SATELLITE COMMUNICATION

Overview

- Satellite technology has progressed tremendously over the last 50 years since Arthur C. Clarke first proposed its idea in 1945 in his article in Wireless World.
- Today, satellite systems can provide a variety of services including broadband communications, audio/video distribution networks, maritime navigation, worldwide customer service and support as well as military command and control.
- Satellite systems are also expected to play an important role in the emerging 4G global infrastructure providing the wide area coverage necessary for the realization of the "Optimally Connected Anywhere, Anytime" vision that drives the growth of modern telecom industry.

Pioneers in Satellite Communication

- **Konstantin Tsiolkovsky (1857 - 1935)**
  Russian visionary of space flight First described the multi-stage rocket as means of achieving orbit.
  - Link: The life of Konstantin Eduardovitch Tsiolkovsky

- **Hermann Noordung (1892 - 1929)**
  Postulated the geostationary orbit.
  - Link: The Problem of Space Travel: The Rocket Motor

- **Arthur C. Clarke (1917 – 19 March 2008)**
  Postulated the entire concept of international satellite telecommunications from geostationary satellite orbit including coverage, power, services, solar eclipse.
  - Link: "Wireless World" (1945)

Satellite History

- 1957
  - October 4, 1957: - First satellite - the Russian Sputnik 01
  - First living creature in space: Sputnik 02
- 1958
  - First American satellite: Explorer 01
  - First telecommunication satellite: This satellite broadcast a taped message: Score
- 1959
  - First meteorology satellite: Explorer 07
- 1960
  - First successful passive satellite: Echo 1
  - First successful active satellite: Courier 1B
  - First NASA satellite: Explorer 08
- April 12, 1961: - First man in space
- 1962
  - First telephone communication & TV broadcast via satellite: Echo 1
  - First telecommunication satellite, first real-time active, AT&T: Telstar 1
  - First Canadian satellite: Alouette 1
  - On 7th June 1962 at 7:53p the two-stage rocket; Rehbar-I was successfully launched from Sonmiani Rocket Range. It carried a payload of 80 pounds of sodium and soared to about 130 km into the atmosphere. With the launching of Rehbar-I, Pakistan had the honour of becoming the third country in Asia and the tenth in the world to conduct such a launching after USA, USSR, UK, France, Sweden, Italy, Canada, Japan and Israel.
  - Rehbar-II followed a successful launch on 9th June 1962
- 1963
  - Real-time active: Telstar 2
- 1964
  - Creation of Intelsat
  - First geostationary satellite, second satellite in stationary orbit: Syncom 3
  - First Italian satellite: San Marco 1

Satellite History

- 1965
  - Intelsat 1 becomes first commercial comsat: Early Bird
  - First real-time active for USSR: Molniya 1A
- 1967
  - First geostationary meteorology payload: ATS 3
- 1968
  - First European satellite: ESRO 2B
- July 21, 1969: - First man on the moon

- 1970
  - First Japanese satellite: Ohsumi
  - First Chinese satellite: Dong Fang Hong 01
- 1971
  - First UK launched satellite: Prospero
  - ITU-WARC for Space Telecommunications
  - INTELSAT IV Launched
  - INTERSPUTNIK - Soviet Union equivalent of INTELSAT formed
- 1974
  - First direct broadcasting satellite: ATS 6
- 1976
  - MARISAT - First civil maritime communications satellite service started
- 1977
  - EUTELSAT - European regional satellite
  - ITU-WARC for Space Telecommunications in the Satellite Service
- 1979
  - Creation of Inmarsat

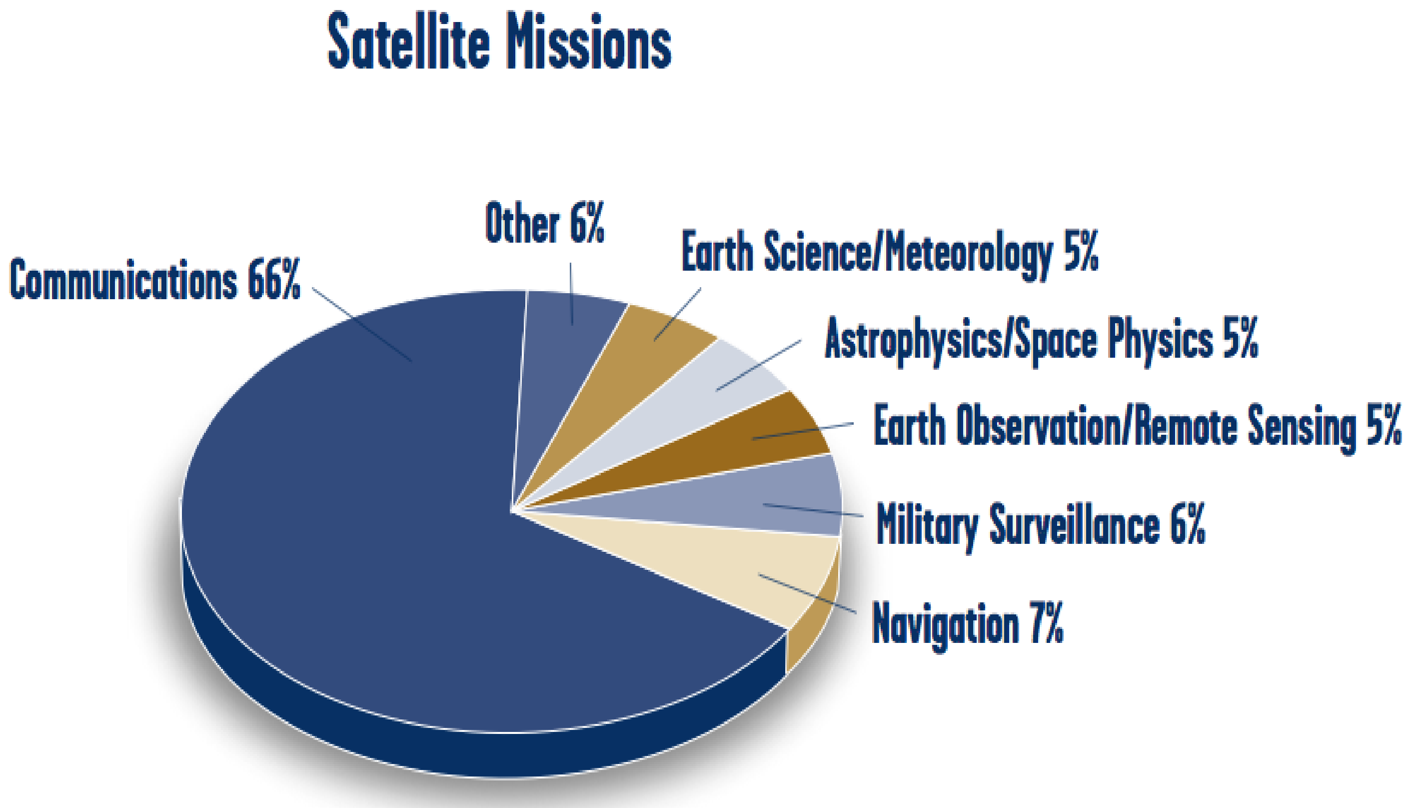
Satellite History

- 1980
  - INTELSAT V launched - 3 axis stabilized satellite built by Ford Aerospace
- 1983
  - ECS (EUTELSAT 1) launched - built by European consortium supervised by ESA
- 1984
  - UK's UNISAT TV DBS satellite project abandoned
  - First satellite repaired in orbit by the shuttle: SMM
- 1985
  - First Brazilian satellite: Brazilsat A1
  - First Mexican satellite: Morelos 1
- 1988
  - First Luxemburg satellite: Astra 1A
- 1989
  - INTELSAT VI - one of the last big "spinners" built by Hughes
  - Creation of Panamsat - Begins Service
  - On 16 July 1990, Pakistan launched its first experimental satellite, BADR-I from China
- 1990
  - IRIDIUM, TRITIUM, ODYSSEY and GLOBALSTAR S-PCN projects proposed - CDMA designs more popular
  - EUTELSAT II
- 1992
  - OLYMPUS finally launched - large European development satellite with Ka-band, DBTV and Ku-band SS/TDMA payloads - fails within 3 years
- 1993
  - INMARSAT II - 39 dBW EIRP global beam mobile satellite - built by Hughes/British Aerospace
- 1994
  - INTELSAT VIII launched - first INTELSAT satellite built to a contractor's design
  - Hughes describe SPACEWAY design
  - DirecTV begins Direct Broadcast to Home
- 1995
  - Panamsat - First private company to provide global satellite services.

Satellite History

- 1996
  - INMARSAT III launched - first of the multibeam mobile satellites (built by GE/Marconi)
  - Echostar begins Diresct Broadcast Service
- 1997
  - IRIDIUM launches first test satellites
  - ITU-WRC'97
- 1999
  - AceS launch first of the L-band MSS Super-GSOs - built by Lockheed Martin
  - Iridium Bankruptcy - the first major failure?
- 2000
  - Globalstar begins service
  - Thuraya launch L-band MSS Super-GSO
- 2001
  - XM Satellite Radio begins service
  - Pakistan's 2nd Satellite, BADR-B was launched on 10 Dec 2001 at 9:15a from Baikonour Cosmodrome, Kazakistan
- 2002
  - Sirius Satellite Radio begins service
  - Paksat-1, was deployed at 38 degrees E orbital slot in December 2002, Paksat-1, was deployed at 38 degrees E orbital slot in December 2002
- 2004
  - Teledesic network planned to start operation
- 2005
  - Intelsat and Panamsat Merge
  - VUSat OSCAR-52 (HAMSAT) Launched
- 2006
  - CubeSat-OSCAR 56 (Cute-1.7) Launched
  - K7RR-Sat launched by California Politechnic University
- 2007
  - Prism was launched by University of Tokyo
- 2008
  - COMPASS-1; a project of Aachen University was launched from Satish Dawan Space Center, India. It failed to achieve orbit.

Satellite Missions



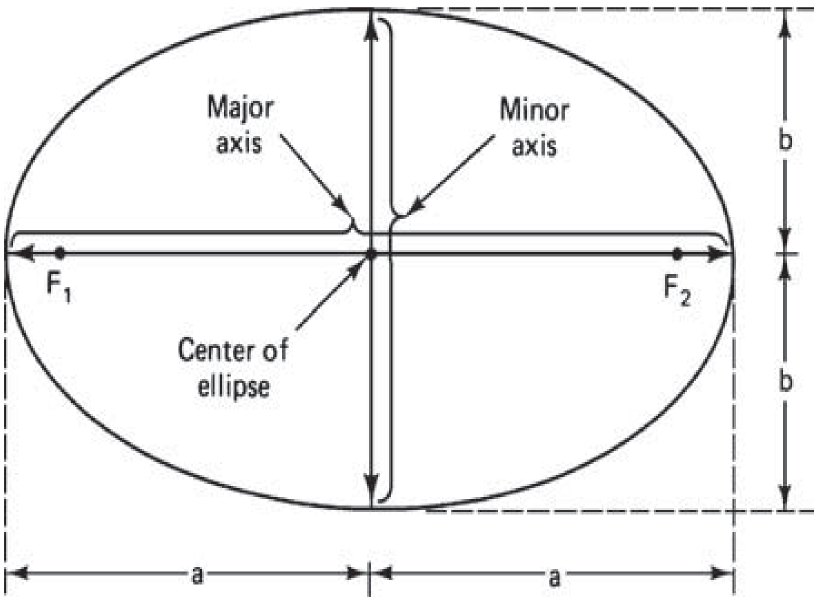
Source: Union of Concerned Scientists [www.ucsusa.org]

Kepler’s law

- Satellites (spacecraft) orbiting the earth follow the same laws that rule the motion of the planets around the sun.
- Kepler’s laws apply quite generally to any two bodies in space which interact through gravitation.
- *Kepler’s first law* states that the path followed by a satellite around the primary will be an ellipse.

Kepler's first law

- An ellipse has Two focal points shown as $F1$ and $F2$



Kepler’s first law

- The semi major axis of the ellipse is denoted by *a*, and the semi minor axis, by *b*. The eccentricity *e* is given by

$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

- The center of mass of the two-body system, termed the *bary center,* is always center of the foci.
- For elliptical orbit $0<e<1$, when $e=0$ the orbit becomes circular.

Kepler’s 2nd law

- *Kepler’s second law* states that, for equal time intervals, a satellite will sweep out equal areas in its orbital plane, focused at the barycenter.
- Referring to Fig. 2.2, assuming the satellite travels distances $S1$ and $S2$ meters in 1 s, then the areas $A1$ and $A2$ will be equal.
- The average velocity in each case is $S1$ and $S2$ m/s, and because of the equal area law, it follows that the velocity at $S2$ is less than that at $S1$.

Kepler's 2nd law

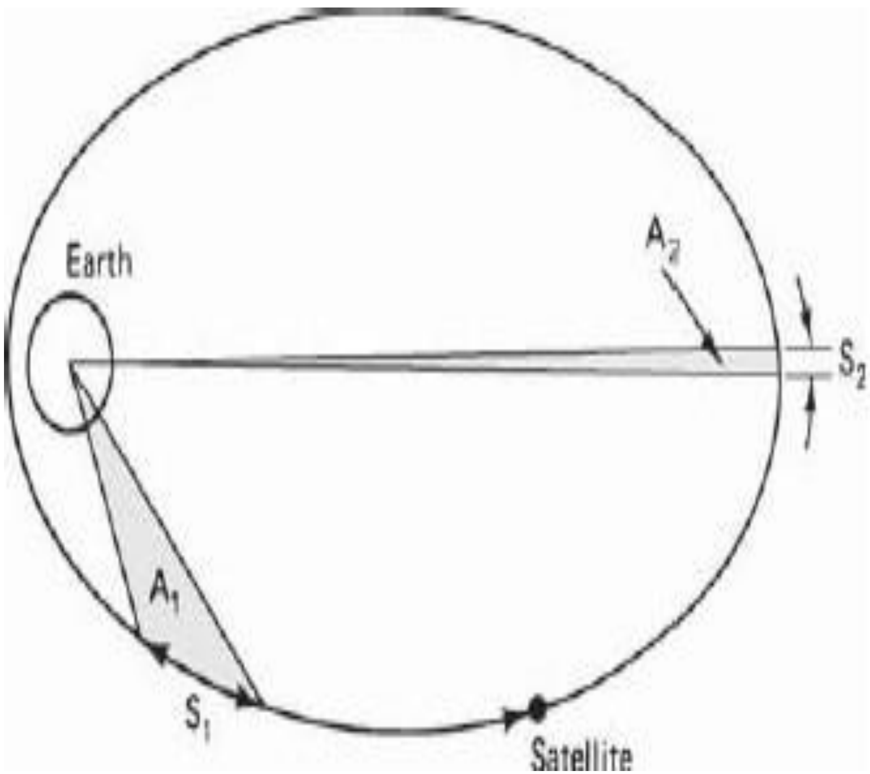


Figure 1.2 Kepler's second law. The areas $A1$and $A2$swept out in unit time are equal.

Kepler’s 3rd law

- *Kepler’s third law* states that the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.
- The mean distance is equal to the semi major axis a.
- For the artificial satellites orbiting the earth, Kepler’s third law can be written in the form

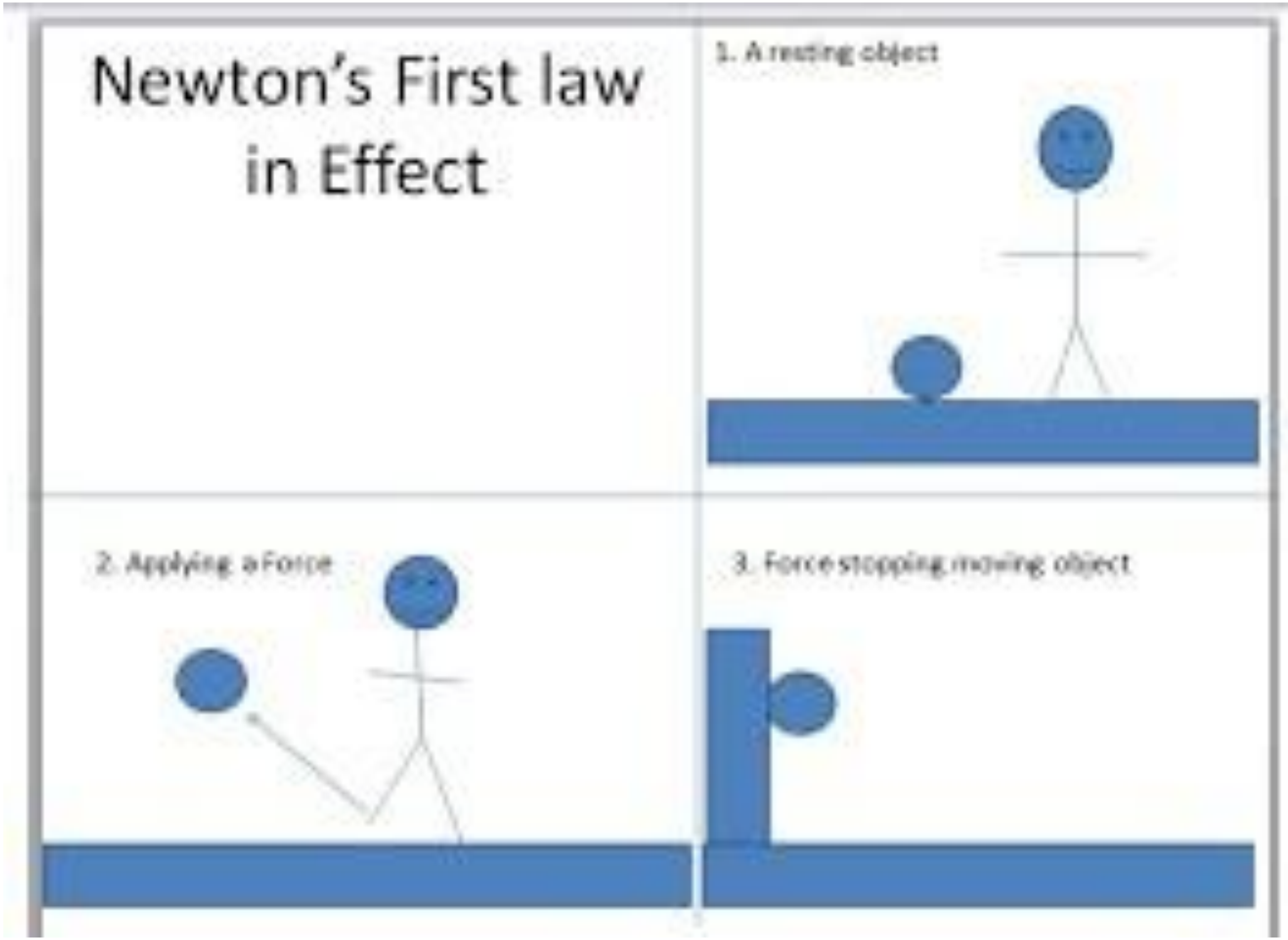
Kepler's 3rd law

$$a^3 = \mu/n^2$$

- Where n is the mean motion of the satellite in radians per second and is the earth's geocentric gravitational constant $\mu=3.986005 \times 10^{14} m^3/s^2$.
- with n in Rad/s, the orbital period in s is given by P=2pi/n.

Newton's law:

- **Newton's first law:**
- An object at rest will remain at rest unless acted on by an un balanced force.
- An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force. This law is often called "the law of inertia".

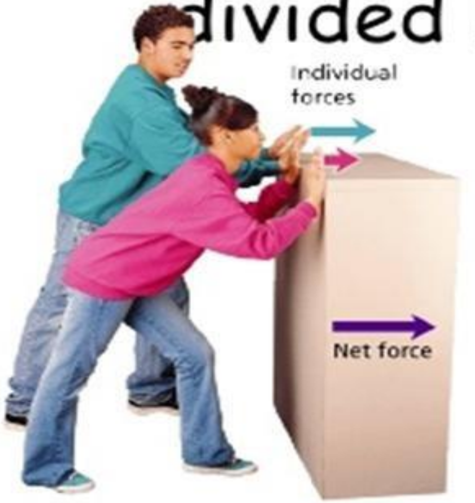

Newton's First law in Effect
1. A resting object
2. Applying a Force
3. Force stopping moving object

Newton's second law:

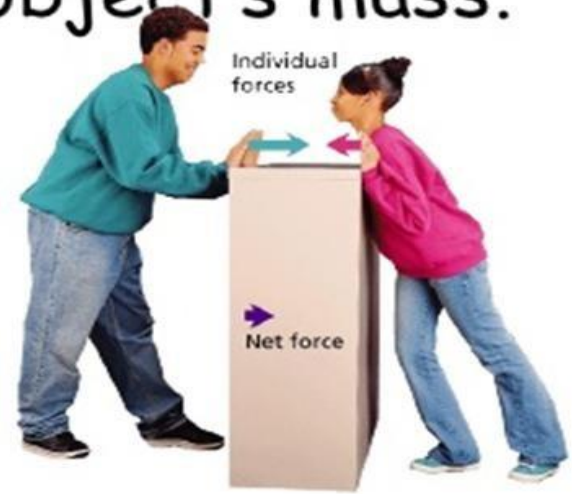
- Acceleration is produced when a force acts on a mass.
- The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).
- F=ma

Newton's Second Law

An unbalanced force causes an object to accelerate. The acceleration of the object is equal to the net force acting on it divided by the object's mass.



Unbalanced Forces in the Same Direction
When two forces act in the same direction, the net force is the sum of the two individual forces. The box moves to the right.

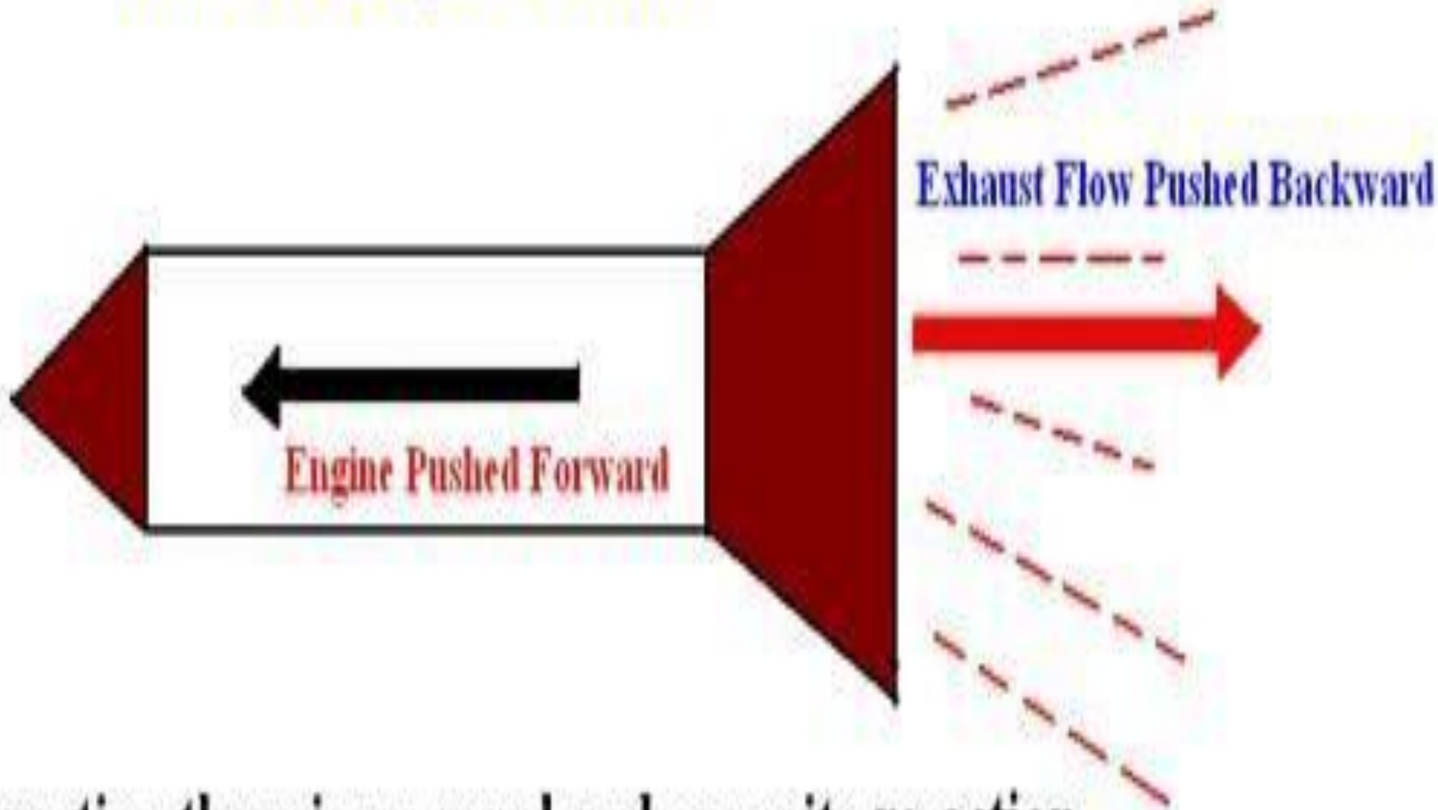


Unbalanced Forces in the Opposite Direction
When two forces act in opposite directions, the net force is the difference between the two individual forces. The box moves to the right.

Newton's 3rd law:

- For every action there is an equal and opposite re-action.
- This means that for every force there is a reaction force that is equal in size, but opposite indirection.
- That is to say that whenever an object pushes another object it gets pushed back in the opposite direction equally hard.

Rocket Engine Thrust



For every action,there is an equal and opposite re-action

Orbital Elements

- In general the artificial satellites are defined by six orbital elements. These elements are referred to as the Keplerian element set.
- *Semi -major axis(a)*
- *Eccentricity (e)*
- *Mean anomaly (M_0)*
- *Argument Perigee ( )*
- *Inclination (i)*
- *Right ascension of the ascending node(Ω)*

Apogee & Perigee heights

- In order to find the apogee & perigee heights, the radius of the earth must be subtracted from the radii lengths.
- The length of the radius vector at apogee & perigee can be obtained from the geometry of the ellipse.
- $r_a=a(1+e)$
- $r_p=a(1-e)$
- Assume mean earth radius R so
- Apogee & Perigee heights are
- $h_a=r_a - R$ and $h_p=r_p - R$

Orbit Perturbations

- Theoretically, an orbit described by Kepler is ideal as Earth is considered to be a perfect uniform spherical mass and the force acting around the Earth is the centrifugal force.
- This force is supposed to balance the gravitational pull of the earth.
- In reality, other forces also play an important role and affect the motion of the satellite.
- These forces are the gravitational forces of Sun and Moon along with the atmospheric drag.

Orbit Perturbations

- Effect of Sun and Moon is more pronounced on geostationary earth satellites where as the atmospheric drag effect is more pronounced for low earth orbit satellites below about 1000km.
- *Effects of non-Spherical Earth:*

For a spherical earth of uniform mass, Kepler's third law (Eq. 2.2) gives the nominal mean motion n_0.

$$n_0 = \sqrt{\frac{\mu}{a^3}}$$

The 0 subscript as a reminder that this result applies for a perfectly spherical earth of uniform mass.

Effects of non-Spherical Earth:

- However, it is known that the earth is not perfectly spherical, there being an equatorial bulge and flattening at the poles, a shape described as an *oblate spheroid*.
- When the earths oblateness is taken into account, the mean motion is

$$n = n_0\left[\frac{1+K_1\left(1-1.5\sin^2 i\right)}{a^2\left(1-e^2\right)^{1.5}}\right]$$

Effects of non-Spherical Earth:

K1 = 66,063.1704 km^{2} ^{a} (constant).
The earth's oblateness has negligible effect on the semimajor axis a.

- If a is known, the mean motion (n) is calculated.
- The orbital period taking into account the earths oblateness is termed the anomalistic period.

$$P_A = \frac{2\pi}{n} \sec$$

- Where n is the rad/sec.

