Cellular Telephone And Satellite Networks

17.1 Cellular Telephony

Frequency Reuse Principle

Transmitting

Receiving

Handoff

Roaming

First Generation

Second Generation

Third Generation

Figure 17.1 Cellular system

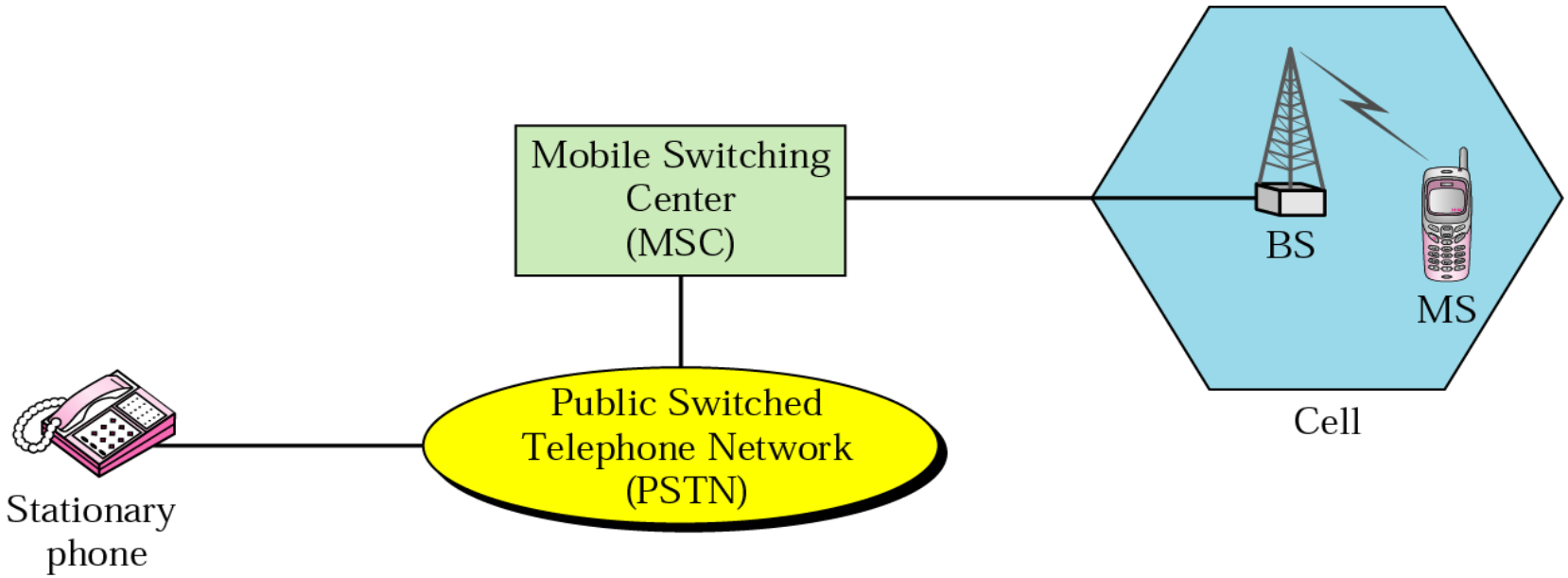
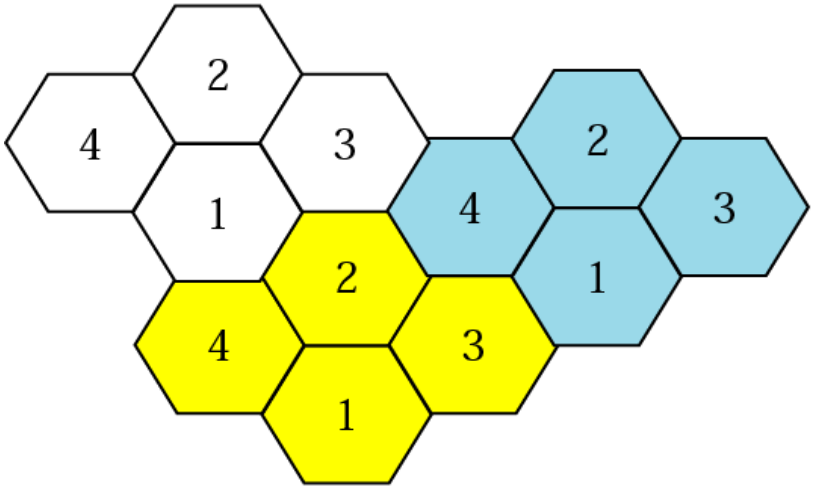
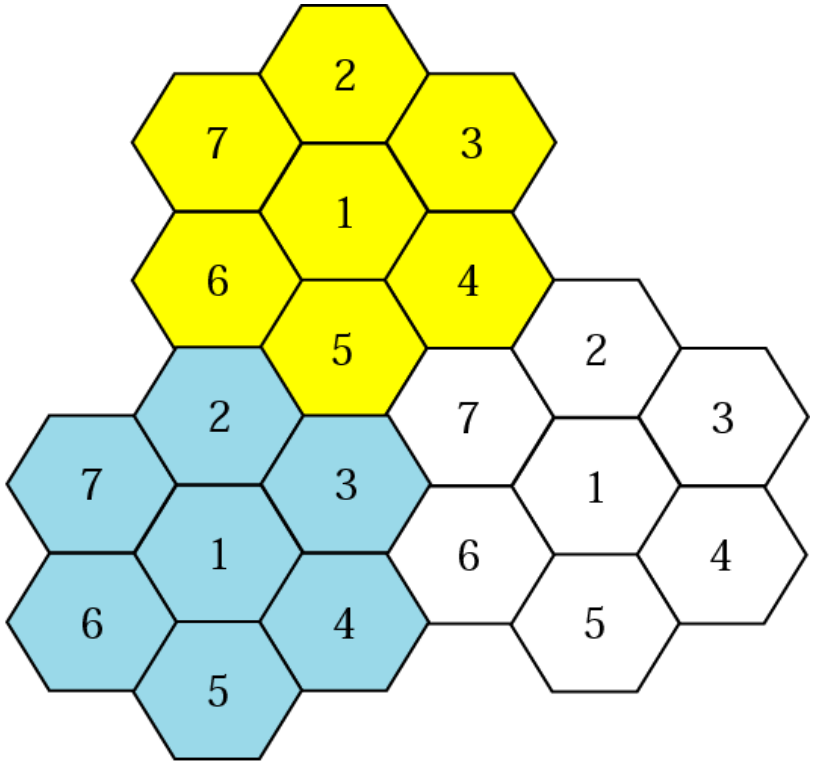


Figure 17.2 Frequency reuse patterns

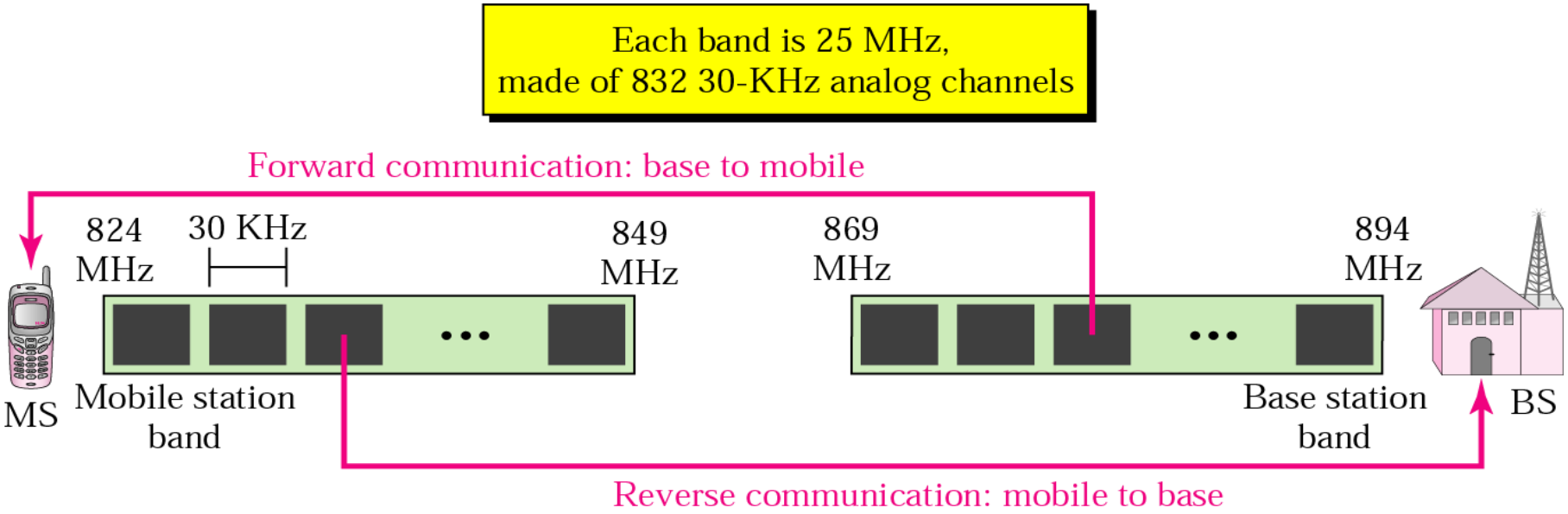


a. Reuse factor of 4



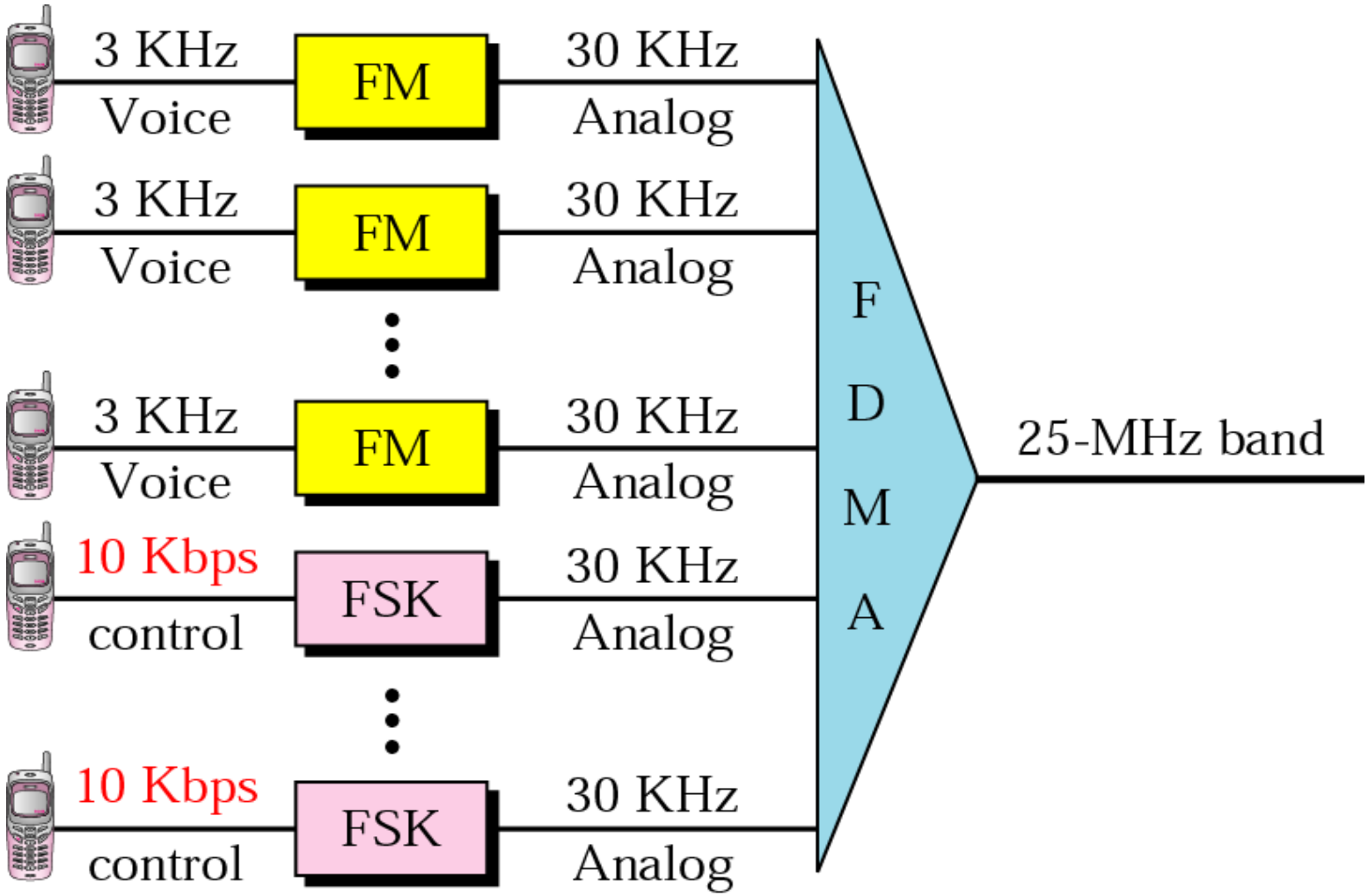
b. Reuse factor of 7

AMPS is an analog cellular phone system using FDMA.

