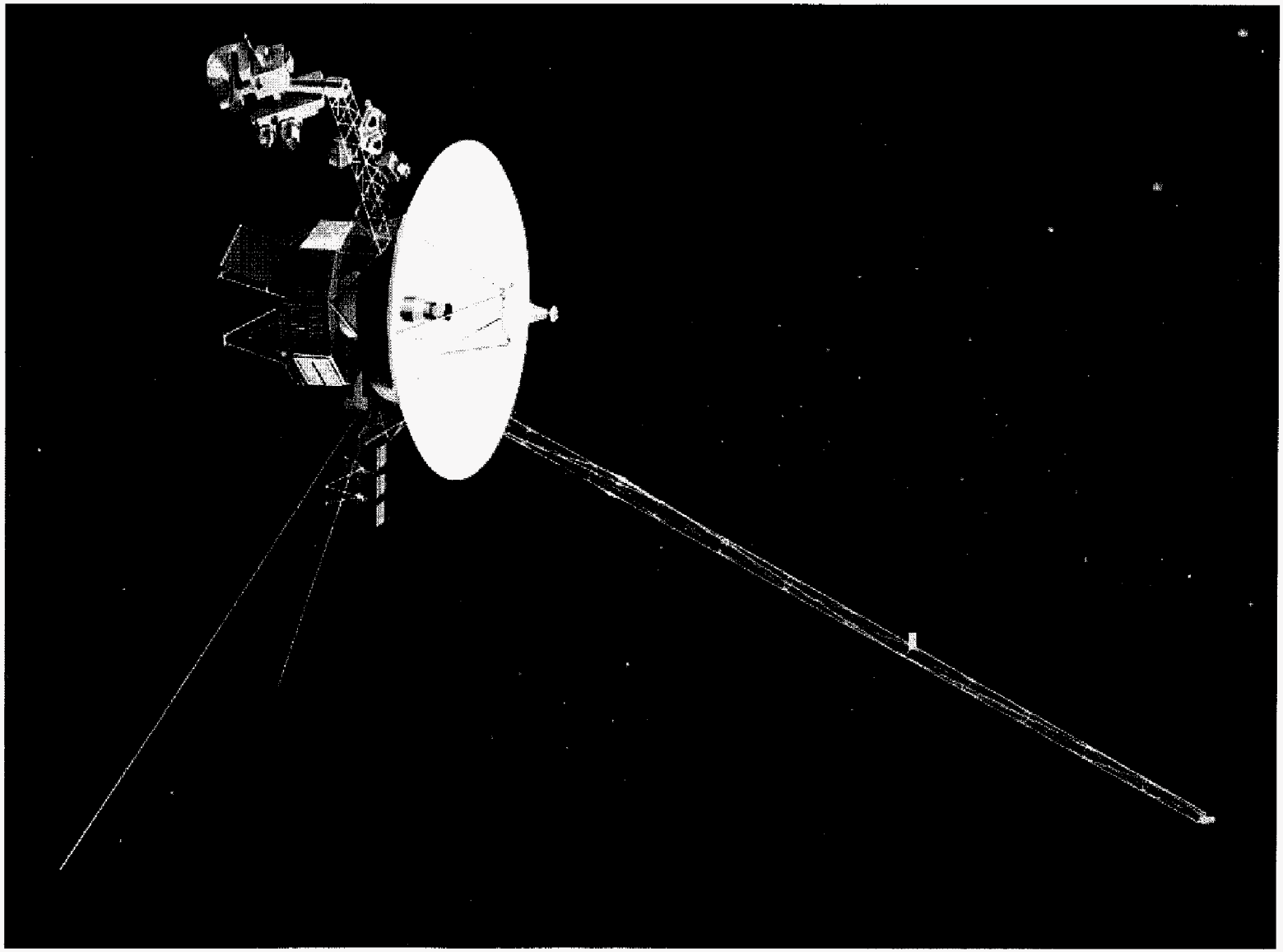
How to Go to Another Planet

Gravity Assist

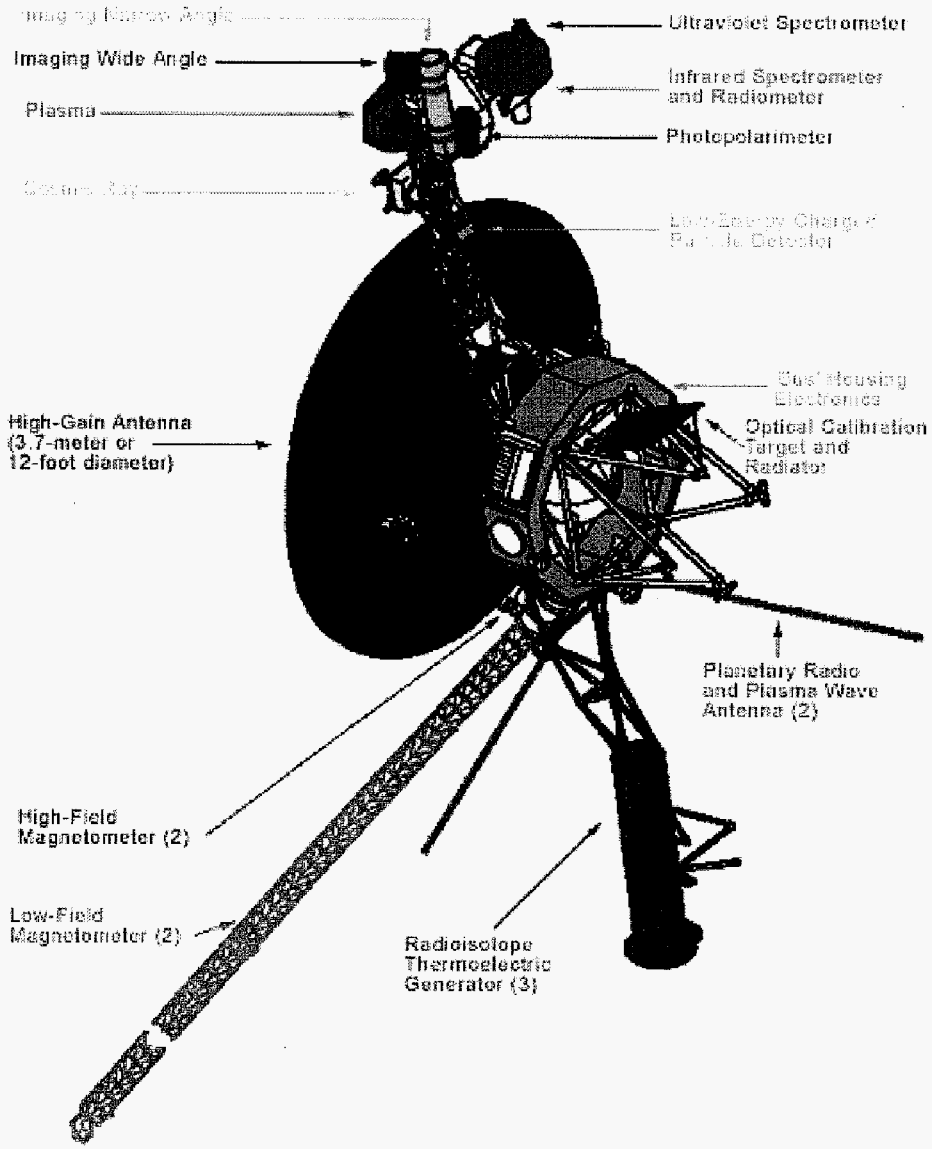


Basics of Spacecraft Design

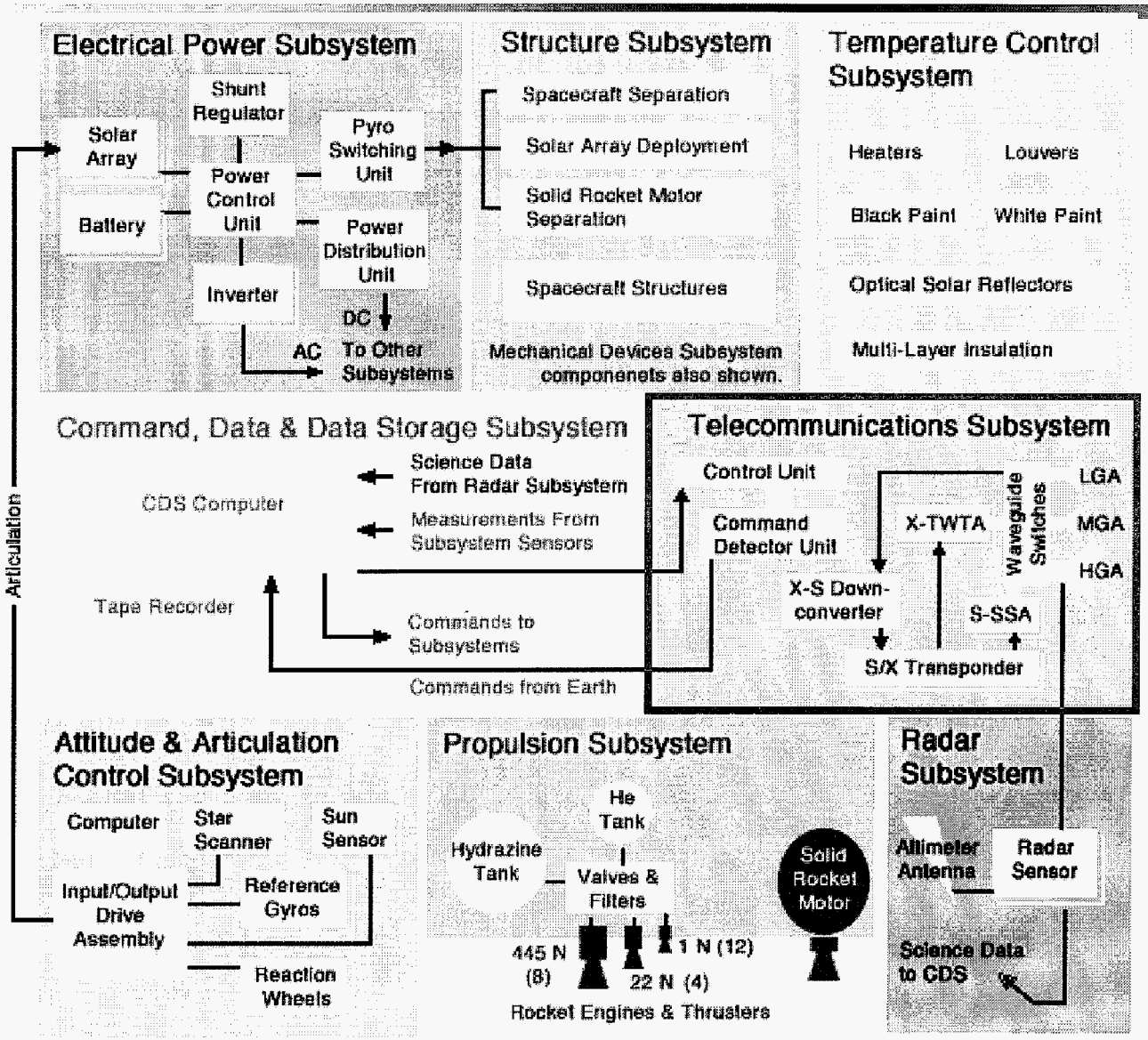
Spacecraft Example: Voyager