Effects of non-Spherical Earth:

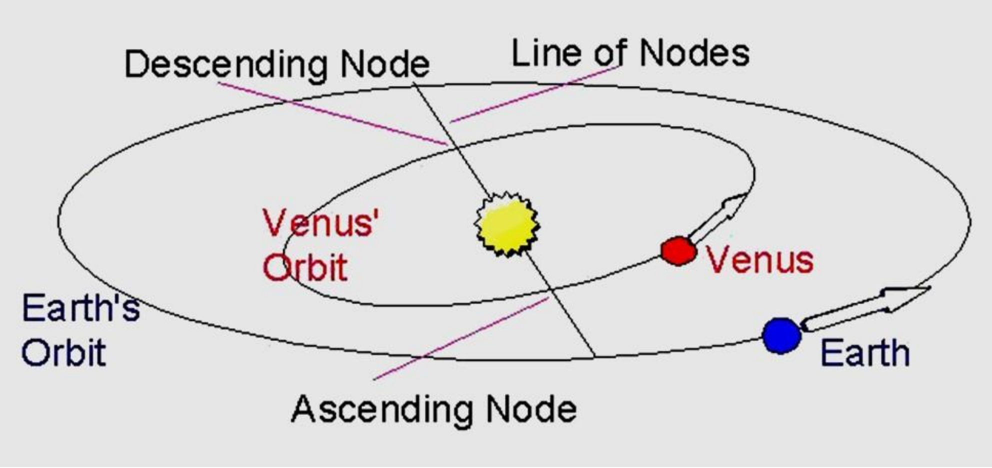
- If n is known and n_0 is function of a. the root of the following equation:

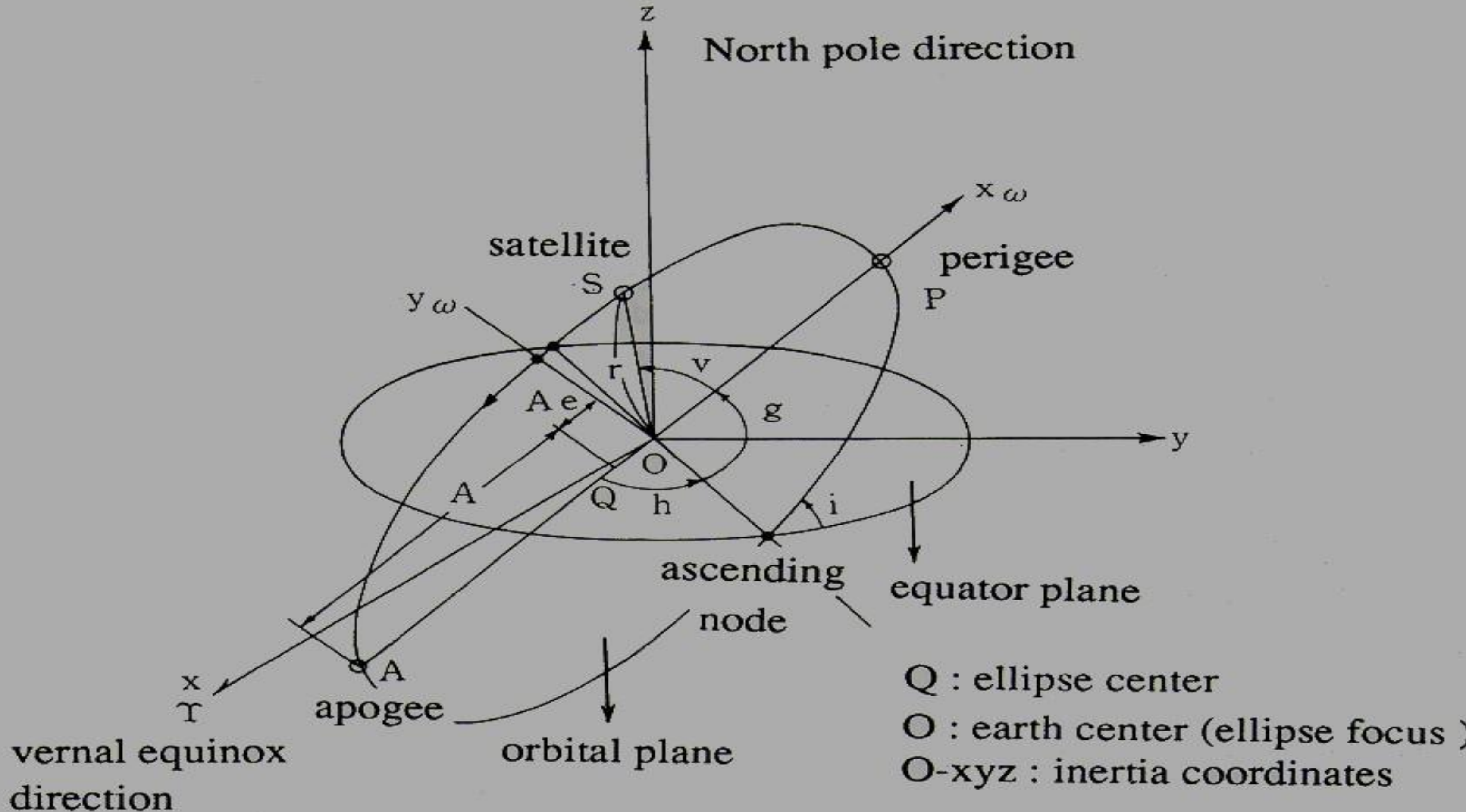
$$n - \sqrt{\frac{\mu}{a^3}}\left[\frac{1 + K_1\left(1 - 1.5\sin^2 i\right)}{a^2\left(1 - e^2\right)^{1.5}}\right] = 0$$

- The oblateness of the earth produces two rotations of the orbital plane.
  - *Regression of the nodes*
  - *Rotation of apsides in the orbital plane*

Regression of the nodes

- The nodes appear to slide along the equator.
- The line of nodes, which is in the equator plane, rotates about the center of the earths.
- Thus Ω, , the right ascension of the ascending node, shifts its positions.





A : semi-minor axis   e : orbital essentricity   i : inclination angle

h : right ascension of ascending node   g : argument of perigee   v : time of passage of perigee

Figure 5.5.1 Orbital element of Kepler

Regression of the nodes

- If the orbit is prograde, the nodes slide westward & if retrograde, they slide eastward.
- As seen from ascending node a satellite in prograde orbit moves eastward and in retrograde orbit westward.
- The nodes therefore move in direction opposite to the direction of satellite motion, hence the term *regression of the nodes.*
- If polar orbit($i=90^0$) the regression is zero.

Rotation of apsides

Rotation of the line of apsides in the orbital plane, the argument of perigee changes with time.

Both effects depend on the mean motion *n*, the semimajor axis *a*, and the eccentricity *e*. These factors can be grouped into one factor ***K*** given by

$$K = \frac{nK_1}{a^3(1-e^2)^2}$$

K will have the same units as *n*.

The rate of regression of the nodes

$$\frac{d\Omega}{dt} = -K(\cos i)$$

Rotation of apsides

Where *i* is the inclination. The rate of change of the nodes will have the same units as *n*.

- When the rate of change is –ve, the regression is westward and the rate is +ve, the regression is eastward.
- Rotation of the line of apsides:
- The other major effect produced by the equatorial bulge is rotation of the line apsides.

Rotation of apsides

- This line rotates in the orbit plane, resulting in the argument of perigee changing with time. The rate of change is given by

$$\frac{d\omega}{dt} = K(2 - 2.5\sin^2 i)$$

Units: same as *n*

Given Epoch time = t_0, right ascension of the ascending node Ω_0 at epoch, argument of the perigee ω_0 at epoch, the new values for Ω and ω at time t is:

Rotation of apsides

$$\Omega = \Omega_0 + \frac{d\Omega}{dt}(t - t_0)$$

$$\omega = \omega_0 + \frac{d\omega}{dt}(t - t_0)$$

- In addition to the equatorial bulge, the earths is not perfectly circular in the equatorial plane; it has small eccentricity of the order of 10^{-5}. This is referred to as the *equatorial ellipticity.*

Atmospheric drag

The effects of atmospheric drag are significant for near-earth satellites,(below about 1000 km).
The drag is greatest at the perigee, which reduce the velocity at this point, thus the satellite does not reach the same apogee height on successive revolutions.

The result is that the semimajor axis and the eccentricity are both reduced. Drag does not noticeably change the other orbital parameters, including perigee height. An approximate expression for the change of major axis is

Atmospheric drag

$$a \cong a_0 + \left[\frac{n_0}{n_0 + n_0'(t - t_0)} \right]^{2/3}$$

The mean anomaly is also changed. An approximate expression for the amount by which it changes is

$$\delta M = \frac{n_0'}{2}(t - t_0)^2$$

Station Keeping

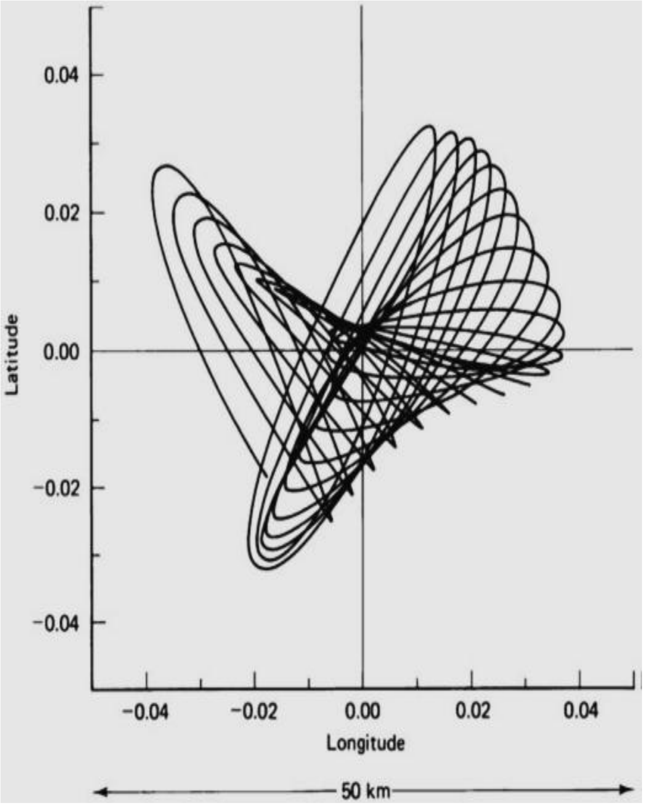
- The process of keeping a geostationary satellite in its orbital slot is termed as the station-keeping.
    - *east-west station-keeping*
    - *north-south station-keeping*

east-west station-keeping:

- It is important that geostationary satellite be kept in its orbital slot.
- The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.

east-west station-keeping:

- To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks.
- These maneuvers are termed *east-west station-keeping maneuvers*.



North-south station-keeping

- A satellite which is nominally geostationary also will drift in latitude, due to the gravitational pull of the sun and the moon.
- These forces cause the inclination to change at a rate of about 0.85°/year.
- If not corrected, the drift would result in a cyclic change in the inclination, going from 0° to 14.67° in 26.6 years and back to zero, at which the cycle is repeated.

North-south station-keeping

- To prevent the shift in inclination from exceeding specified limits, jets may be pulsed at the appropriate time to return the inclination to zero.
- These maneuvers are termed *north-south station-keeping maneuvers*, and they are much more expensive in fuel than are east-west station-keeping maneuvers.
- The north-south station-keeping tolerances are the same as those for east-west station keeping, +-0.1° in the C band and+- 0.05° in the Ku band.

Geostationary & Non-Geostationary orbit

- A satellite in a geostationary orbit appears to be stationary with respect to the earth, hence the name *geostationary.*
- Three conditions are required for an orbit to be geostationary:
  - *The satellite must travel eastward at the same rotational speed as the earth.*
  - *The orbit must be circular.*
  - *The inclination of the orbit must be zero*.

Geostationary orbit

- A Geostationary orbit is a prograde orbit whose orbital period is equal to the earth’s rotational period.
- A Geostationary orbit which lies in the equator plane that contains the equator.
- Such a satellite seems to be fixed at one point above the earth's surface when viewed from the earth.

Non-Geostationary orbit

- ***Prograde Orbit:*** an orbit in which satellite moves in the same direction as the Earth"s rotation.
- Its inclination is always between 0^0 to 90^0.
- ***Retrograde Orbit:*** an orbit in which satellite moves in the direction opposite to the Earth's rotation.
- Its inclination is always between 90^0 to 180^0.

Non-Geostationary orbit

- **High elliptical orbit(HEO):** it is elliptical orbit approximately 18500 to 35000 km above the earth's surface, not necessary above the equator.
- An HEO satellite is a specified orbit in which a satellite continuously swings very close to earth, loops out into space and the repeats its swing by the earth.
- HEOs are designed to give better coverage to countries with higher northern or southern latitudes.

Non-Geostationary orbit

- Medium earth orbit(MEO): an MEO is a circular orbit, orbiting approximately 8000 to 18000 km above the earths surface, again not necessarily above the equator.
- An MEO satellite is a compromise between the LEO and GEO.
- MEO system design involves more delays and higher power levels than satellites in the LEOs.

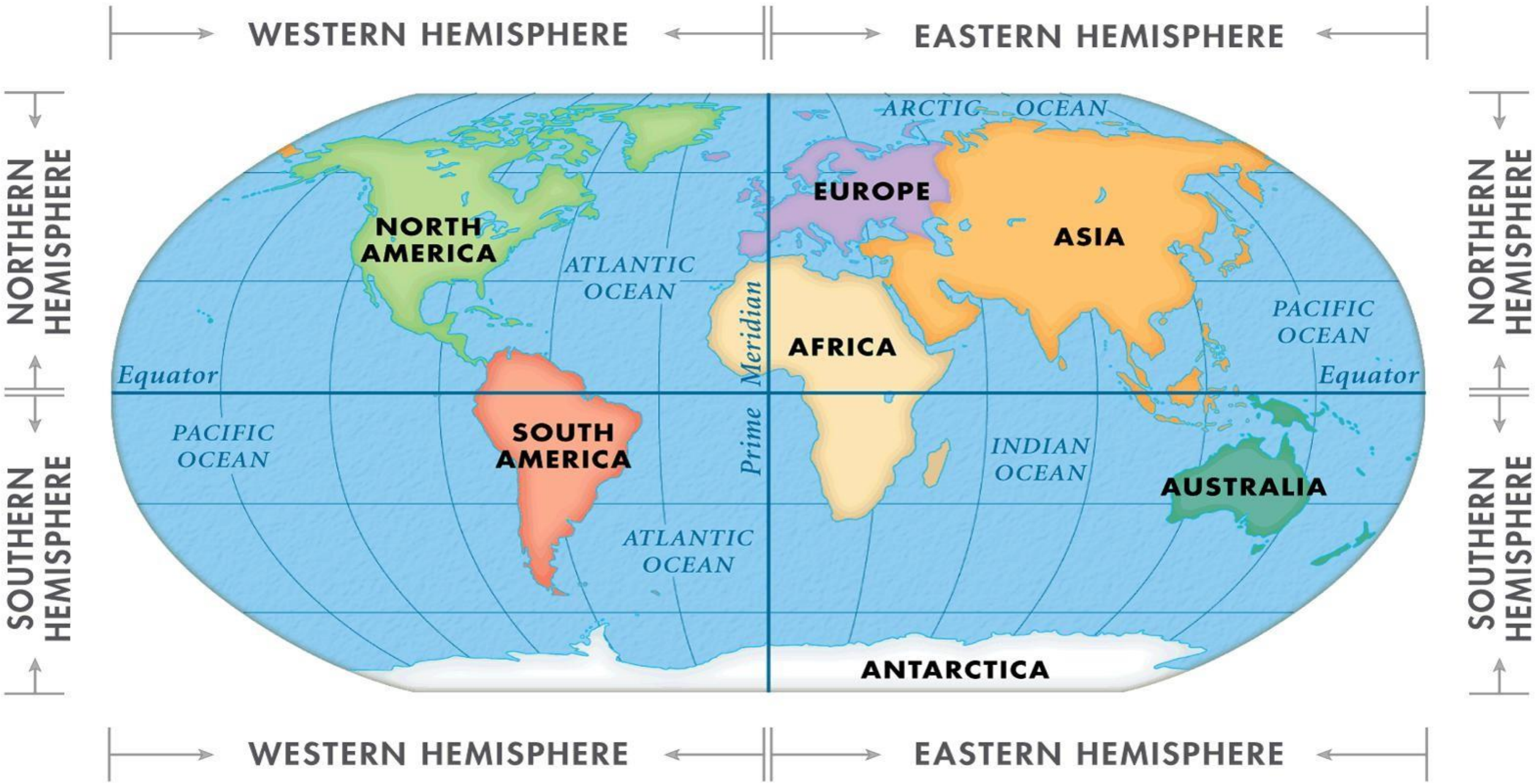
Non-Geostationary orbit

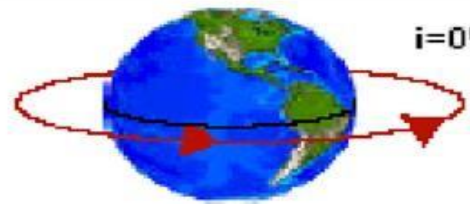
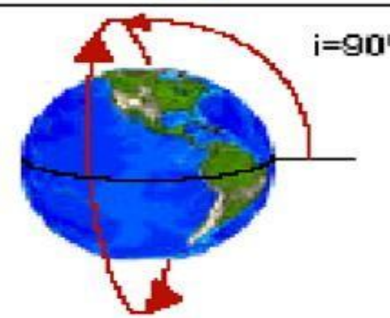
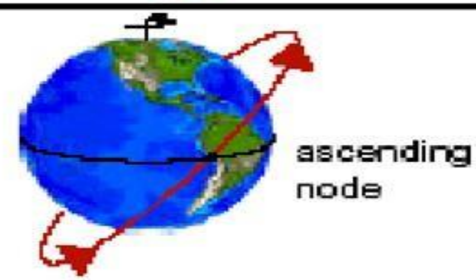
- **Low earth orbit:** A LEO is an orbit around the earth in grids that stretch approximately 160 to 1600 km above the earth surface.
- The LEO satellites are small, are easy to launch and lend themselves to mass product ion techniques.
- A network of LEO satellites typically has the capacity to carry vast amounts of facemile, electronic mail, batch file and broadcast data at great speed and communicate to end users through terrestrial links on ground based stations.

Advantages of Geostationary satellites

- Since the satellite is stationary with respect to one point on the earth, the earth station need not to track the satellite periodically. The earth station antenna can be accurately aimed towards the satellite. This eliminates the need for rotatory antenna and consequently reduces the cost.
- With minimum elevation angle of 5^0, a GSS can cover 38% of the earth surface.
- The effect of the Doppler shift is minimum.
- Three GSS can cover the entire earths surface.

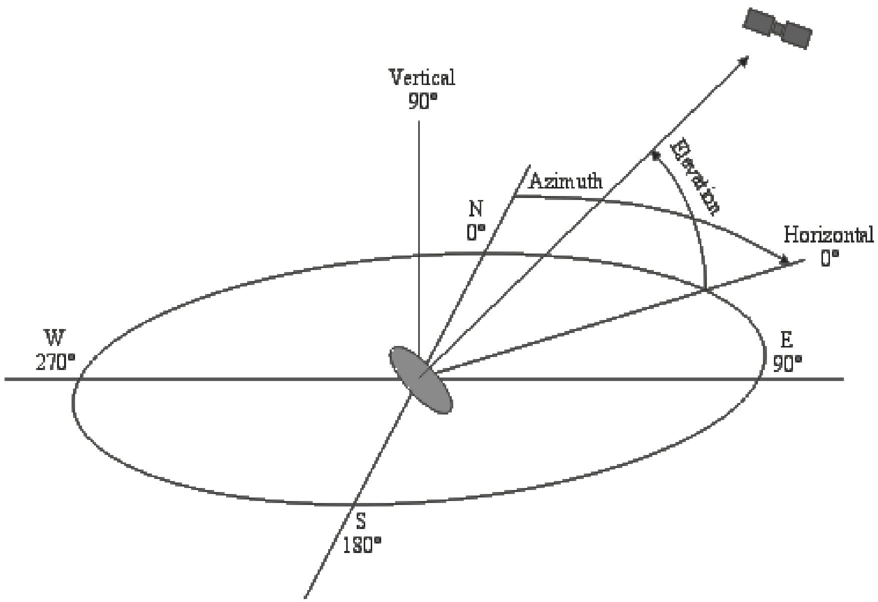
Look Angle Determinations



Inclination	**Orbit Type**	**Diagram**
0° = i = 180°	Equatorial	
i = 90°	Polar	
0° ≤ i < 90°	Direct or posigrade (moves in direction of Earth's rotation)	
90° < i ≤180°	Indirect or retrograde (moves against the direction of Earth's rotation)	

Look Angle Determinations

- The look angles for the ground station antenna are the azimuth and elevation angles required at the antenna so that it points directly at the satellite.



Look Angle Determinations

- The three pieces of information that are needed to determine the look angles for the geostationary orbit are
- *1. The earth-station latitude, denoted here by*
- *2. The earth-station longitude, denoted here by*
- *3. The longitude of the sub satellite point, denoted here by (often this is just referred to as the satellite longitude)*

Look Angle Determinations

- When calculating the look angles for *low-earth-orbit* (LEO) satellites, it was necessary to take into account the variation in earth's radius.
- With the geostationary orbit, this variation has negligible effect on the look angles, and the average radius of the earth will be used.
- Denoting this by R= 6371 km

Heights of GSS

$$a_{GSO} = \left(\frac{\mu P^2}{4\pi^2} \right)^{1/3} \qquad a_E = 6378 km$$

The geostationary height is

$$\begin{aligned} h_{GSO} &= a_{GSO} - a_E \\ &= 42{,}164 - 6378 \\ &= 35{,}786 km \end{aligned}$$

This value is often rounded up to 36,000 km for approximate calculations.

Earth Eclipse of Satellite

- When the sun is crossing the equator, the satellite does pass into the earths shadow at certain periods, these being the period of eclipse.
- Generally, the GSS would be eclipsed by the earth once each day.
- Since earth equatorial plane is tilted at angles of 23.4^0 and this will keep the satellite in view of sun for most of the days in year.
- The eclipse begin 23 days before equinox and end 23 days after equinox.

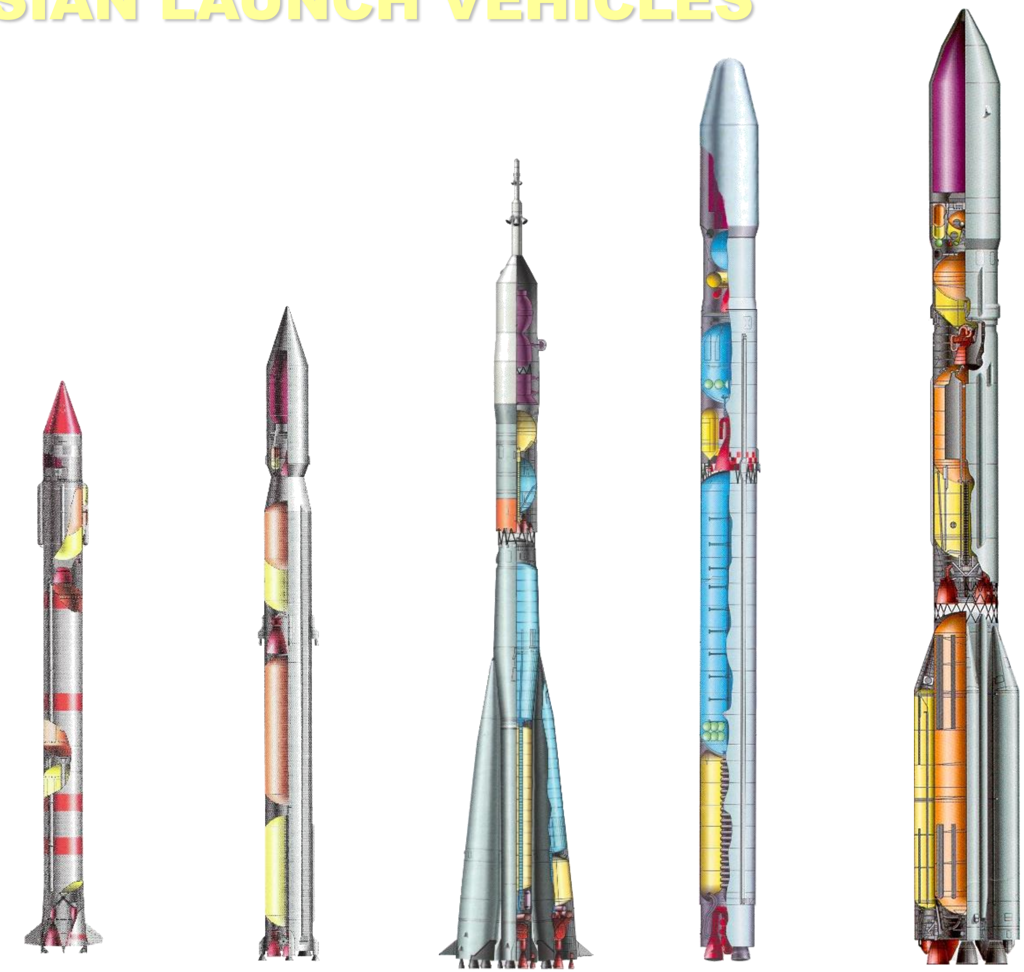
Earth Eclipse of Satellite

- This will last for 10 minutes at the beginning and end of the eclipse period and increases to a maximum duration of about 72 minutes at full eclipse.
- The solar cells do not function during the eclipse and power must supplied from batteries.
- If the satellite longitude is east, then the satellite enters the eclipse during day light hours of the earth station.
- If the satellite longitude is west, then the eclipse does not occurs until the earth station is in darkness.
- The west longitude of the satellite are desirable than the east.

