Satellite Communications

Part III-Satellite Launch, Orbital Effects, Space Qualification, Satellite Services

Lecturer Madeeha Owais

Learning Objectives

- Launch and Launch Vehicles
- Orbital effects in communication system performance
- Space Qualification and Equipment Reliability
- Satellite Services

Key Points for Achieving Correct Orbit

- Correct Velocity(vector)

- Correct Altitude

Both must be correct, simultaneously

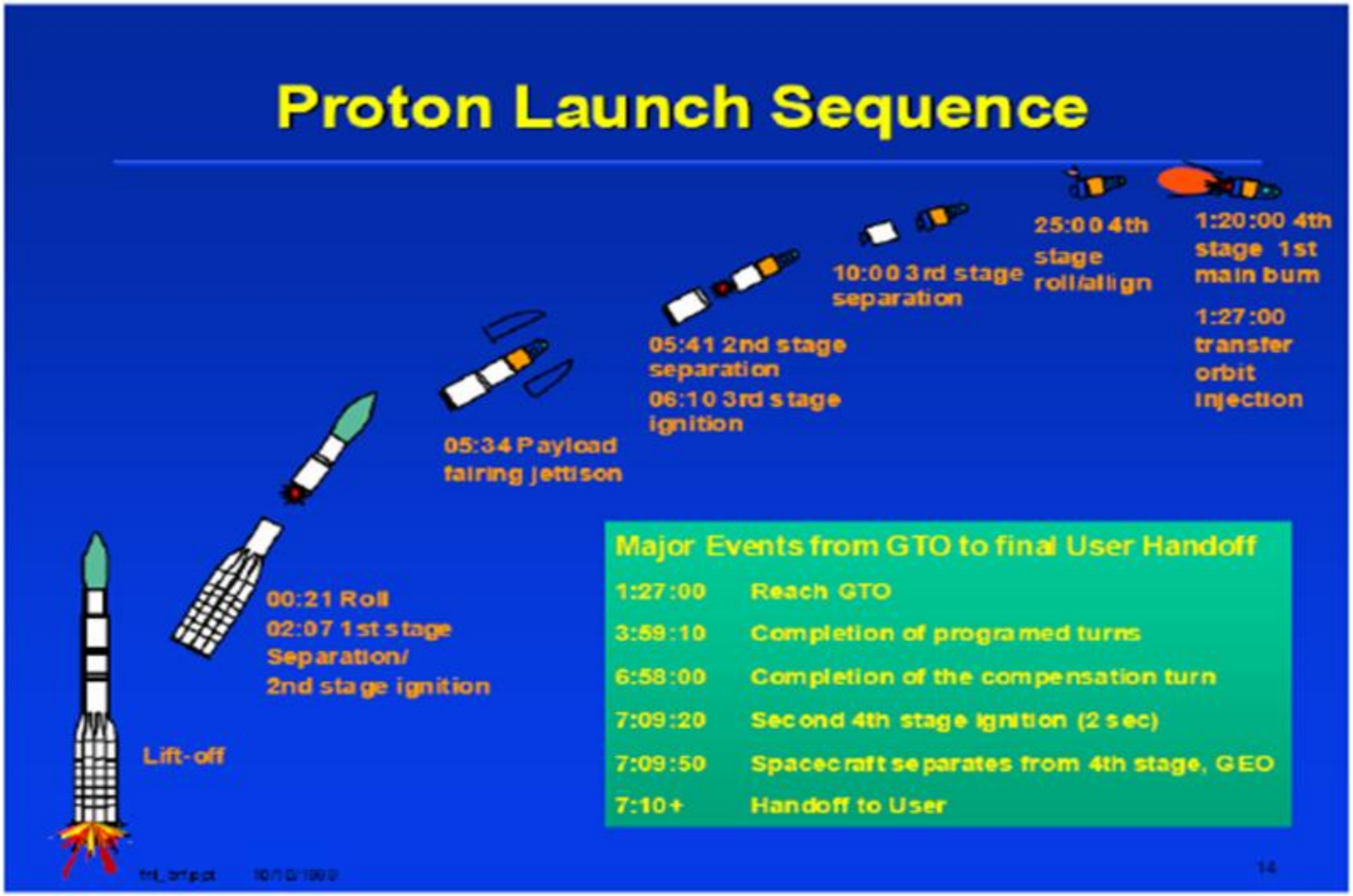
Launch Vehicles

- Largest Fraction of energy expenditure is to accelerate the vehicle from rest to about 20miles above the earth