Voyager Spacecraft

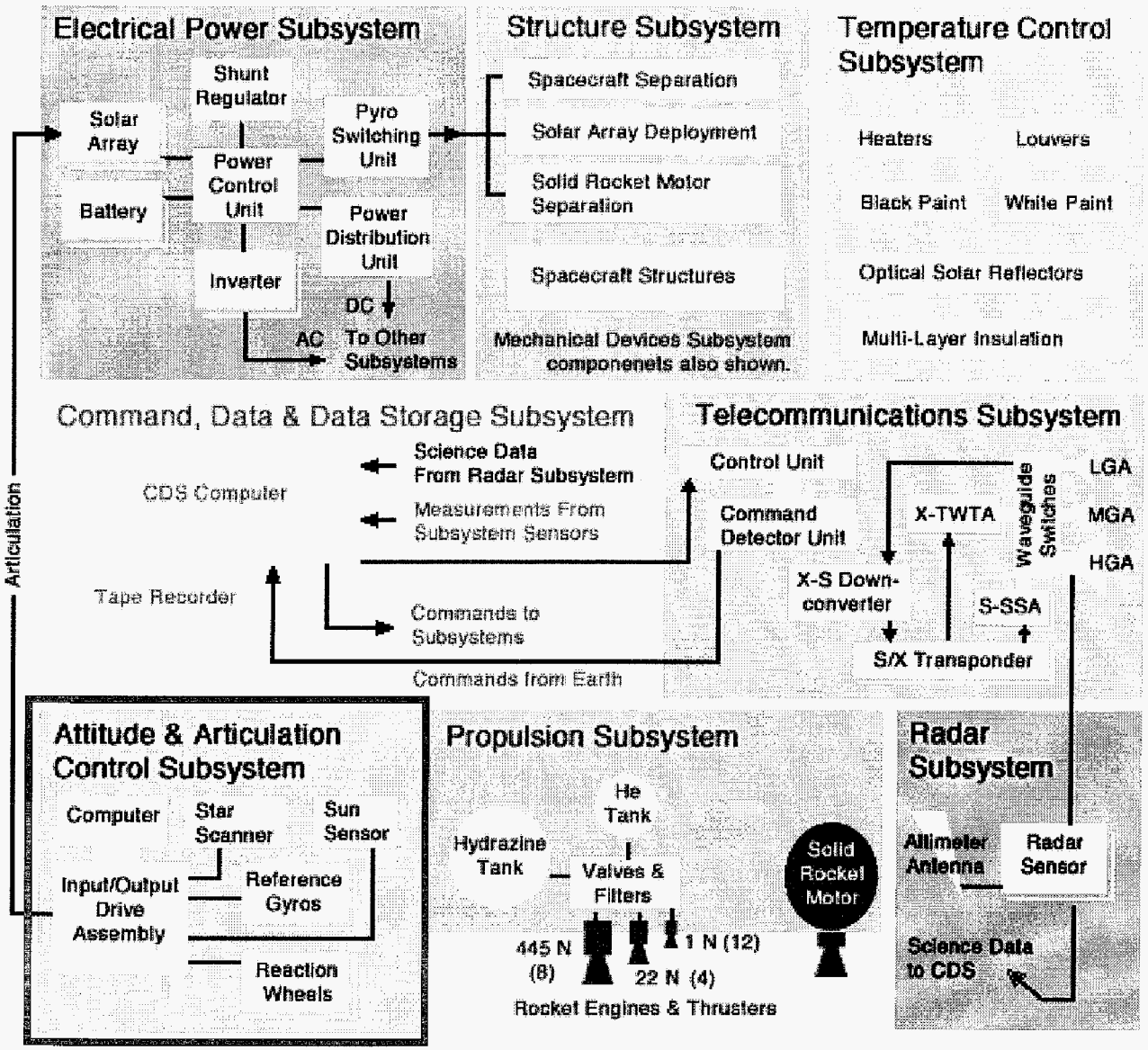


Typical Structure of a Spacecraft



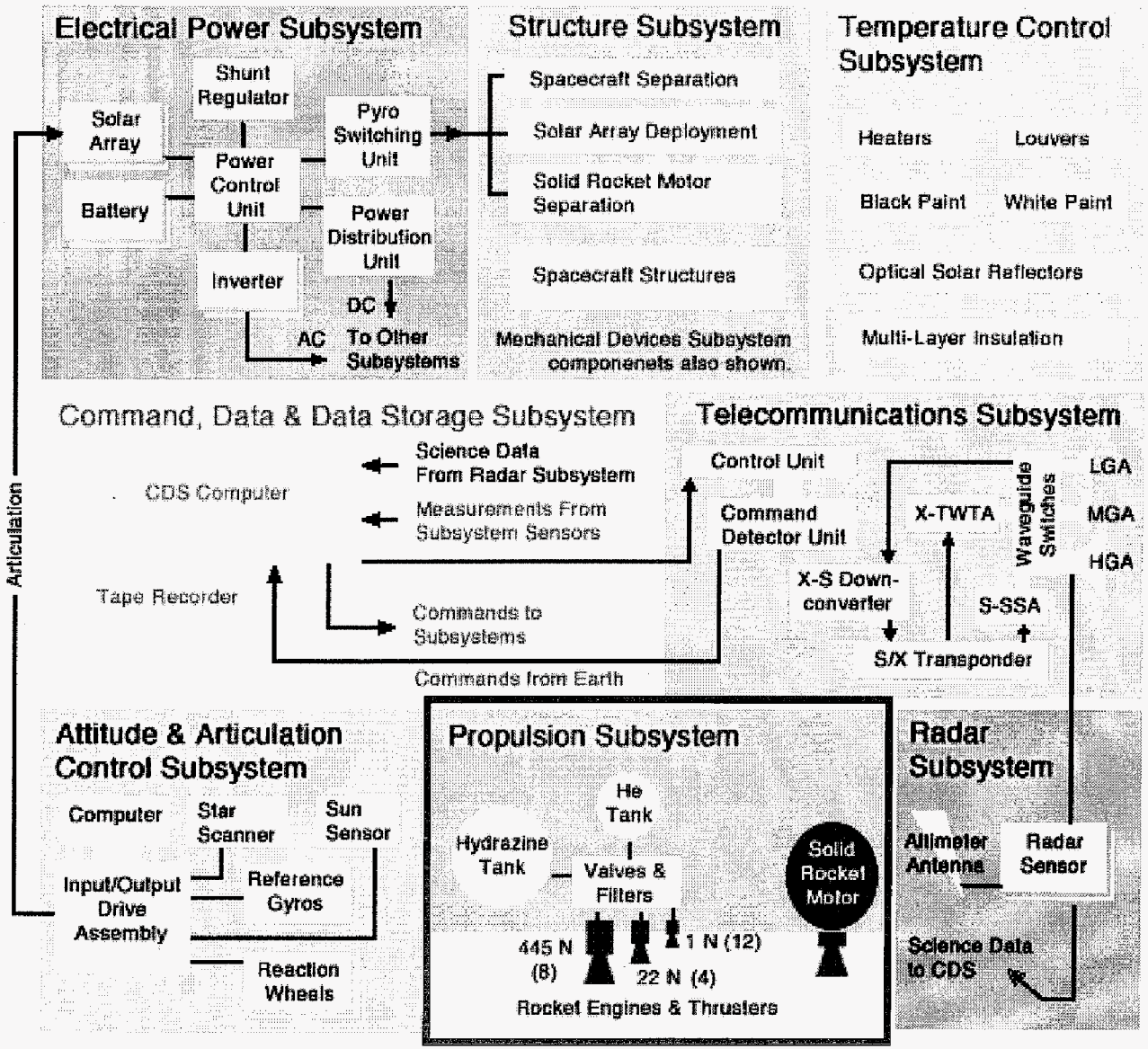
- Telecommunication Subsystem
  - To enable the spacecraft to talk to the ground operator