Sun Transit outage

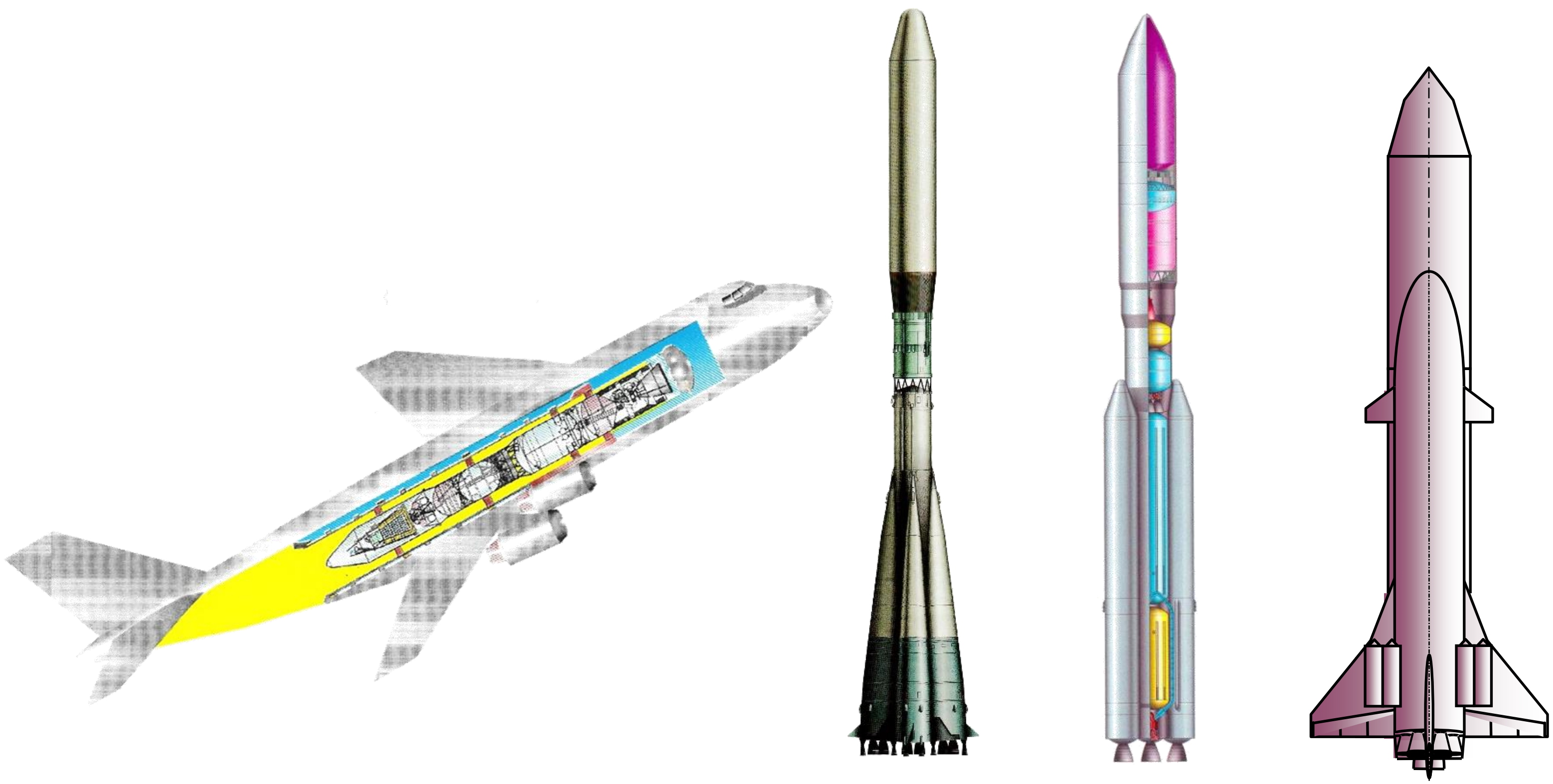
- The sun transit is nothing but the sun comes within the beam width of the earth station antenna.
- During this period the sun behaves like an extremely noisy sources and it blanks out all the signal from the satellite. This effete is termed as *Sun Transit Outage.*
- The duration of the sun transit outage depends on the latitude of the earth station, generally maximum of 10 minutes per day
- Sub Satellite Point: The point on the earth vertically under satellite is referred to as the sub satellite point

PRESENT-DAY RUSSIAN LAUNCH VEHICLES



Launch vehicle	«Kosmos»	«Cyclon»	«Soyuz»	«Zenit»	«Proton»
Takeoff mass, t	108	185	310	460	700
Payload mass, t (H_{cir} = 200 km, i = 51°)	1.4	3.6	7.1	13.7	22

DEVELOPMENT OF NEW RUSSIAN LAUNCH VEHICLES

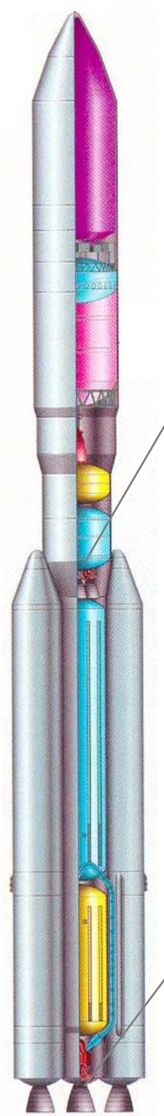


Launch vehicle	«Air start»	«Onega»	«Angara»	(RSRS-1)*
Takeoff mass, t	100	375	770	935
Payload mass, t (Hcir = 200 km, i = 51°)	3.65	12.8	24,5	35

* - **Reusable space rocket system for the first stage**

ENGINES OF "ANGARA-A5" LV

«Angara-A5» LV

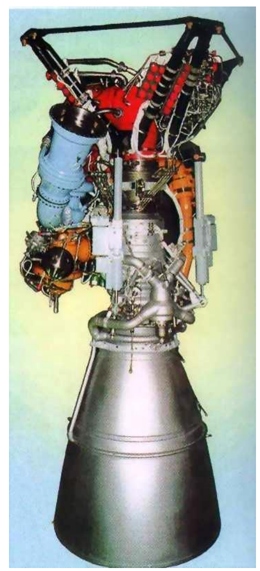


1 x РД-0124
Thrust: 30 tf
I_{sp} ~ 359 s
Propellants: O_2 + kerosene

5 x РД-191
Thrust: 5 x 196 tf
I_{sp} ~ 311 c
Propellants: O_2 + kerosene

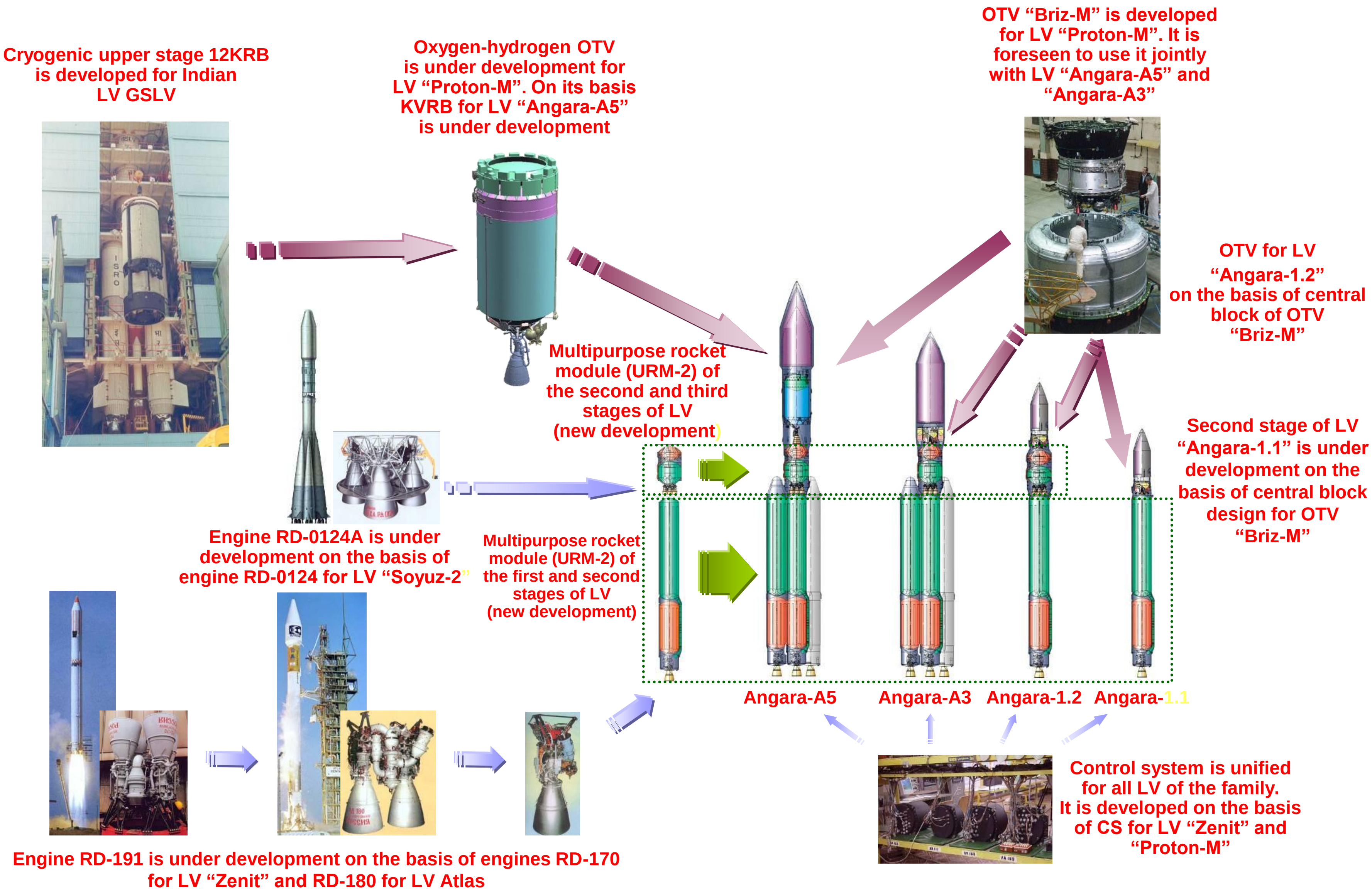
Engines

РД-191



РД-0124

UNIFICATION OF LAUNCH VEHICLES OF “ANGARA” FAMILY. USE OF AVAILABLE SCIENTIFIC AND TECHNICAL WORKS AND TECHNOLOGIES



MAIN TRENDS IN THE FIELD OF ROCKET AND SPACE ENGINE MANUFACTURING

- Increase of engine reliability (no less than 0.997 for sustainer LRE in LV).
- Decrease of engine life cycle cost (development, manufacturing, operation).
- Use of ecological propellant.
- Increase of energy characteristics of engines.
- Decrease of specific mass characteristics of engines.

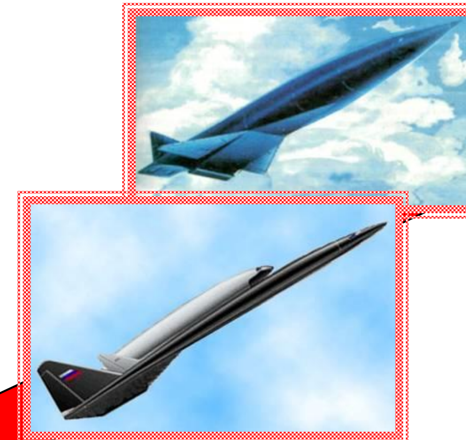
Launch vehicles evolution

From multi-stage launch vehicles with vertical take-off, expendable LRE and SRM…

1957-2000

2015-2020

2025-2035



2030-2040

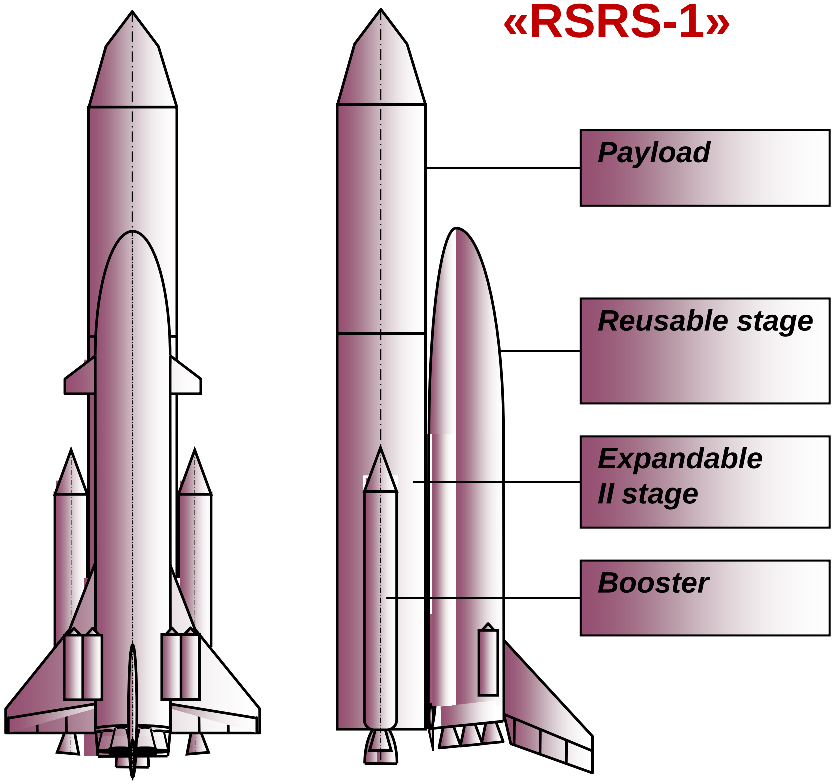
...to single-stage launch vehicles with vertical or horizontal take-off, reusable ABE and LRE

Orbit insertion cost reduction

1 | 0,5 - 0,2 | 0,1 | 0,05 - 0,02

THE FIRST PHASE OF DEVELOPMENT OF REUSABLE SPACE ROCKET SYSTEM RSRS-1

«RSRS-1»



Takeoff mass – 935 t

Payload mass in base line orbit H_{cir} = 200 km – 35 t (50 t when using a solid booster)

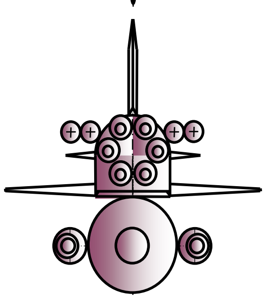
I stage propellants – oxygen and hydrocarbon fuel

II stage propellants – oxygen and hydrogen

Predicted reliability – 0.9995

Reusability of the first stage – 100 return as an aircraft using supplementary turbojet engines

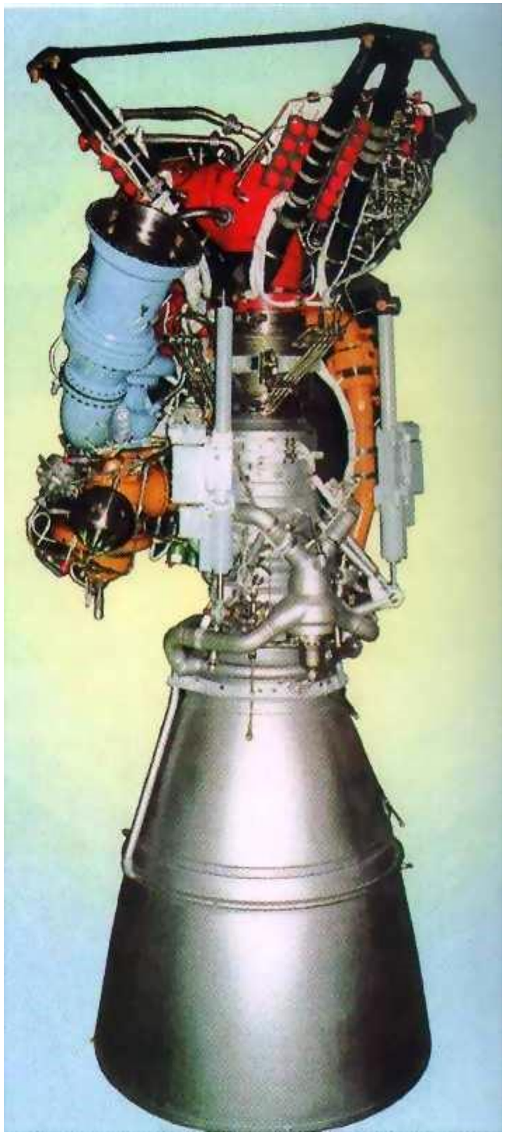
Stage separation speed – 2500 m/s



The cost of SC injection is reduced by nearly half

The mass of payload (delivered and returned) – 12 t

REUSABLE LIQUID-PROPELLANT ENGINES



Problems

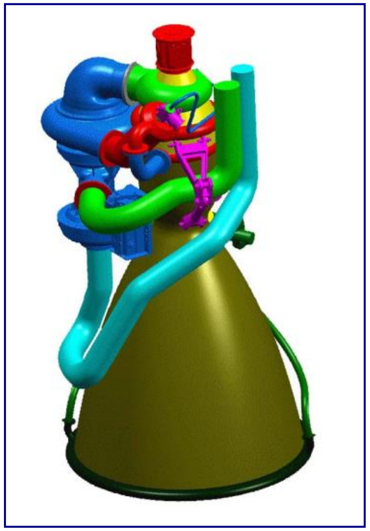
1. **Choice of propellants**
   (oxygen + kerosene, oxygen + metane, oxygen + hydrogen)
2. **Choice of engine cycle**
   (generator gas exhaust cycle, staged combustion cycle, with additional coolant-propellant)
3. **Provision of strength and life characteristics**
   (reusability of engine prior to overhaul ≥ 25)
4. **Minimization of the cost of between – flight servicing**
5. **Metodology of test development**
6. **Ensuring reliability of multi-propulsion systems not less 0.999**
7. **Development of an effective system of diagnostics and emergency protection of engine and propulsion system as a whole**

Reusable Launch Vehicle

Europe-Russia cooperation

Reusable Liquid Rocket Engines	
Propellant	LOX-METHANE
Vacuum Thrust, tf	200 - 400
Vacuum Specific Impulse, s	360
Mixture Ratio	3.5
Dry Engine Mass, kg	5000
Reusability	25

The Launch Vehicle with the winged reusable liquid-propellant booster and a expandable cryogenic stage



To provide development of the oxygen - methane engine, the following scientific and technical problems are solved:

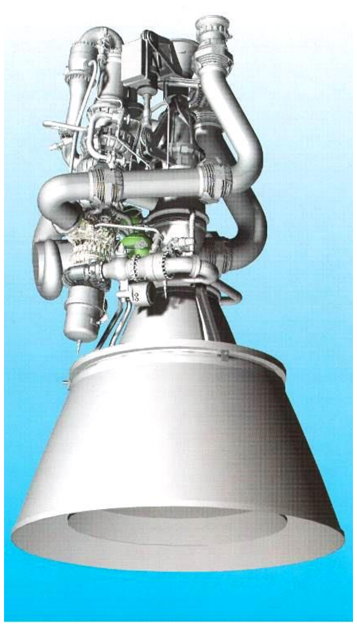
- fuel-rich gas generation;
- atomizing process (efficiency of working process in a combustion chamber $\varphi c = 0.98$);
- chamber cooling (high cooling properties of methane and its thermal stability)
- reliable ignition system

Available base

- Experience in cycle-design study on Propulsion System
- Tests of model engines on methane fuel

Introduction of composites to use them in PS with LRE

Nozzles	Tanks



On June 10, 2003, within the programme “Sea Launch” the РД-58 engine was successfully fired with a nozzle extension made from carbon-carbon composite as a part of the DM-SL orbital transfer stage.

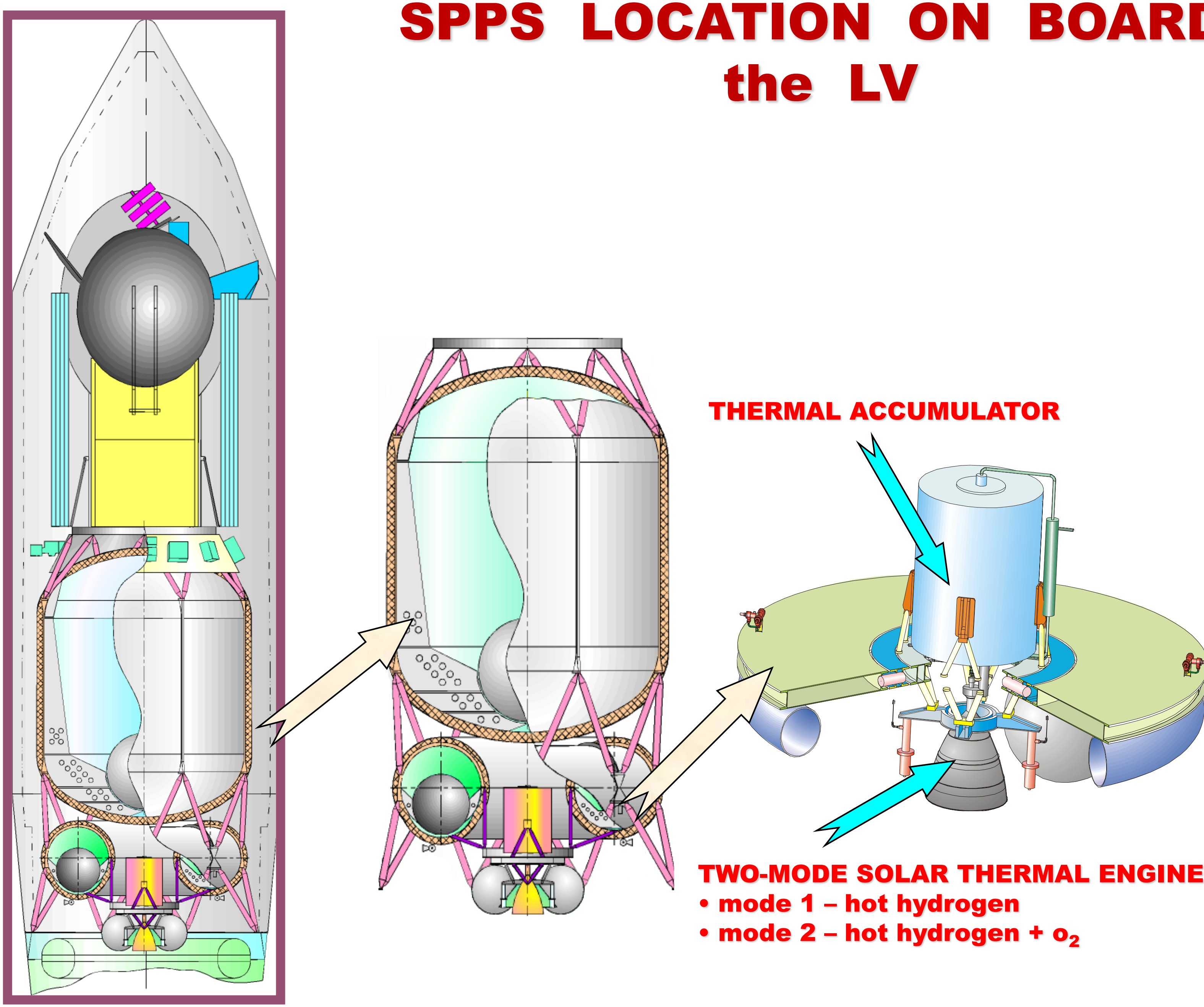
Patent 2196917

Variable-geometry nozzles
(expandable extensions from carbon-carbon composite)

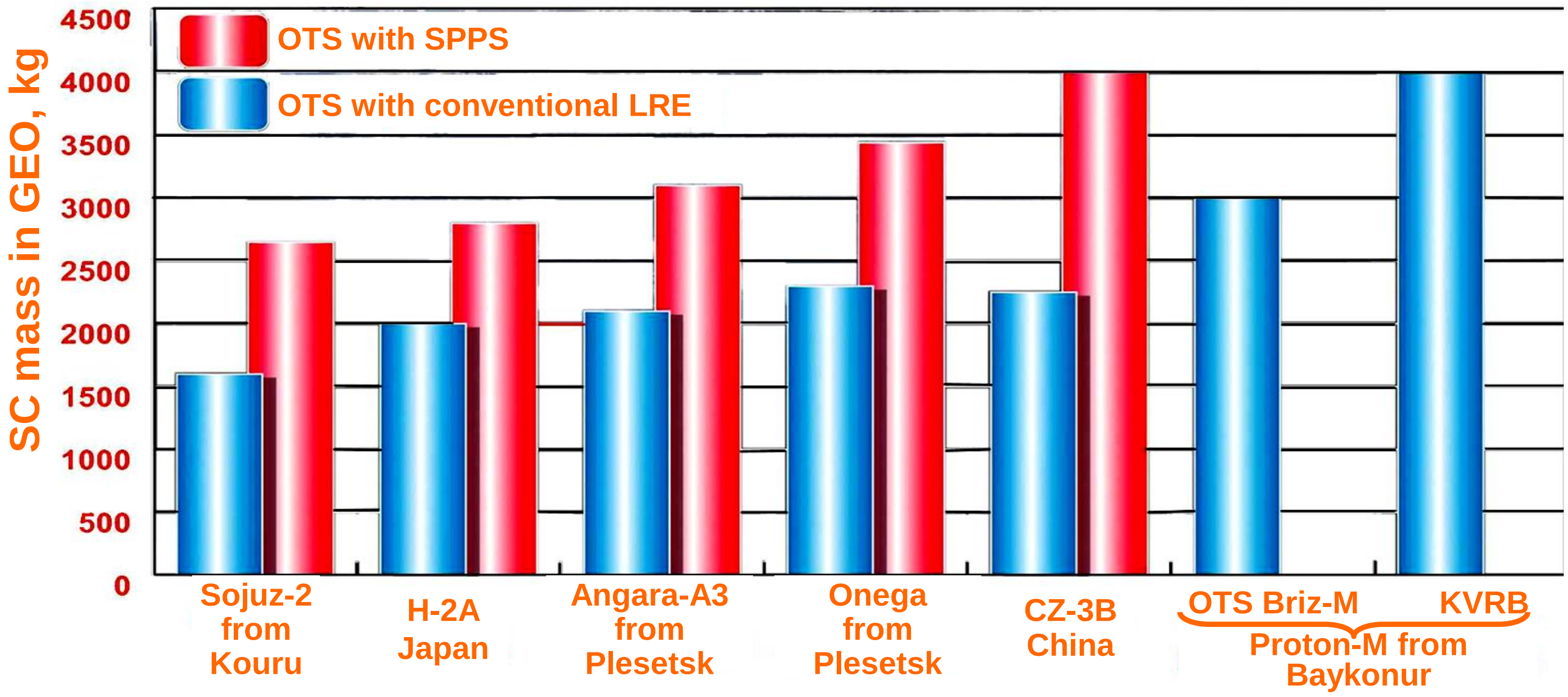
Model tank from organic plastic with a combined pressure shell

SOLAR THERMAL PS
(SPPS)

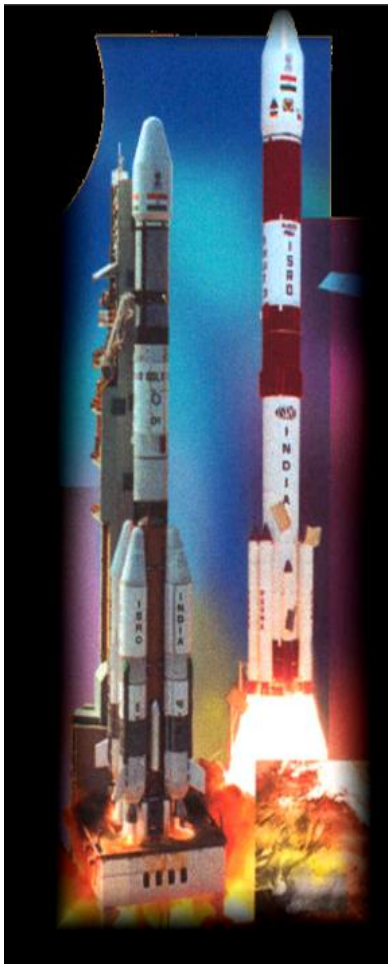
SPPS LOCATION ON BOARD the LV

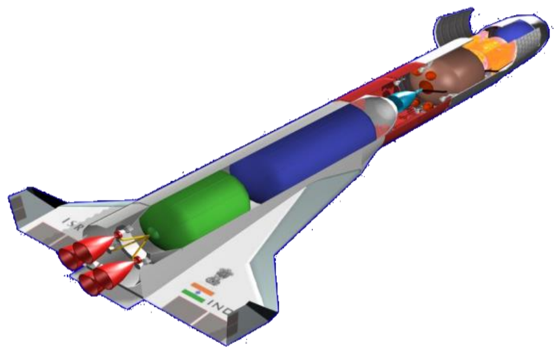


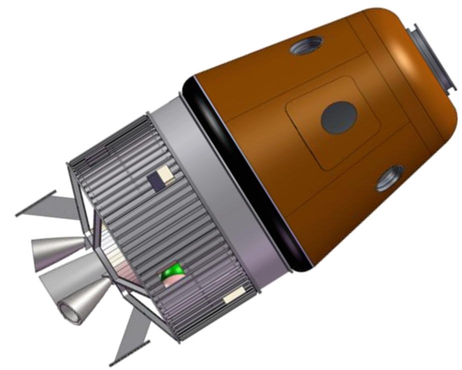
SOLAR POWER PROPULSION SYSTEM FOR ORBITAL TRANSFER STAGES (OTS)



Indian Space Transportation System
Present Scenario and Future Directions







Rocket by Tippu Sultan

- He used world's first war rocket against the British.
- A long bamboo stick using 2 kg gun powder as rocket & sword as its weapon.
- Each rocket weighed 3.5 kg and traveled 1.5 km.
- An outstanding performance.
- Multiple rockets fired at the same time pierced through the British cavalry.