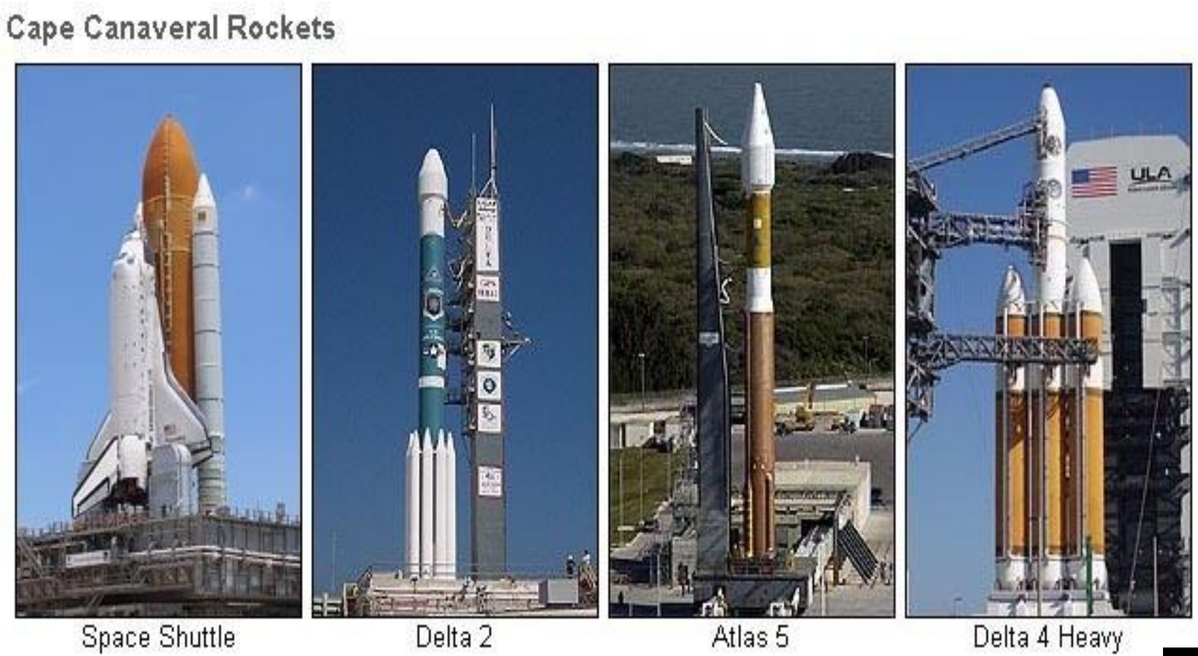
- **Staging**
  - Shedding of mass from the launcher as it moves upward on launch
  - For efficient use of the fuel

- **Two Types of Vehicles**
  - Expendable Launch Vehicle (ELV)
  - Reusable Launch Vehicle(RLV)

Staging


Proton Launch Sequence
Lift-off
00:21 Roll
02:07 1st stage
Separation/
2nd stage ignition
05:34 Payload
fairing jettison
05:41 2nd stage
separation
06:10 3rd stage
ignition
10:00 3rd stage
separation
25:00 4th
stage
roll/allign
1:20:00 4th
stage 1st
main burn
1:27:00
transfer
orbit
injection
Major Events from GTO to final User Handoff
1:27:00 Reach GTO
3:59:10 Completion of programed turns
6:58:00 Completion of the compensation turn
7:09:20 Second 4th stage ignition (2 sec)
7:09:50 Spacecraft separates from 4th stage, GEO
7:10+ Handoff to User

ELVs



http://eprnetworkblog.com/category/aerospace/

http://www.losangeles.af.mil/news/story_media.asp?id=123075662

RLVs

http://www.groomlakes4.blogspot.com/

spaceflightnow.com/news/n0205/01sli/

http://www.aero.org/publications/crosslink/winter2004/08.html

Launching Satellites

- LEO
  - Shuttle, small-to-Large ELVs
- MEO
  - Medium ELVs, shuttle + booster stage
- HEO
  - Medium ELVs, shuttle + booster stage
- GEO
  - Large ELVs, shuttle + booster stage