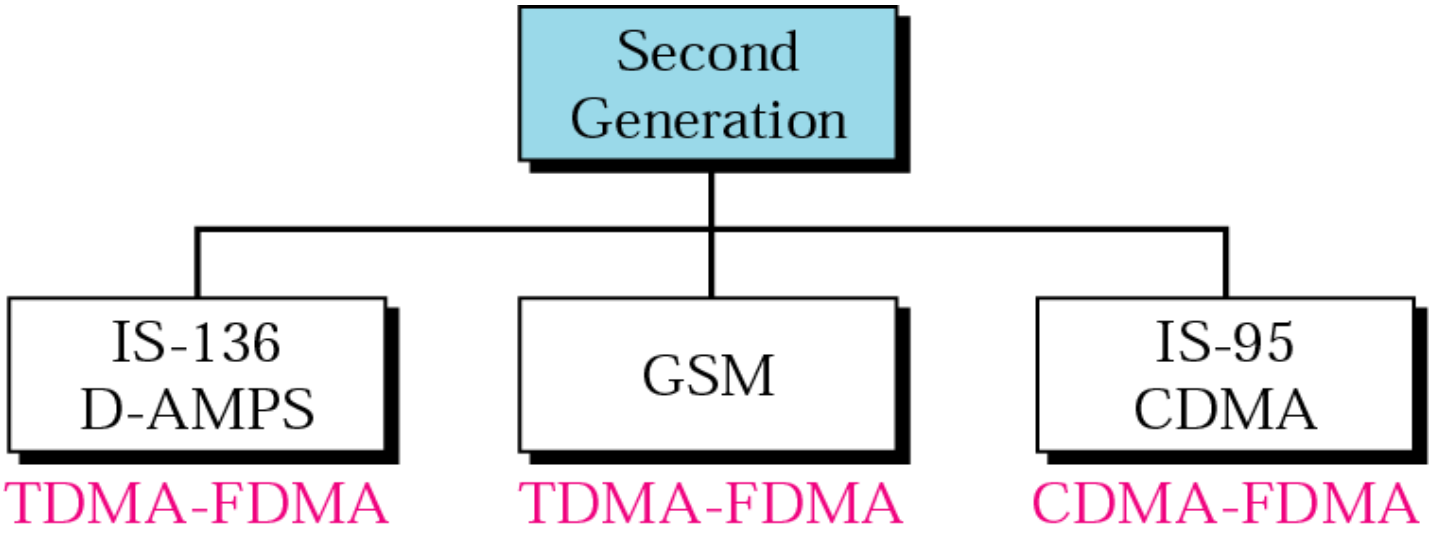


Advanced Mobile Phone System (AMPS) was an analog mobile phone system standard developed by Bell Labs
Was used until in 2010 in some countries

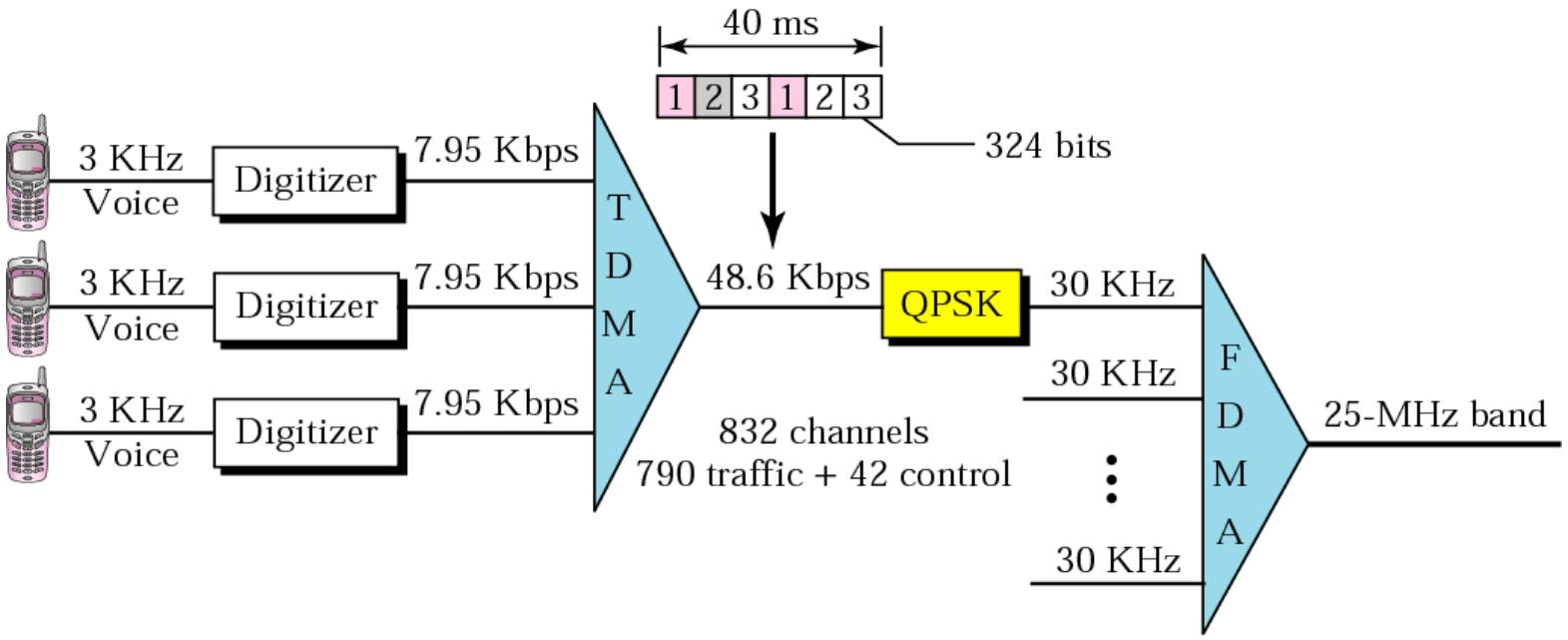
AMPS reverse communication band



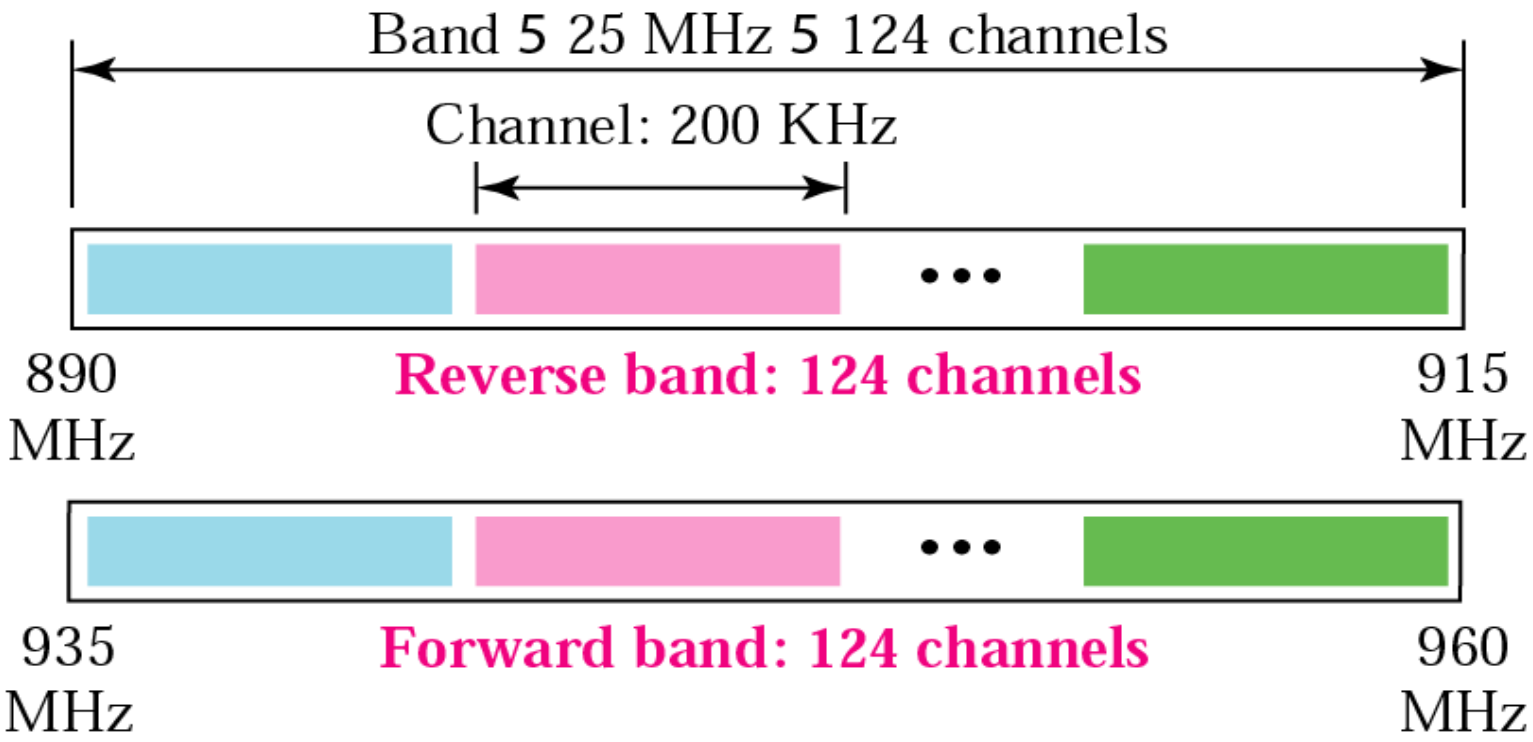
Second-generation cellular phone systems



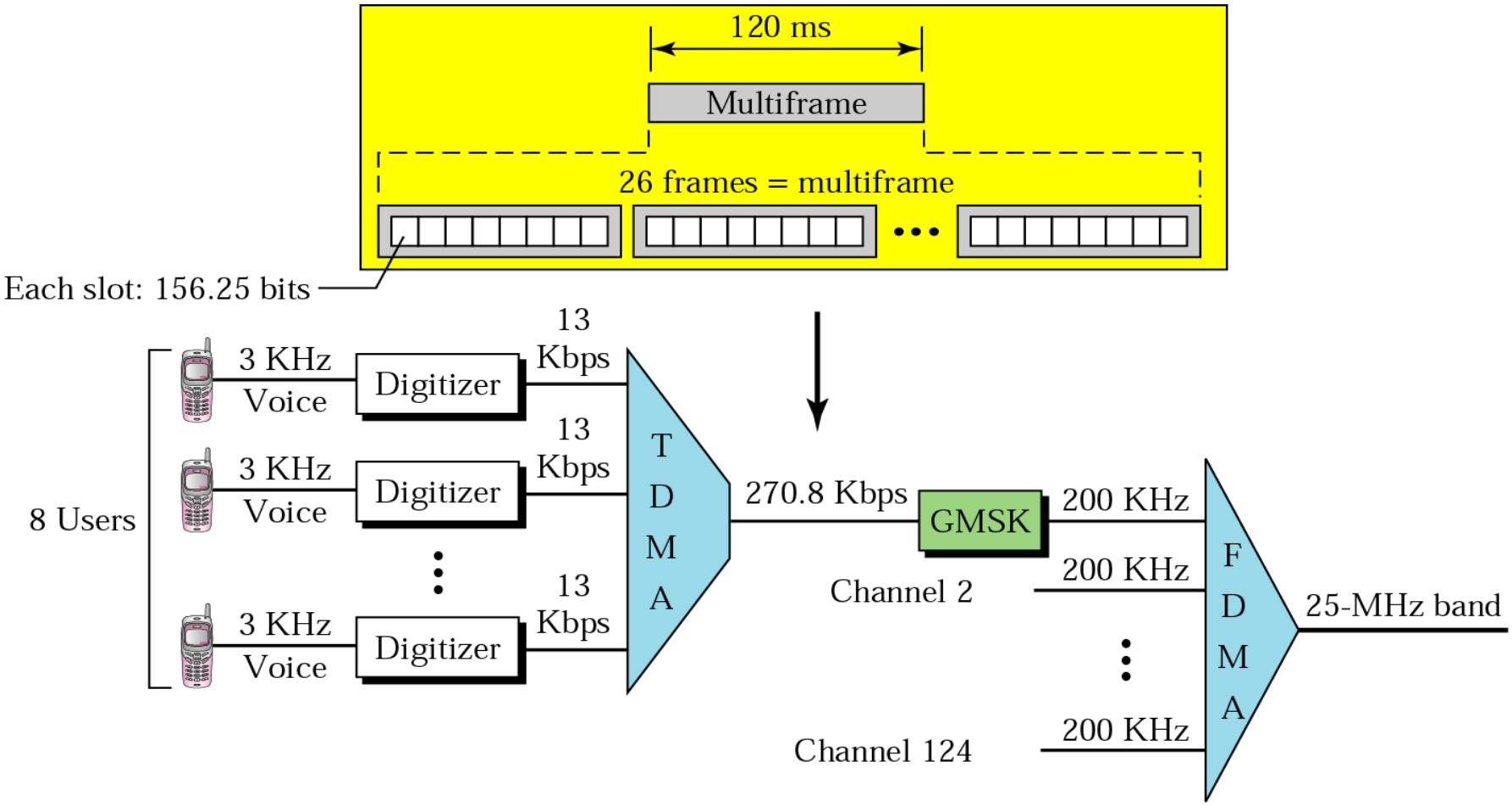
D-AMPS, or IS-136, is a digital cellular phone system using TDMA and FDMA.



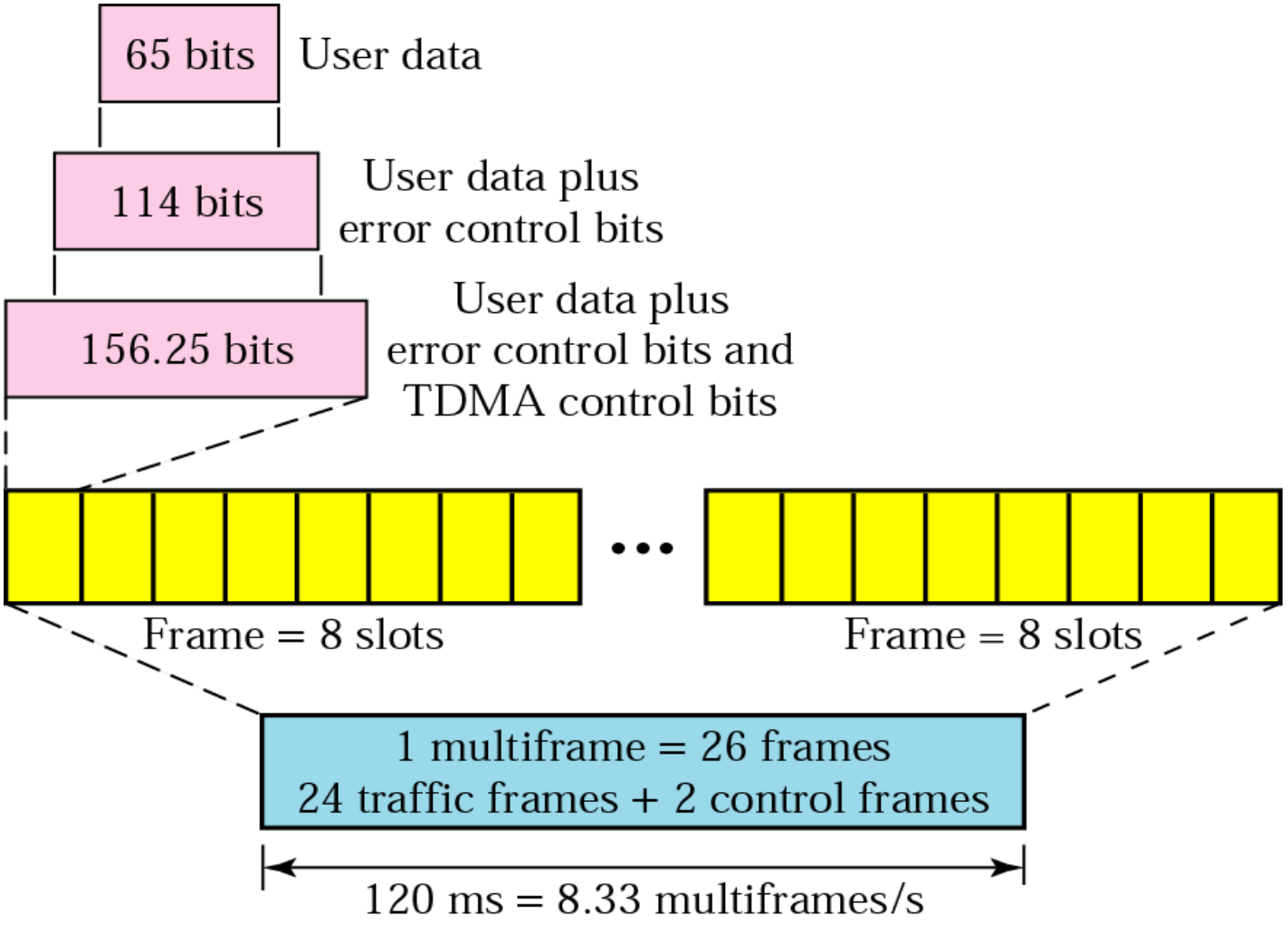
GSM bands


Band 5 25 MHz 5 124 channels
Channel: 200 KHz
890 MHz
Reverse band: 124 channels
915 MHz
935 MHz
Forward band: 124 channels
960 MHz