- Tippu's rocket is displayed at the Artillery Museum in Woolwich, London.

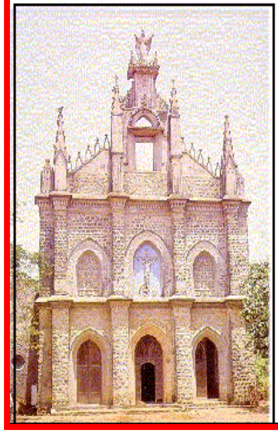
Four decades of indian Rocketry

One among the six Nations

First launch of Nike Apache on 21st Nov 1963

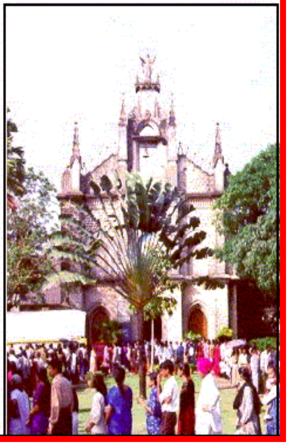
Evolution of Rocketry in India

1963 In the beginning the St. Mary Magdalene Church at Thumba served as the office and laboratories



In 1962 a church

From 1988 onwards a space museum

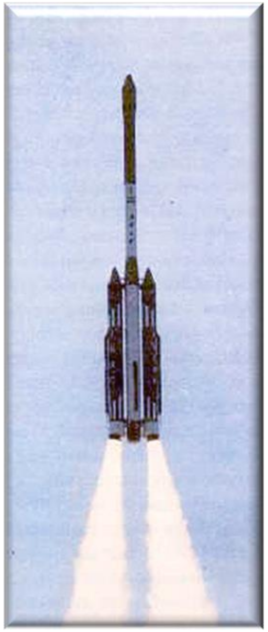


Humble beginning : 28 launches so far

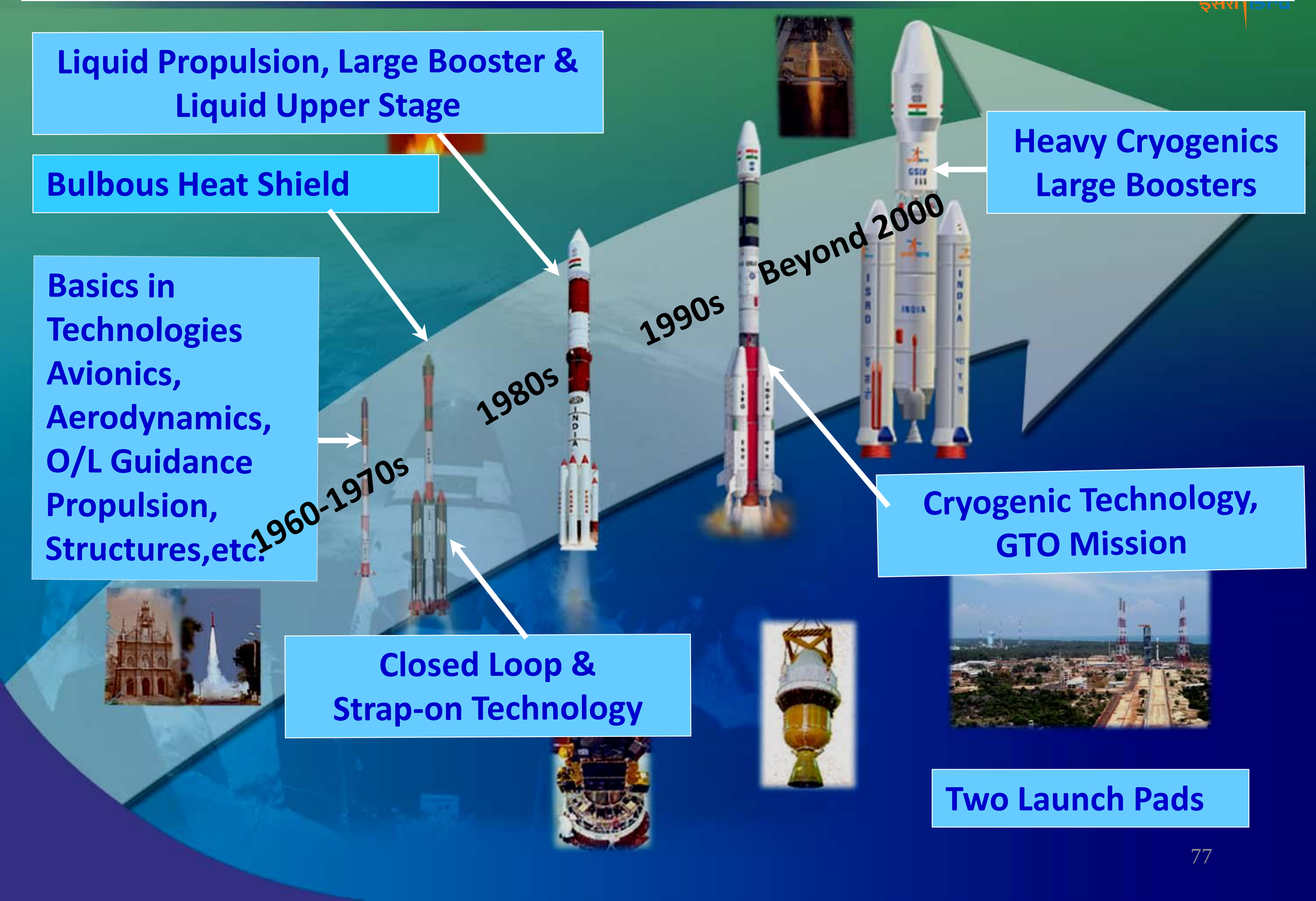
Sounding Rockets of ISRO

Features	RH-200	RH-300	RH-300 MK II	RH-560 MK II
No. of stages	2	1	1	2
Length (m)	3.6	4.8	4.9	7.7
Lift-off weight (kg)	108	370	510	1350
Payload Wt. (kg)	10	60	70	100
Altitude (km)	85	100	150	550
Application	Meteorology	Middle Atmosphere	Middle Atmosphere	Ionosphere

ISRO Launch Vehicle Family

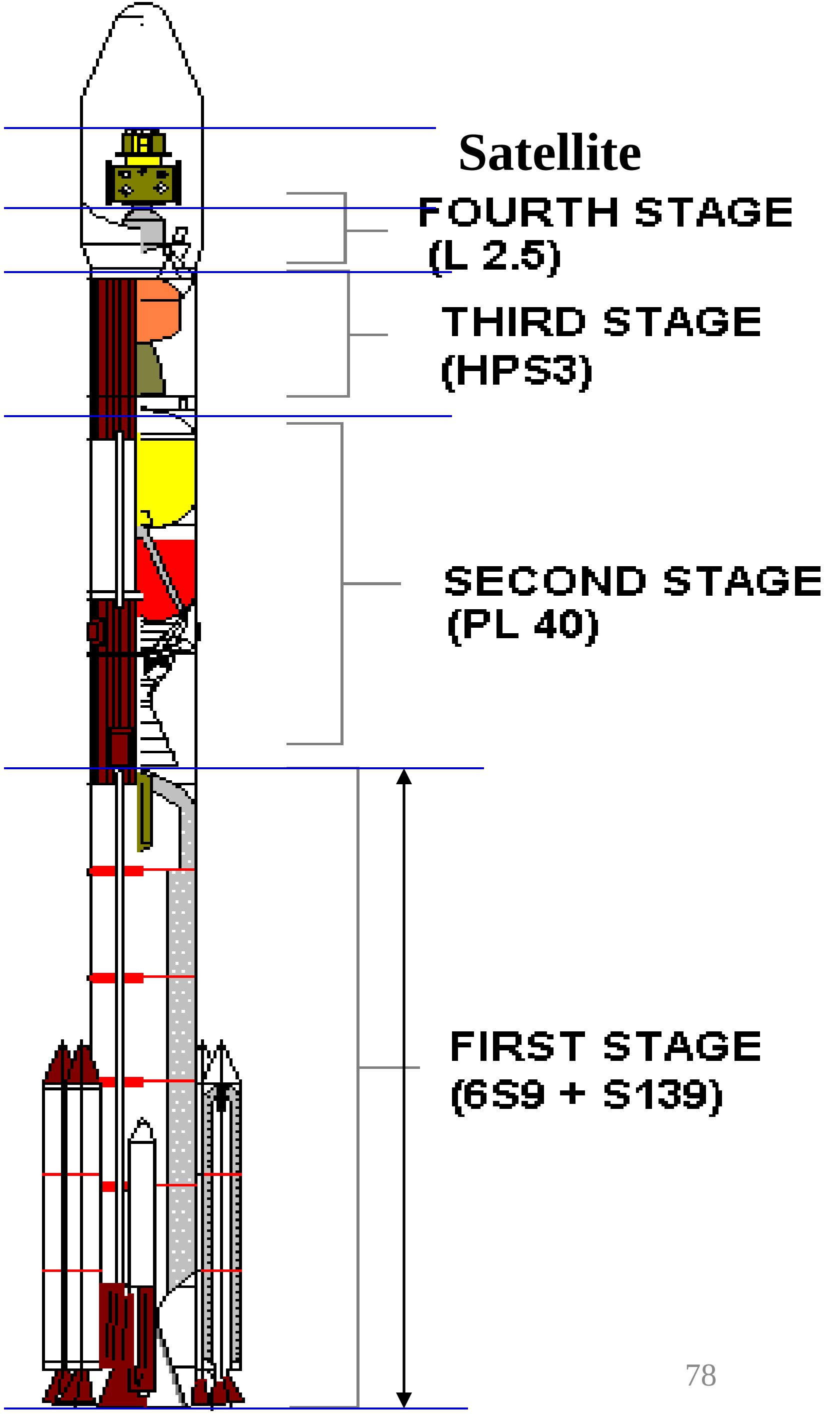
	Aug 1979 /July 1980	May 1992	Oct 1994	Apr 2001	Middle 2010
	SLV	ASLV	PSLV	GSLV	GSLV Mk-III
					
	4(1)	4(2)	15(1)	5(1)	
Height (m)	22	23.5	44	49	42.43
Lift-off wt(t)	17	39	295	414	632
Payload kg	40	150	1400	2000	4000
Orbit	LEO	LEO	POLAR	GTO	GTO

Technology Progression in Launch Vehicle Development

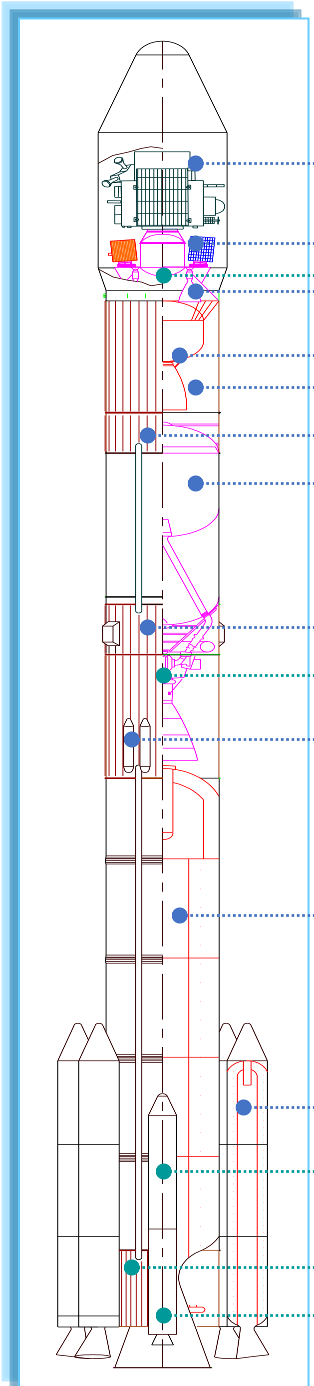


PSLV Configuration

- 6S9 + S139 + PL40 + HPS3 +L2.5
- Gross weight : 294 T
- Overall height: 44 m
- Diameter :   2.8 m
- Heatshield: 3.2 m
- Features :
  - 4 stage vehicle
  - Multiple satellite launch capability
  - Multi orbit capability
  - Performance :
    - GTO : 1.2 T
    - SSPO : 1.7 T



Important elements of PSLV



A
1. Payload
2. Heat shield
3. Payload adapter
4. Equipment bay
5. Auxiliary payload

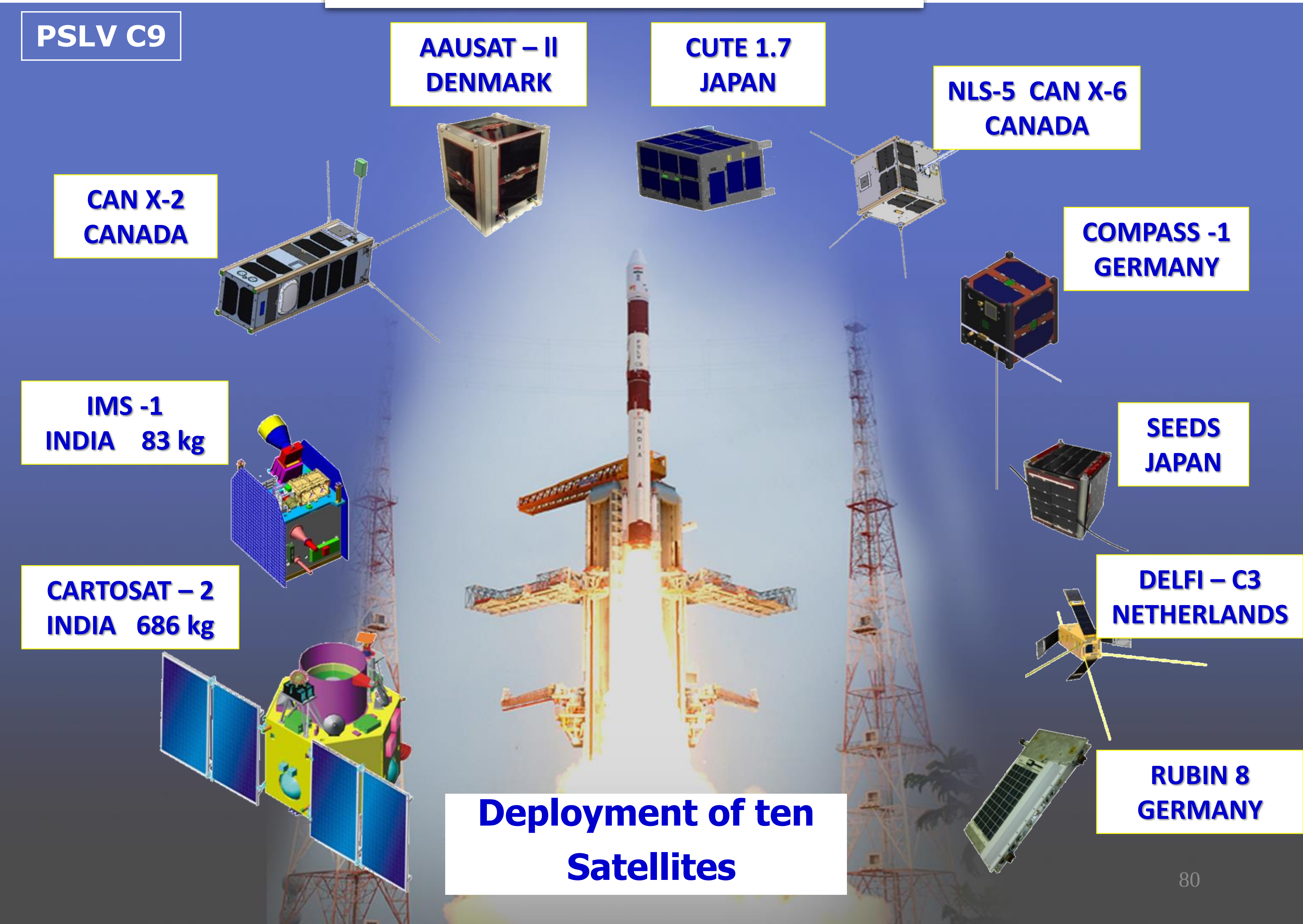
B
6. 4th stage tank
7. 4th stage engine

C
8. Antennae
9. Reaction thruster
10. Interstage 3/4
11. 3rd stage adapter

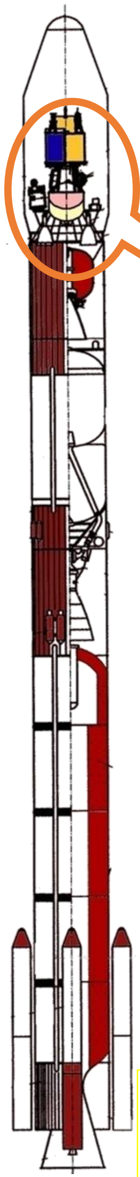
D
12. 3rd stage motor
13. Flex nozzle control
14. Interstage 2/3 U
15. Interstage 2/3 L
16. 2nd stage tank
17. Interstage ½ U
18. 2nd stage retros
19. Ullage rocket (4)
20. Gimbal control
21. Interstage ½ L
22. 2nd stage engine
23. 1st stage retro
24. First stage motor
25. TVC injectant tank
26. Strap-on motor
27. TVC system
28. Core base shroud
29. Roll control engine

Red – Control and Guidance Subsystems
Green – Propulsion Subsystems

PSLV : Commercial phase



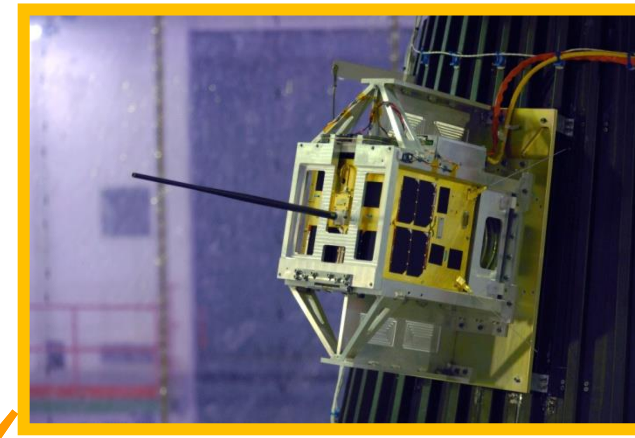
PSLV C9: Spacecraft accommodation

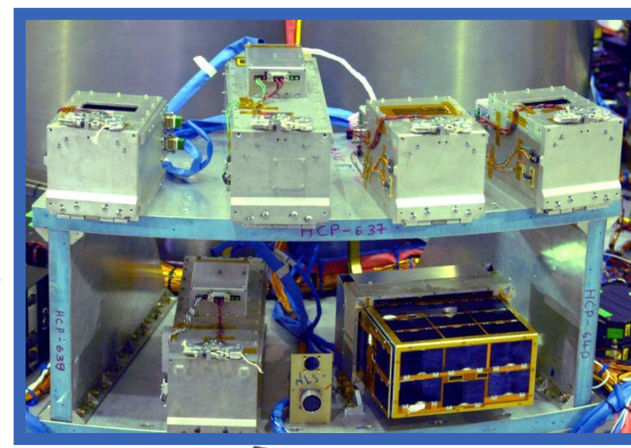


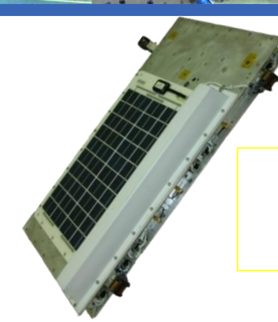
CARTOSAT – 2
INDIA 686 kg

IMS -1
INDIA 83 kg

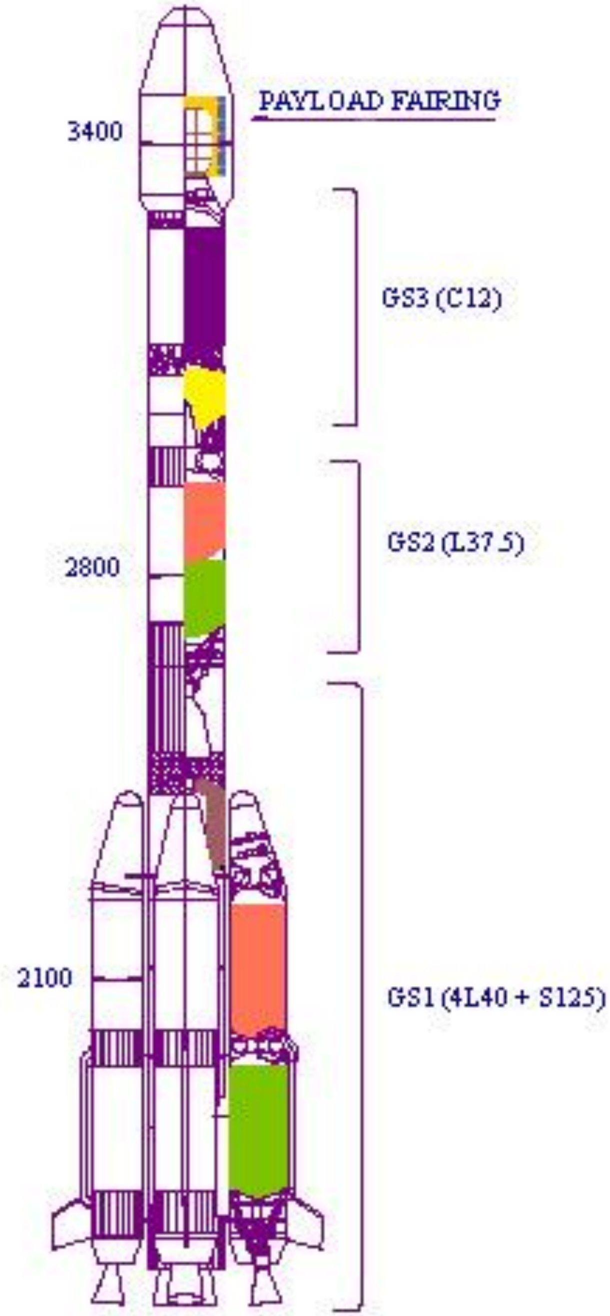
NLS-5







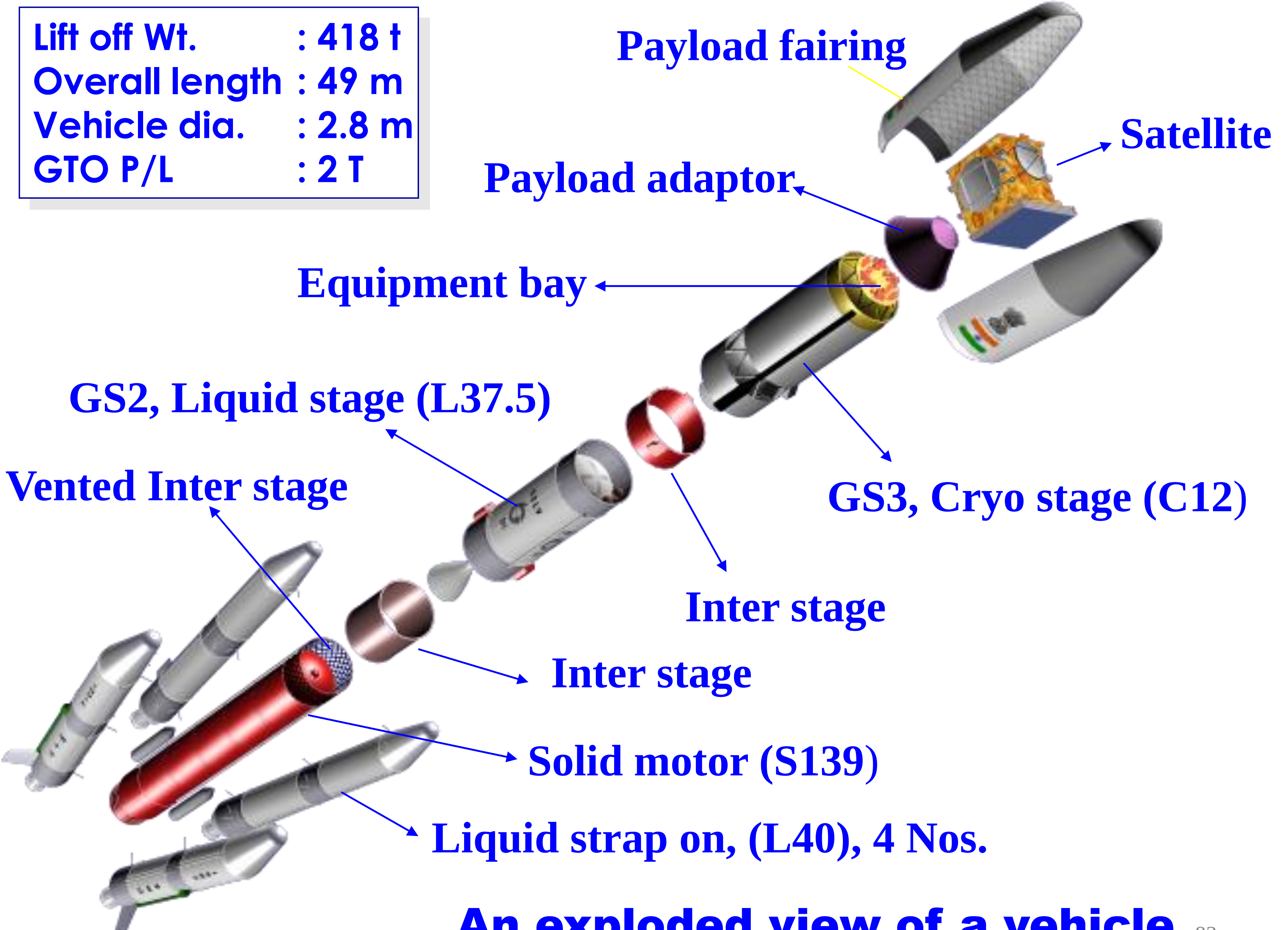
RUBIN 8
GERMANY



GSLV Configuration

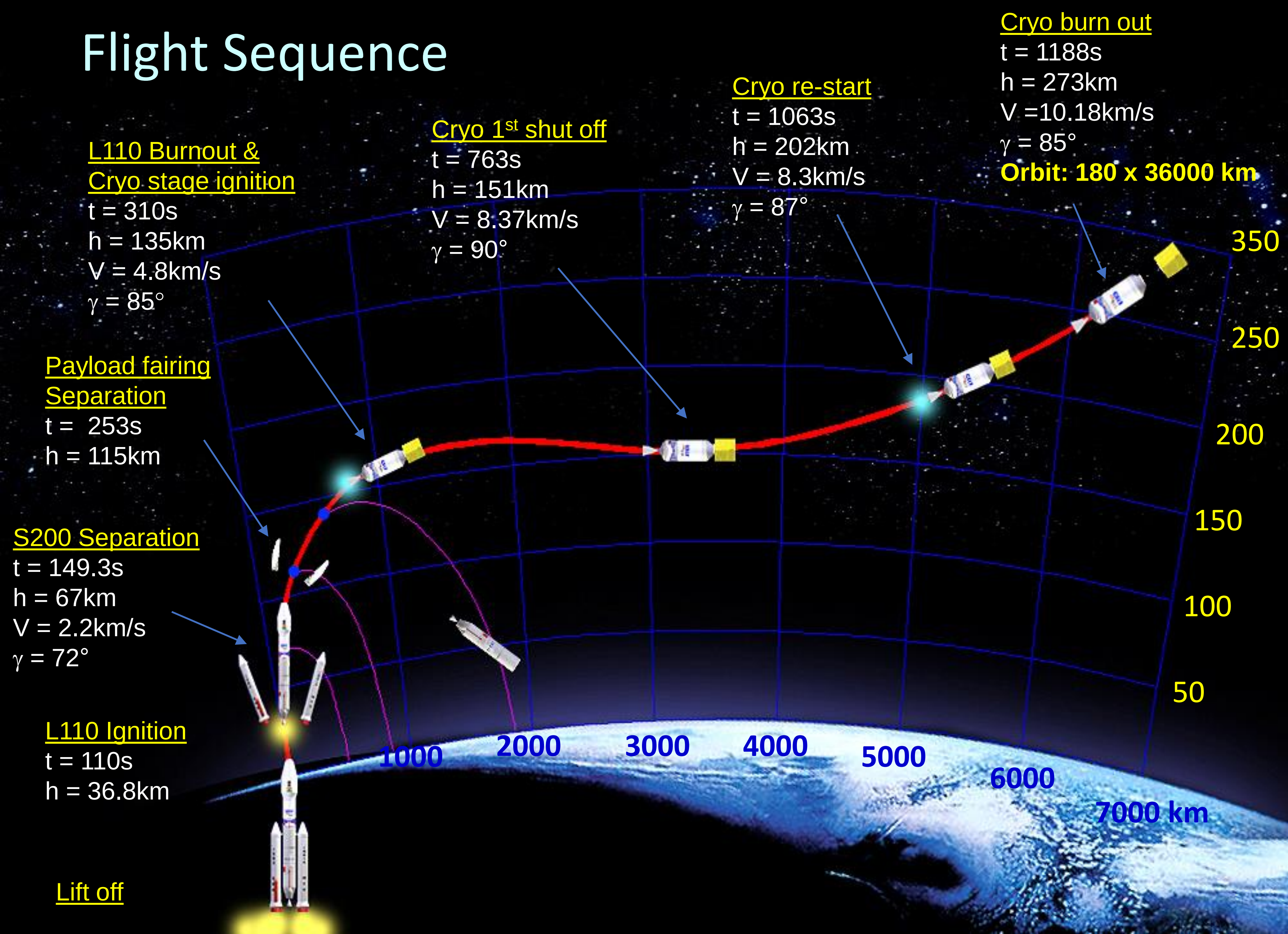
- **4L40 + S125 + L37.5 + C12**
  - **LOW : 414 T**
  - **Diameter : 3.4 m**
  - **Heatshield : 3.8 m**
- **Features :**
  - **3 stage vehicle**
  - **Performance :**
  - **GTO : 2 t.**
- **Performance growth**
  - **Potential : 2.5 t (with indigenous Cryo stage**