  - To assist navigation
  - To perform radio science

Typical Structure of a Spacecraft



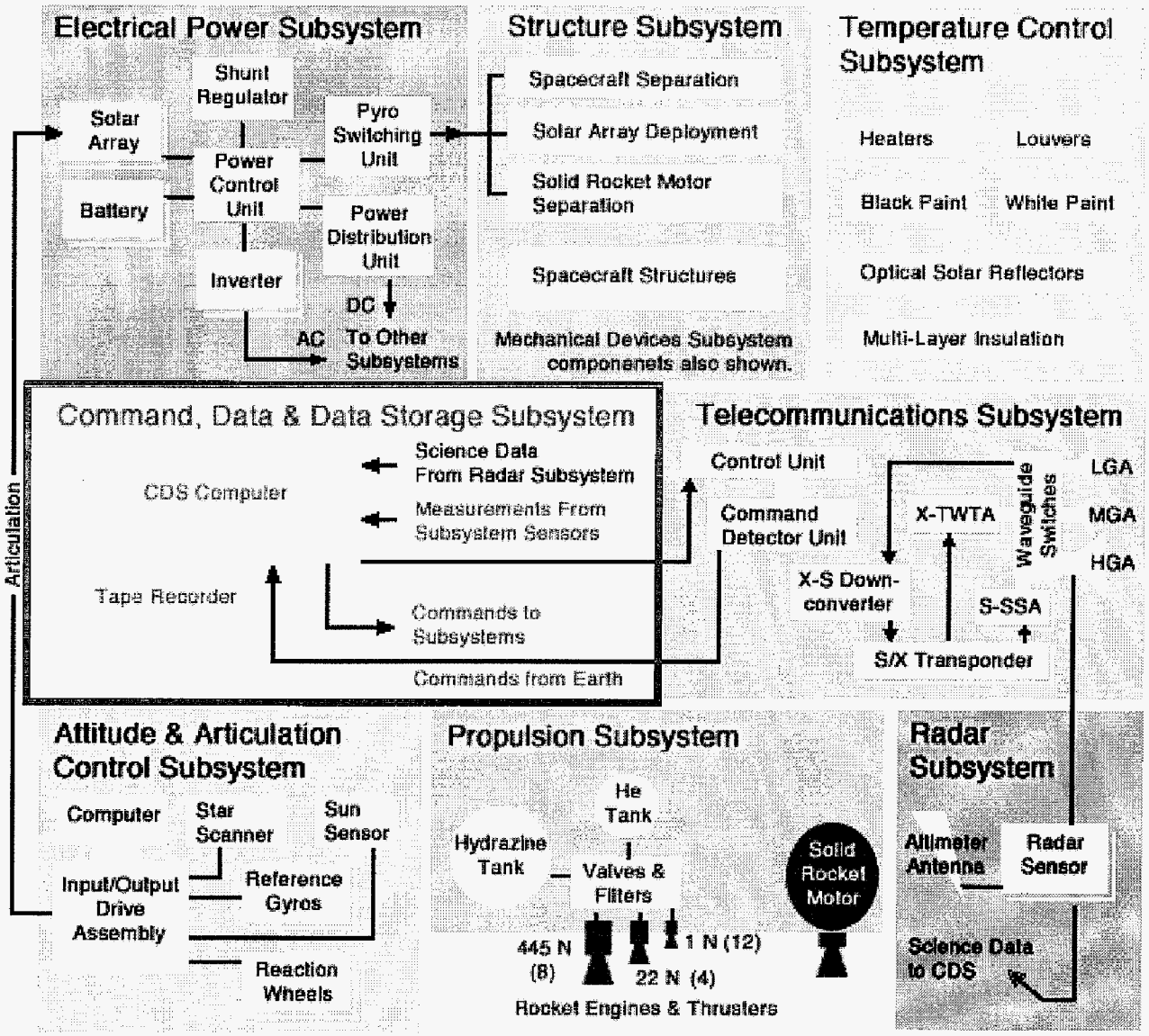
- Attitude Control Subsystem
  - To point the spacecraft to a fix direction (e.g., Earth)
  - To assist navigation