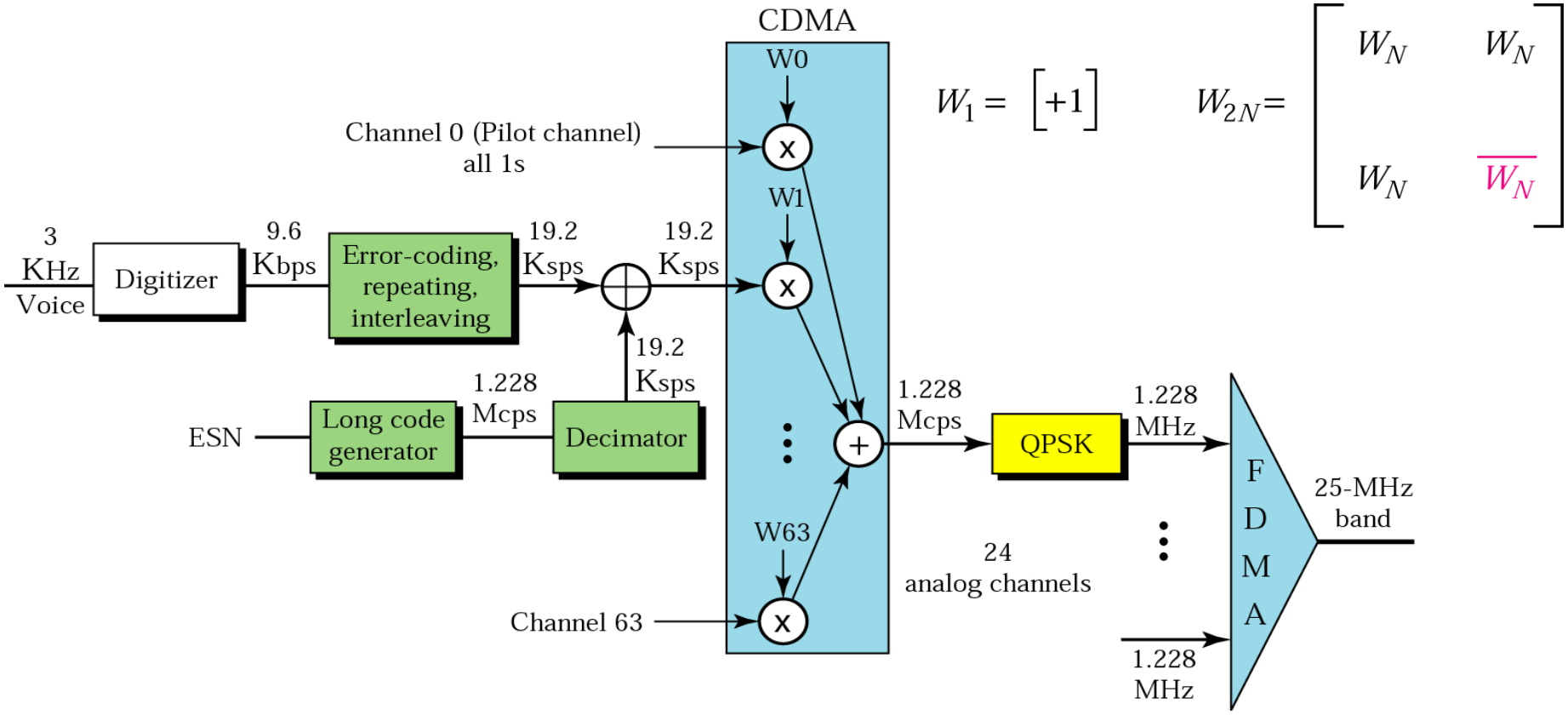
GSM is a digital cellular phone system using TDMA and FDMA.



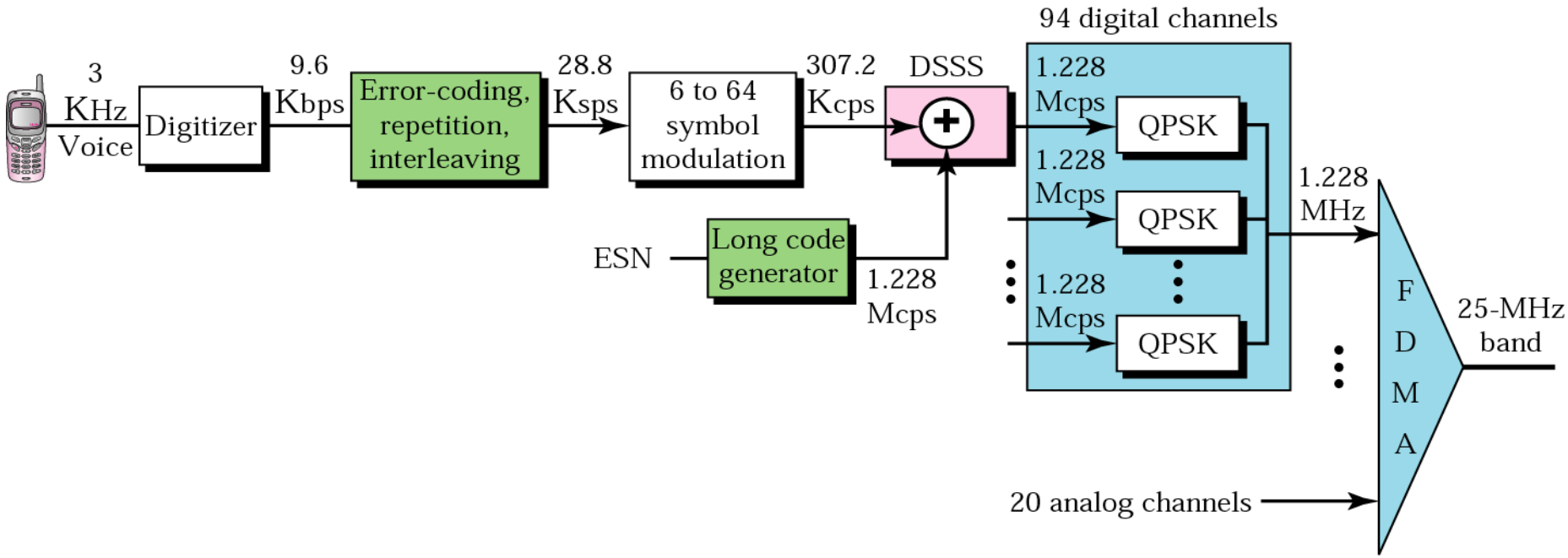
Multiframe components



IS-95 is a digital cellular phone system using CDMA/DSSS and FDMA.

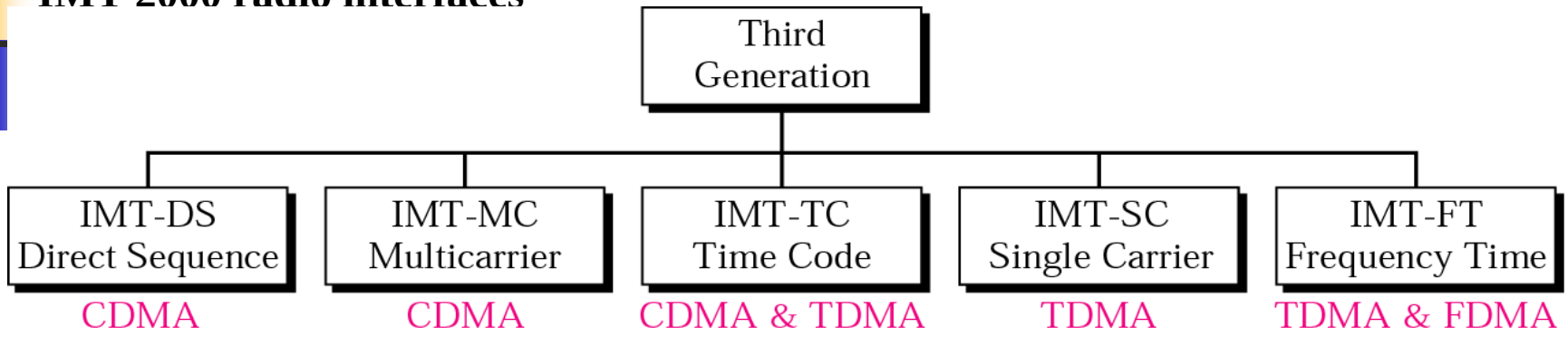


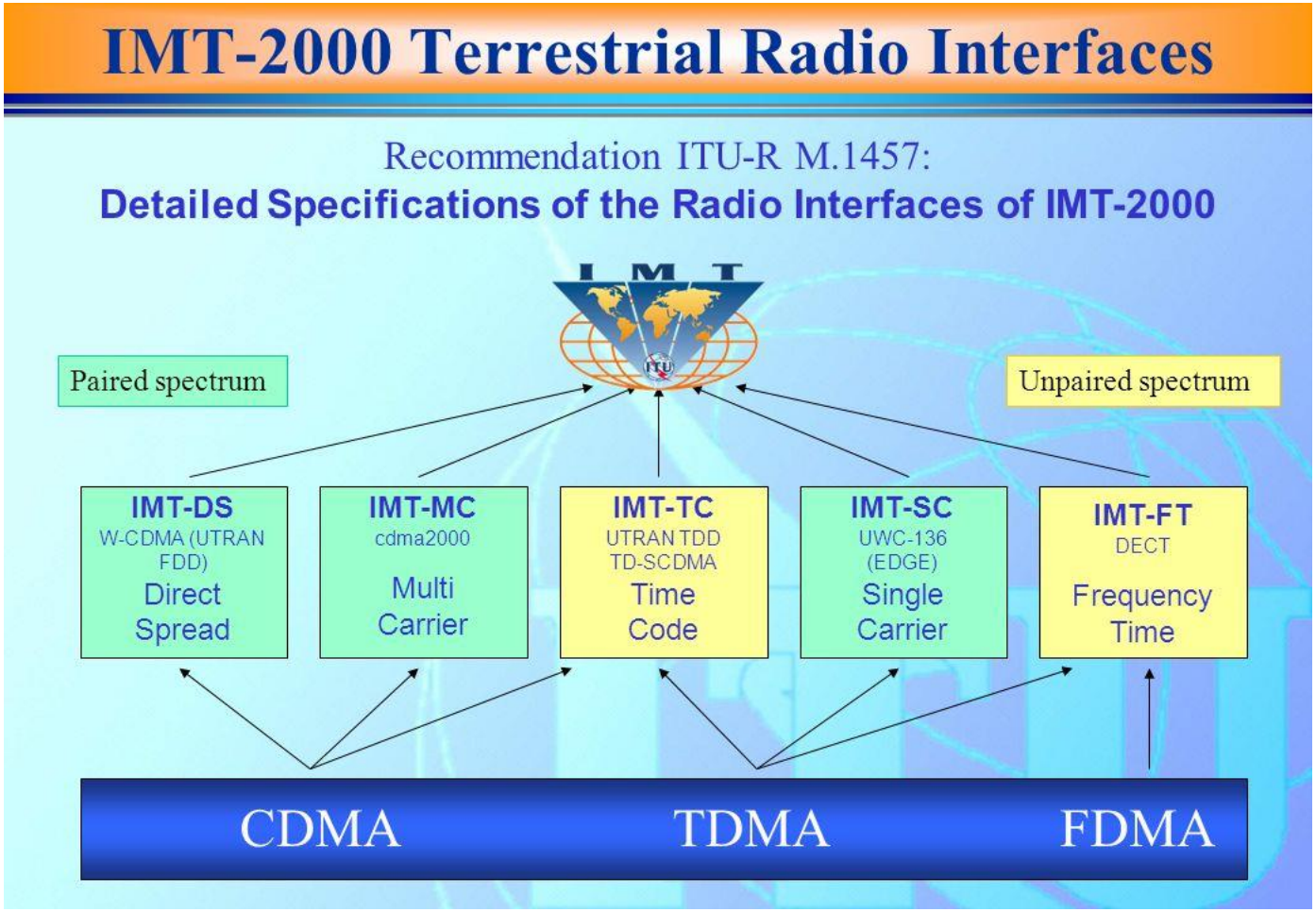
IS-95 reverse transmission



The main goal of third-generation cellular telephony is to provide universal personal communication.

IMT-2000 radio interfaces





Satellite Networks

Orbits

Three/Four Categories of Satellites

GEO Satellites

MEO Satellites

LEO Satellites

HEO Satellites

1. **Weather Forecasting**

Satellites can be used to take pictures of the earth using the satellite we can predict the rainfall, temperature etc during the next 24 hrs.

2. **Radio and TV broadcasting**

Several TV and radio channels use satellite for broadcasting their environment programs.

3. **Military Purposes**

Military personnel can communicate in a more secured manner by making use of separate satellite for communication.

4. **Navigation**

To determine the exact location of ships, aircrafts, etc a special service called GPS (Global Positioning System) can be used with the help of a satellite.

5. **Global Telephone Backbones**

Satellite can also be used for telephone conversation such satellite are called as geo-stationary satellite.

6. **Connections to Global Network**

Few countries cannot afford to have fixed wired networks so as to connect to interact. In such countries, satellites are used.