Reusable Launch Vehicle = RLV

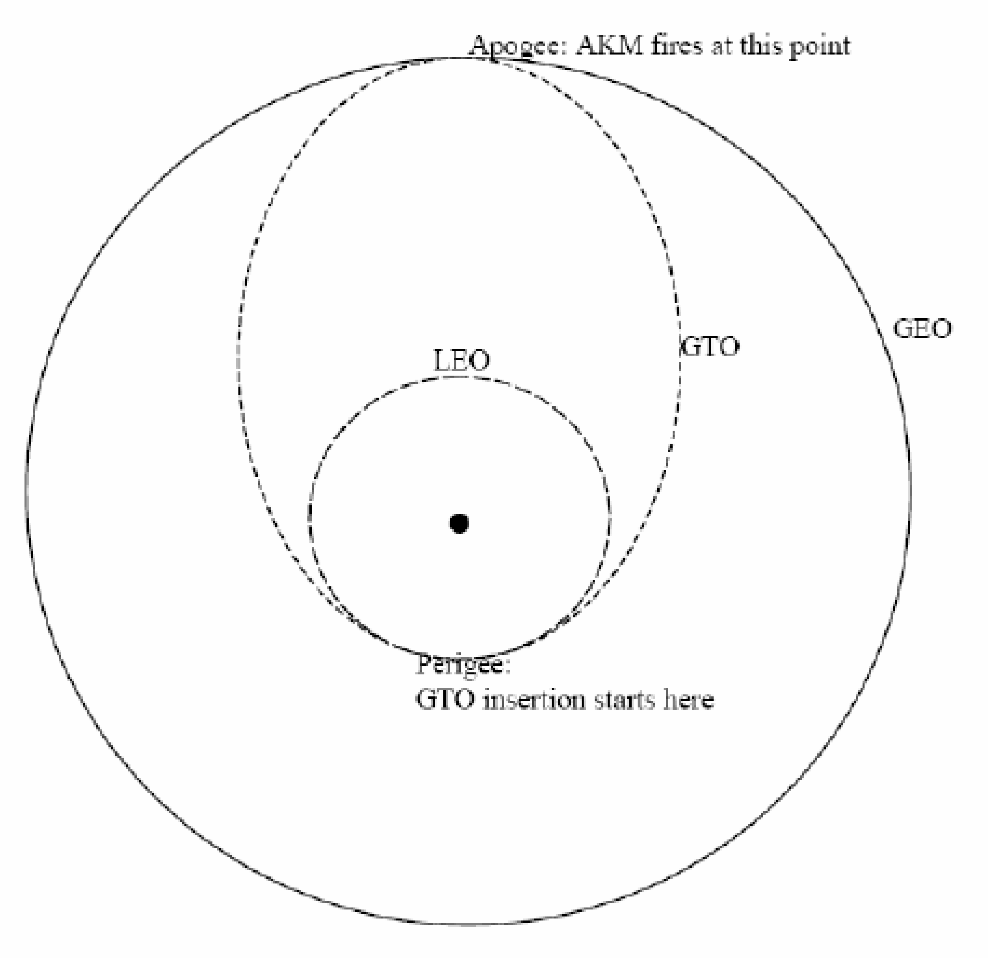
ELV = Expendable Launch Vehicle

Two Launch Approaches for GEO

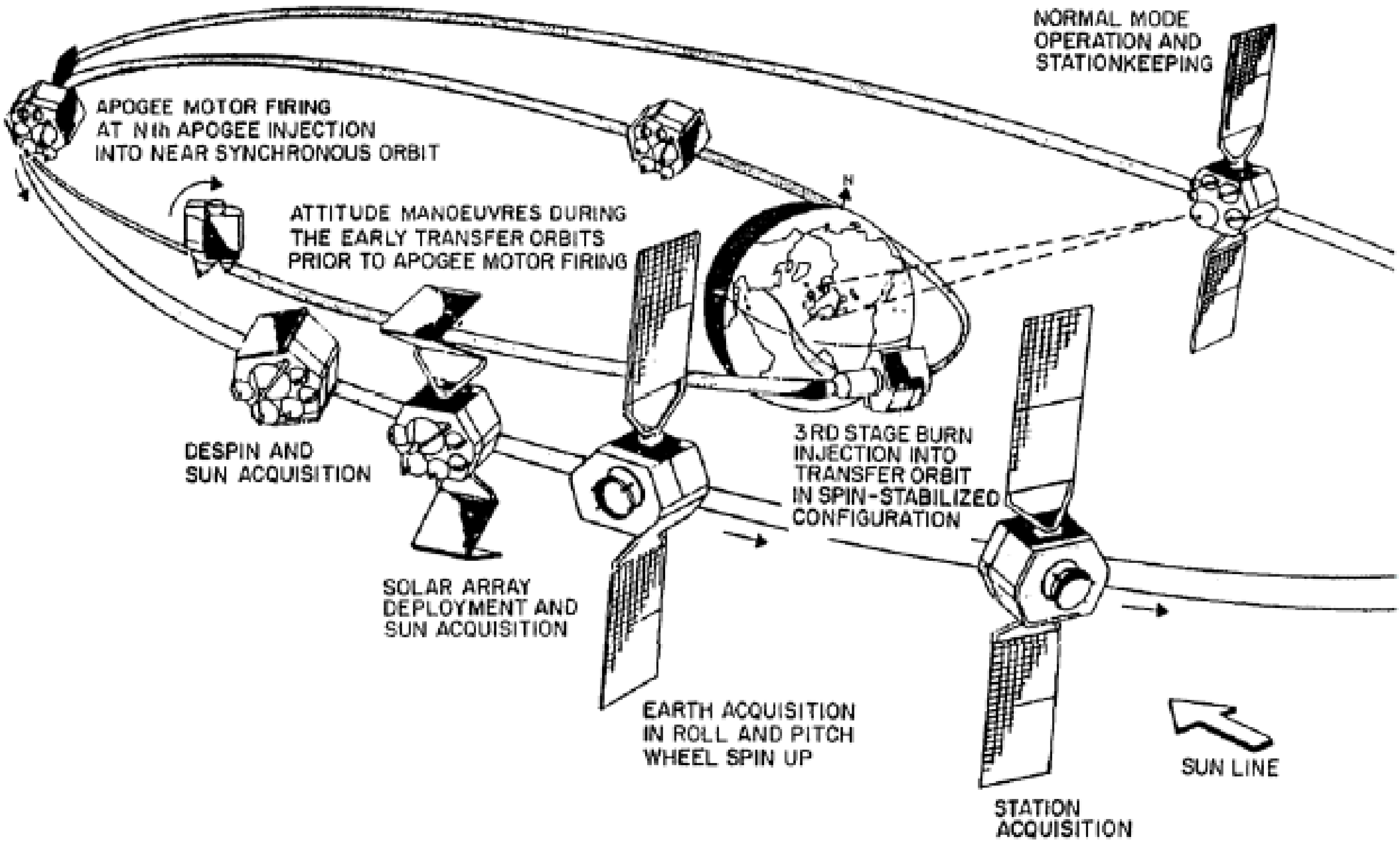
- Transfer Trajectory+onboard velocity augmentation
  - Geostationary Transfer Orbit(GTO) and Apogee Kick Motor
  - Geostationary Transfer Orbit with Slow Orbit Raising
- Direct Insertion

Placing Sat in GEO→GTO and AKM

- Transfer orbit is raised to
  GEO orbit in one rocket firing("burn")
- Use of AKM
- At the Apogee of GTO
  - Fire AKM
  - Velocity increased to 3070m/s
  - Orbit circularized
  - Inclination reduced to 0 deg