Typical Structure of a Spacecraft



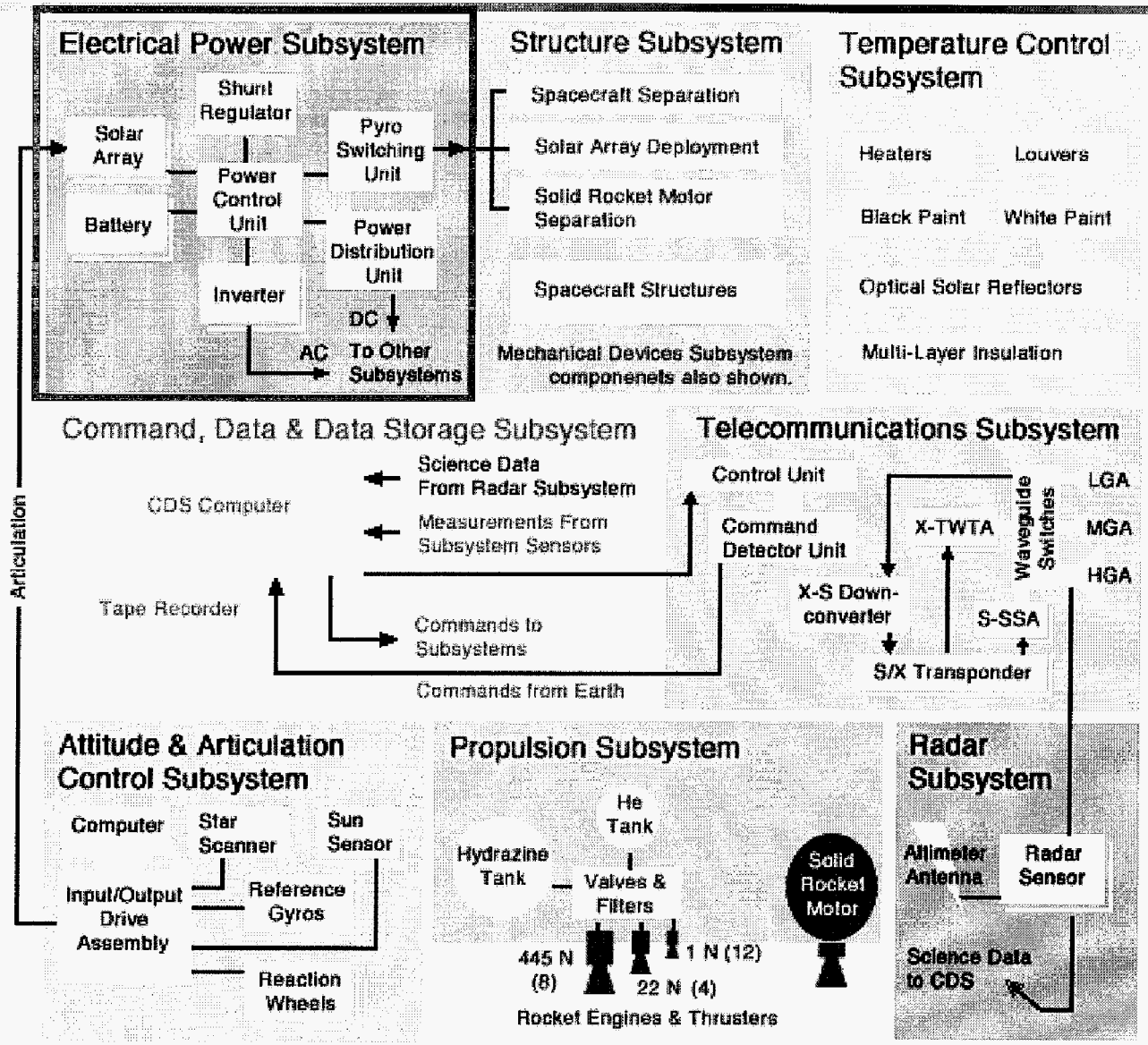
- Propulsion Subsystem
  - To provide the thrust for the spacecraft to change course