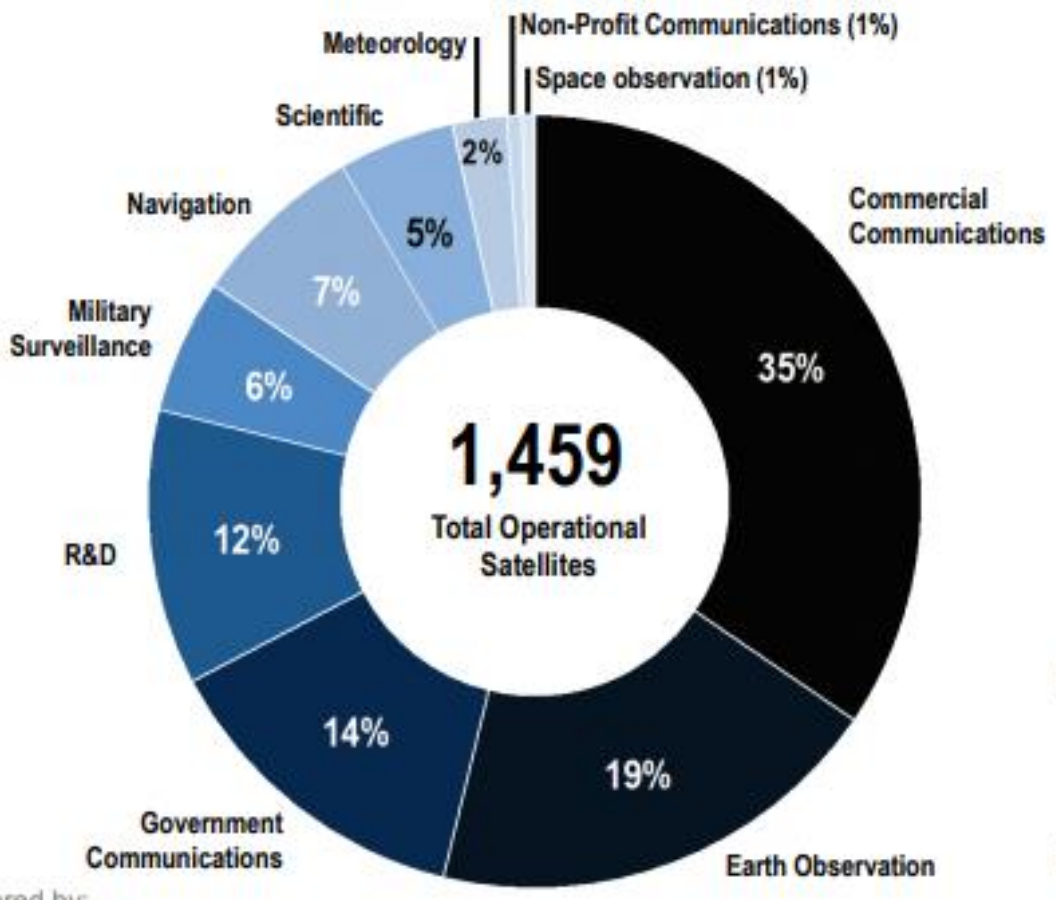
7. **Global Mobile Communication**

So as to extend the area of coverage, we can use satellites that are placed at lower orbits. These orbits can be used for global mobile communication.

The Satellite Network in Context

Operational Satellites by Function

(as of December 31, 2016)



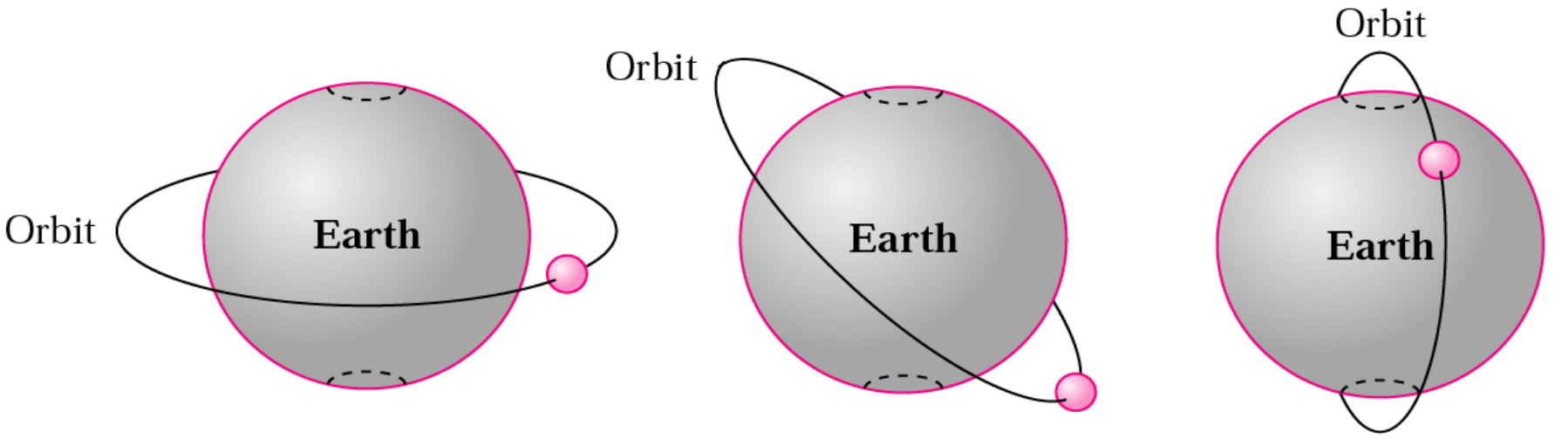
- Number of satellites increased 47% over 5 years (from 994 in 2012)
  - » Satellites launched 2012 — 2016 increased 53% over previous 5 years
    - » Average 144/year
    - » Due mostly to small/very small satellites in LEO (<1200 kg)
  - » Average operational lives of larger (mostly communications) satellites becoming longer, exceeding 15 years; 247 active sats launched before 2002
  - » 520 satellites in GEO (mostly communications)
- 59 countries with operators of at least one satellite (some in regional consortia)
- U.S. entities operate 594 satellites

Prepared by:

BRYCE

Formerly Tauri Group Space and Technology

Satellite orbits



a. Equatorial-orbit satellite b. Inclined-orbit satellite c. Polar-orbit satellite

Example 1

What is the period of the moon according to Kepler's law?

$$Period = (1/100)^{*} (Distance\_to\_Earth + Earth\_Radius)^{1.5}$$

Solution

The moon is located approximately 384,000 km above the earth. The radius of the earth is 6378 km. Applying the formula, we get

$$Period = (1/100)\ (384{,}000 + 6378)^{1.5} = 2{,}439{,}090\ s$$

$$= 1\ month$$

Example 2

According to Kepler's law, what is the period of a satellite that is located at an orbit approximately 35,786 km above the earth?

Solution

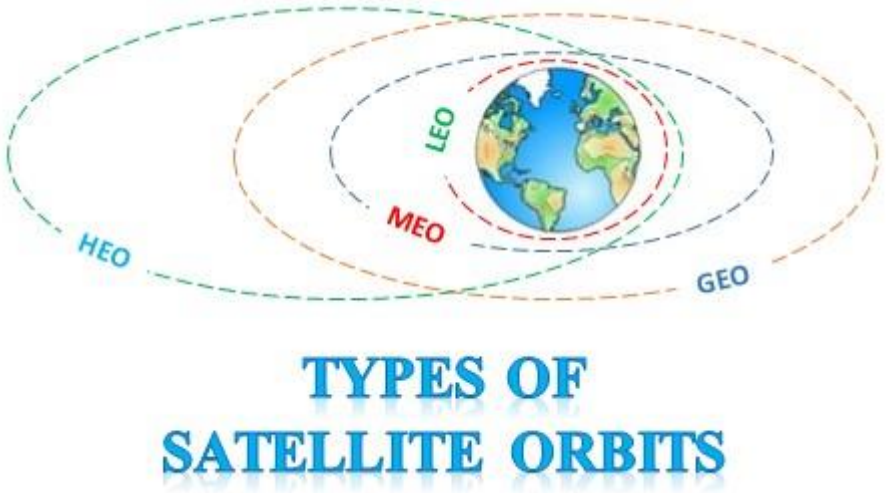
Applying the formula, we get

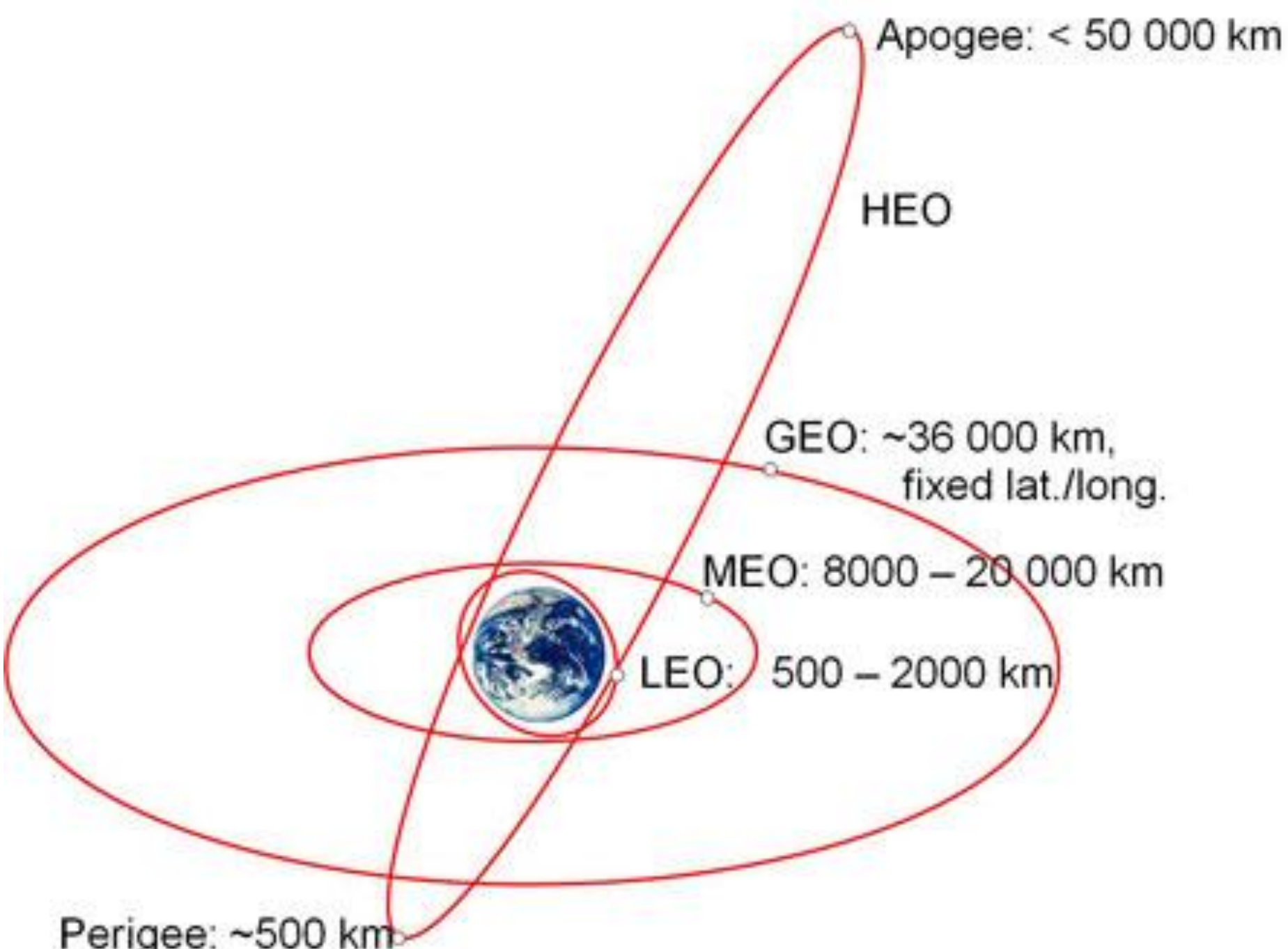
$$\textit{Period} = (1/100)\,(35{,}786 + 6378)^{1.5} = 86{,}579\ s = 24\ h$$

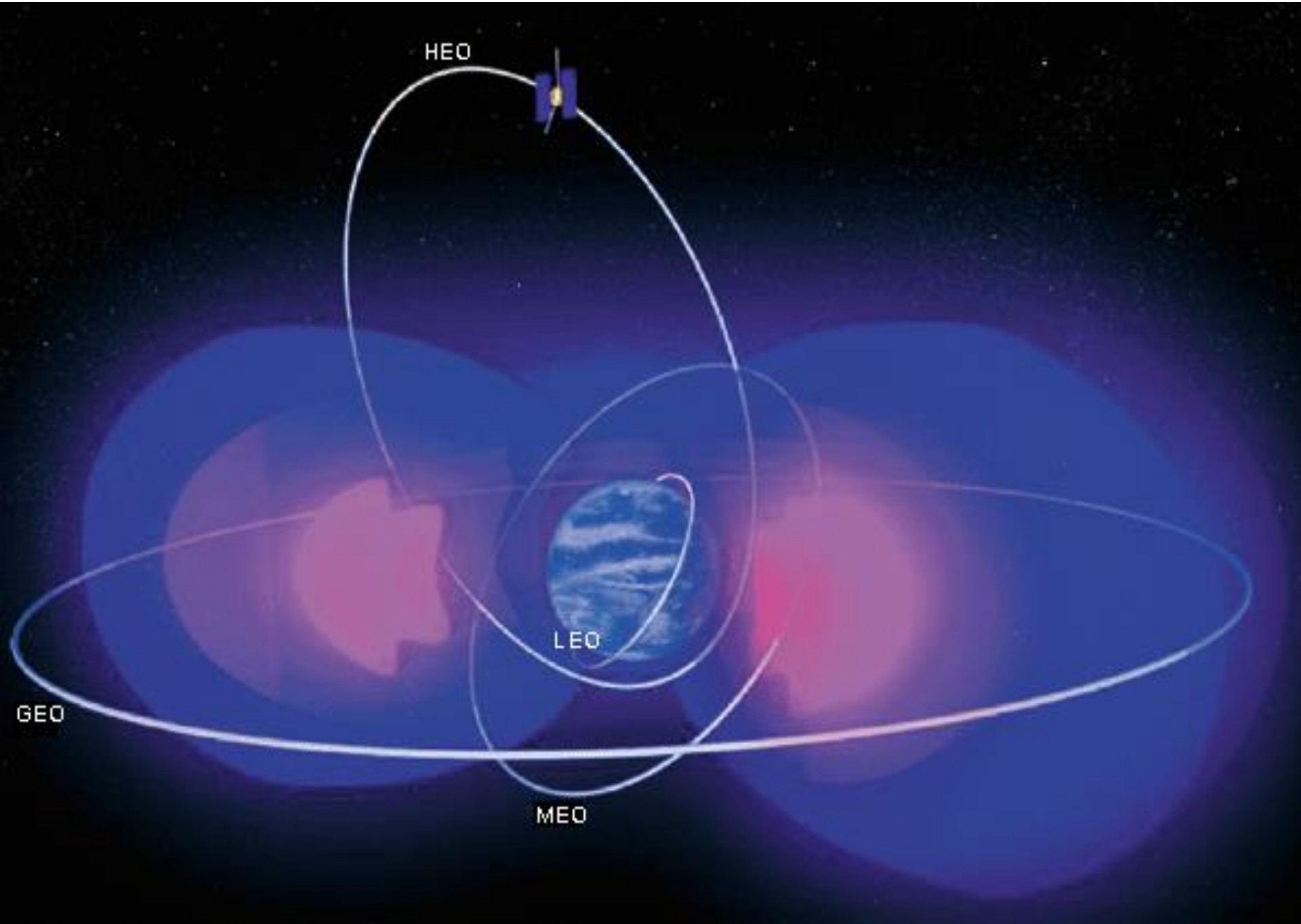
A satellite like this is said to be stationary to the earth. The orbit, as we will see, is called a geosynchronous orbit.