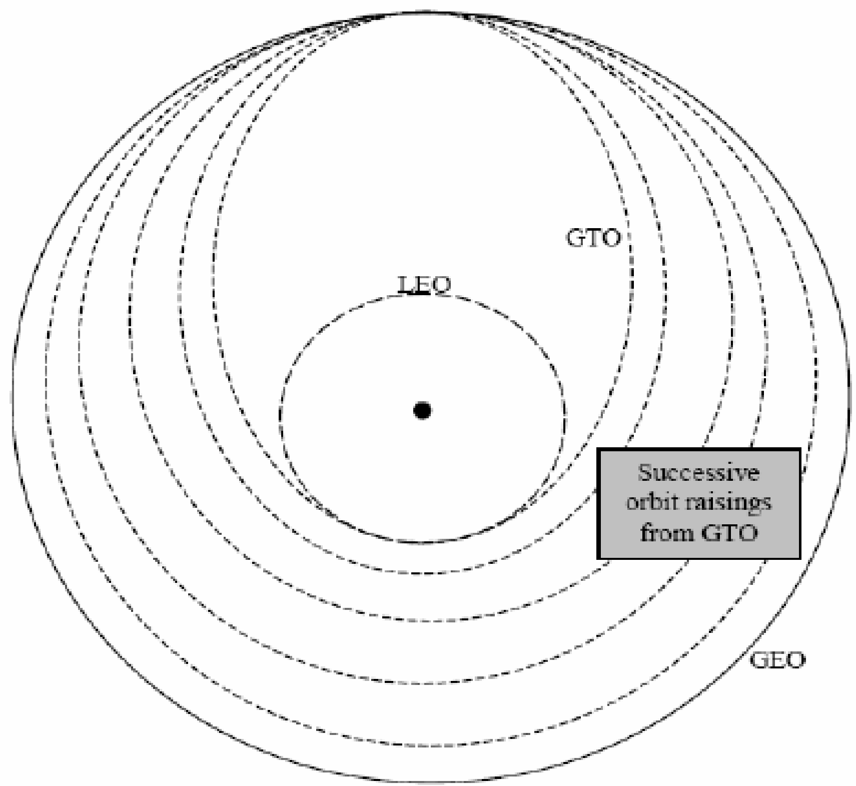


Placing Sat in GEO→GTO and AKM



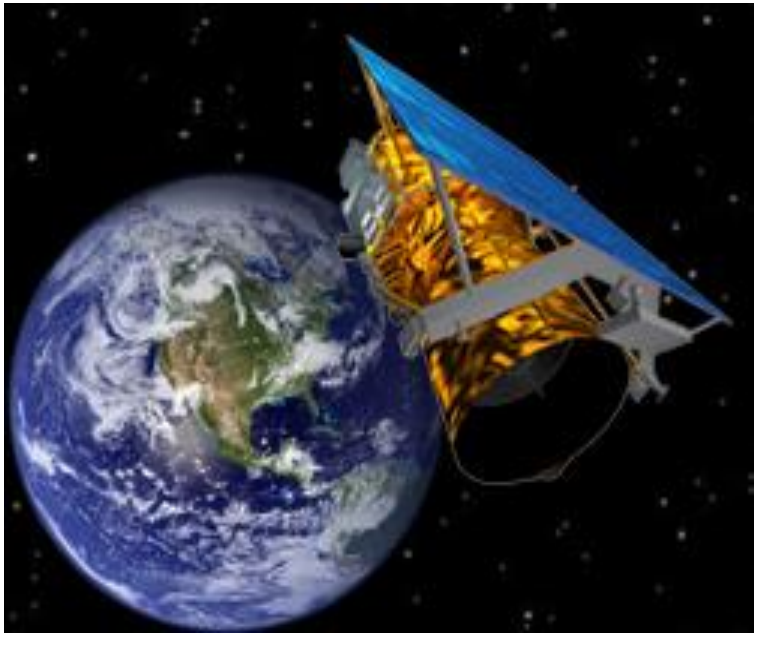
Placing Sat in GEO→GTO with Slow Orbit Raising

- Raise Transfer Orbit to GEO orbit in a number of burns
- Perigee is raised slowly to achieve GEO orbit



Placing Sat in GEO→ Direct Insertion

- Launch vehicle contains all necessary propulsion energy to take satellite into its correct orbit



Typical Falcon 1 flight profile for direct insertion from launch through deployment and recovery of 1st stage

http://www.spacex.com/falcon1.php

Energy Note

- Earth spins towards the east
- At equator, rotational velocity=0.465km/s or 1610km/h
- An easterly launch from equator has a velocity increment of 0.465km/s imparted by the rotation of earth

- A satellite in a circular, equatorial orbit at an altitude of 900km requires orbital velocity of 7.4km/s. A rocket launched from equator need to impart additional (7.4-0.47)km/s=6.93km/s
- Equatorial launch has reduced the energy by about 6%

Orbital Effects in Communication

Doppler Shift

- Movement towards (away) from observer causes increase (decrease) in observed frequency known as *Doppler shift*