Typical Structure of a Spacecraft



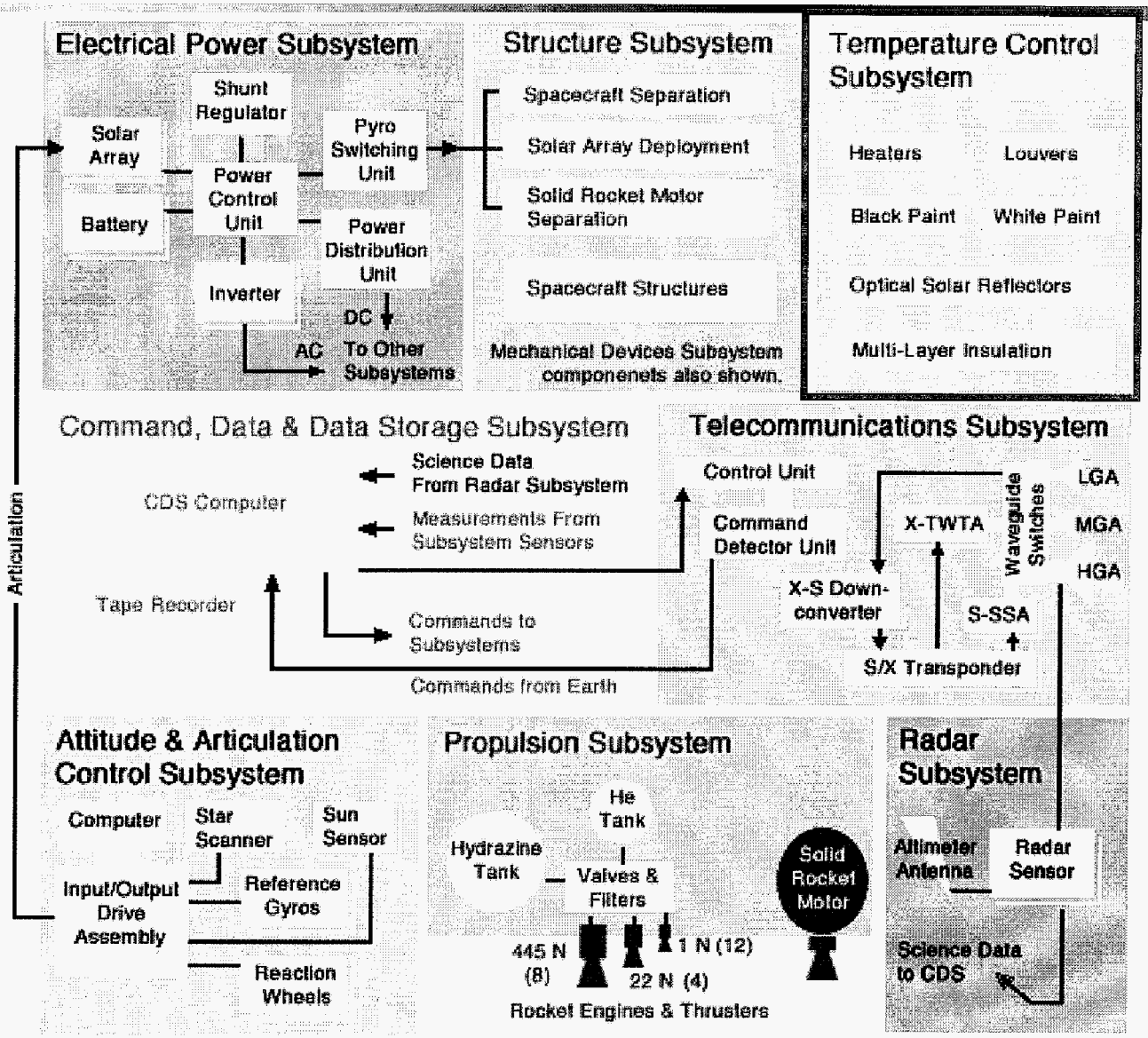
- Command and Data Handling Subsystem
  - To process commands from ground
  - To distribute commands to subsystems
  - To collect telemetry and science data
  - To send all data to ground

Typical Structure of a Spacecraft



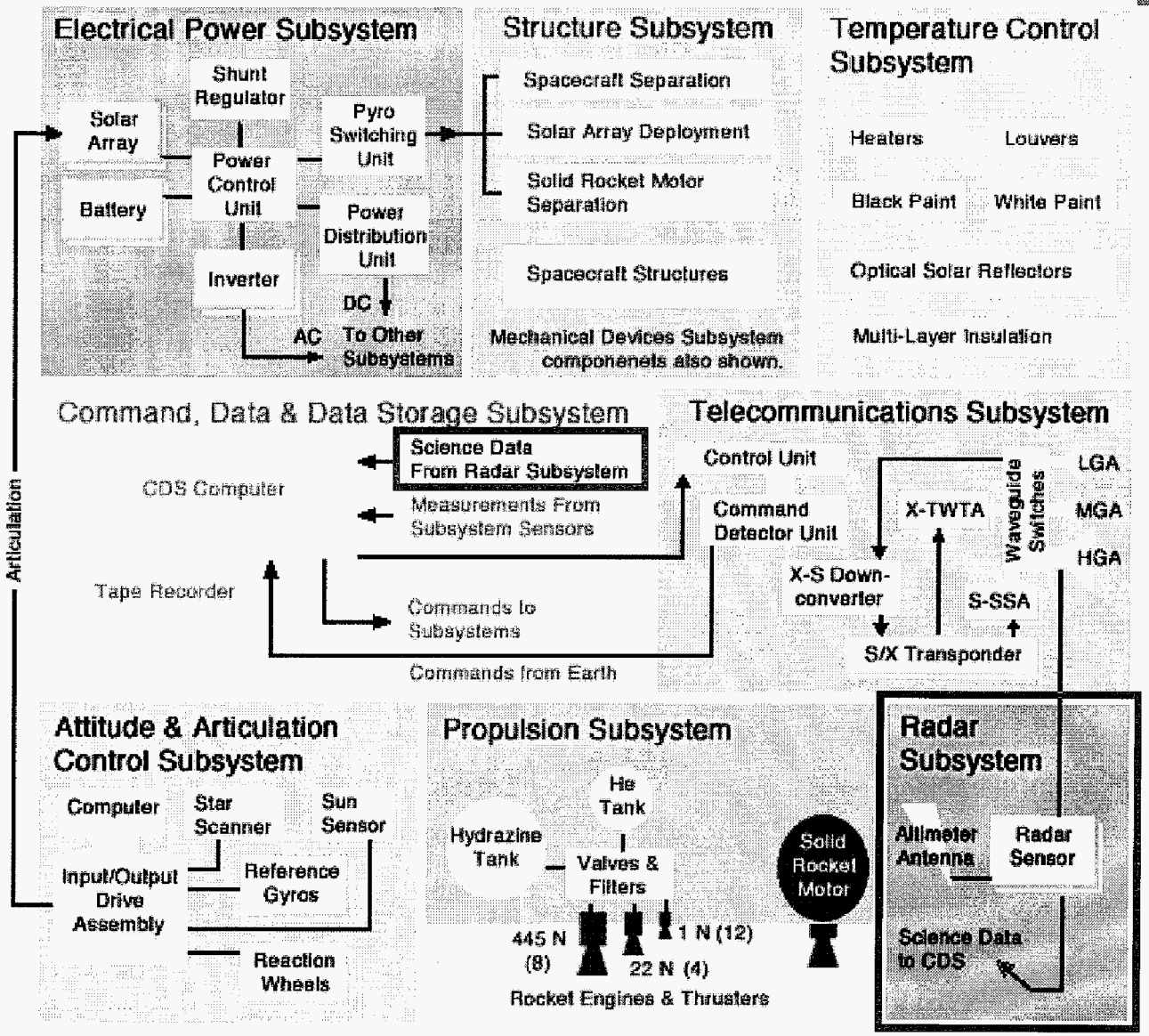
- Power Subsystem
  - To provide power source
  - To regulate the raw power
  - To distribute power to all subsystems