There are 4 types of orbits, they are:

1. GEO (Geo-stationary earth orbit)
2. MEO (medium earth orbit)
3. LEO (Low earth orbit) and
4. HEO (Highly elliptical orbit)




Apogee: < 50 000 km
HEO
GEO: ~36 000 km,
fixed lat./long.
MEO: 8000 – 20 000 km
LEO: 500 – 2000 km
Perigee: ~500 km


HEO
LEO
GEO
MEO

Geo-Stationary Earth Orbit

These satellites have almost a distance of 36,000 km to the earth.

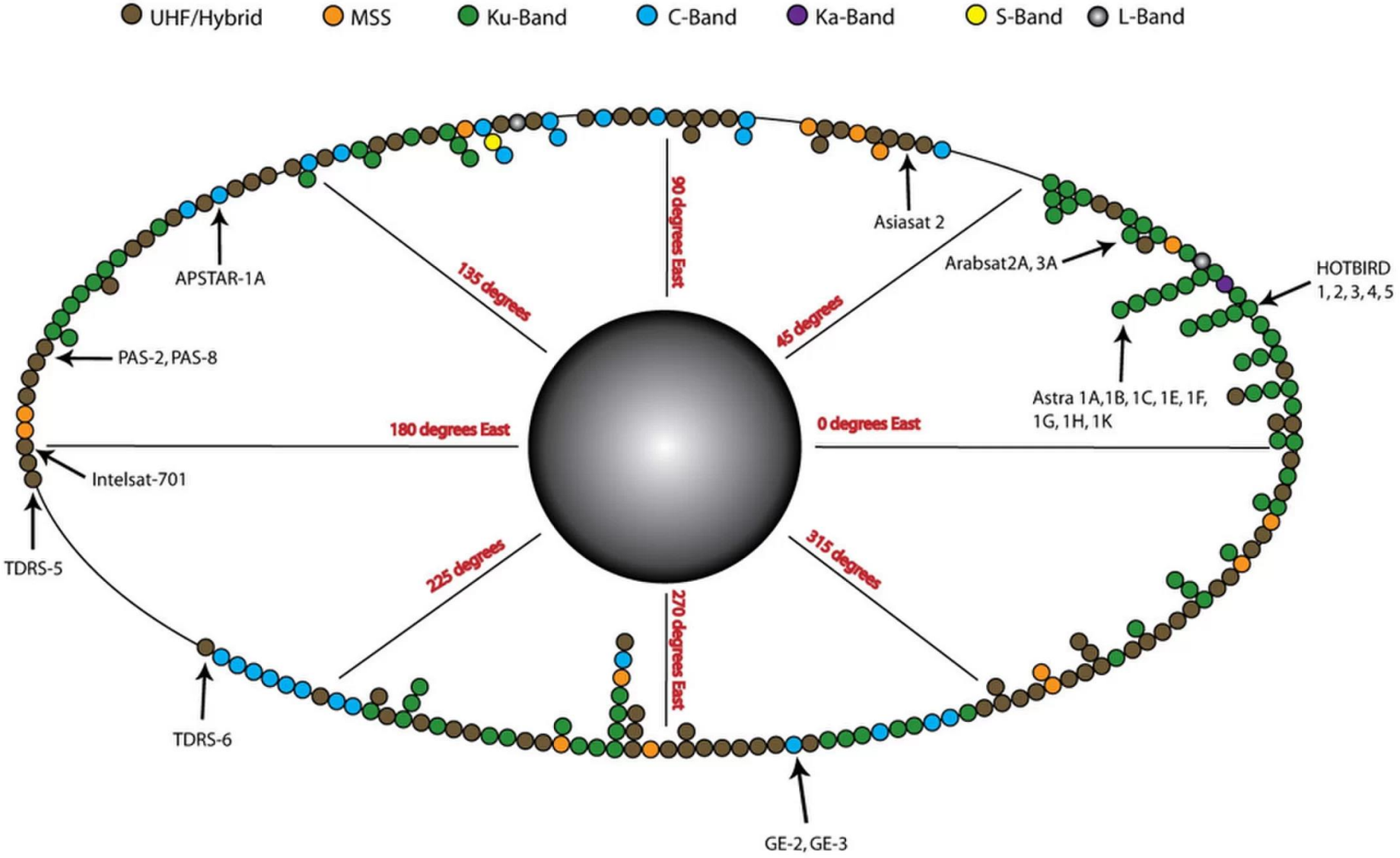
All radio and TV, whether satellite etc, are launched in this orbit.

Advantages of Geo-Stationary Earth Orbit

1. It is possible to cover almost all parts of the earth with just 3 geo satellites.
2. Antennas can be fixed permanently.
3. The life-time of a GEO satellite is quite high usually around 15 years.

Disadvantages of Geo-Stationary Earth Orbit

1. Larger antennas are required for northern/southern regions of the earth.
2. High buildings in a city limit the transmission quality.
3. High transmission power is required.
4. These satellites cannot be used for small mobile phones.
5. Fixing a satellite at Geo stationary orbit is very expensive.


UHF/Hybrid
MSS
Ku-Band
C-Band
Ka-Band
S-Band
L-Band
APSTAR-1A
135 degrees
90 degrees East
Asiasat 2
Arabsat2A, 3A
45 degrees
HOTBIRD
1, 2, 3, 4, 5
PAS-2, PAS-8
Astra 1A,1B, 1C, 1E, 1F,
1G, 1H, 1K
180 degrees East
0 degrees East
Intelsat-701
TDRS-5
225 degrees
315 degrees
270 degrees East
TDRS-6
GE-2, GE-3

Medium Earth Orbit

Satellite at different orbits operates at different heights. The MEO satellite operates at about 5000 to 12000 km away from the earth's surface.

These orbits have moderate number of satellites.

Advantages of Medium Earth Orbit

1. Compared to LEO system, MEO requires only a dozen satellites.
2. Simple in design.
3. Requires very few handovers.

Disadvantages of Medium Earth Orbit

1. Satellites require higher transmission power.
2. Special antennas are required.

Low Earth Orbit

LEO satellites operate at a distance of about 500-1500 km.

Advantages of Low Earth Orbit

1. The antennas can have low transmission power of about 1 watt.
2. The delay of packets is relatively low.
3. Useful for smaller foot prints.

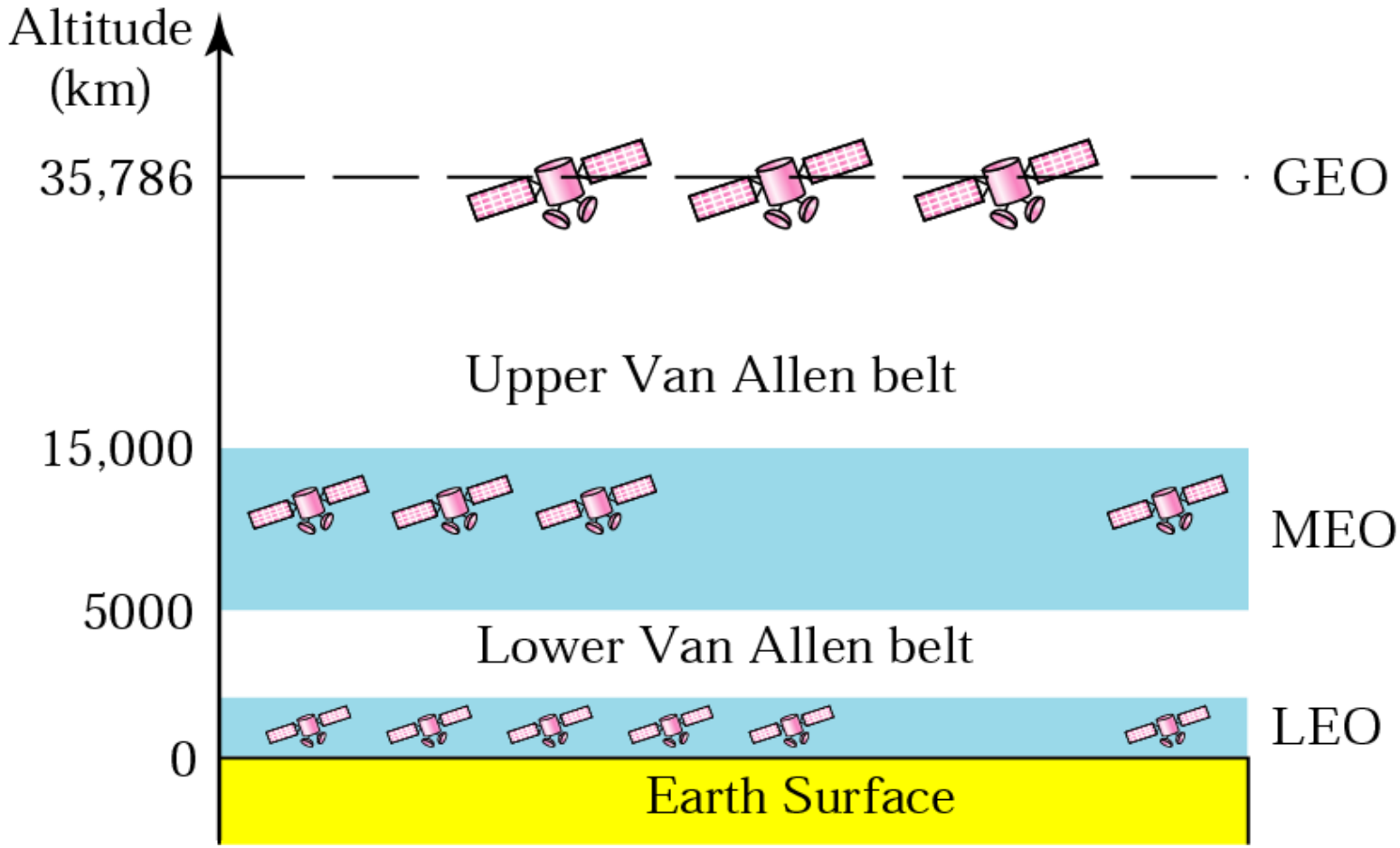
Disadvantages of Low Earth Orbit

1. If global coverage is required, it requires at least 50-200 satellites in this orbit.
2. Special handover mechanisms are required.
3. These satellites involve complex design.
4. Very short life: Time of 5-8 years. Assuming 48 satellites with a life-time of 8 years each, a new satellite is needed every 2 months.
5. Data packets should be routed from satellite to satellite.

Highly Elliptical Orbit

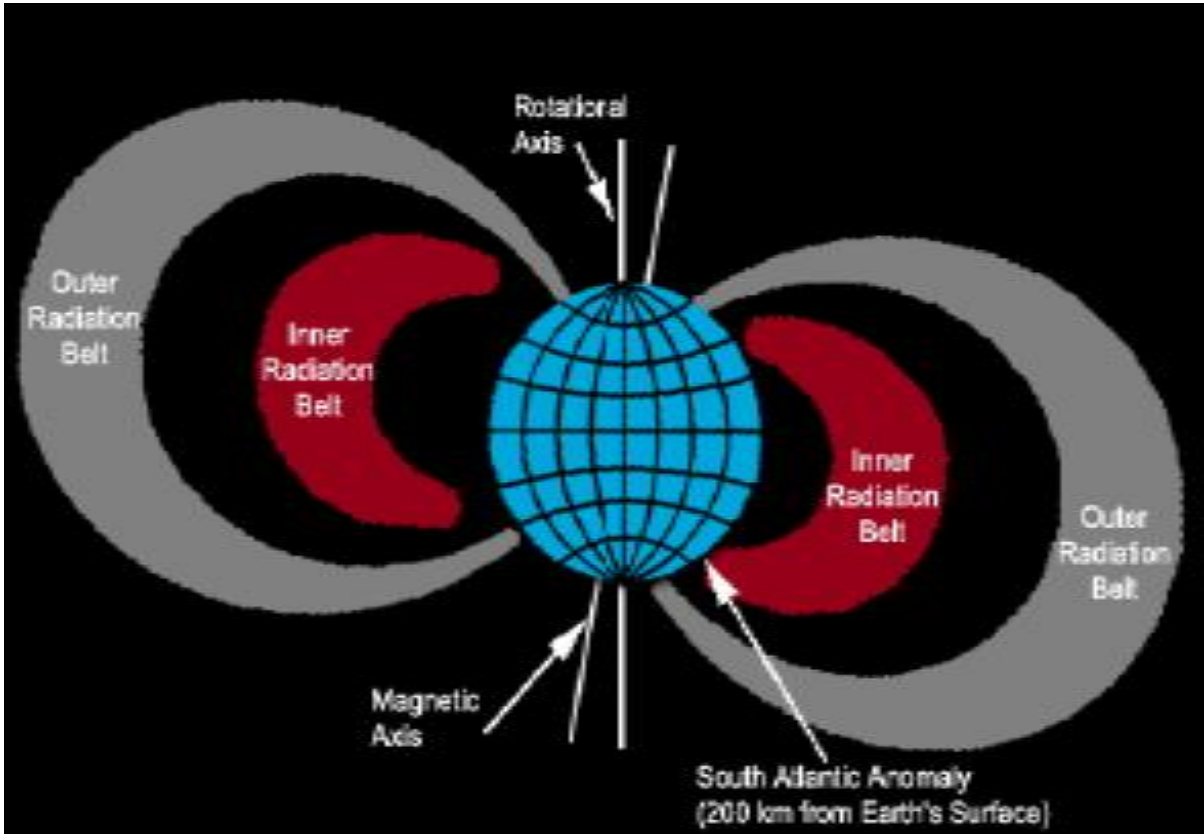
This orbit is made for satellites that do not revolve in circular orbits, only a very few satellites are operating in this orbit