Lift off Wt.	: 418 t
Overall length	: 49 m
Vehicle dia.	: 2.8 m
GTO P/L	: 2 T



An exploded view of a vehicle

Flight Sequence

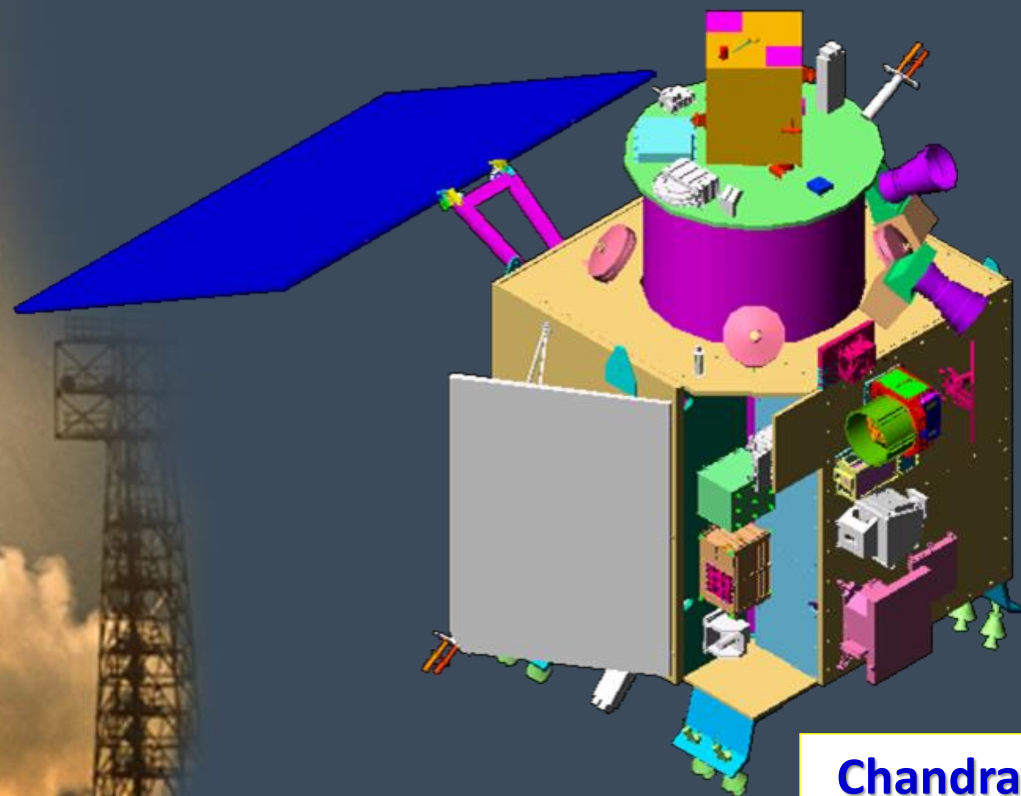


Indigenous Cryo Stage Development

- **Detailed qualifications tests have been carried out in engine in several ground tests.**
- **Flight stage is getting ready and expected to fly by September 2009.**

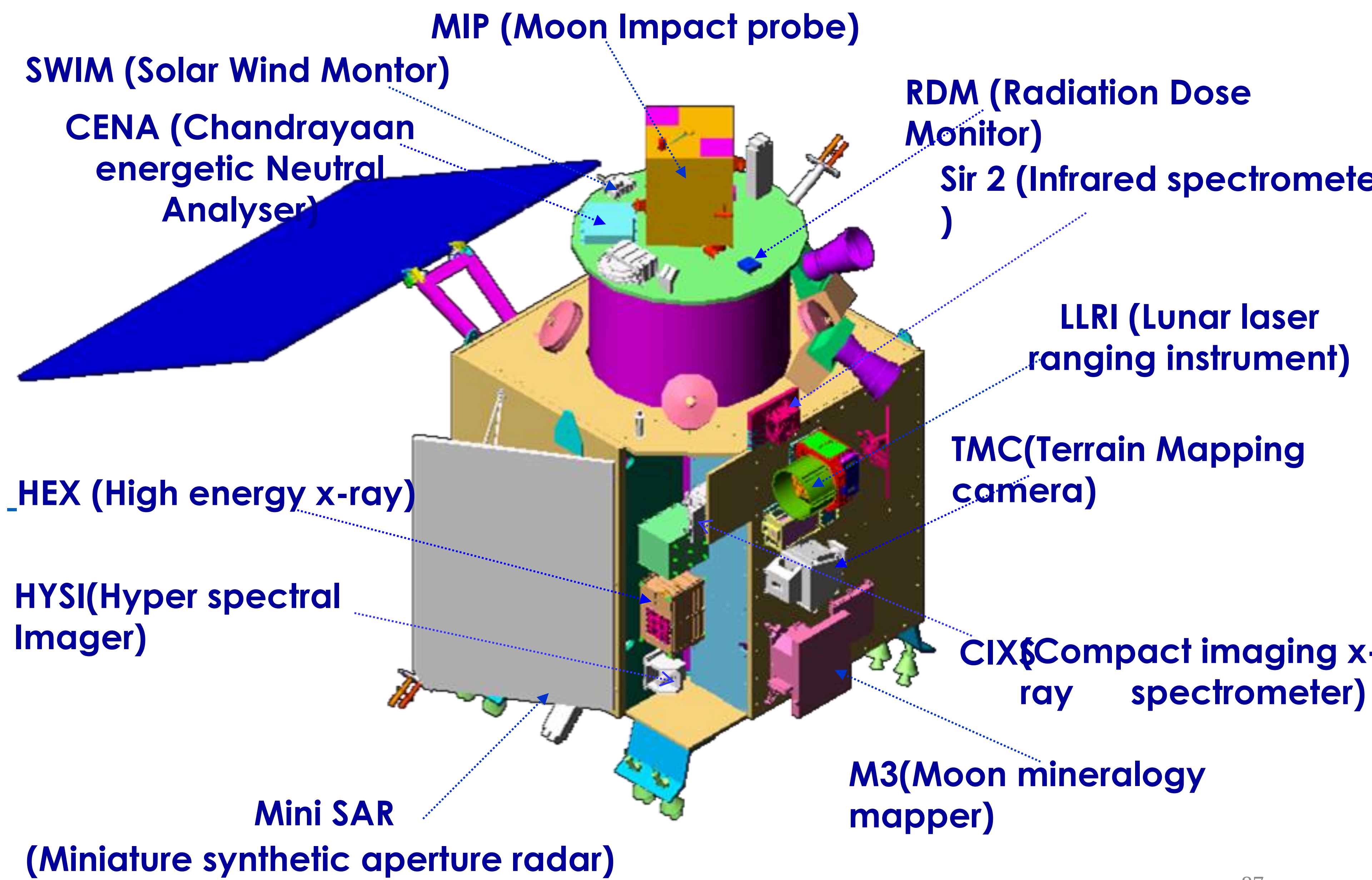
Chandrayaan 1

- Launched by PSLV 11: 313 t
- Date of Launch : 22nd Oct 2008



Chandrayaan 1
India 1380 kg

Chandrayaan-1 Payloads

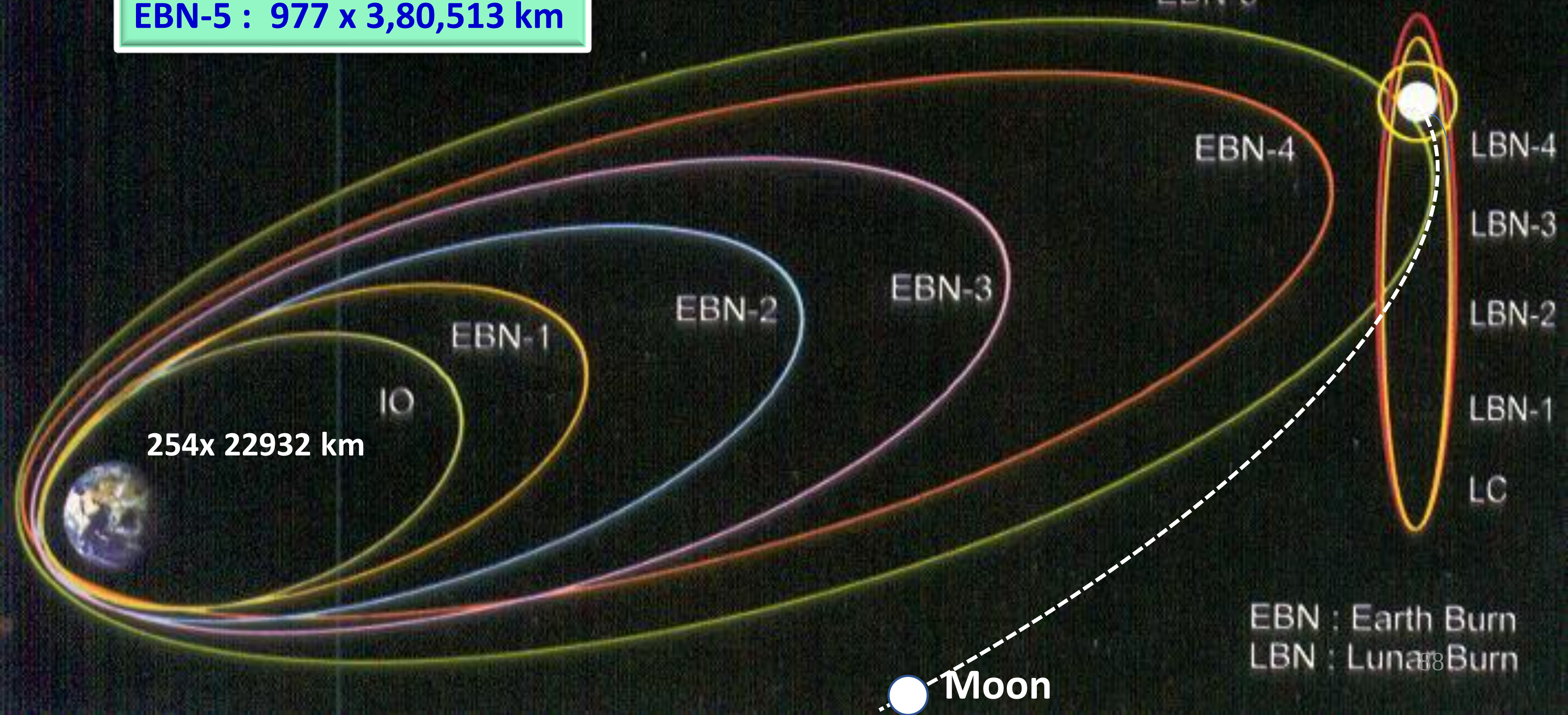


Chandrayaan 1 Mission Profile

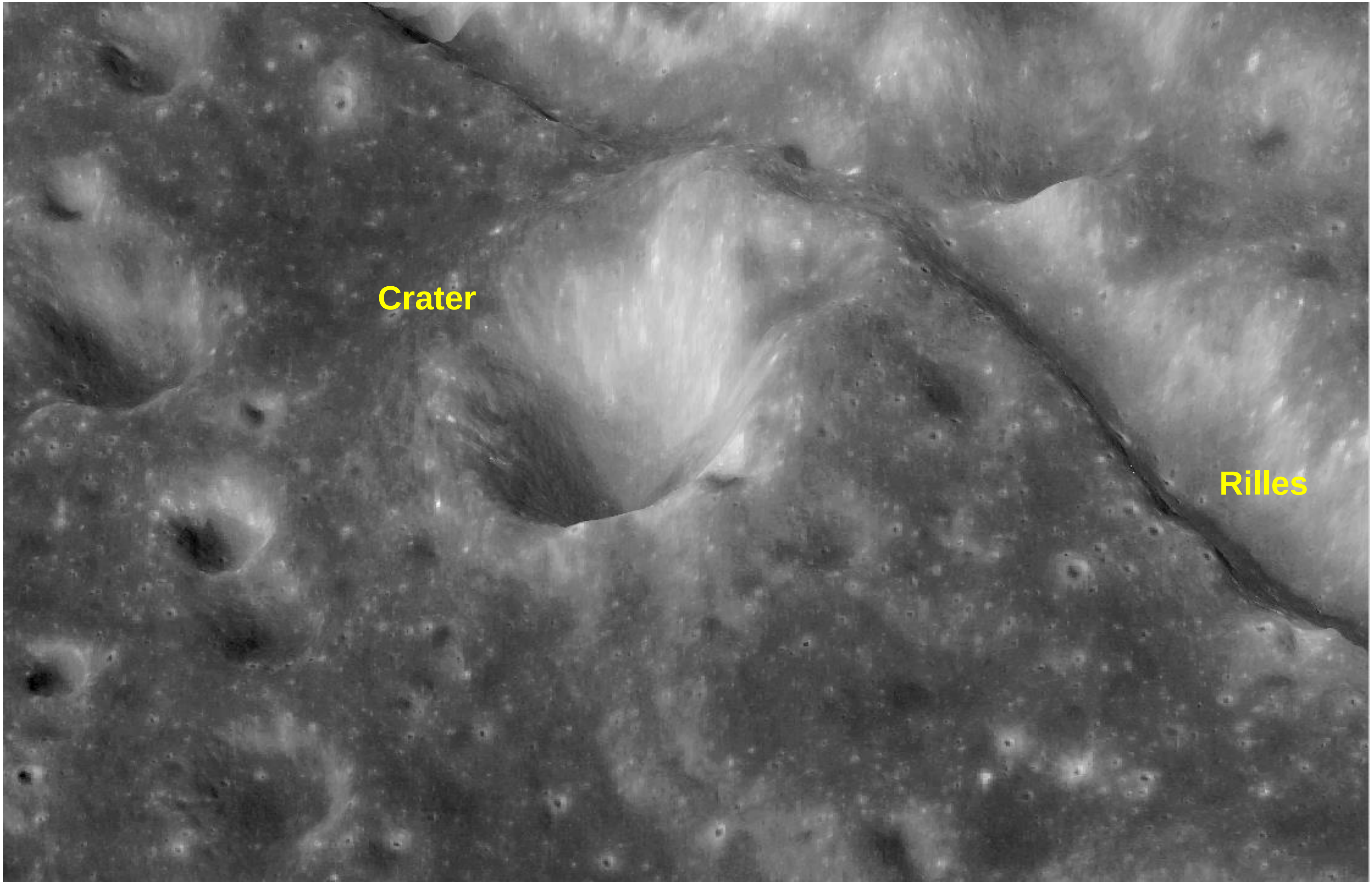
IO	: 254x 22,932	km
EBN-1	: 301 x 37,832	km
EBN-2	: 336 x 74,716	km
EBN-3	: 348 x 1,65,016	km
EBN-4	: 460 x 2,66,509	km
EBN-5	: 977 x 3,80,513	km

8th Nov 2008

LC	: 508 x 7510	km
LBN-1	: 201 x 7502	km
LBN-2	: 183 x 255	km
LBN-3	: 102 x 255	km
LBN-4	: 102 x 103	km

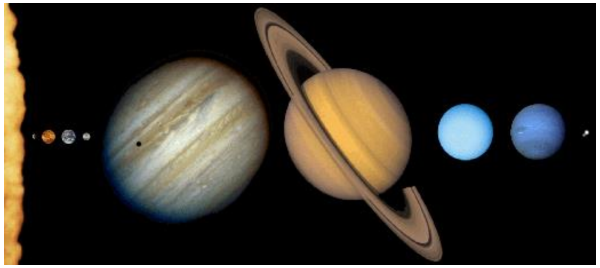


Chandrayaan1: 3D-view of crater on moon



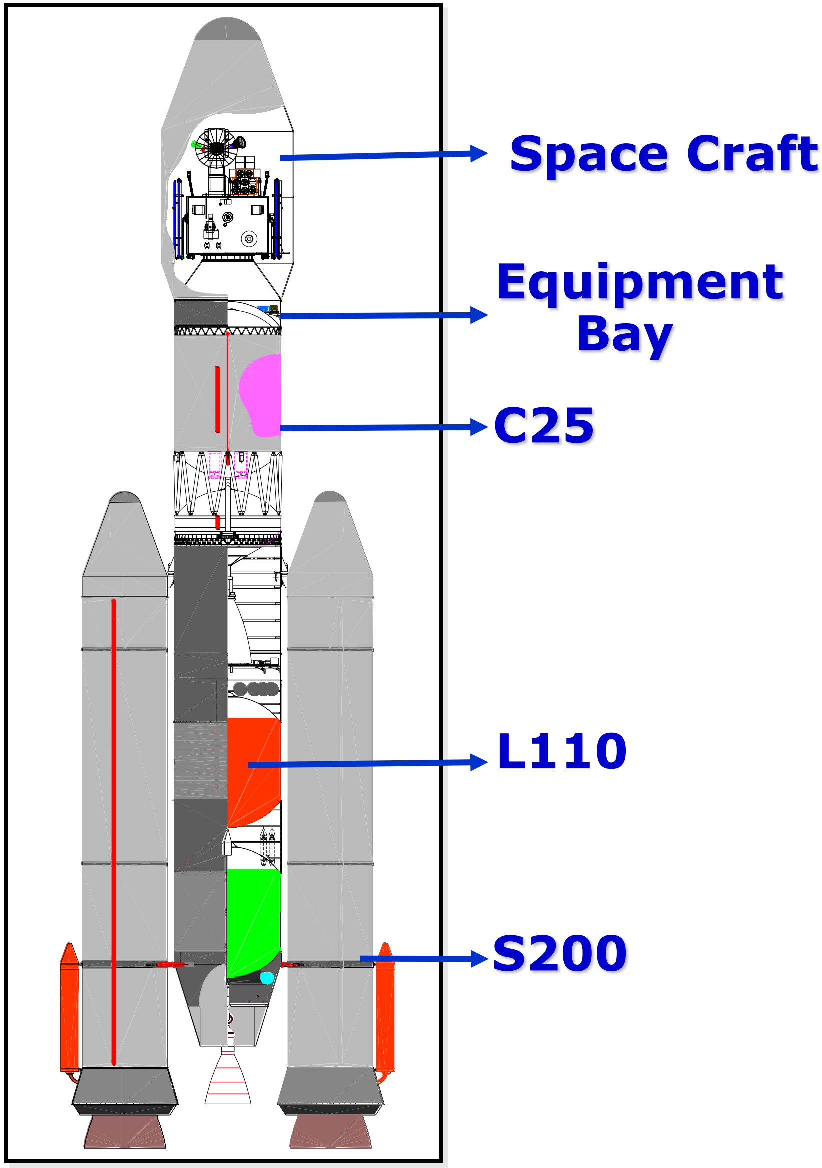
Terrain Mapping Camera : 5M resolution; Area – 5 X 4.5 Km; Date of pass - Nov 23, 2008

Missions to Mars, Venus, Asteroids



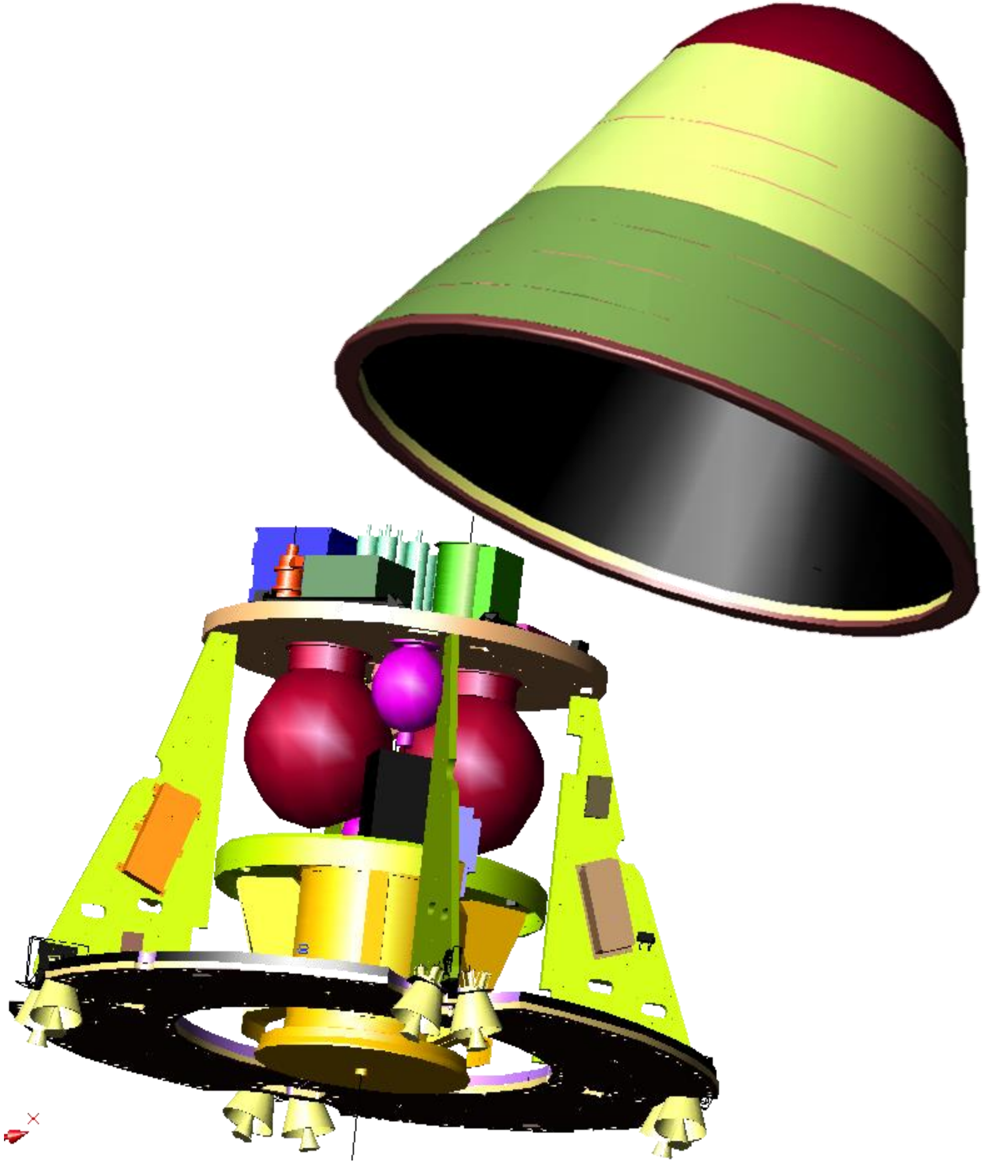
Flyby Capabilities (kg)			Orbital Capabilities (kg)			
Mars	Venus	Asteroid		Mars	Venus	Asteroid
728-777	717-766	556-862	PSLV	172-213	107-146	80-186
1219-1302	1260-1346	625-1514	GSLV	402-584	247-328	150-443
2617-2793	2705-2890	1342-3250	Mk III	882-1060	542-719	182-972

GSLV MK-III

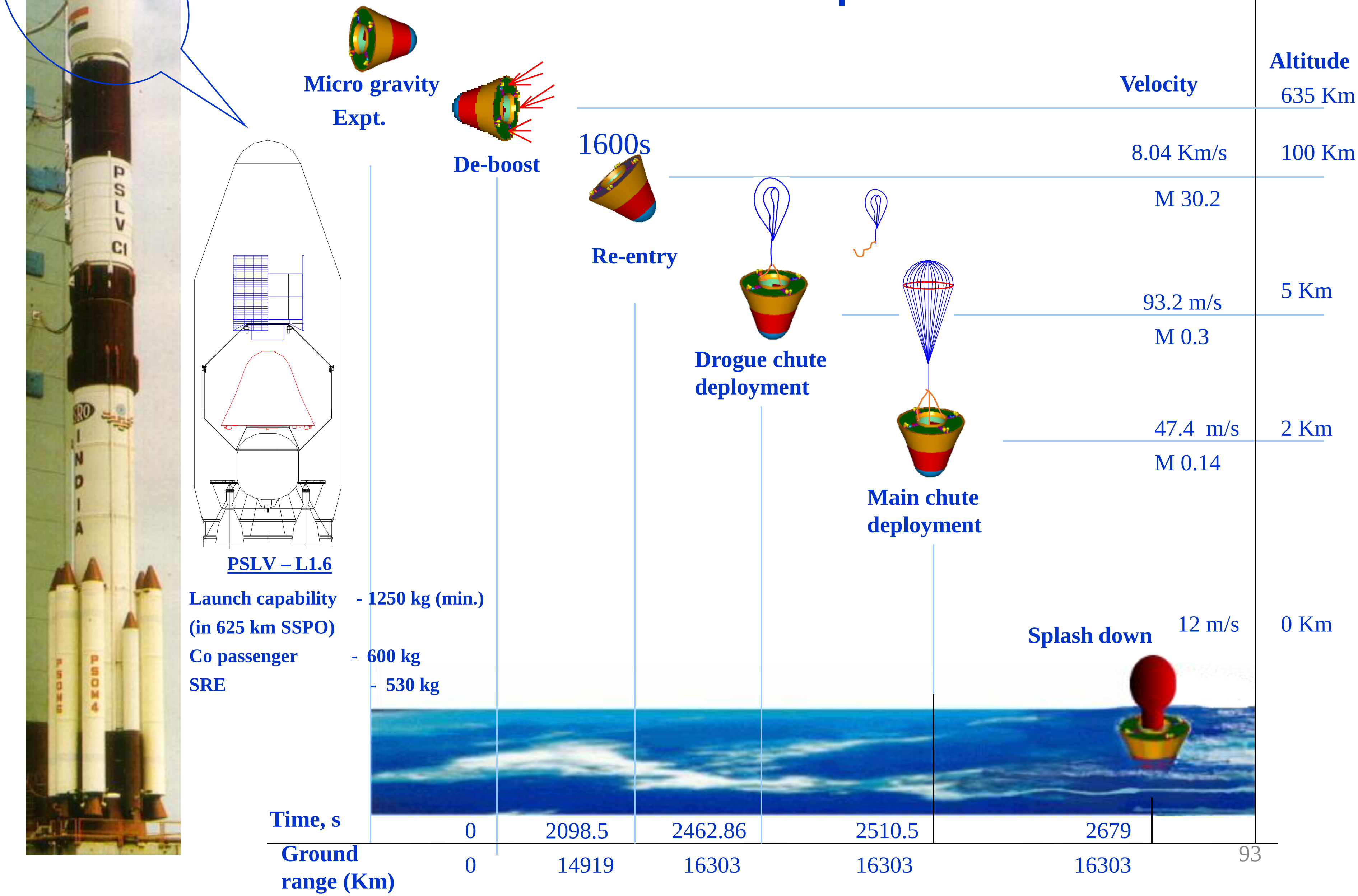


- 2S200 + L110 + C25
- GLOW : 620 T
- MAX Dia :4 m
- Features :
  - 3 stage vehicle
  - Safe impact of all stages
  - Performance :
    - GTO P/L : 4.5 t
    - 400 km LEO : 10 T
    - Performance growth potential : 5 to 6 t