Typical Structure of a Spacecraft



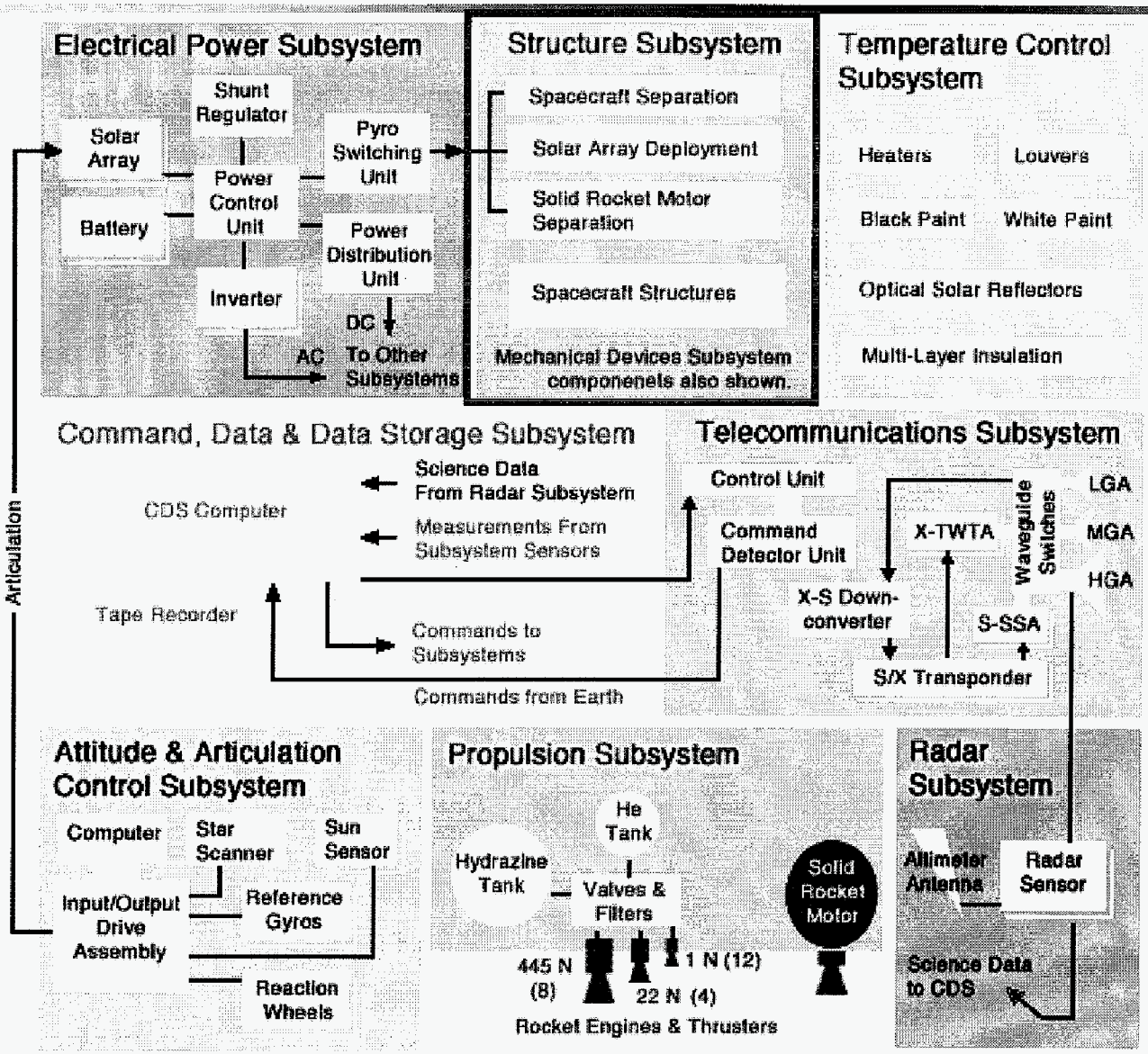
- Thermal Control Subsystem
  - To keep the spacecraft at the proper temperature

Typical Structure of a Spacecraft



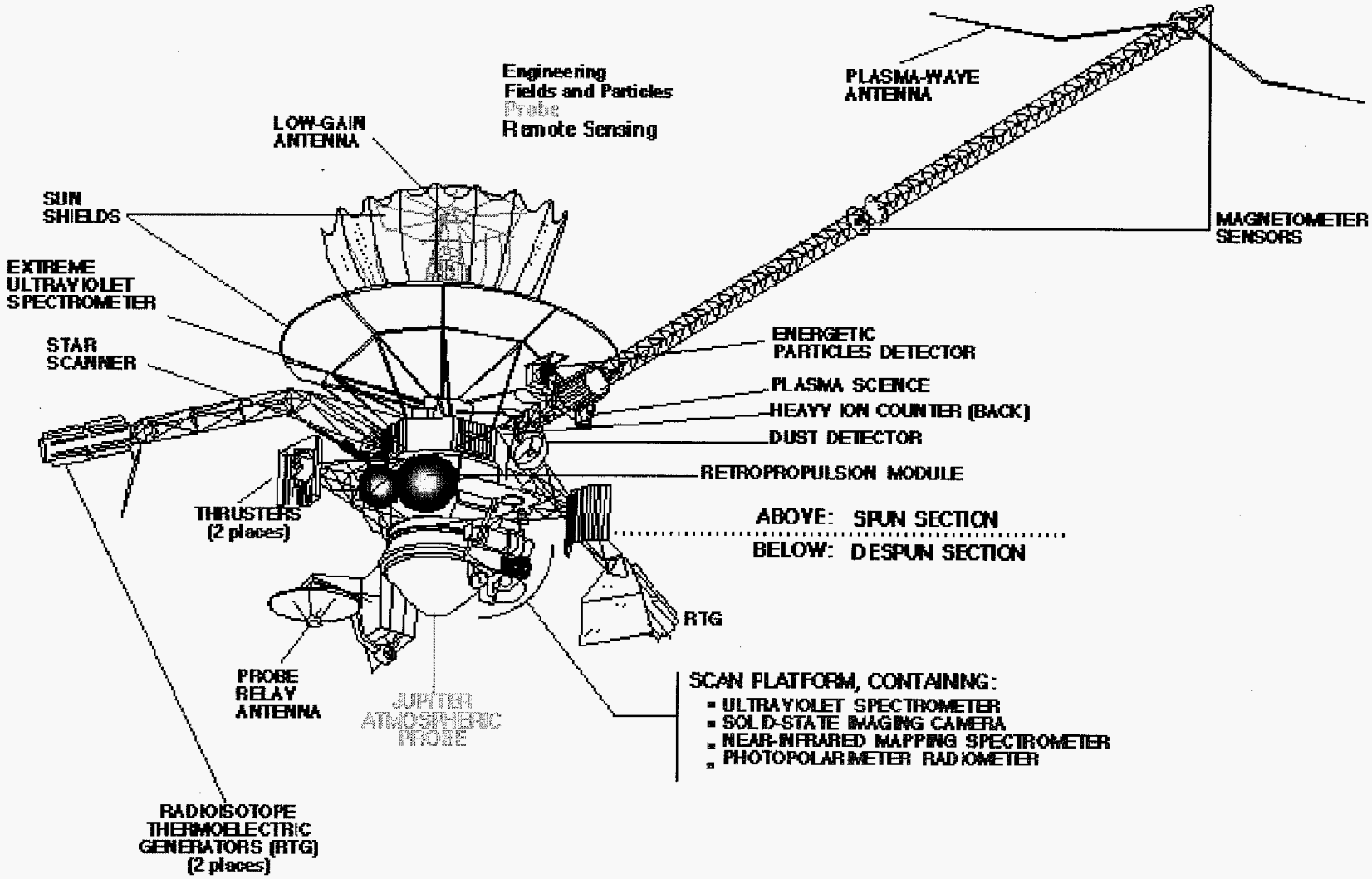
- Science Instruments
  - To collect science data
  - Typical Instruments
    - Imager
    - Spectrometer
    - Magnetometer
    - Radar science