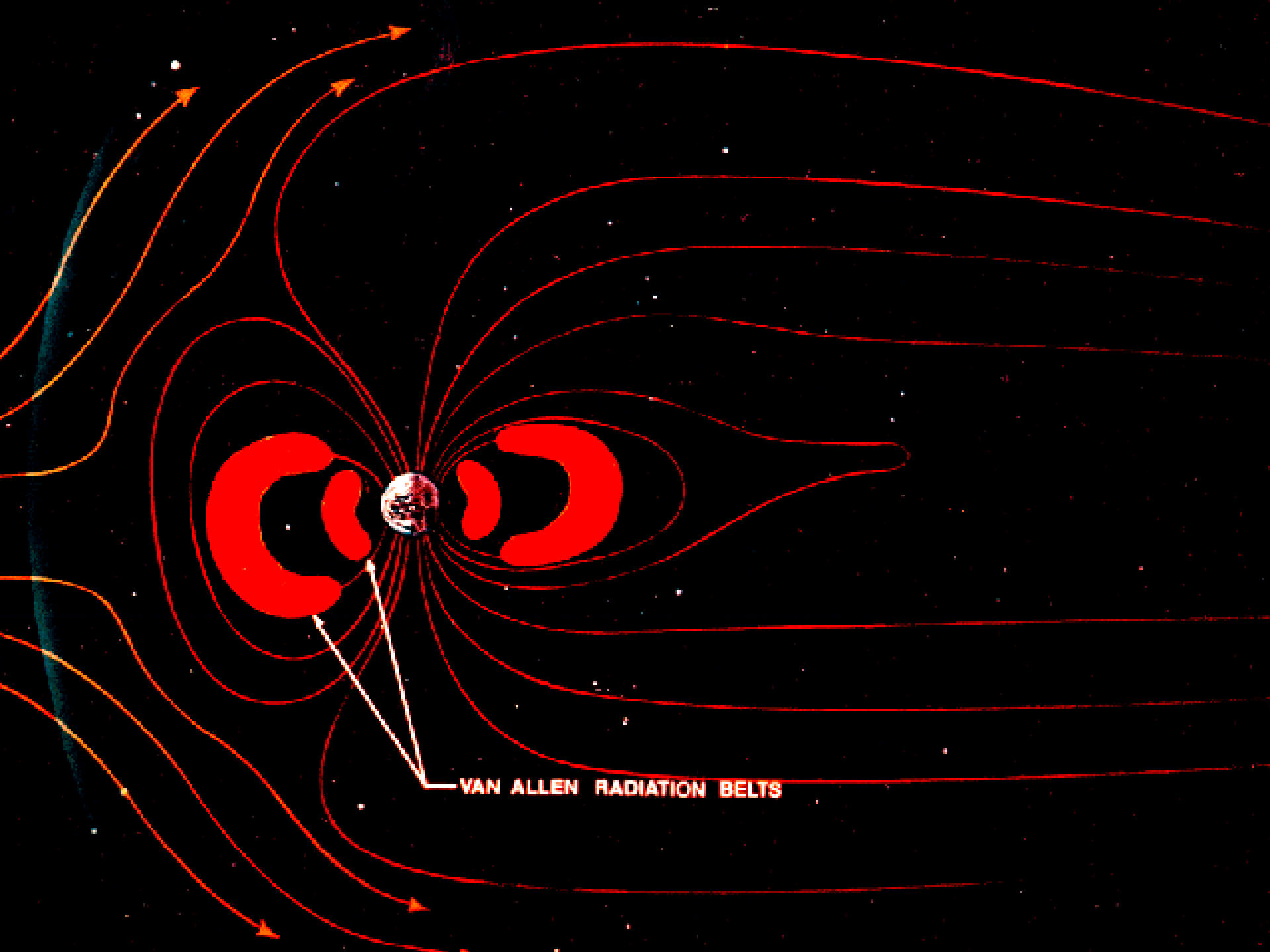
Satellite orbit altitudes



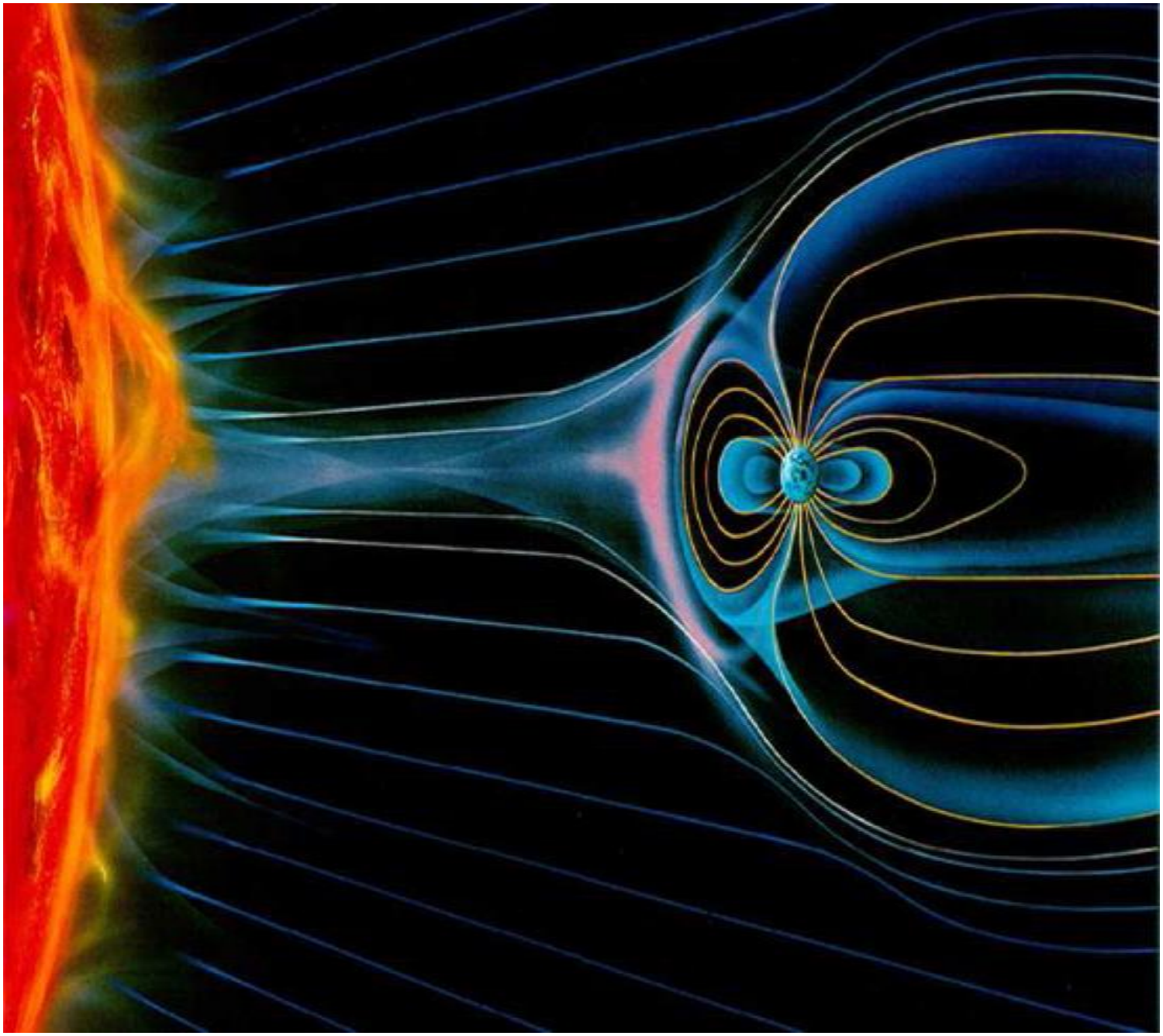
The Earth's Radiation Belts

Also known as "Van Allen Belts", is a torus of energetic charged particles (i.e. a plasma) around Earth, trapped by Earth's magnetic field.
When the belts "overload", particles strike the upper atmosphere and fluoresce, causing the polar aurora.
The inner belt consists mostly of protons while the outer belt consists mostly of electrons.
It is generally understood that the Van Allen belts are a result of *the collision of Earth's magnetic field with the solar wind.*