- Expressed as

$$\frac{f_R - f_T}{f_T} = \frac{\Delta f}{f_T} = \frac{V_T}{v_p}$$

V_T = radial velocity to observer

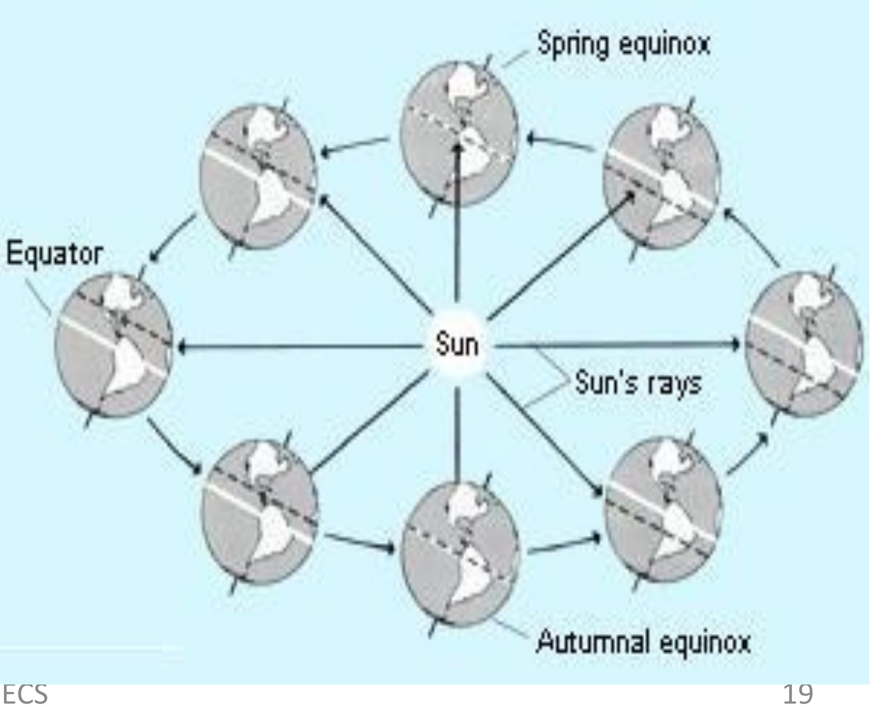
v_p = velocity of light

Range Variations

- Even with best station-keeping tolerances position of satellite with respect to earth exhibits a daily variation
- Leads to variation in range between satellite and user terminals
- Essential to know range for TDMA access
  - User frames MUST arrive at correct instant
  - Increased guard times help in range/timing inaccuracies but reduces transponder capacity

Solar Eclipse

- Earth gets between Sun and Satellite
- Occurs close to equinoxes, as these are the times when the sun, earth and satellite are in same plane
- Major source of power is solar panels
  - Eclipse operation must be on batteries



Sun Transit Outage

- Satellite solar outages occur because the Sun which is a powerful broadband microwave noise source passes directly behind the satellite (when viewed from Earth) and the receiver with the beam directed towards the satellite picks up both the satellite signal and the noise from the Sun.
- The degree of interference caused by a satellite solar outage varies from slight signal degradation to complete loss of signal as the downlink is swamped by the noise from the Sun.

Sun outage message on cable television, seen in Singapore, September 23, 2006

http://en.wikipedia.org/wiki/Sun_outage

Equipment Reliability and Space Qualification

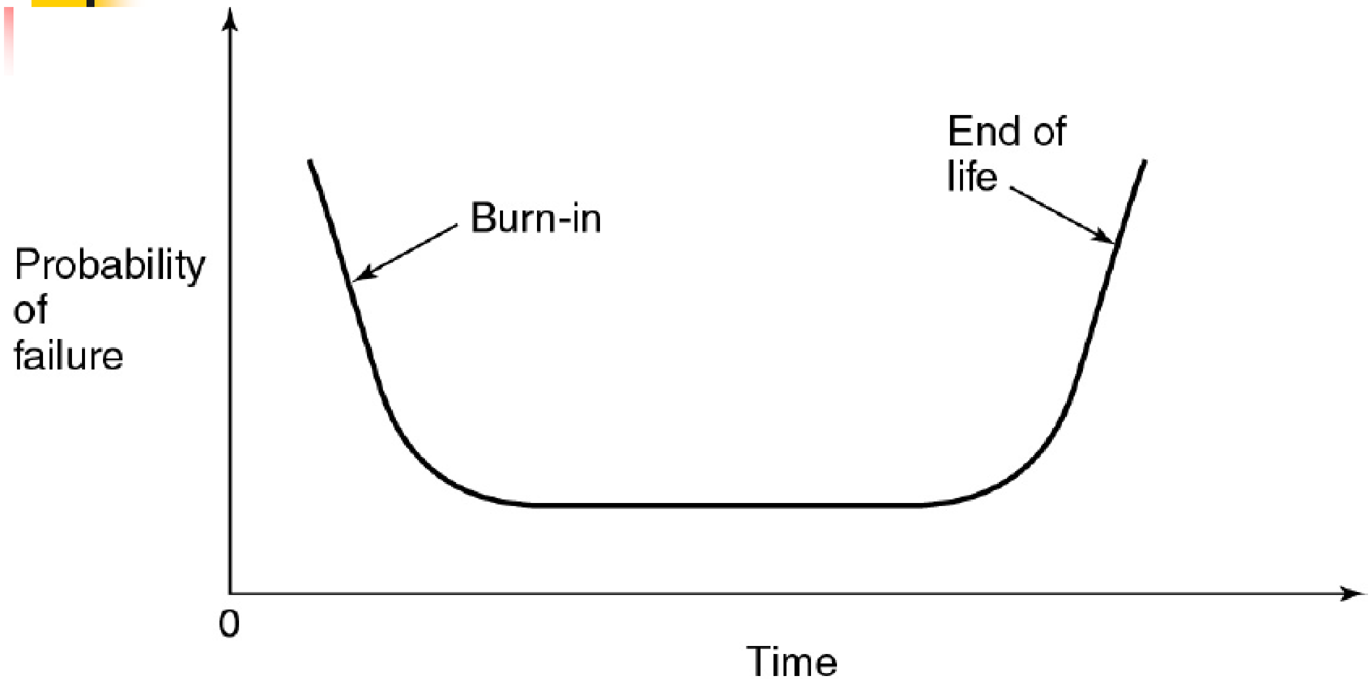
- When in orbit, there is little possibility of repairing components that fails
- This calls for:
  - Highly reliable components
  - Strategy to allow vulnerable ones to fail without communication outage
- Two Approaches
  - Space Qualification
  - Redundancy