Typical Structure of a Spacecraft

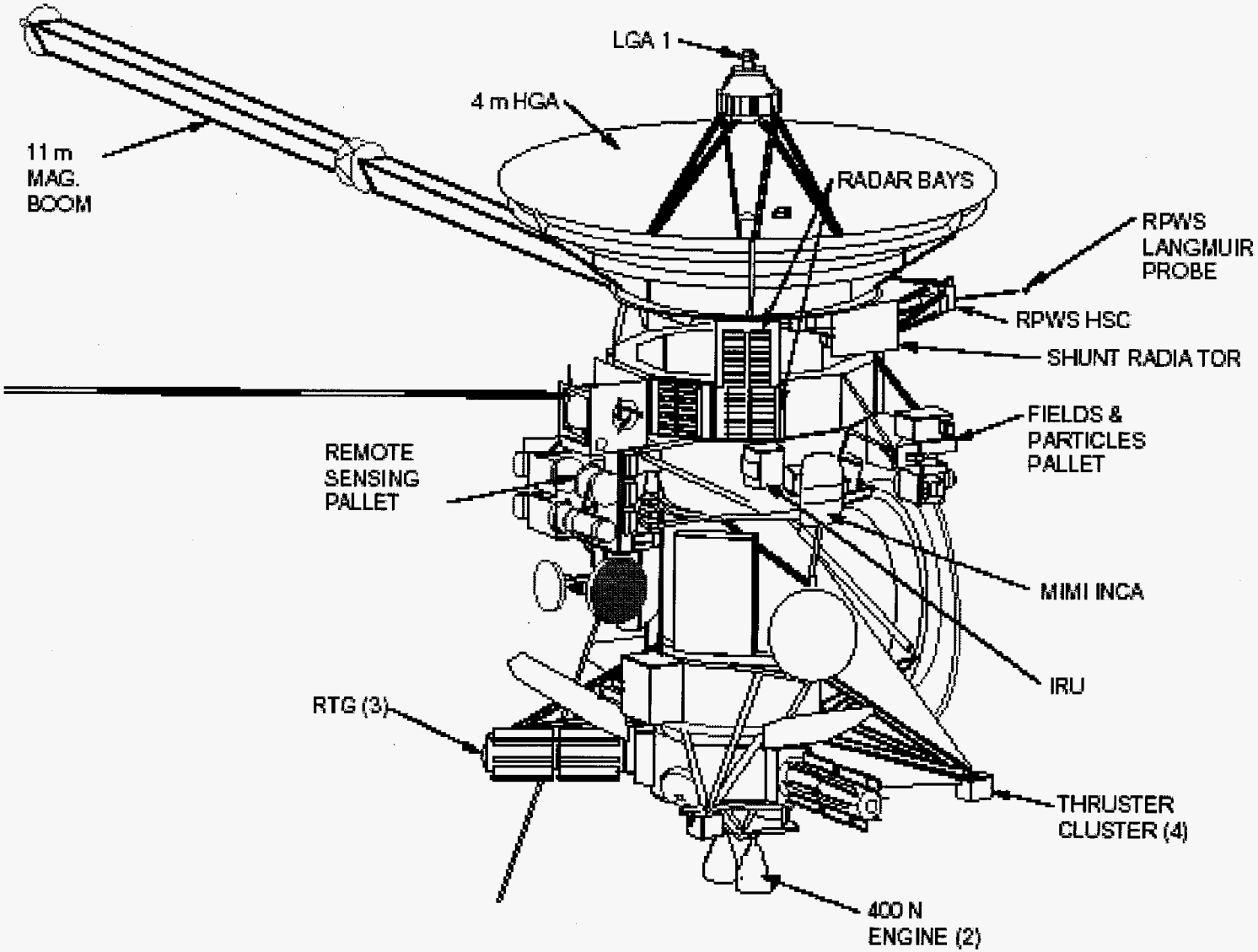


- Structure Subsystem
  - To provide the structure for the spacecraft
  - To provide mechanism for deployable parts

Galileo Spacecraft



Cassini Spacecraft

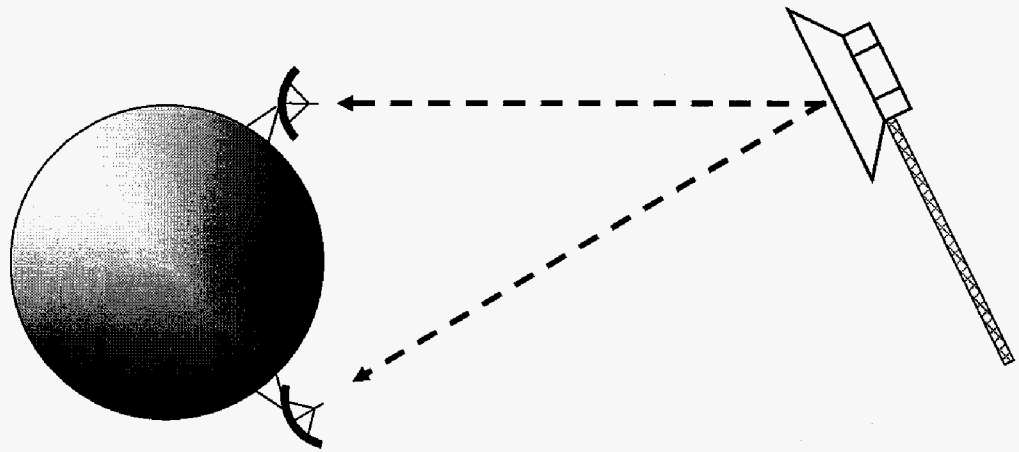


Navigation

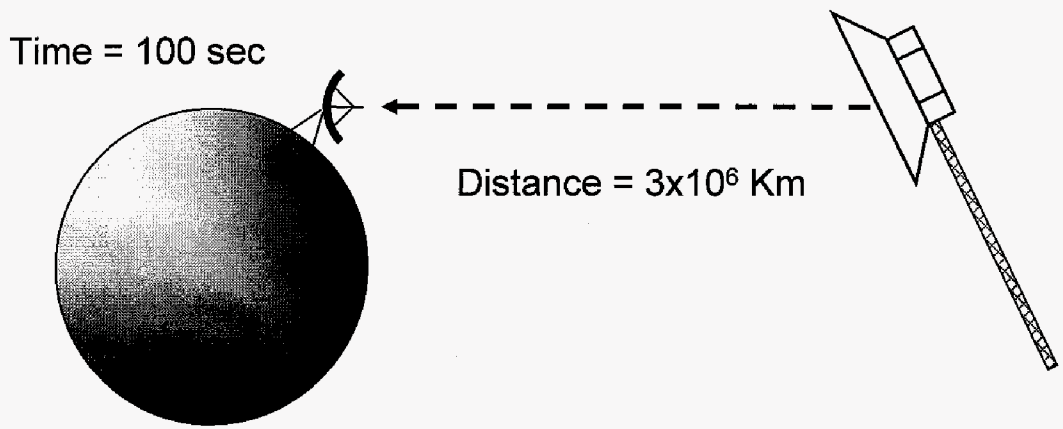
- To guide the spacecraft to the destination
- Need to know the current state of the spacecraft:
  - Where is the spacecraft in the sky?
  - How far is the spacecraft from the Earth?
  - What direction it is facing?
  - How fast it is traveling?
- Need to know what actions need to be taken in order to get to the destination
  - Trajectory Correction Maneuver

Navigation

- **To find out where is the spacecraft in the sky:**
  - Differential One-Way Ranging: Compare time different between 2 antennas