SRE -Configuration

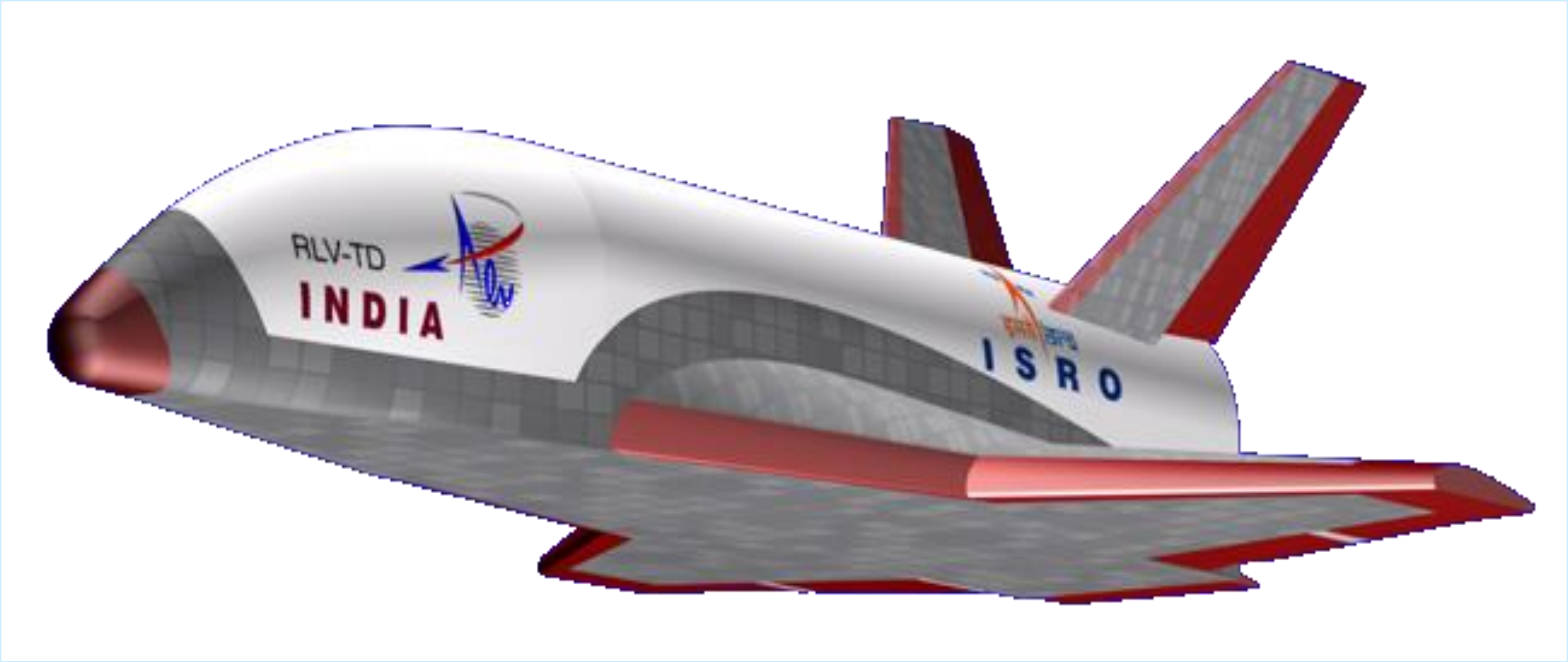


Space capsule Recovery Experiment (SRE) Mission Sequence



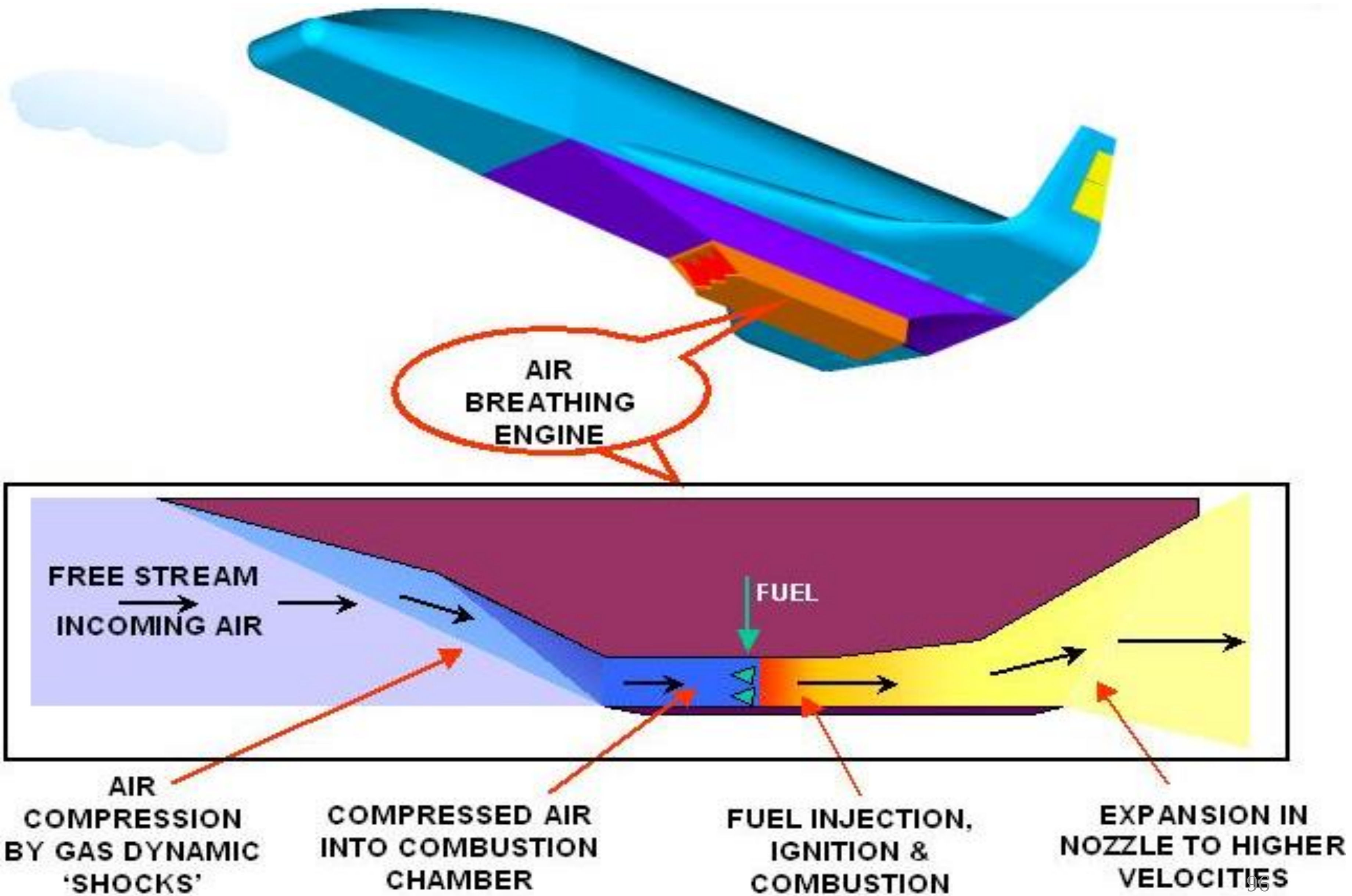
SRE-1 Return to earth 2007

Reusable Launch Vehicle



... for repeated use of the costly hardware

Reusable Launch Vehicle using Air Breathing Propulsion

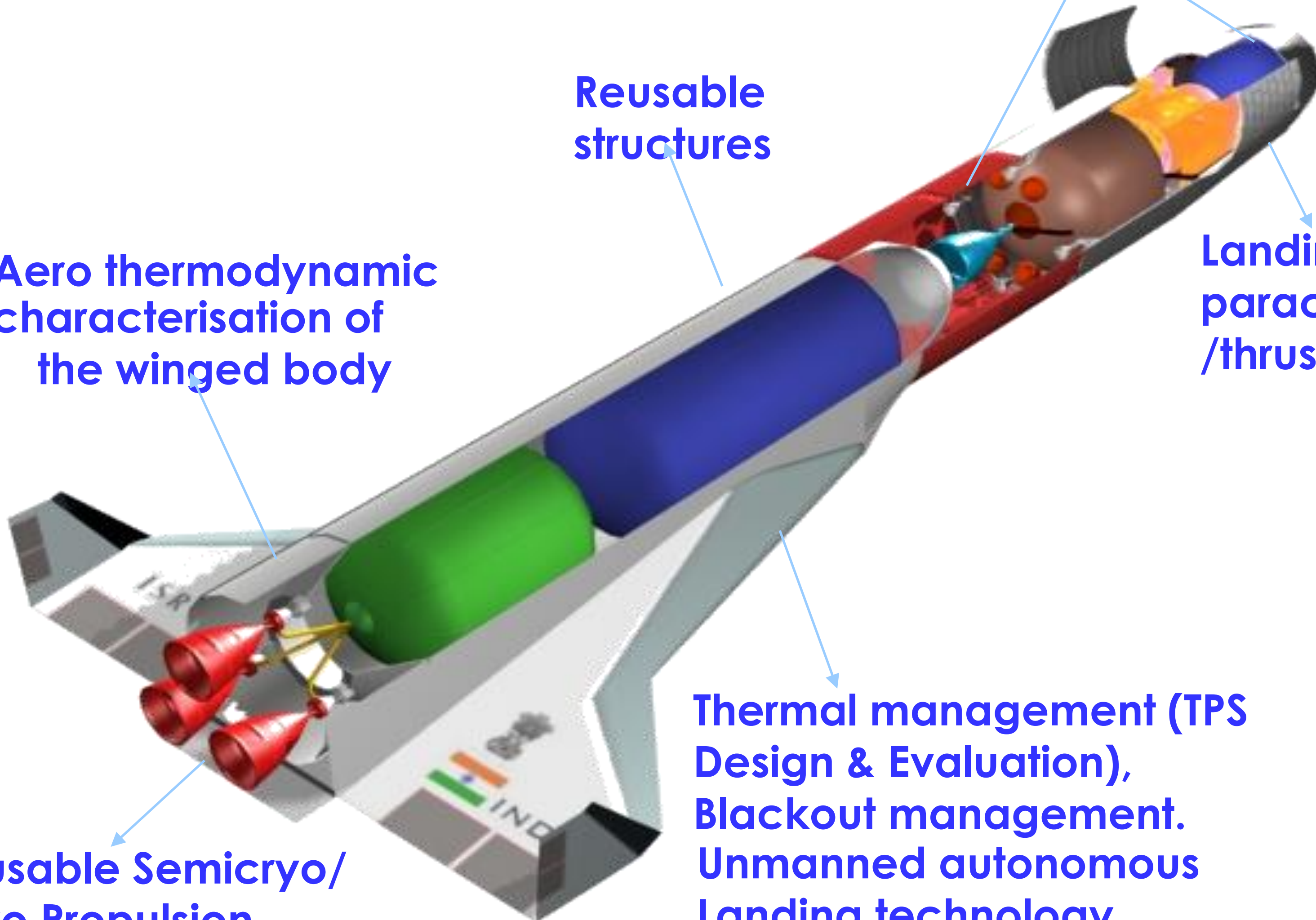


Two Stage To Orbit (TSTO)

NG&C during re-entry, gliding, cruise, approach & landing regimes

Reusable structures

Aero thermodynamic characterisation of the winged body

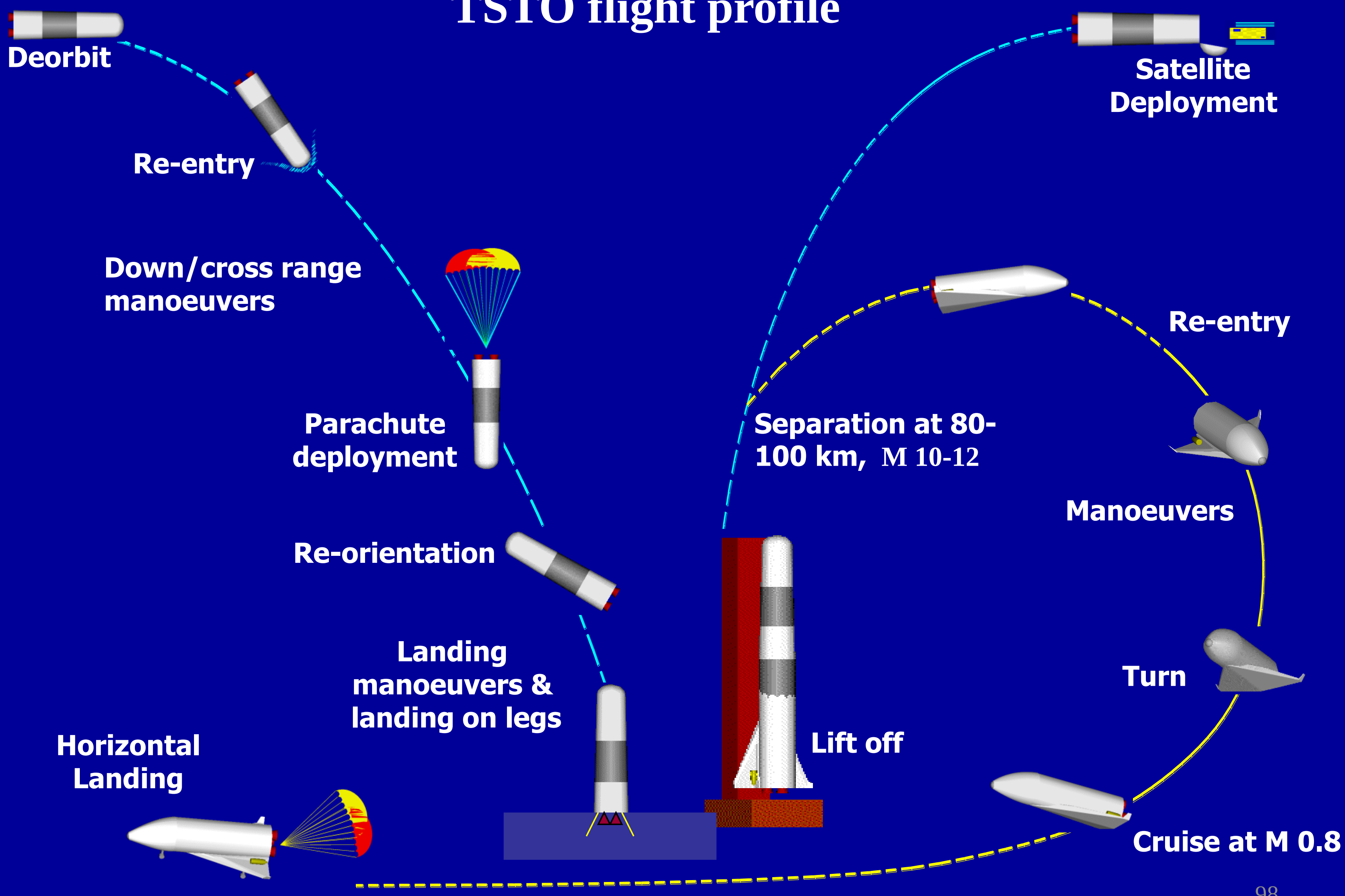


Landing using parachute /thrusters/ airbags

Thermal management (TPS Design & Evaluation), Blackout management. Unmanned autonomous Landing technology

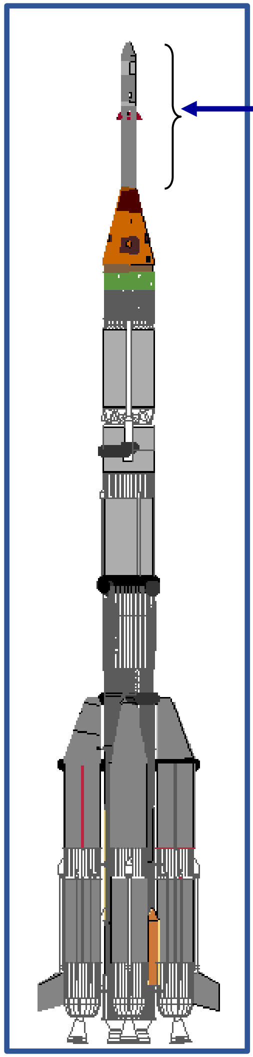
Reusable Semicryo/ Cryo Propulsion Systems

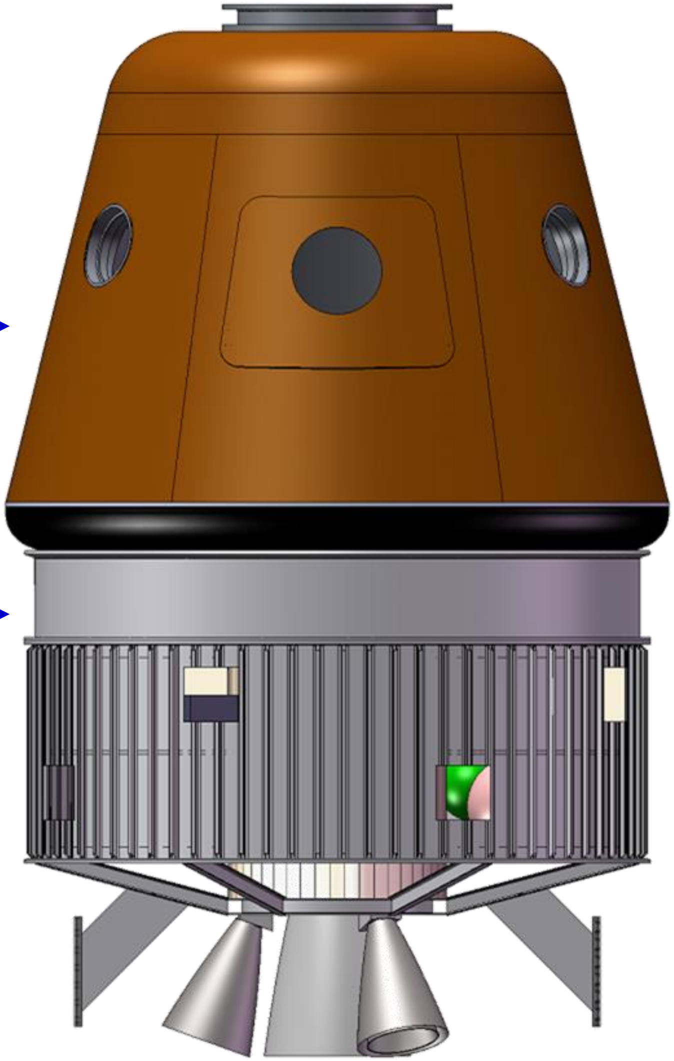
Fully reusable
TSTO flight profile



Indian Human Space Flight Programme

To develop a space vehicle to carry crew of two to LEO and return safely to a predetermined destination on earth



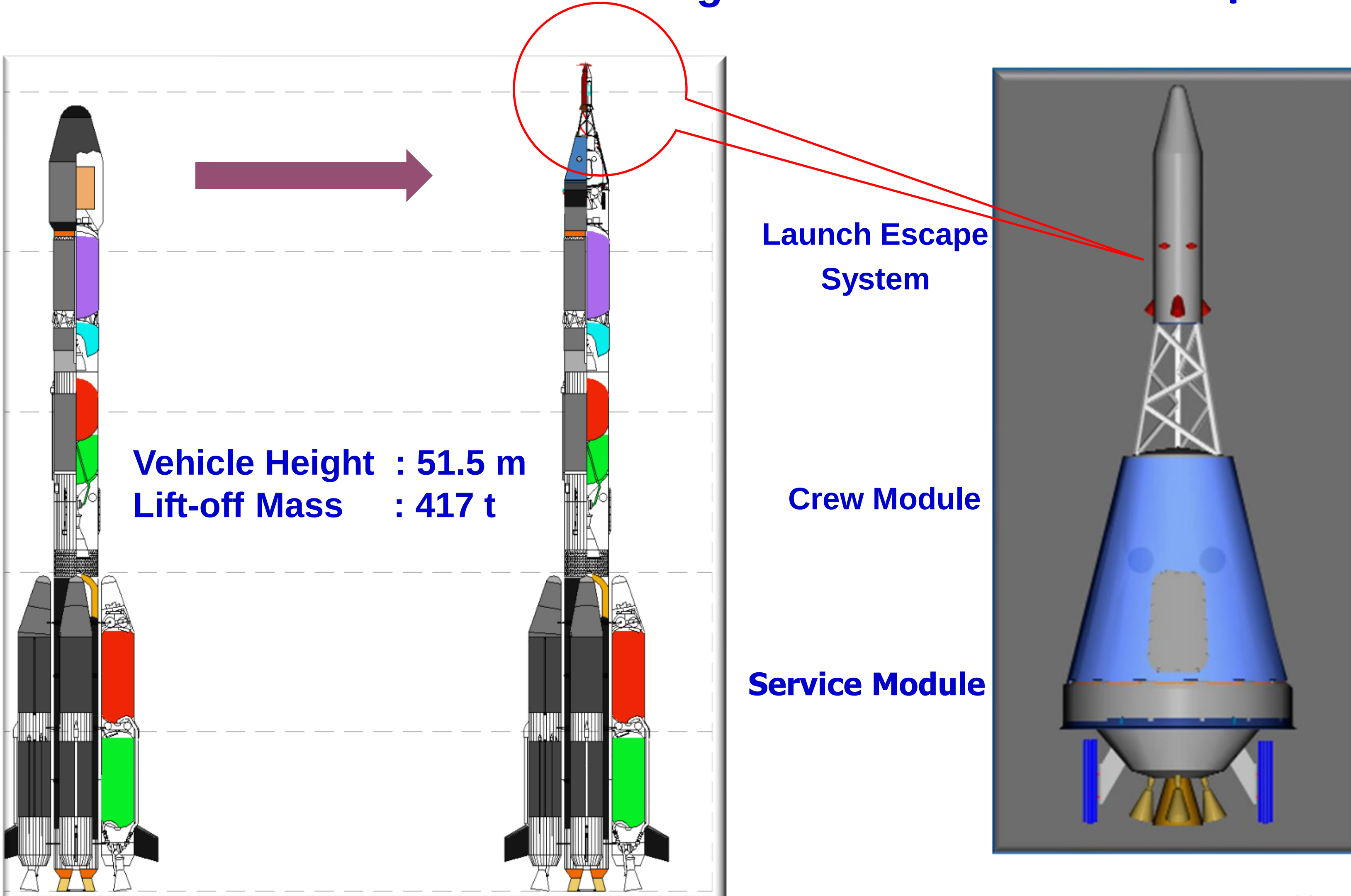


- Mission duration up to 7 days
- Emergency mission abort and crew rescue provision
- Crew module designed for re-entry and service module for mission management.

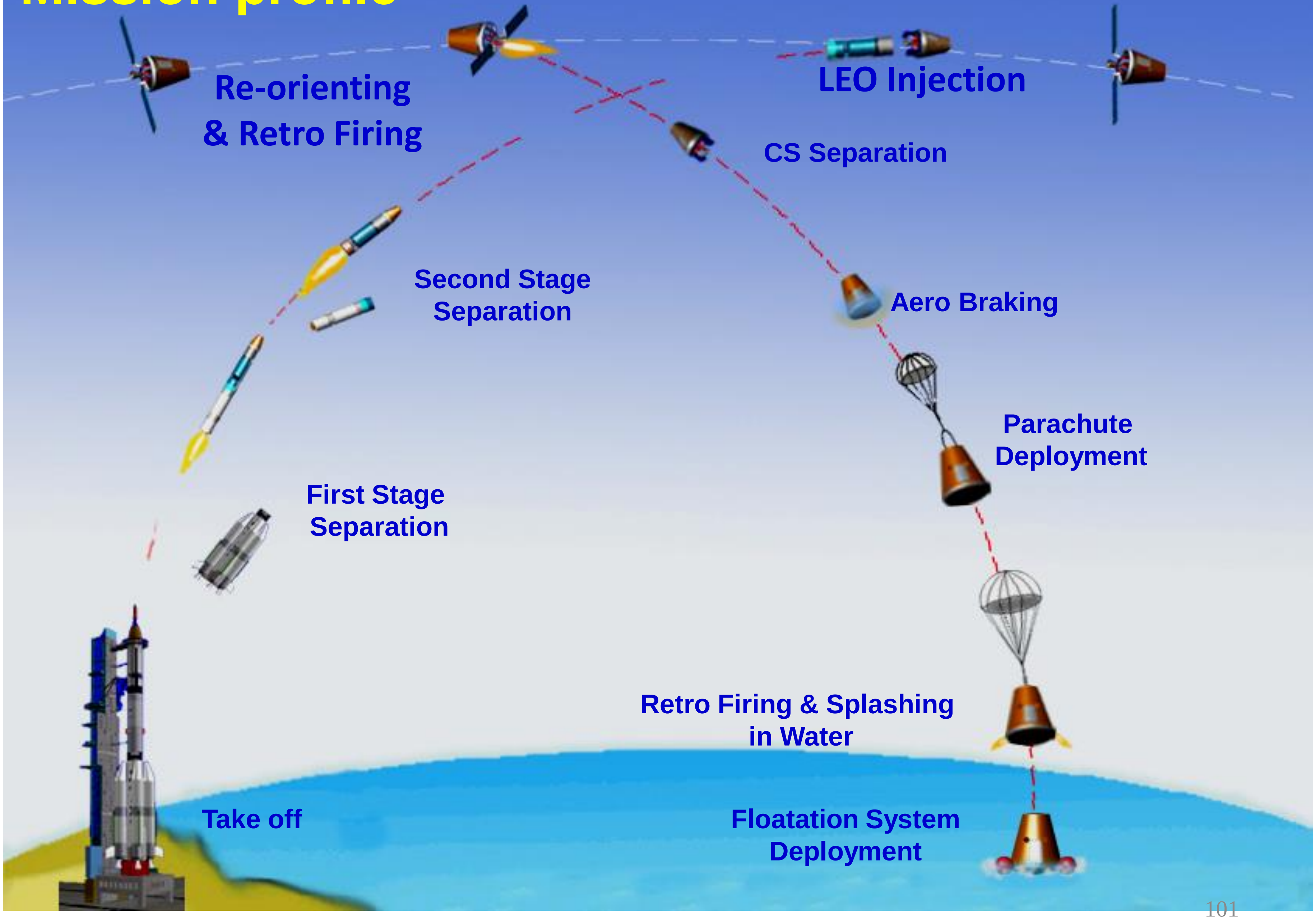
Orbital vehicle

Human Space Mission : Vehicle configuration

GSLV MkII | **Manned Configuration** | **Manned capsule**



Mission profile



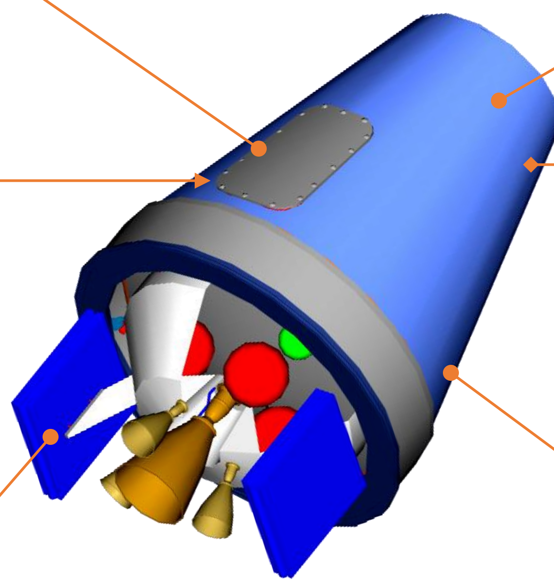
Manned mission - New Technologies

Crew Escape System

Crew Module Design and Aerodynamic Control

Environment Control and Life Support Systems

Space Suit & Crew Seat



Manned Space Vehicle Simulators

Robust Thermal Protection Systems

Redundant NGC System/Advanced Power Bus

Crew Health Monitoring Systems

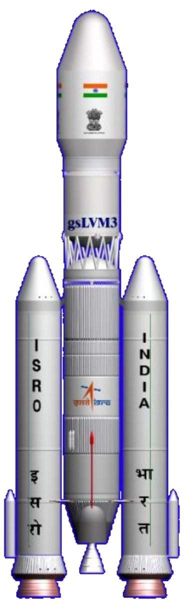
Mission Management with Human in Loop

Man – Rating of Launch Vehicle

Crew Training & Facilities

To reach Moon by human and return...