Space Qualification

- Mechanical Model
- Thermal Model
  - Shake and Bake Test in thermal vacuum chamber
- Electrical Model

Reliability Curve

Figure 3.20 (p. 89)
Bathtub curve for probability of failure.



Redundancy

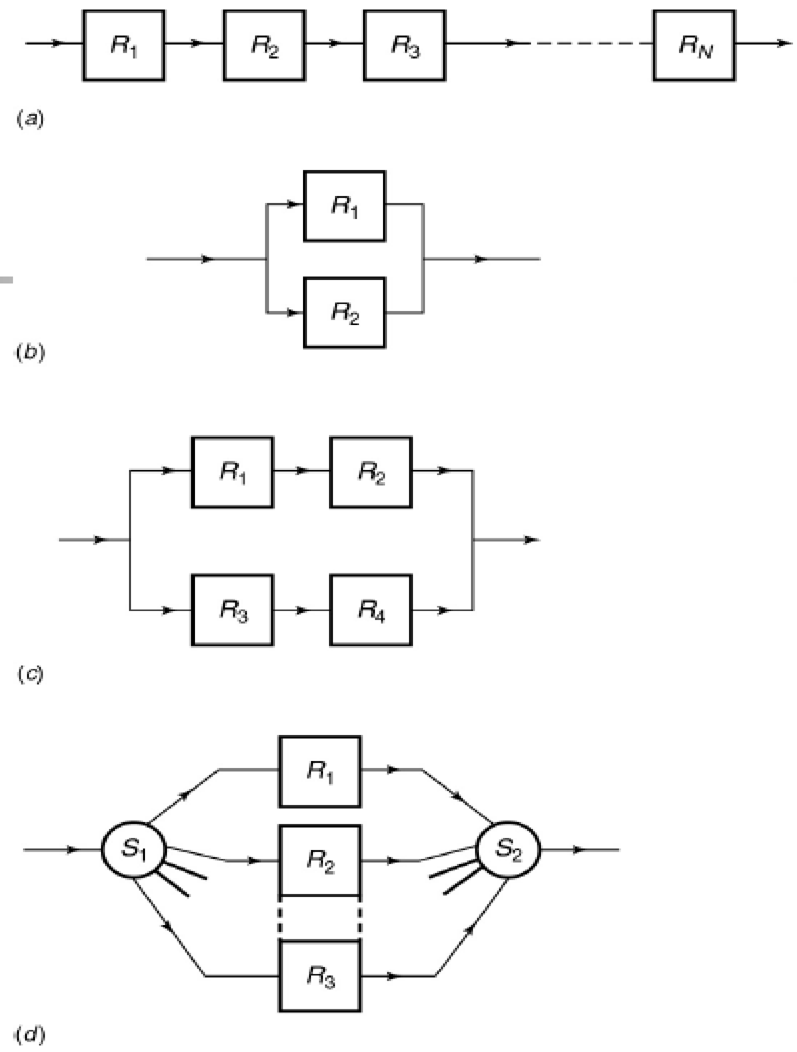
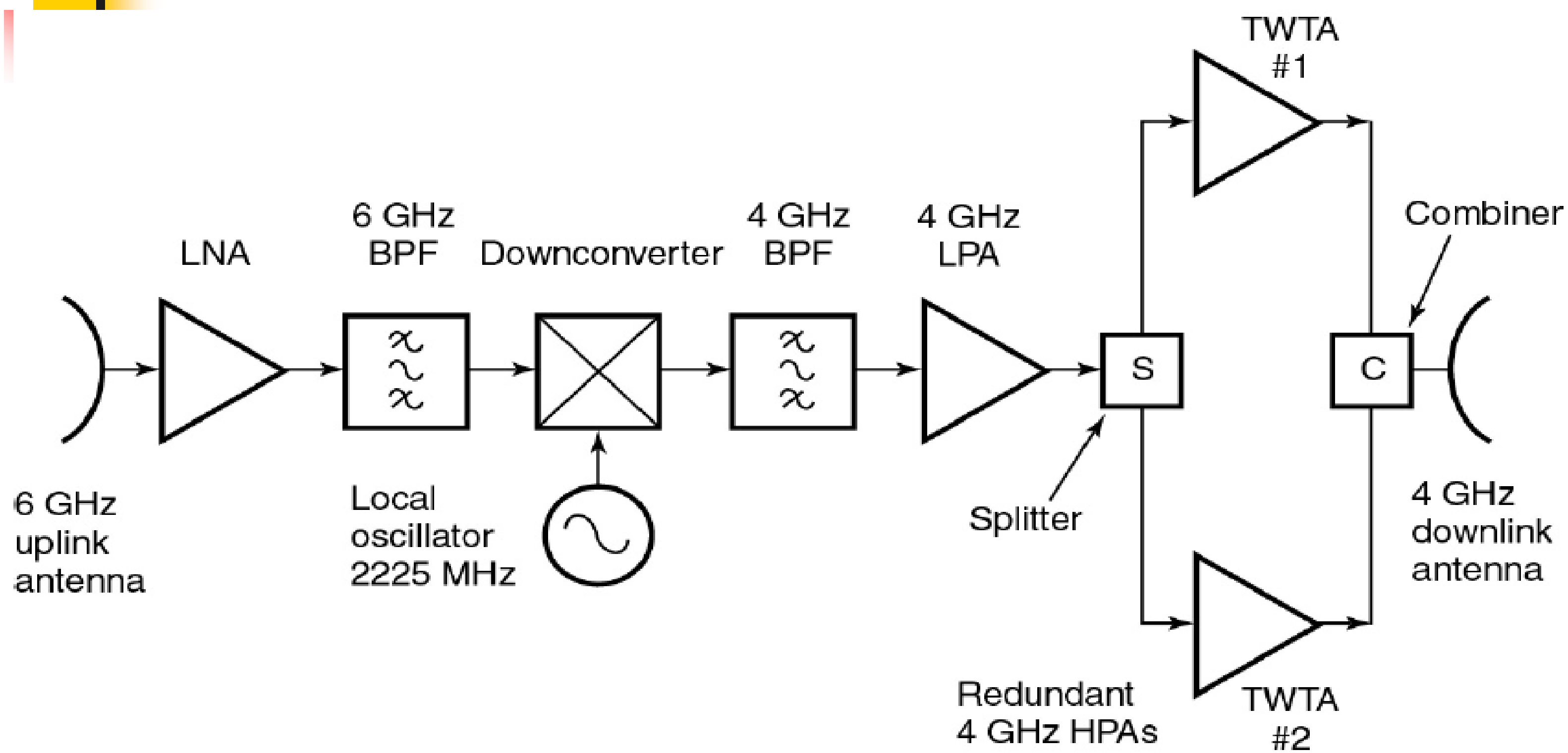