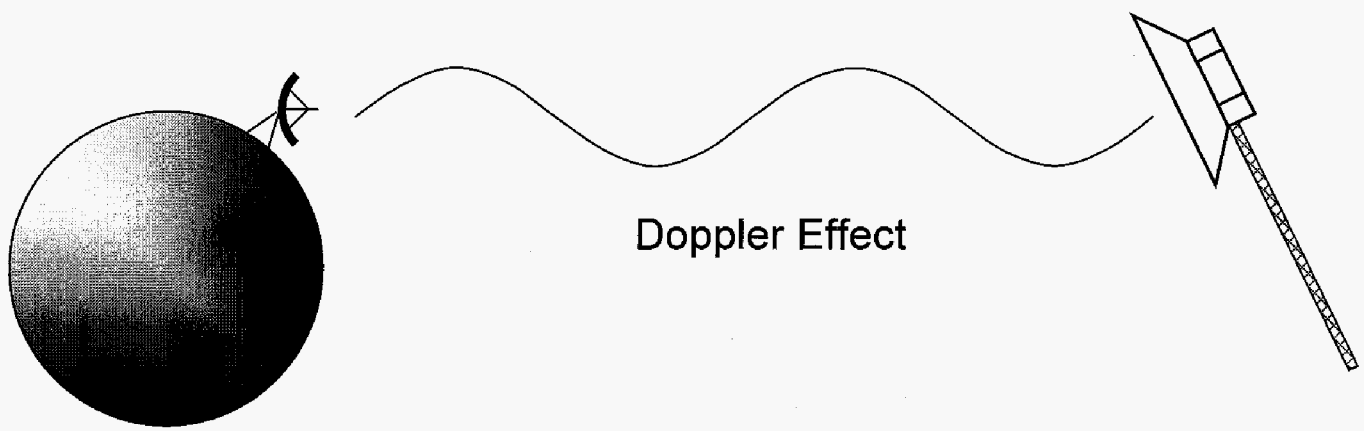
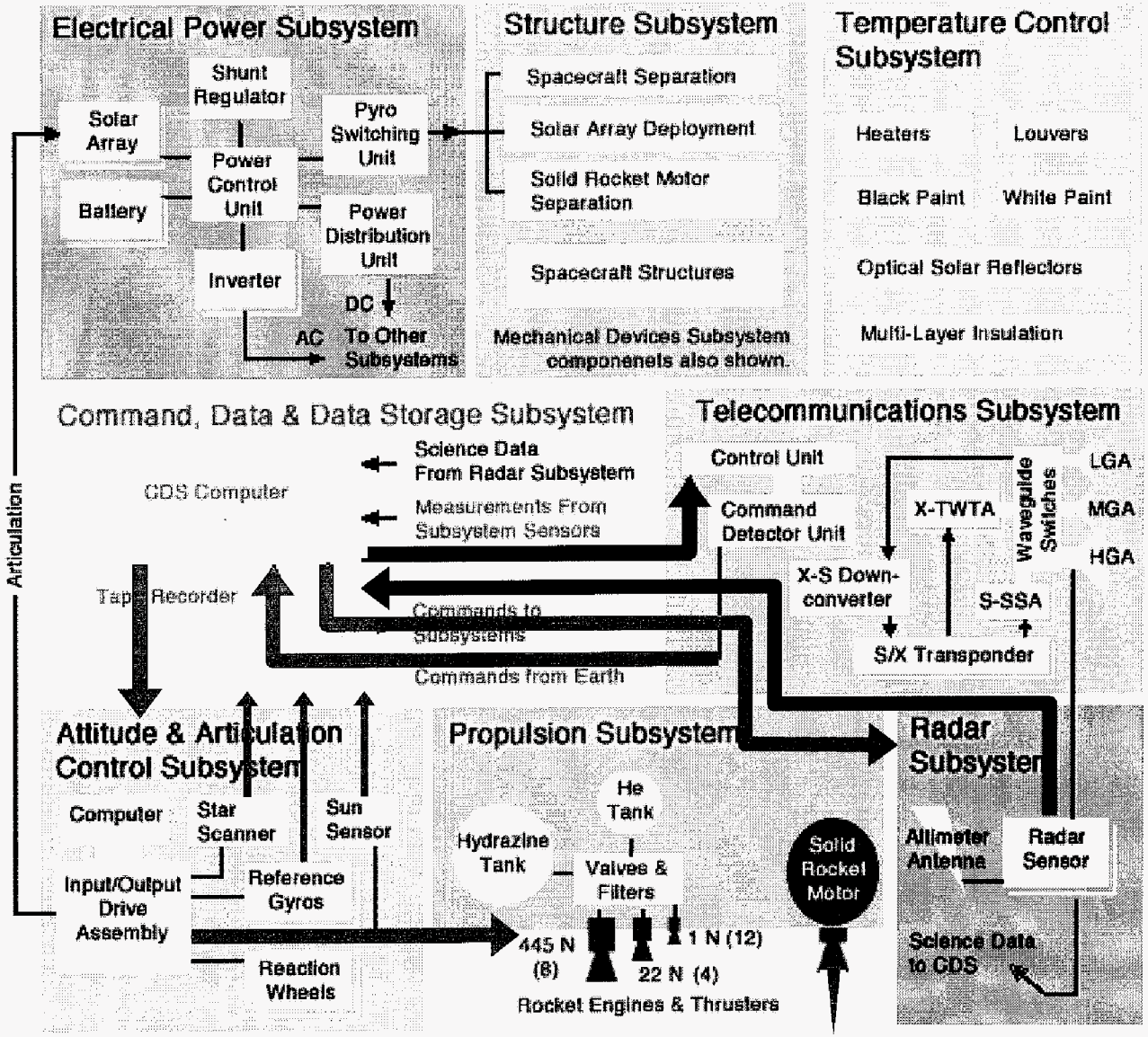
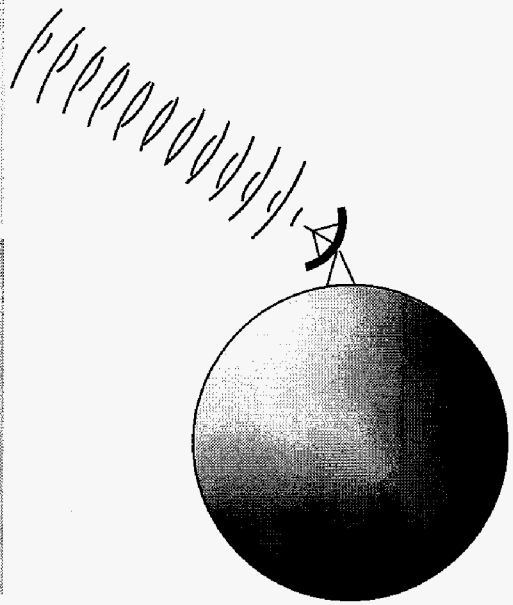


- **To find out how far is the spacecraft from Earth**
  - Two-Way Ranging: Measure round trip time of a signal to spacecraft



Navigation

- What direction is the spacecraft facing?
  - Use Attitude Control Sensors:
    - Star Tracker
    - Gyroscope
- How fast is the spacecraft traveling?
  - Doppler Effect: Measure the change in signal frequency



Operation of a spacecraft