ΔV : 10.23 km/s
GTO P/L : 4 t



42 m

Long - Term Perspective

4t LEO	20 t in Lunar Orbit
10.2 km/s	19.2 km/s

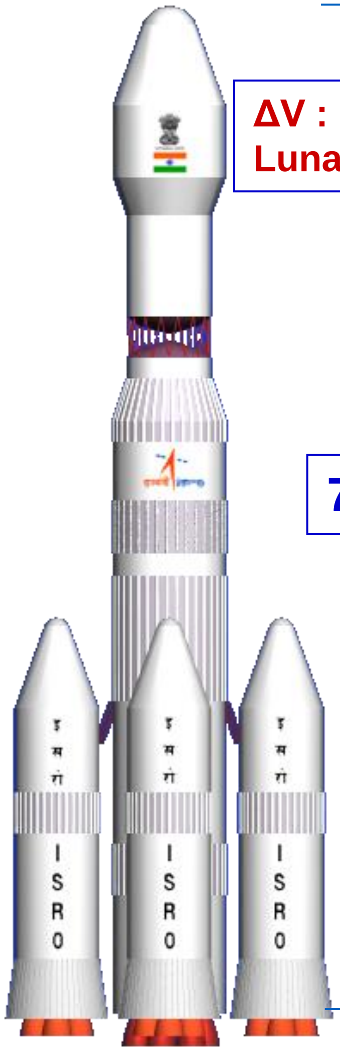
GSLV MKIII can be used to carry crew of 4 to 6 for demonstrating

- Rendezvous, Docking and EVA
- Long duration missions

Manned Mission to Moon/Mars

Heavy lift launch vehicle, engines

ΔV : 19.2 km/s
Lunar P/L : 20t

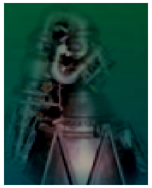


73 m

GSLV MKIII : 3 stage
2S200+L110+C25
LEO : 10 t
Lunar circular orbit : 2 t

ISRO HEAVY LIFT VEHICLE
(4SC460+SC800)+SC460+C100
LEO : 100 t
Lunar circular orbit : 20 t

Indian Space Transportation Vision 2025



Indigenous Cryogenic Upper Stage (CUS) 2009

Geo Synchronous Launch Vehicle MK III

2010

Semi cryogenic Engines

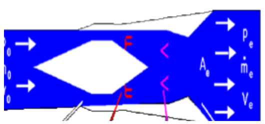
2015

Indian Human Space Mission

Reusable Launch Vehicle 2016

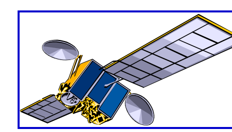
High thrust cryogenic Engine Boosters

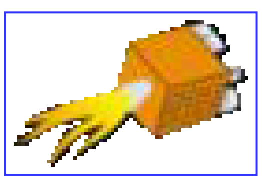
2017



Air- breathing Engines

2018 Interplanetary Mission to beyond MARS





Advanced Propulsion for Planetary Exploration

2020

Two Stage To Orbit to reduce the Cost

Single Stage To Orbit using Air breathing Propulsion

2025

Thank You

Space Segment

- A satellite communications system can be broadly divided into two segments-a ground segment and a space segment.
- The space segment will obviously include the

satellites, but it also includes the ground facilities needed to keep the satellites operational, these being referred to as the *telemetry, tracking, and command* (TT&C) facilities.

Space Segment

- The payload and bus are the equipment present in the satellite.
- The *payload* refers to the equipment used to provide the service for which the satellite has been launched.
- The *bus* refers not only to the vehicle which carries the payload but also to the various subsystems which required for service.

Space Segment

- In a communications satellite, the equipment which provides the connecting link between the satellite's transmit and receive antennas is referred to as the *transponder*.
- The transponder forms one of the main sections of the payload, the other being the antenna subsystems.

Spacecraft Subsystems

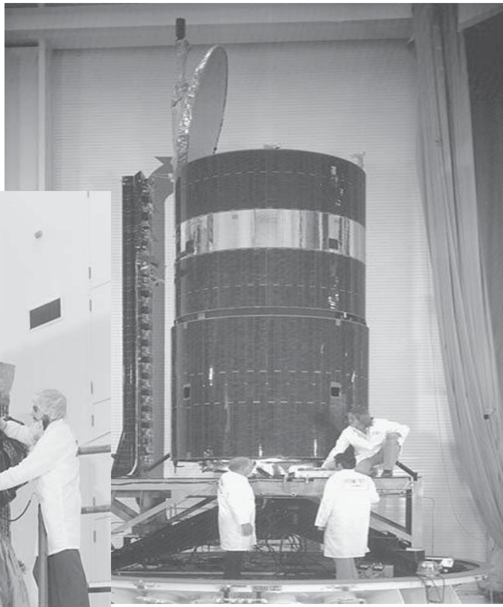
- Power Subsystems
- Attitude & orbit control subsystems
- Telemetry, Tracking & Command subsystems
- Communication subsystems
- Antenna Subsystems

Primary power or Power supply

- The primary electrical power for operating the electronic equipment is obtained from solar cells.
- Individual cells can generate only small amounts of power, and therefore, arrays of cells in series-parallel connection are required.

Primary power or Power supply

- The solar cell panels for the HS 376 satellite.
- And HS 601 communications satellite manufactured by Hughes Space and Communications Company.

Primary power or Power supply

- The spacecraft is 216 cm in diameter and 660 cm long when fully deployed in orbit.
- During the launch sequence, the outer cylinder is telescoped over the inner one, to reduce the overall length.
- At the beginning of life, the panels produce 940 W dc power, which may drop to 760 W at the end of 10 years.

Primary power or Power supply

- During eclipse, power is provided by two nickel-cadmium (Ni-Cd) long-life batteries, which will deliver 830 W. At the end of life, battery recharge time is less than 16 h.
- Higher powers can be achieved with solar panels arranged in the form of rectangular *solar sails*.
- Solar sails must be folded during the launch phase and extended when in geostationary orbit.

Primary power or Power supply

- HS601 satellite manufactured by Hughes Space and Communications Company.
- In HS 601 satellite, the solar sails are arranged to rotate to track the sun, so they are capable of greater power output than cylindrical arrays having a comparable number of cells.
- The HS 601 can be designed to provide dc power from 2 to 6 kW.

Primary power or Power supply

- The earth will eclipse a geostationary satellite twice a year, during the spring and autumnal equinoxes.
- Eclipses start approximately 23 days before and end approximately 23 days after the equinox for both the spring and autumnal equinoxes.
- Ni-H2 batteries are used in the Hughes HS601 and Intelsat series with INTELSAT VI and INTELSAT VII satellites.

Attitude Control

- The *attitude* of a satellite refers to its orientation in space.
- In Satellite, Most of the equipment are used for the purpose of controlling its attitude.
- Attitude control is necessary, for example, to ensure that directional antennas point in the proper directions.
- In the case of earth environmental satellites, the earth-sensing instruments must cover the required regions of the earth, which also requires attitude control.

Attitude Control

- A number of forces, such as the gravitational fields of the *earth and the moon, solar radiation, and meteorite impacts* are referred to as *disturbance torques* -can alter the attitude.
- Attitude control must not be confused with station keeping-the two are closely related.

Attitude Control

- To find the any deviation or shift in satellite orientation in space, infrared sensors are used, these sensor are referred to as *horizon detectors*.
- With the use of four such sensors, one for each quadrant, the center of the earth is reference point.
- Any shift in orientation is detected by one or other of the sensors, and a corresponding control signal is generated which activates a restoring torque.

Attitude Control

- Usually, the attitude-control process takes place in the satellite, but it is also possible for control signals to be transmitted from earth, based on attitude data obtained from the satellite.

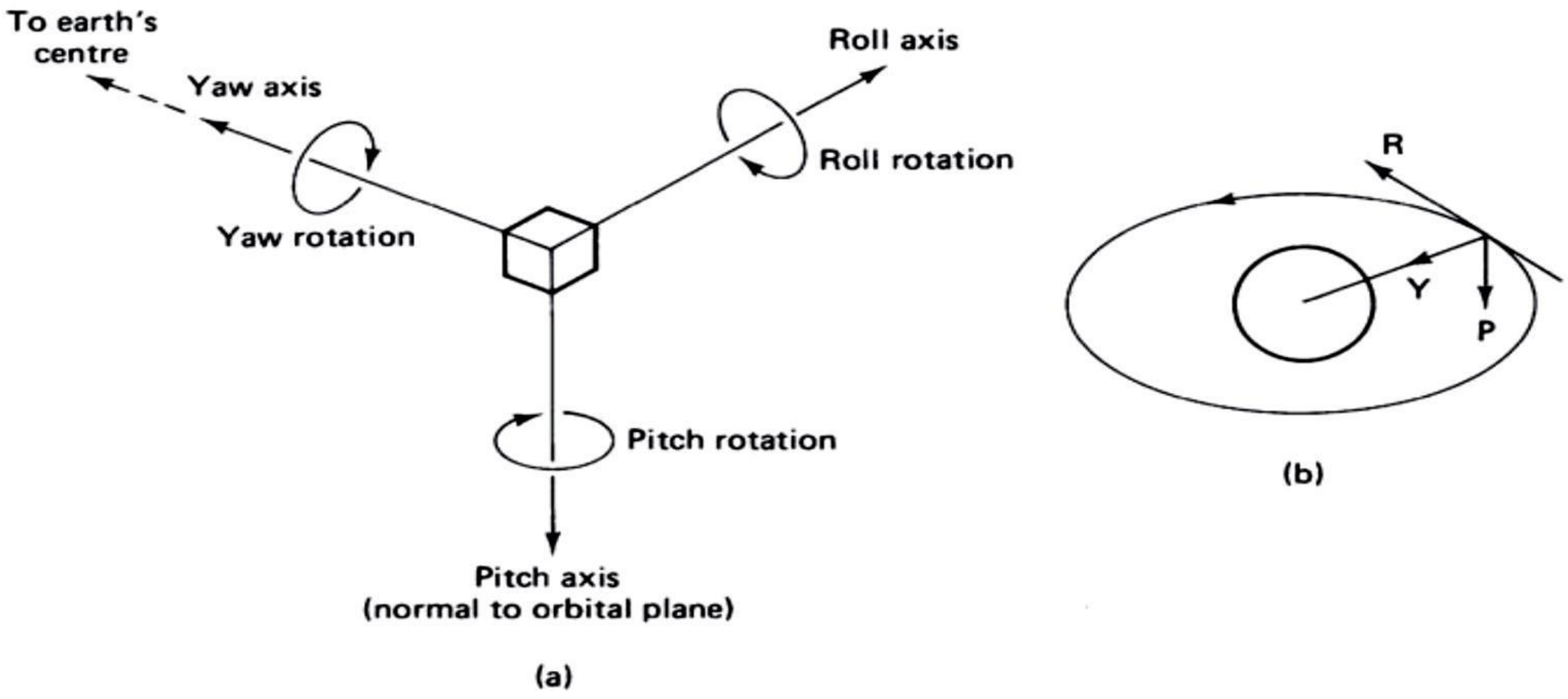
- Controlling torques may be generated in a number of ways.
  - *Passive attitude control*
  - *Active attitude control*

Attitude Control

- *Passive attitude control*
- The satellite stabilizations is achieved without putting a drain on the satellite’s energy supplies.
- Examples of passive attitude control are *spin stabilization* and *gravity gradient stabilization*.
- The *Gravity gradient* depends on the gravitational field of the central body.
  - Ex.Radio Astronomy Explorer-2 satellite.
- For communications satellites, *spin stabilization* is often used

Attitude Control

- *Active attitude control*
- With active attitude control, there is no overall stabilizing torque present to resist the disturbance torques.
- Instead, corrective torques are applied as required in response to disturbance torques.
- Methods used to generate active control torques, include *momentum wheels, EM coils, and mass expulsion devices*.
- The *electromagnetic coil works* on the principle that the earth's magnetic field exerts a torque on a current-carrying coil and that this torque can be controlled through control of the current.



(a)Roll, pitch, and yaw axes. The yaw axis is directed toward the earth's center, the pitch axis is normal to the orbital plane, and the roll axis is perpendicular to the other two.

(b) RPY axes for the geostationary orbit.

Attitude Control

- The three axes which define a satellite's attitude are its *roll, pitch*, and *yaw* (RPY) axes.
- For an equatorial orbit,
  - movement of the satellite about the roll axis moves the antenna footprint north and south;
  - movement about the pitch axis moves the footprint east and west; and
  - movement about the yaw axis rotates the antenna footprint.

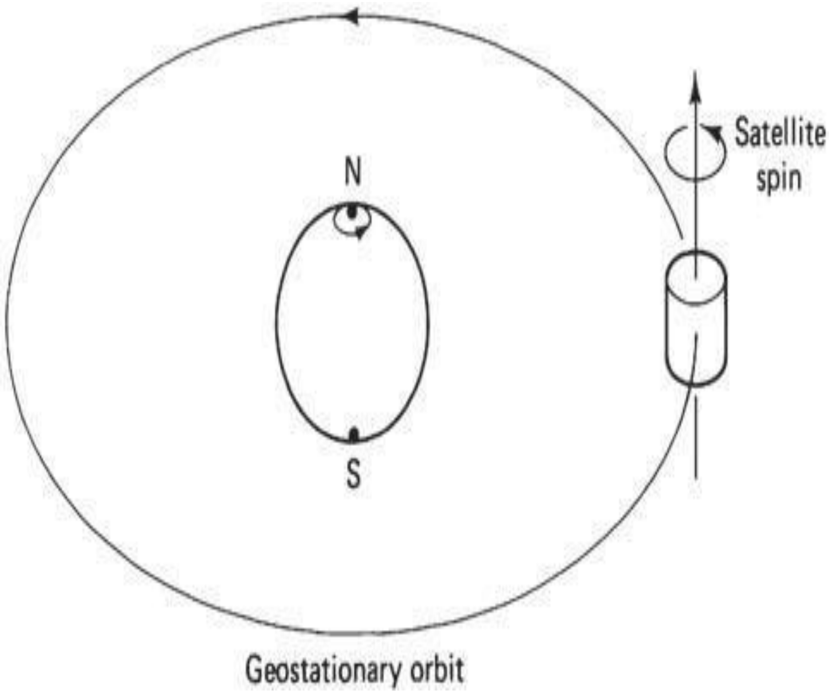
Attitude Control

Spinning satellite stabilization:

- This types of stabilization is applied to the cylindrical type of satellites.
- The satellite is mechanically balanced about one particular axis and is then set spinning around this axis.
- For geostationary satellites, the spin axis is parallel to the N-S axis of the earth.

Spinning satellite stabilization:

- Spin rate is typically in the range of 50to 100 rev/min.
- Spin is initiated during the launch phase by means of small gas jets.



Spinning satellite stabilization:

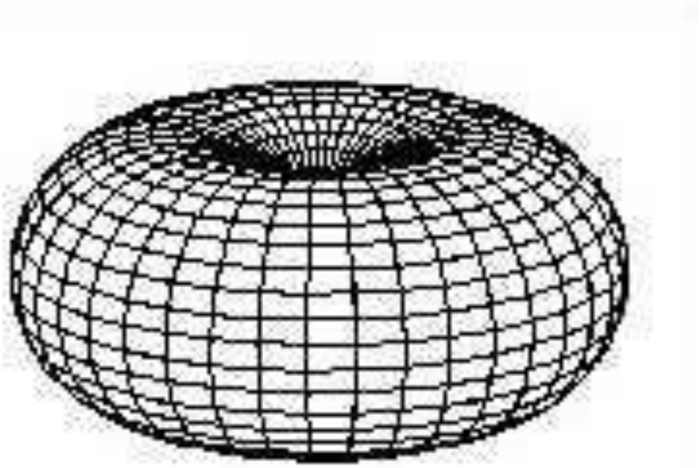
- In the absence of disturbance torques, the spinning satellite would maintain its correct attitude relative to the earth.
- Disturbance torques are generated in a number of ways, both external and internal to the satellite.
- Solar radiation, gravitational gradients, and meteorite impacts are all examples of external forces which can give rise to disturbance torques.
- Motor-bearing friction and the movement of satellite elements such as the antennas also can give rise to disturbance torques - Internal

Spinning satellite stabilization:

- When the Disturbance arise, it will affect the overall spin rate of the satellite- the spin rate will decrease, and the direction of the angular spin axis will change.
- Impulse-type thrusters, or jets, can be used to increase the spin rate again and to shift the axis back to its correct N-S orientation.
- *Nutation*, which is a form of wobbling, can occur as a result of the disturbance torques and from misalignment or unbalance of the control jets.
- This nutation must be damped out by means of energy absorbers known as *nutation dampers*.

Spinning satellite stabilization

- Where an omnidirectional antenna is used, the antenna, which points along the pitch axis, also rotates with the satellite.

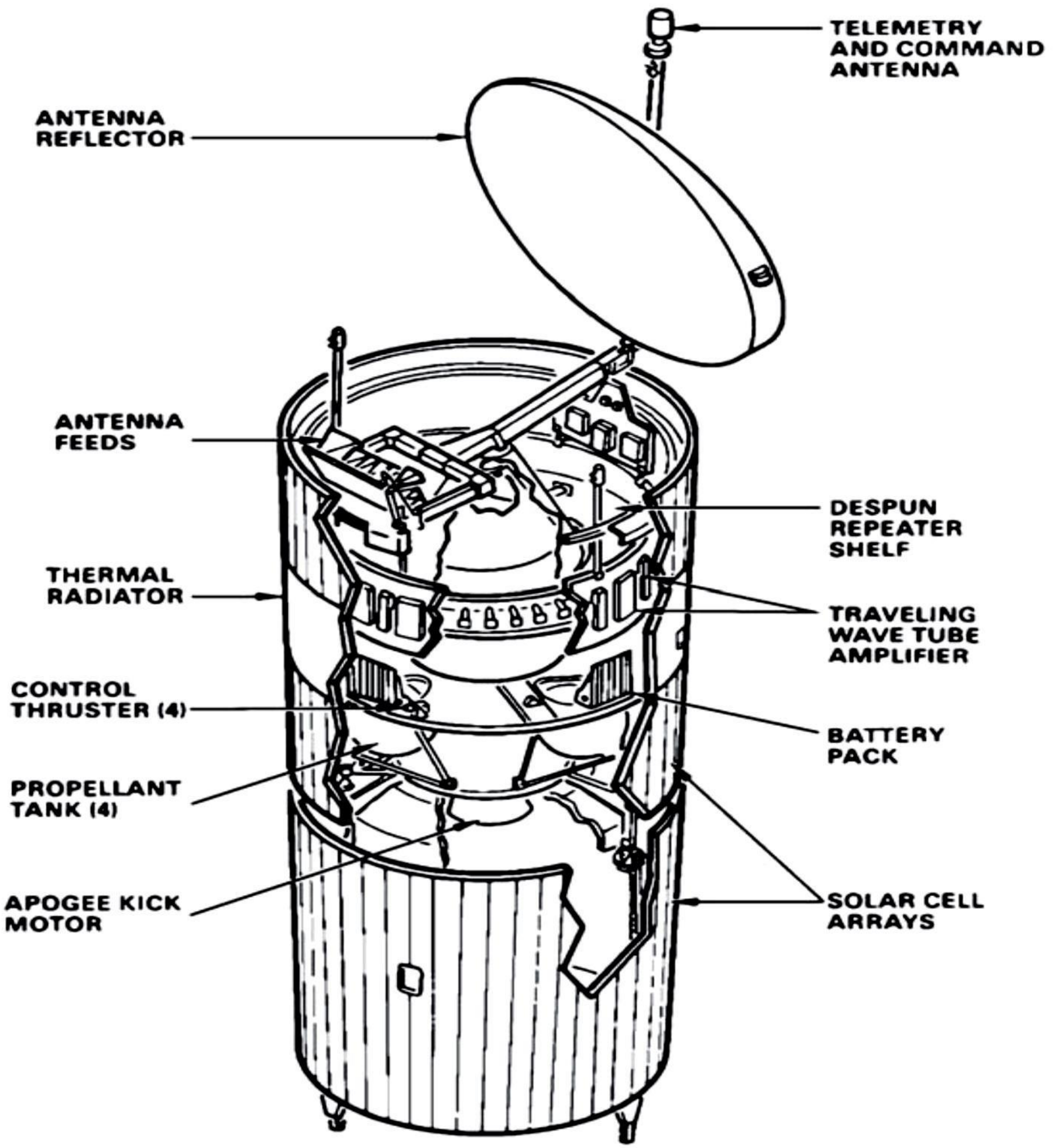


Spinning satellite stabilization

- Where a directional antenna is used, which is more common for communications satellites, the antenna must be despun, giving rise to a dual-spin construction.

- An electric motor drive is used for despinning the antenna subsystem.

HS 376 spacecraft



Spinning satellite stabilization

- The antenna subsystem consists of a parabolic reflector and feed horns mounted on the despun shelf, which also carries the communications repeaters (transponders).
- Of course, control signals and power must be transferred to the despun section, and a mechanical bearing must be provided.
- The complete assembly for this is known as the *bearing and power transfer assembly* (BAPTA).

momentum wheels stabilization

- Certain dual-spin spacecraft obtain spin stabilization from a spinning flywheel rather than by spinning the satellite itself.
- These flywheels are termed *momentum wheels*, and their average momentum is referred to as *momentum bias*.
- Reaction wheels, operate at zero momentum bias.
- In the Intelsat series of satellites, the INTELSAT-VI series spacecraft are spin-stabilized, all the others being 3-axis stabilized (body stabilized) through the use of momentum wheels.

Thermal Control

- Generally the satellite are affected by thermal radiations from the sun, earth and also from earth reflections.
- Satellites are subject to large thermal gradients, receiving the sun’s radiation on one side while the other side faces into space.
- In addition, thermal radiation from the earth and the earth’s *albedo*, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationary satellites.

Thermal Control

- The Equipment present in the satellite will also generates heat, which has to be removed.
- To operate the satellite in temperature stable environment the following thinks are used.
  - *Use of thermal blankets*
  - *Radiation mirrors- to remove the heat from communication payload*
  - *Heaters may be switched on when transponders are switched off.*

Telemetry Tracking &Command Subsystem-TT&C

- For the successful operation of a communication satellite, the TT&C subsystem is essential.
- It involves both earth & space station.
- The main functions of a spacecraft management are given below.
  - *To control the orbit & attitude of the satellite*
  - *To monitor the status of all the sensors in the satellite*
  - *To switch on/off in communication systems.*

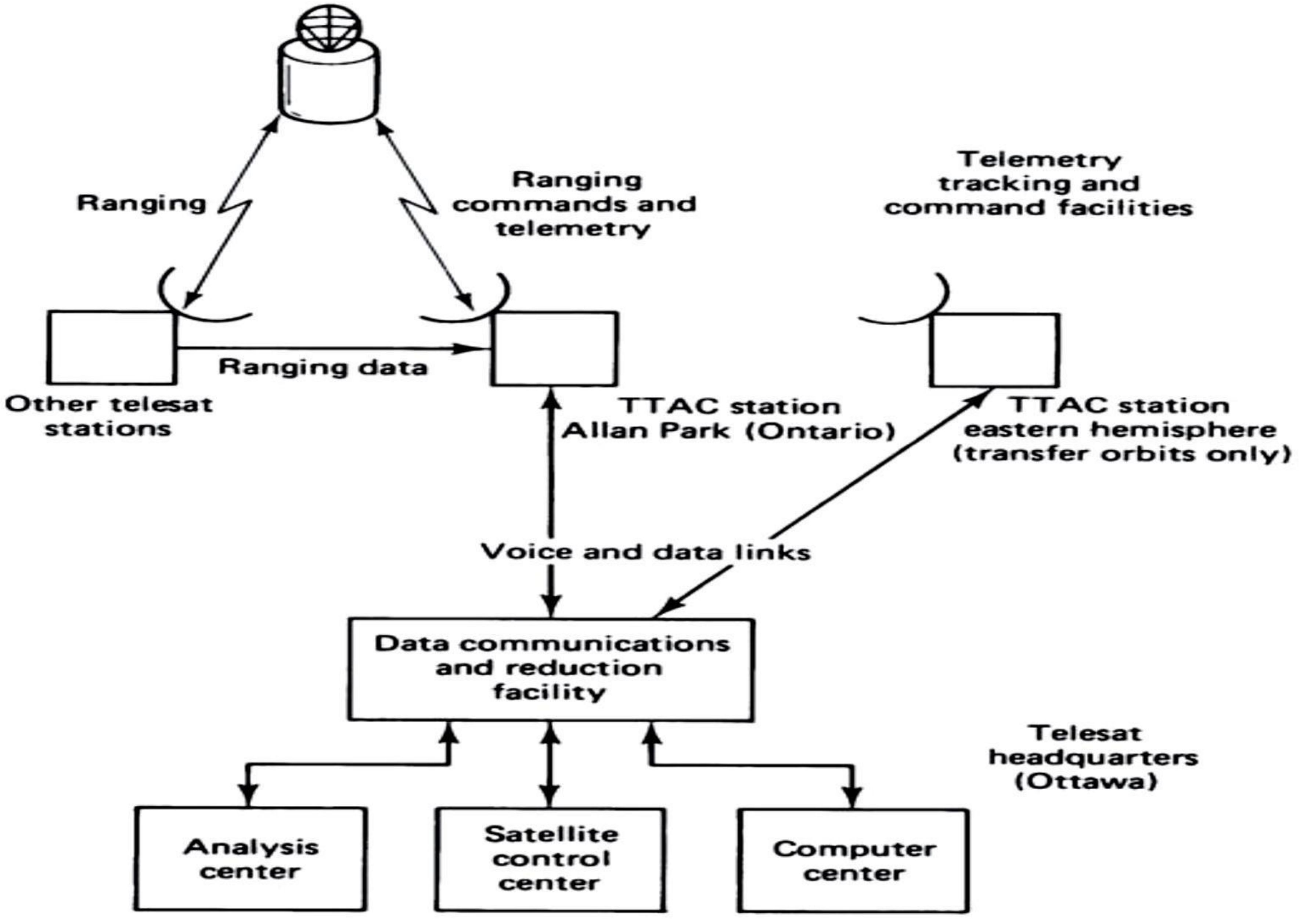
Telemetry

- The telemetry, or telemetering, function could be interpreted as *measurement at a distance*.
  - *Data which are transmitted as telemetry signals include attitude information such as that obtained from sun and earth sensors;*
  - *environmental information such as the magnetic field intensity and direction, the frequency of meteorite impact, and so on; and*
  - *spacecraft information such as temperatures, power supply voltages, and stored-fuel pressure.*

Telemetry

- Telemetry and command may be thought of as complementary functions.
- The telemetry subsystem transmits information about the satellite to the earth station, while the command subsystem receives command signals from the earth station, often in response to telemetered information.