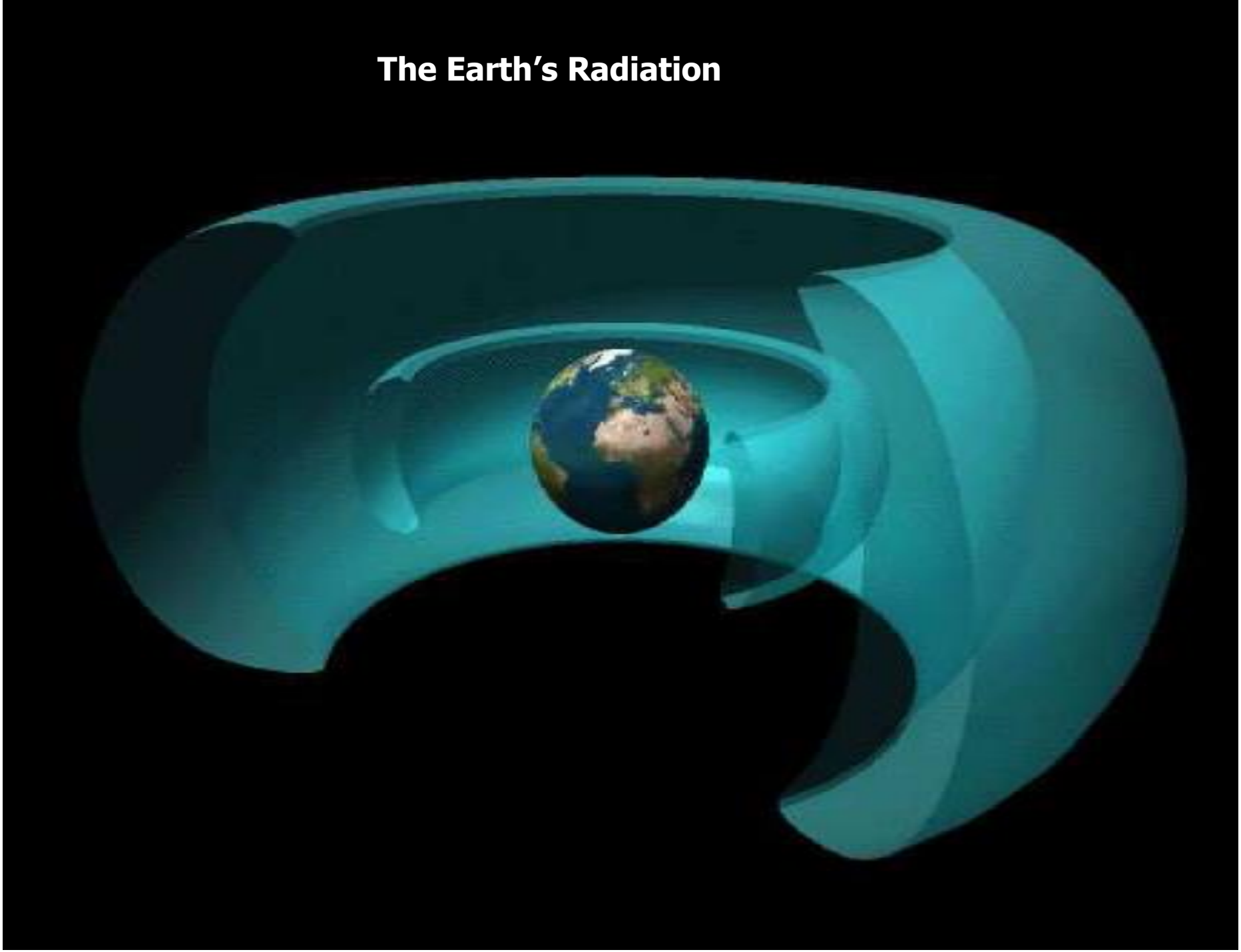


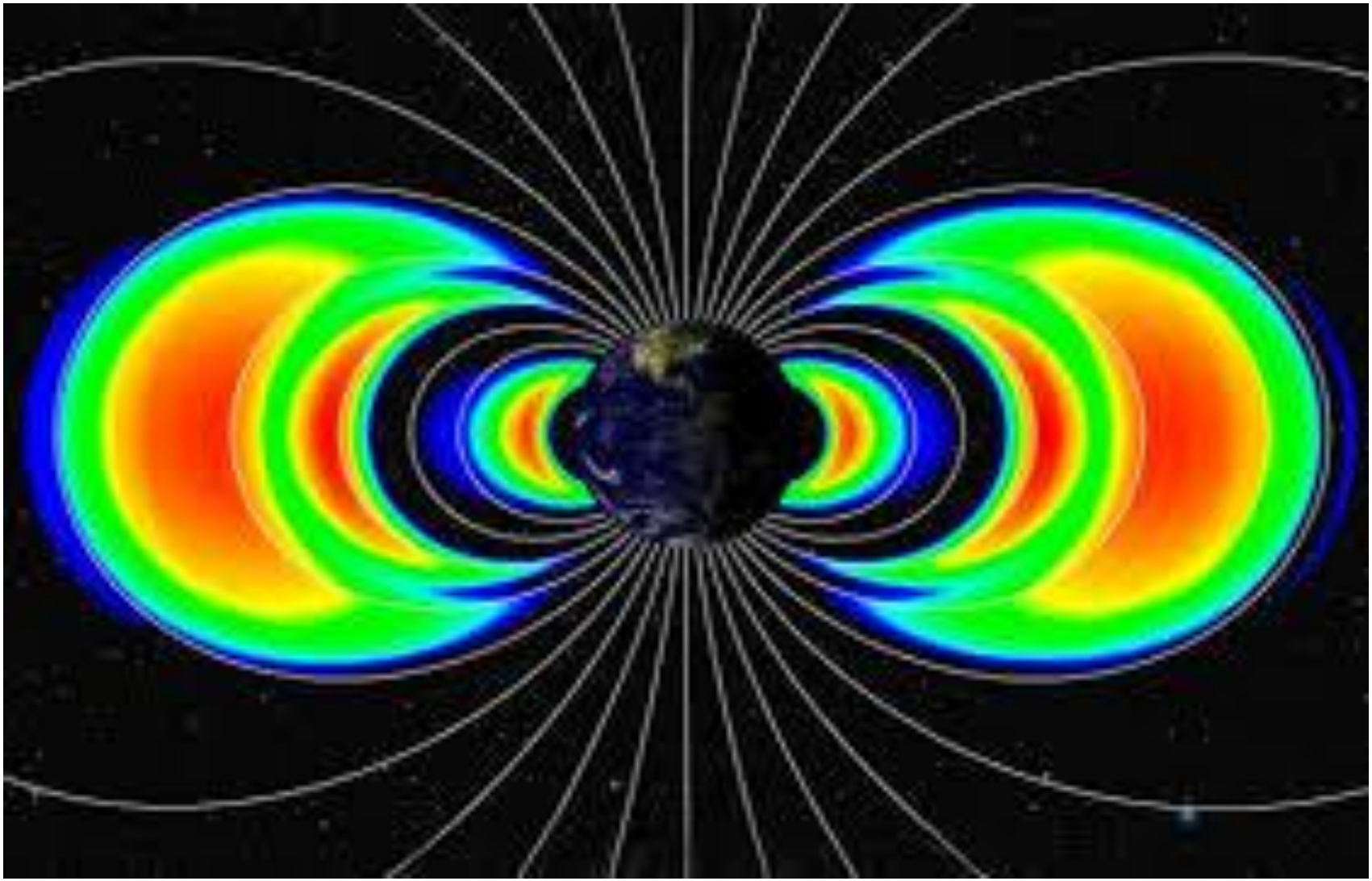

VAN ALLEN RADIATION BELTS

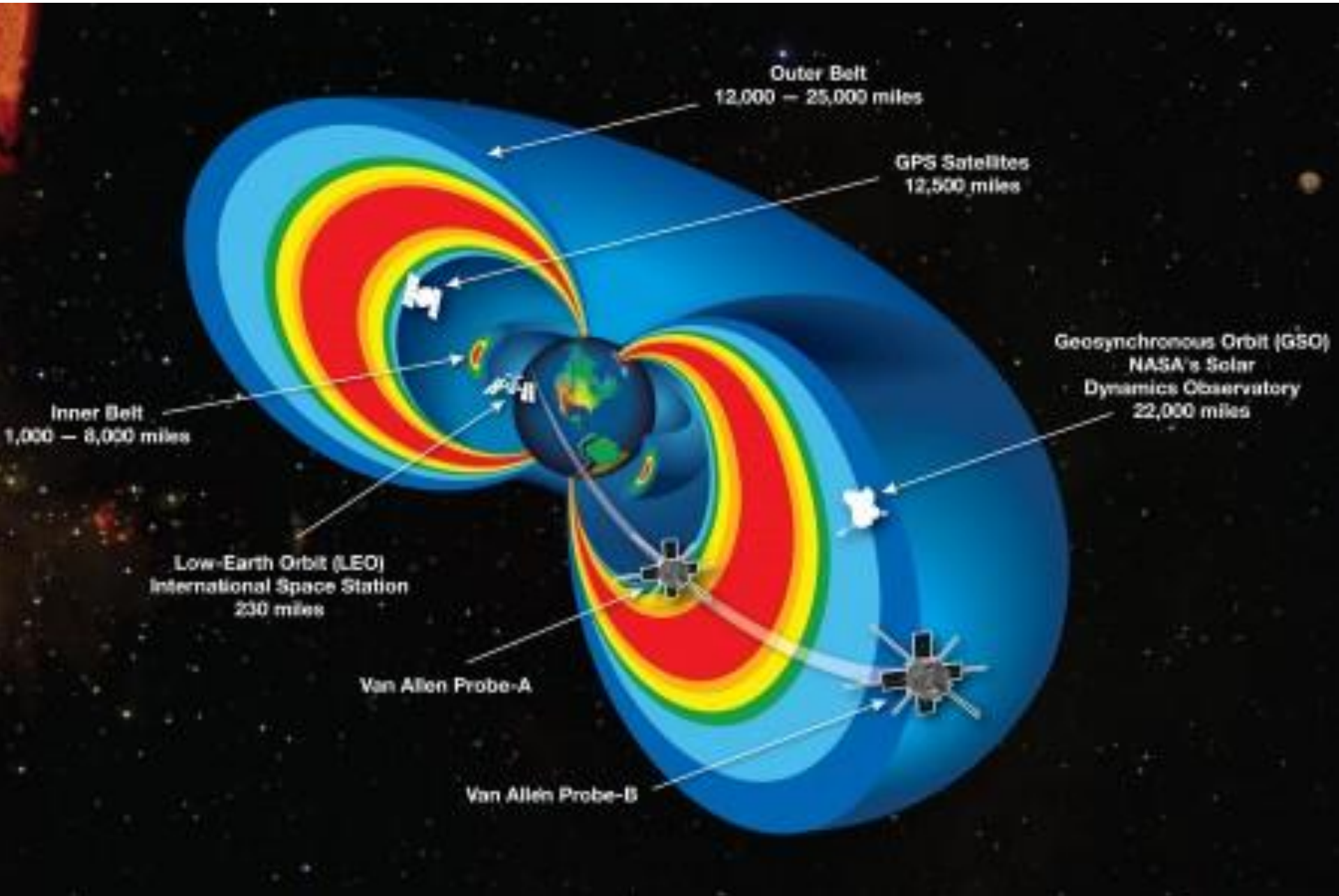
A solar wind is a stream of charged particles (i.e., a plasma) which are ejected from the upper atmosphere of the sun.



The Earth's Radiation






Outer Belt
12,000 — 25,000 miles
GPS Satellites
12,500 miles
Geosynchronous Orbit (GSO)
NASA's Solar
Dynamics Observatory
22,000 miles
Inner Belt
1,000 — 8,000 miles
Low-Earth Orbit (LEO)
International Space Station
230 miles
Van Allen Probe-A
Van Allen Probe-B

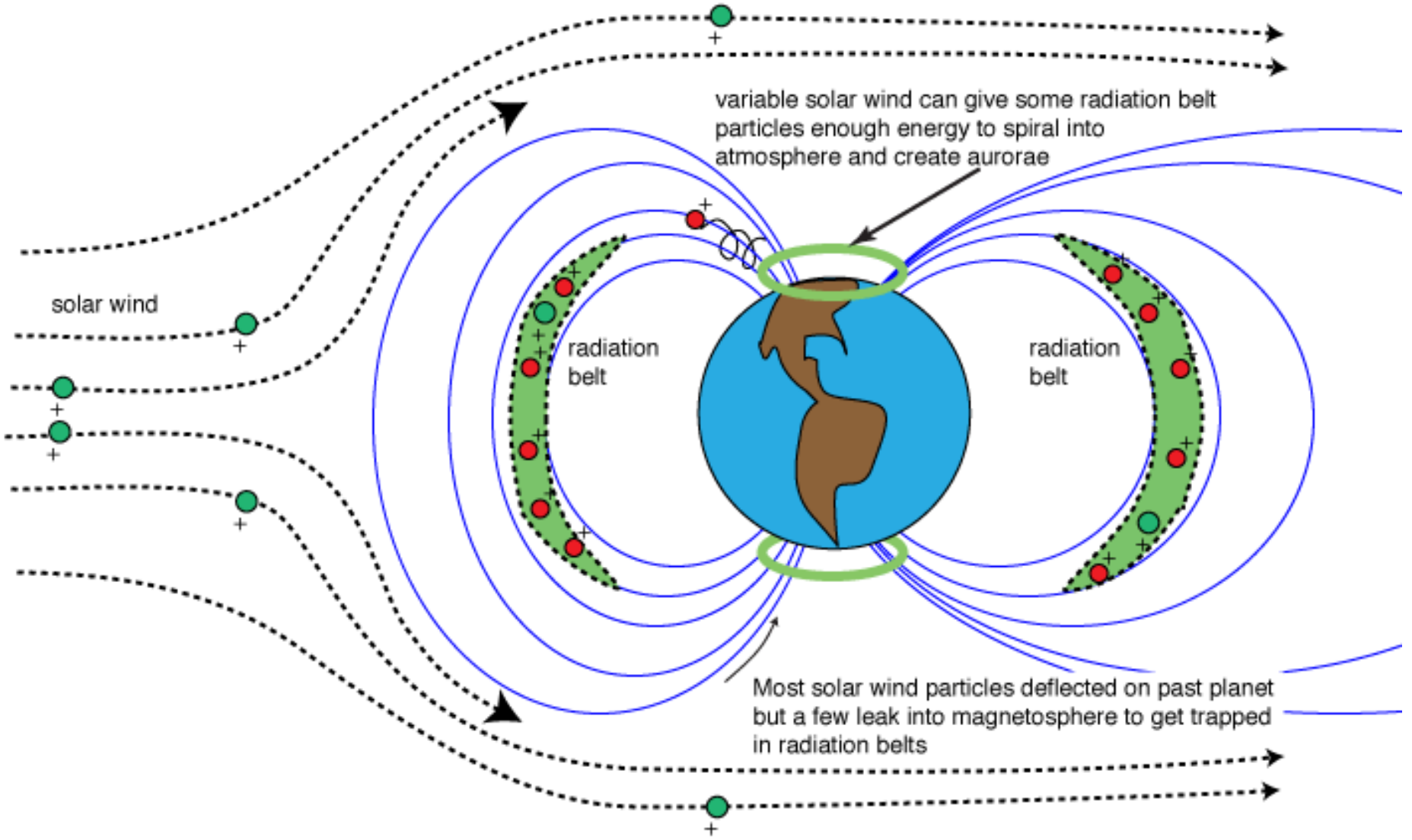
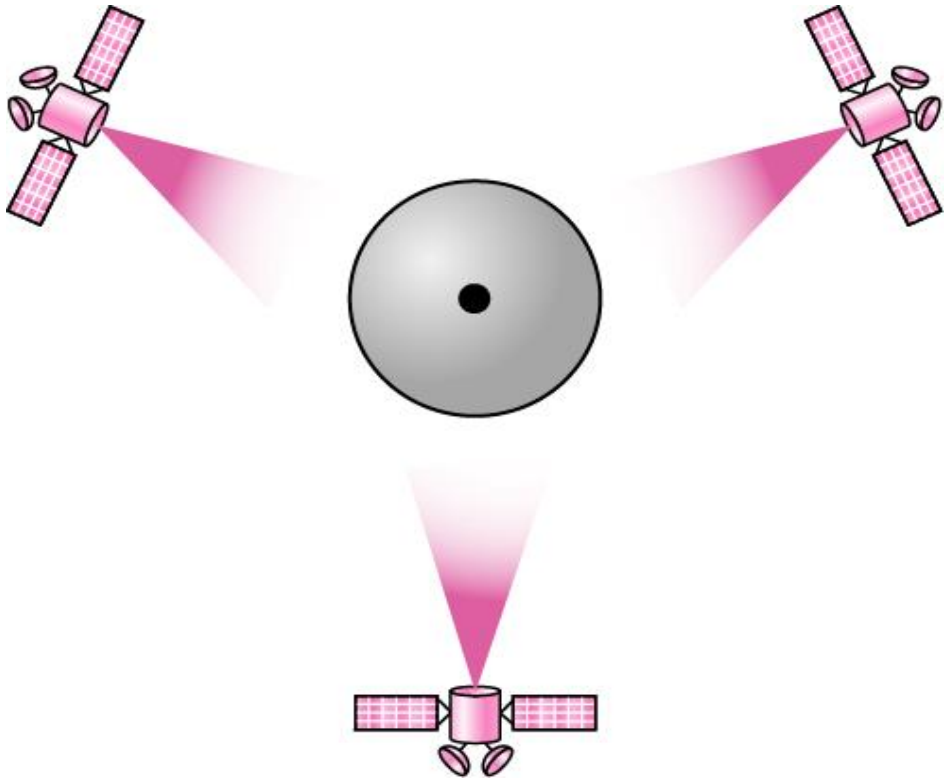

variable solar wind can give some radiation belt particles enough energy to spiral into atmosphere and create aurorae
solar wind
radiation belt
radiation belt
Most solar wind particles deflected on past planet but a few leak into magnetosphere to get trapped in radiation belts

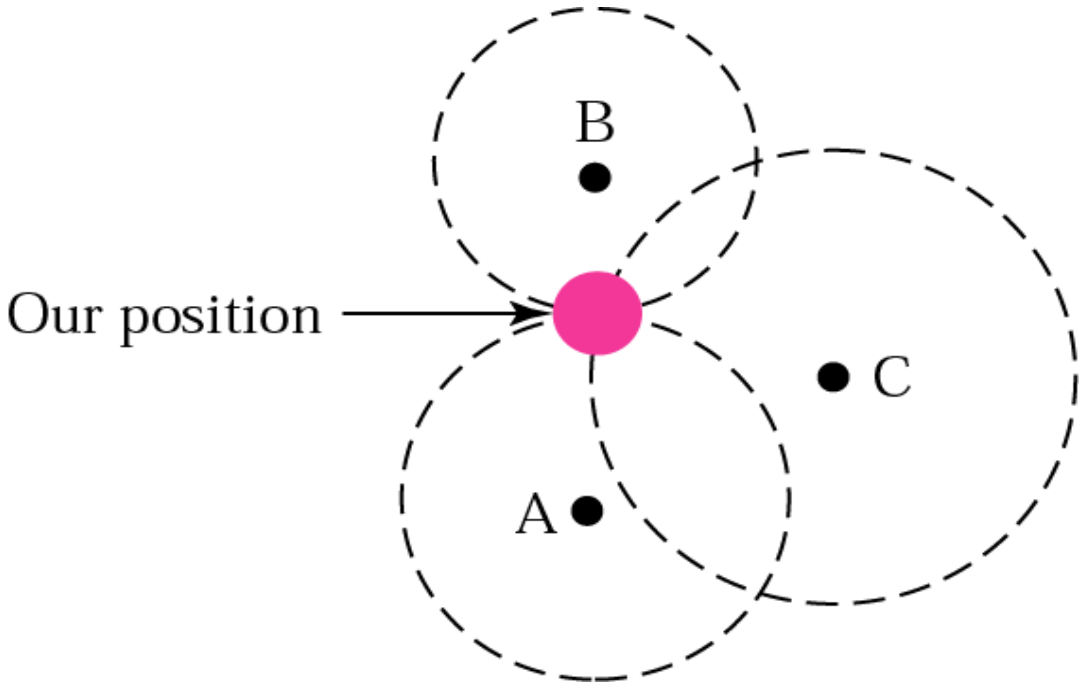
Table 17.1 Satellite frequency band

Band	Downlink, GHz	Uplink, GHz	Bandwidth, MHz
L	1.5	1.6	15
S	1.9	2.2	70
C	4	6	500
Ku	11	14	500
Ka	20	30	3500