Figure 3.21 (p. 91)
Redundancy connections. (*a*) Series connection. (*b*) Parallel connection. (*c*) Series/parallel connection. (*d*) Switched connection.

Figure 3.22 (p. 92)
Redundant W/TA configuration in HPA of a 6/4 GHz bent pipe transponder.



Why is Uplink Frequency greater than Downlink Frequency?

- To avoid interference between the uplink and downlink. There is always the intra-system interference issue, which is the interference caused in your signals by other signals transmitted by your own system.The high power transmit signal would overload the receiver if both operated at the same frequency. In this case, to avoid interference from Uplink to Downlink and vice versa, a frequency channel is assigned to uplink's transmissions and another to downlink's. And so one of them is higher in frequency than the other
- Higher frequency have a greater path loss and require greater transmitter power. This is easily provided by the main-powered earth station whereas the satellite transmitters are reliant on limited battery and solar energy resources so use the low frequency

Why is Uplink Frequency greater than Downlink Frequency?

- In a nutshell:

  a) one reason is interference, to avoid colliding as two cars might do if they travel in opposite sense on a highway

  b) Another is related to propagation of the signals, and to help the site which is more complicated to design and has more compromises of power/transmission power/heat etc (the satellite)

Announcements

- There will be an ACS class on 3rd Jan, Saturday at 1:20 pm
- Assignment Number 2 is being given out/uploaded today

  Due date is 9th Jan at 3:20pm.