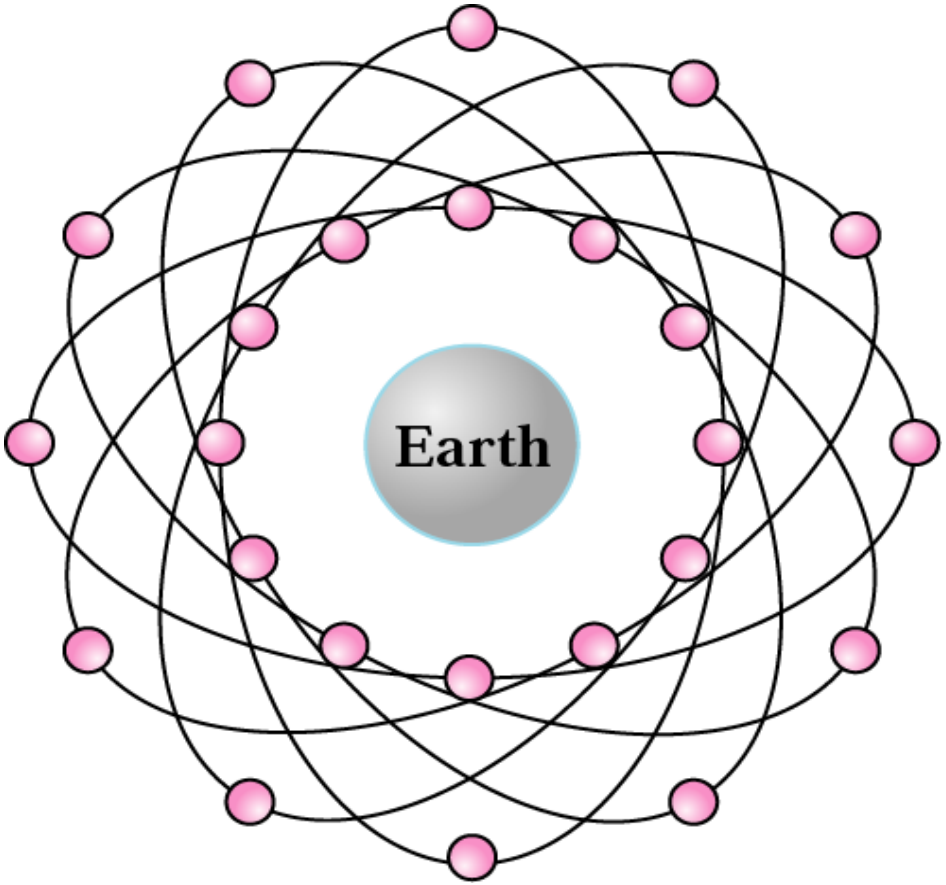
Satellites in geosynchronous orbit



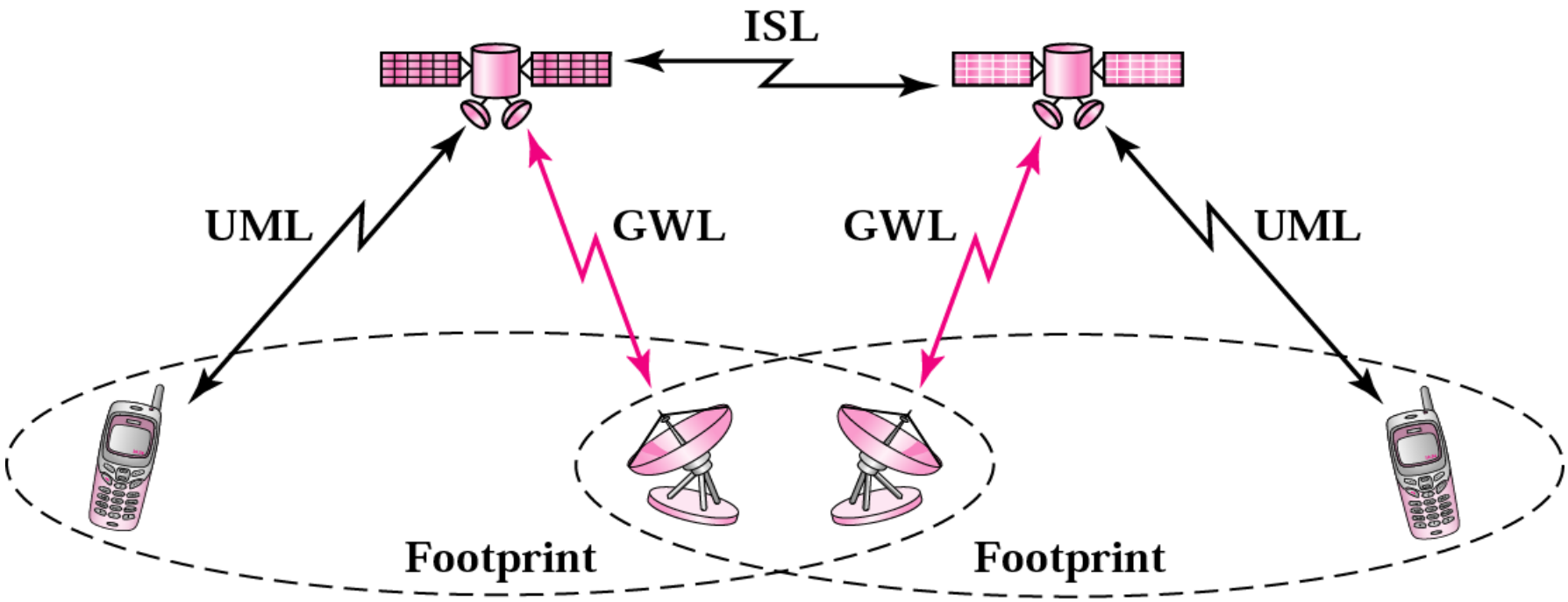
Triangulation



GPS



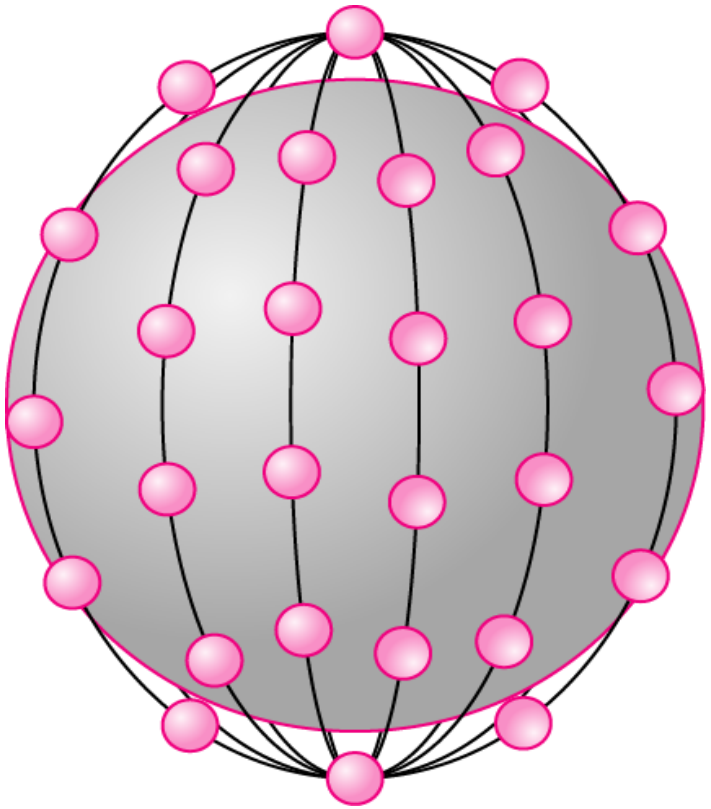
LEO satellite system

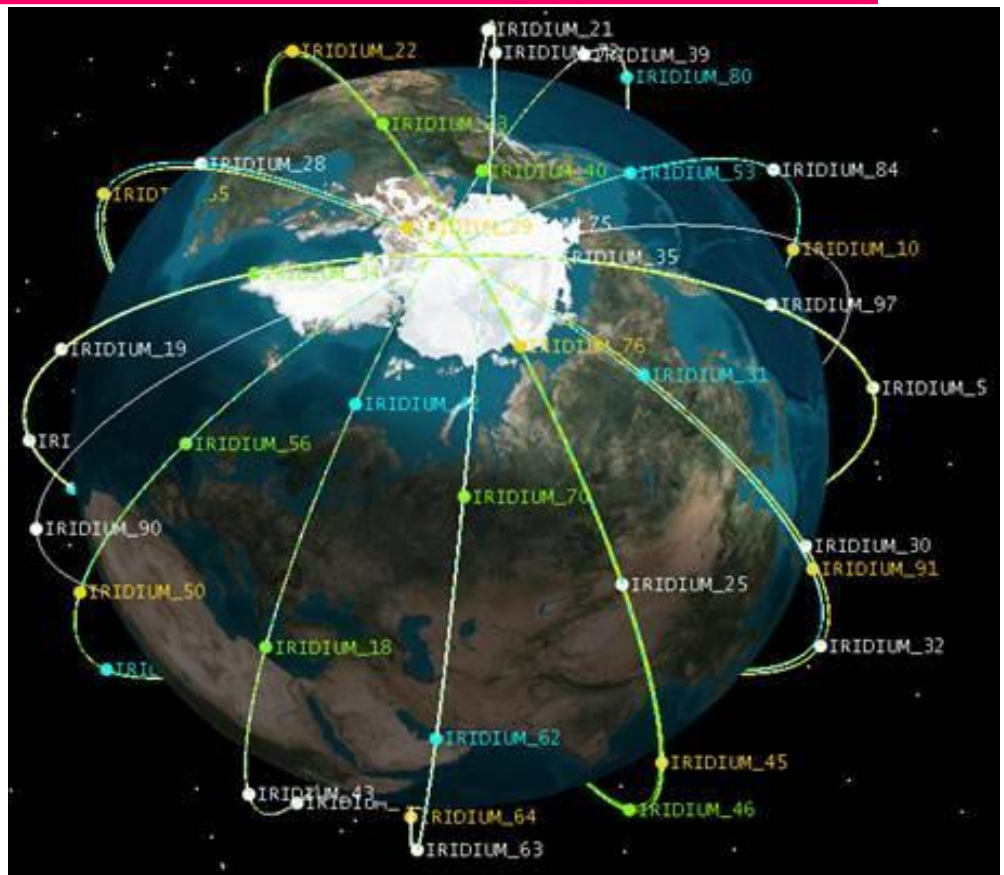


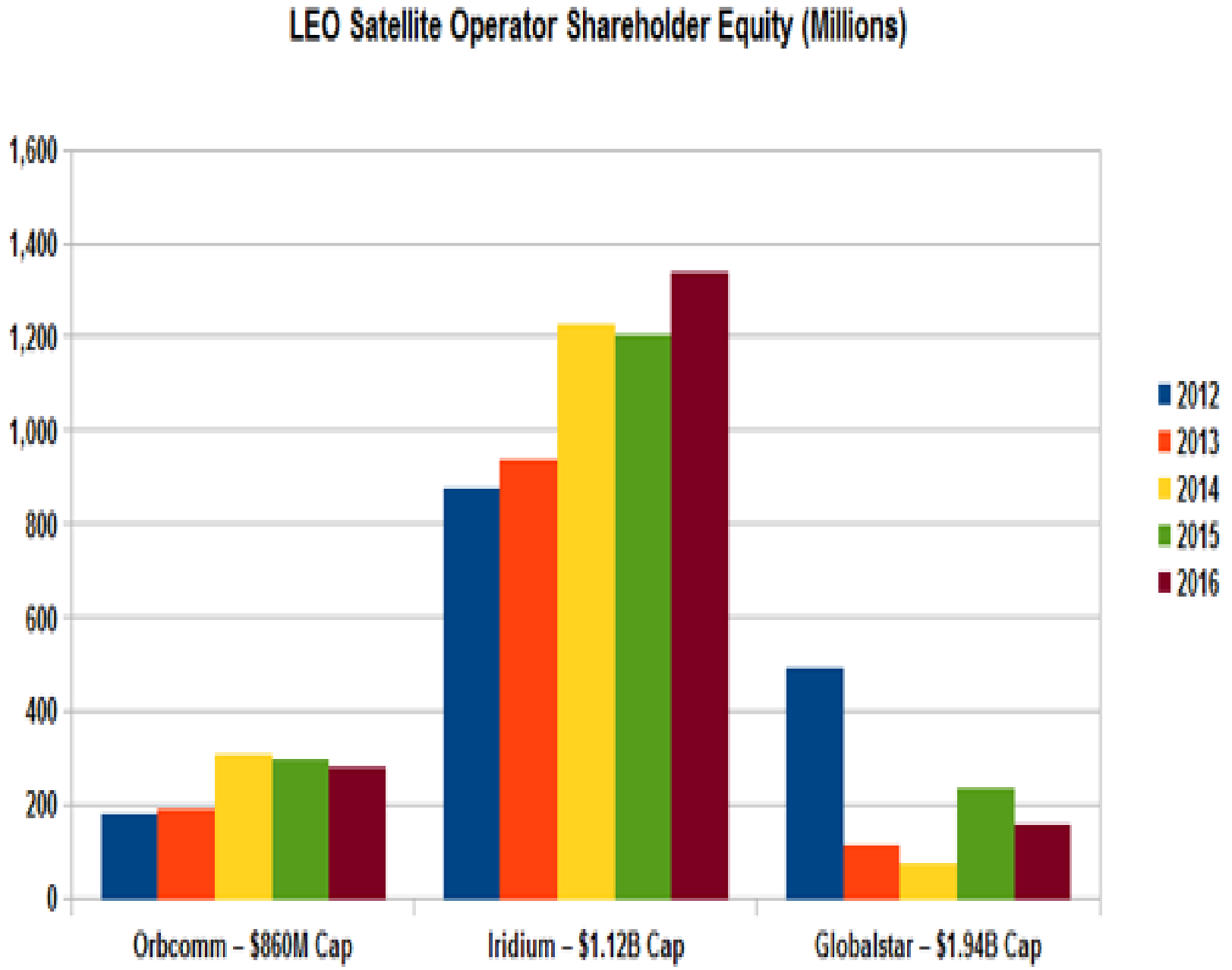
Iridium constellation

The Iridium system has 66 satellites in six LEO orbits, each at an altitude of 750 km.

Iridium is designed to provide direct worldwide voice and data communication using handheld terminals, a service similar to cellular telephony but on a global scale.






LEO Satellite Operator Shareholder Equity (Millions)
1,600
1,400
1,200
1,000
800
600
400
200
0
2012
2013
2014
2015
2016
Orbcomm – $860M Cap
Iridium – $1.12B Cap
Globalstar – $1.94B Cap

Teledesic has 288 satellites in 12 LEO orbits, each at an altitude of 1350 km.