Subsystem-TT&C



Telemetry

- There are many sensors located on the spacecraft to monitor the
  - *Pressure in fuel tanks*
  - *Voltage & Current in power conditioning unit*
  - *Temperature from all subsystem*
  - *Status of each subsystem & switch positions*
  - *Monitoring the attitude control etc*.
  - The data from all the sensors are given to the telemetry unit & this unit digitize the data & transmit the data using FSK or PSK.

Tracking

- Tracking of the satellite is accomplished by having the satellite transmit beacon signals which are received at the TT&C earth stations.
- Tracking is obviously important during the transfer and drift orbital phases of the satellite launch.
- Once it is on station, the position of a geostationary satellite will tend to be shifted as a result of the various disturbing forces.
- Therefore, it is necessary to be able to track the satellite's movement and send correction signals as required.

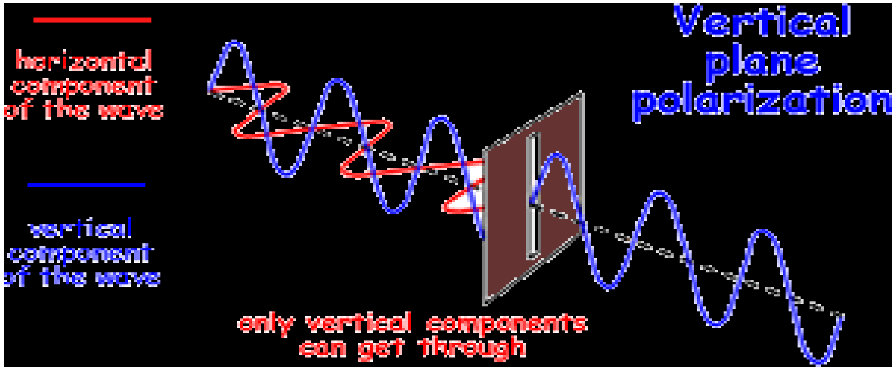
Tracking

- Satellite range from the ground station is also required from time to time.
- This can be determined by measurement of the propagation delay of signals especially transmitted for ranging purposes.
- It is clear that the telemetry, tracking, and command functions are complex operations which require special ground facilities in addition to the TT&C subsystems aboard the satellite.

Transponders

- A transponder is the series of interconnected units which forms a single communications channel between the receive and transmit antennas in a communications satellite.
- The bandwidth allocated for C-band communication satellites service is 500 MHz, and this is divided into sub bands, one for each transponder.
- Atypical transponder bandwidth is 36 MHz, and allowing for a 4-MHz guard band between transponders, 12 such transponders can be accommodated in the 500-MHz bandwidth.

Frequency reuse

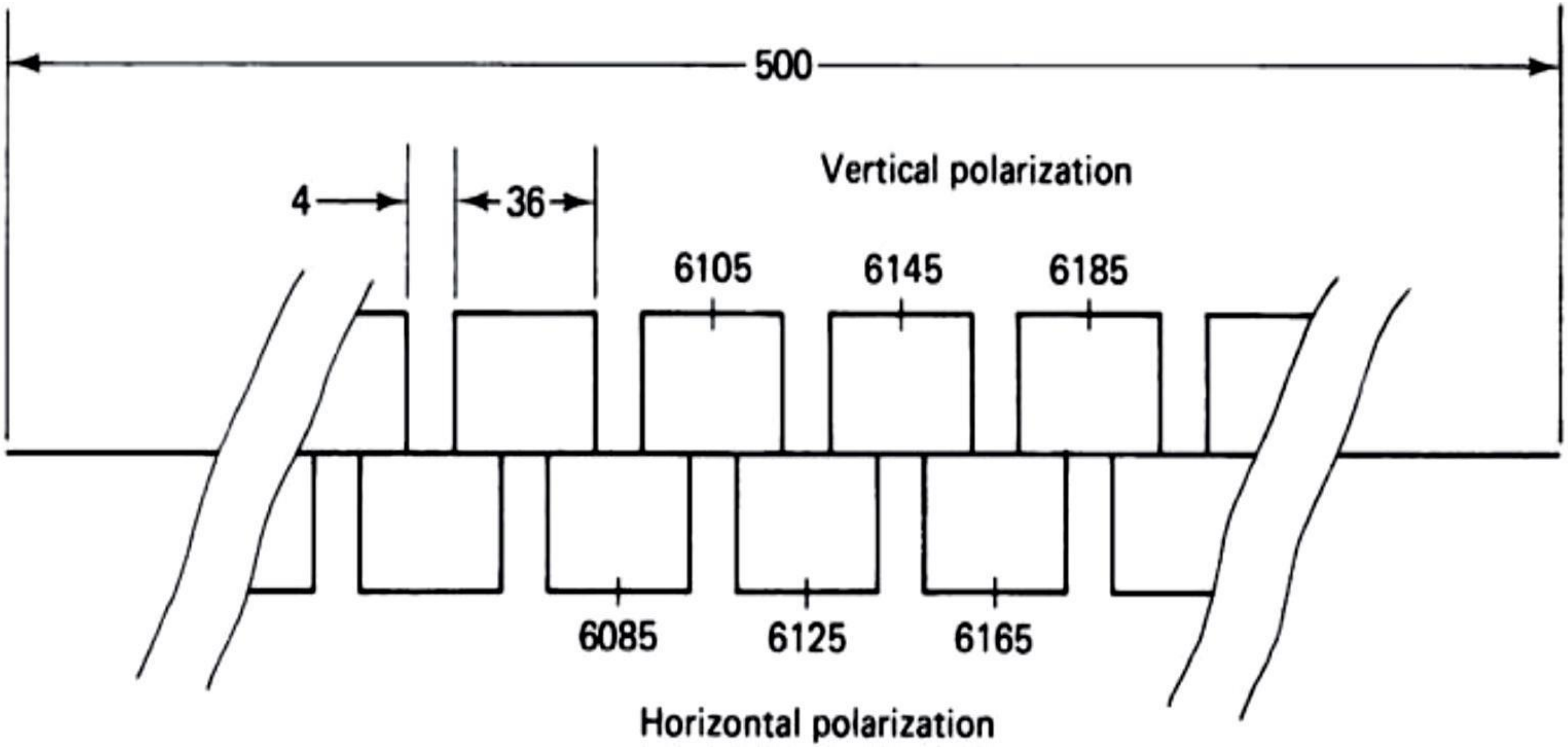


- By making use of *polarization isolation*, this number can be doubled.
- Polarization isolation refers to the fact that carriers, which may be on the same frequency but with opposite senses of polarization, can be isolated from one another by receiving antennas matched to the incoming polarization.

Frequency reuse

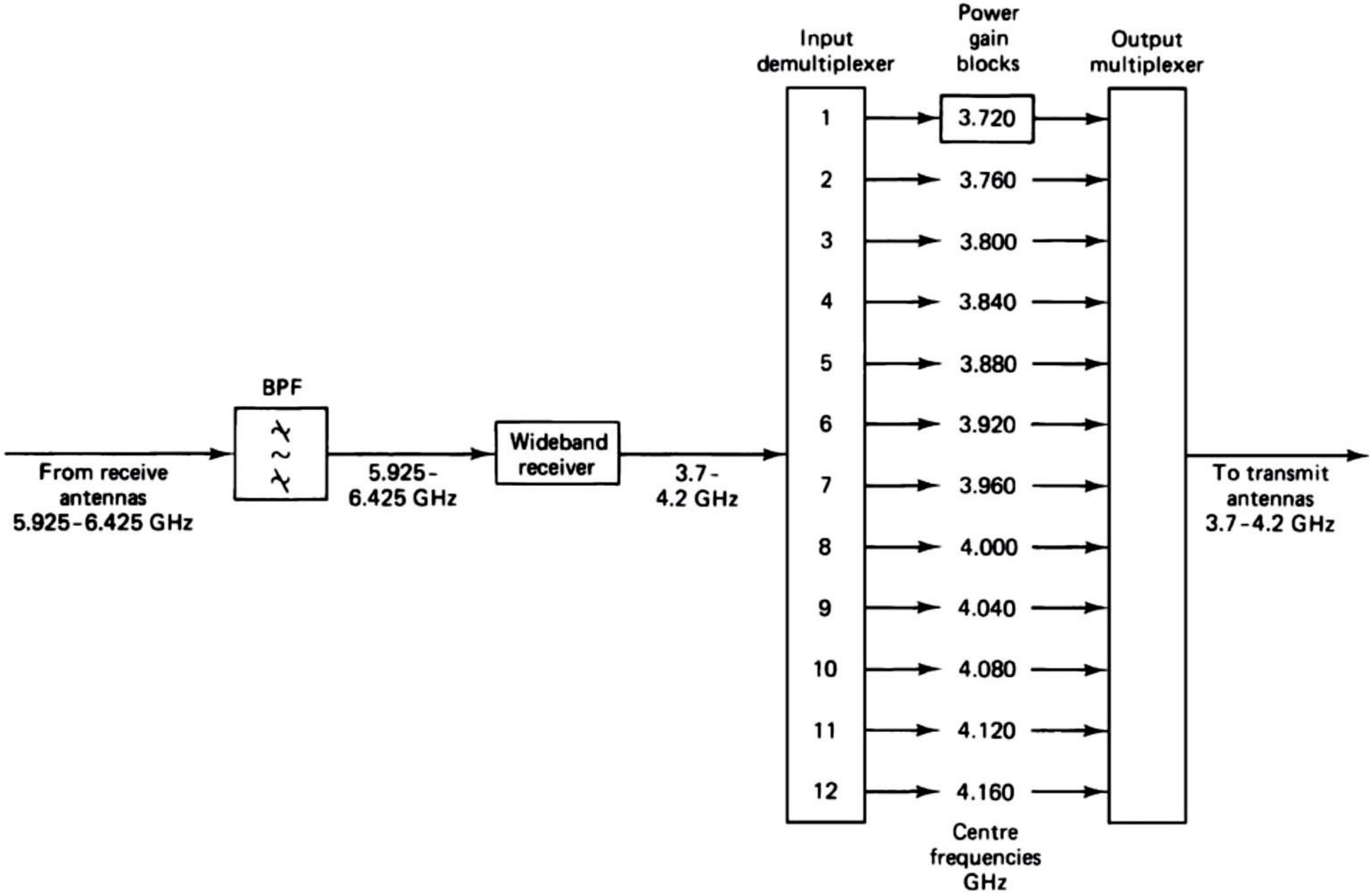
- With linear polarization, vertically and horizontally polarized carriers can be separated in this way, and with circular polarization, left-hand circular and right-hand circular polarizations can be separated.
- Because the carriers with opposite senses of polarization may overlap in frequency, this technique is referred to as *frequency reuse*.

Section of an uplink frequency and polarization plan.



- ***Frequency reuse also may be achieved with spot-beam antennas, and these may be combined with polarization reuse to provide an effective bandwidth of 2000 MHz from the actual bandwidth of 500 MHz.***

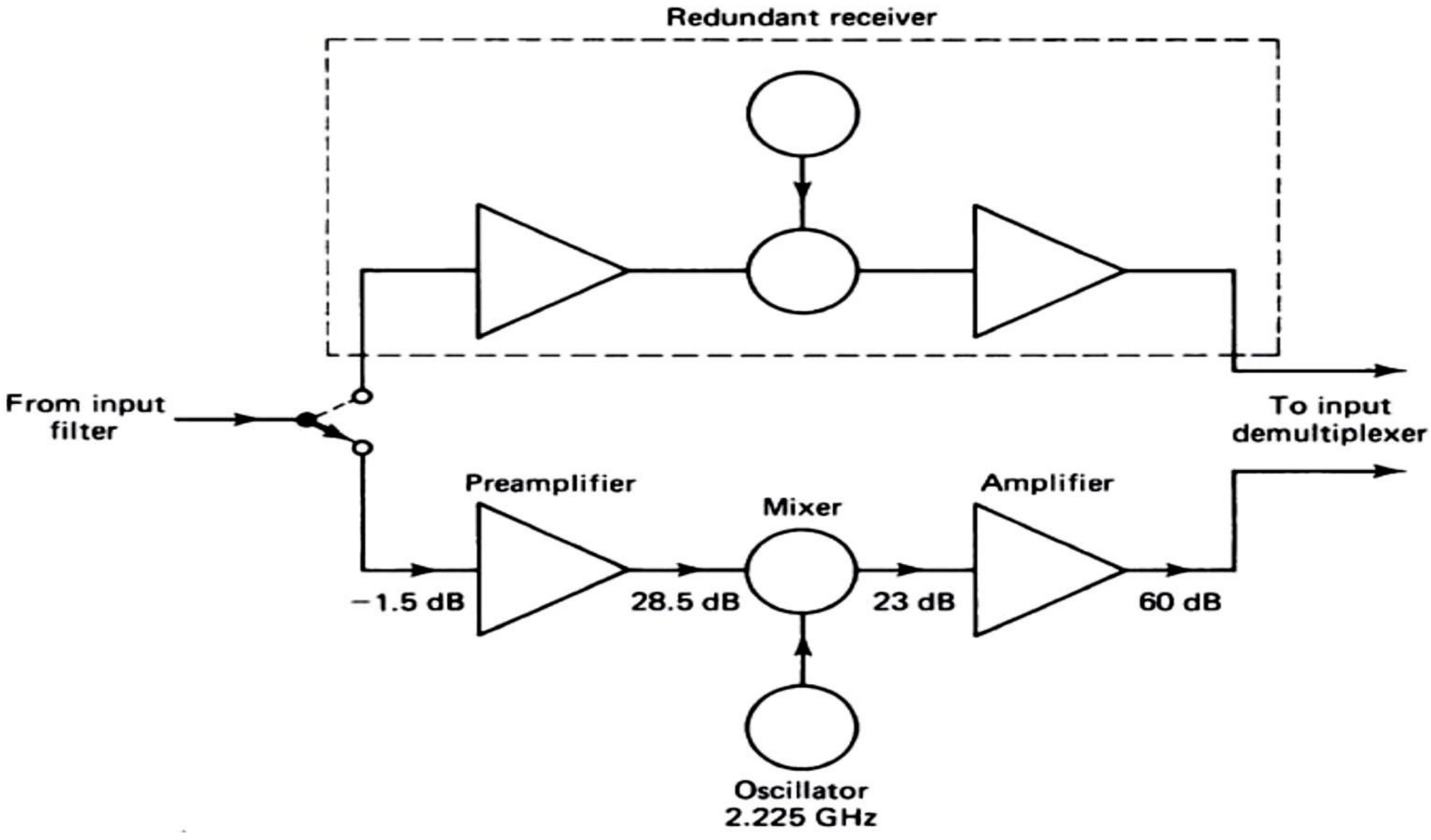
Satellite transponder channels



Wideband receiver

- A duplicate receiver is provided so that if one fails, the other is automatically switched on.
- The combination is referred to as a *redundant receiver*, meaning that although two are provided, only one is in use at a given time.
- The first stage in the receiver is a *low-noise amplifier* (LNA).
- This amplifier adds little noise to the carrier being amplified, and at the same time it provides sufficient amplification for the carrier to override the higher noise level present in the following mixer stage.

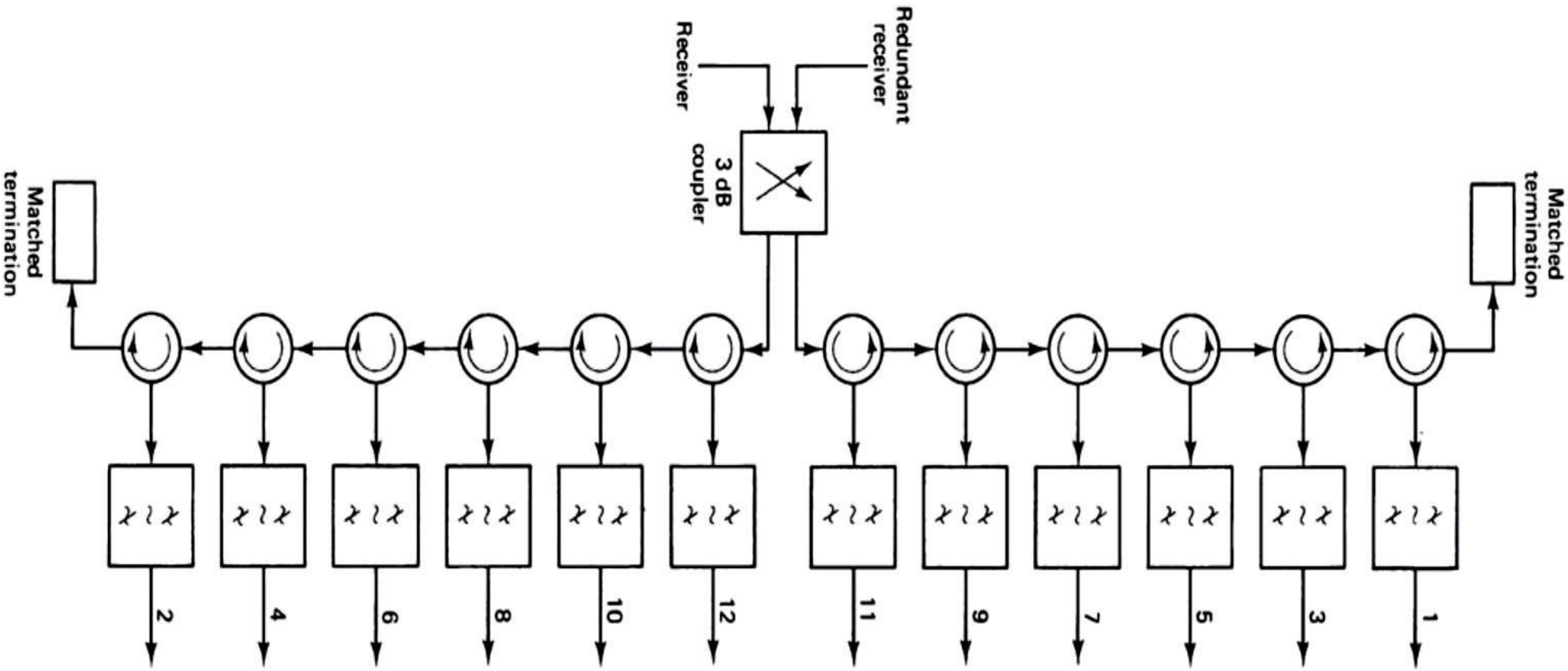
Wideband receiver



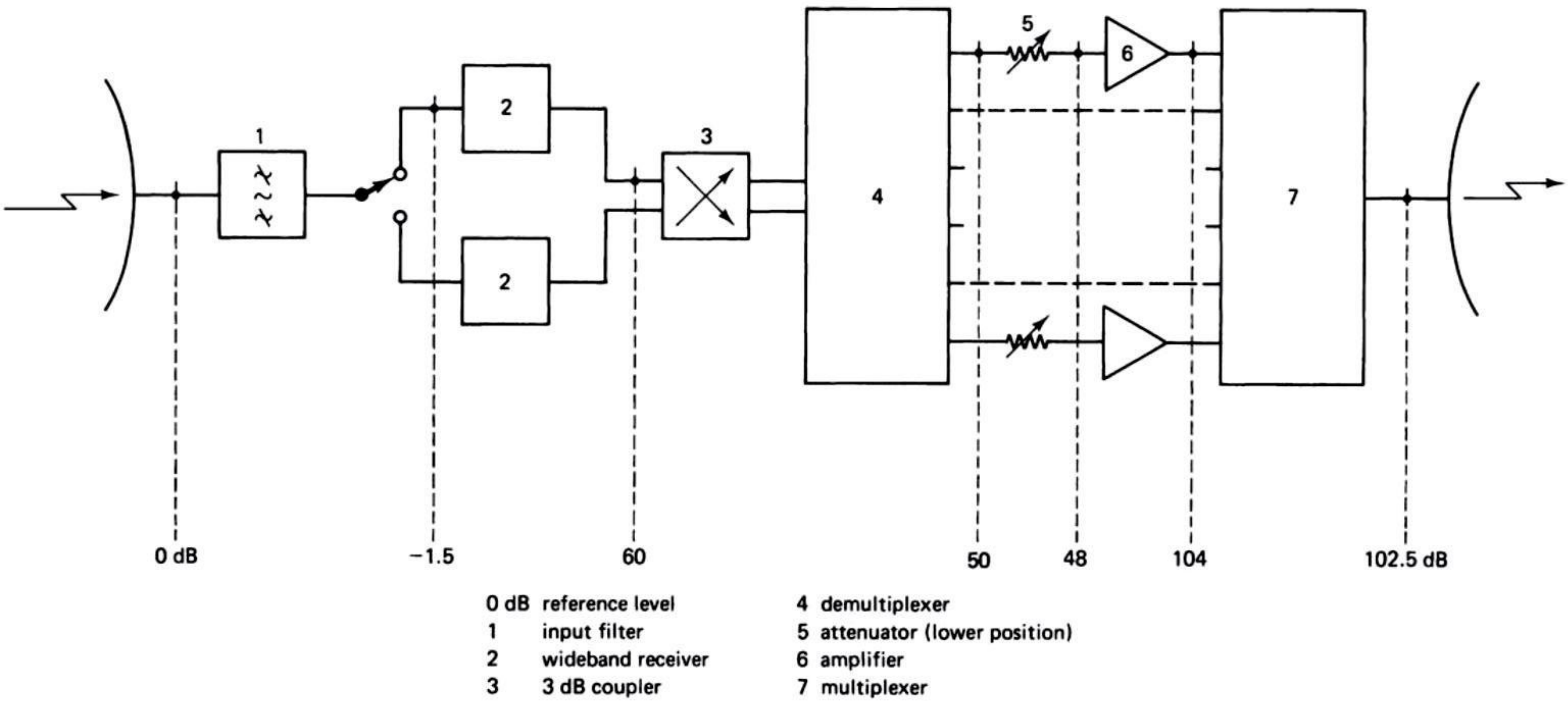
Wideband receiver

- The LNA feeds into a mixer stage, which also requires a *local oscillator* (LO) signal for the frequency-conversion process.
- A second amplifier follows the mixer stage to provide an overall receiver gain of about 60 dB.

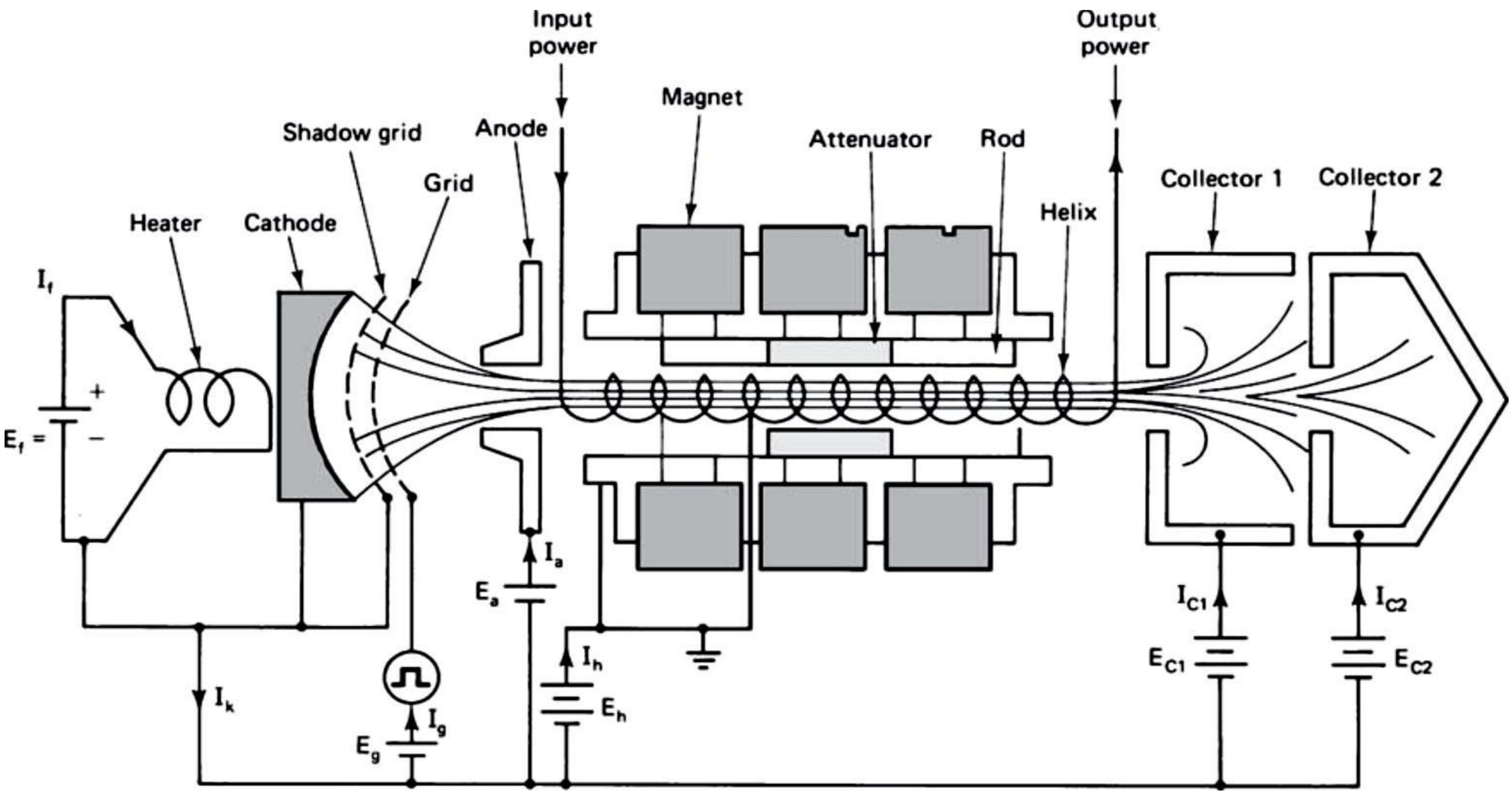
input de-multiplexer



Power amplifier



Schematic of a TWT and power supplies



Power amplifier

- *Traveling-wave tube amplifiers* (TWTAs) are widely used in transponders to provide the final output power required to the transmit antenna.
- In the TWT, an electron-beam gun assembly consisting of a heater, a cathode, and focusing electrodes is used to form an electron beam.
- A magnetic field is required to confine the beam to travel along the inside of a wire helix.
- For high-power tubes, the magnetic field can be provided by means of a solenoid and dc power supply.

Power amplifier

- The comparatively large size and high power consumption of solenoids make them unsuitable for use aboard satellites, and lower-power TWTs are used which employ permanent magnet focusing.
- The advantage of the TWT:
  - over other types of tube amplifiers is that it can provide amplification over a very wide bandwidth.
  - TWT also may be called on to amplify two or more carriers simultaneously, this being referred to as *multicarrier operation*.

Antenna Subsystem

- The antennas present in the satellite, provide the dual functions of receiving the uplink and transmitting the downlink signals.
- The type of the antenna used may be directional or omnidirectional, it depends upon the type of usage.
- Generally, for telecommunication purposes & broadcasting, highly directional antennas are required.

Antenna Subsystem

- Directional beams are usually produced by means of reflector-type antennas.
- The gain of the parabolic reflector is

$$G = \eta_I \left(\frac{\pi D}{\lambda} \right)^2$$

where λ is the wavelength of the signal, D is the reflector diameter, and η_I is the aperture efficiency. A typical value for η_I is 0.55. The −3-dB beamwidth is given approximately by Eq. (6.33) as

$$\theta_{3\text{dB}} \cong 70 \frac{\lambda}{D} \text{ degrees}$$

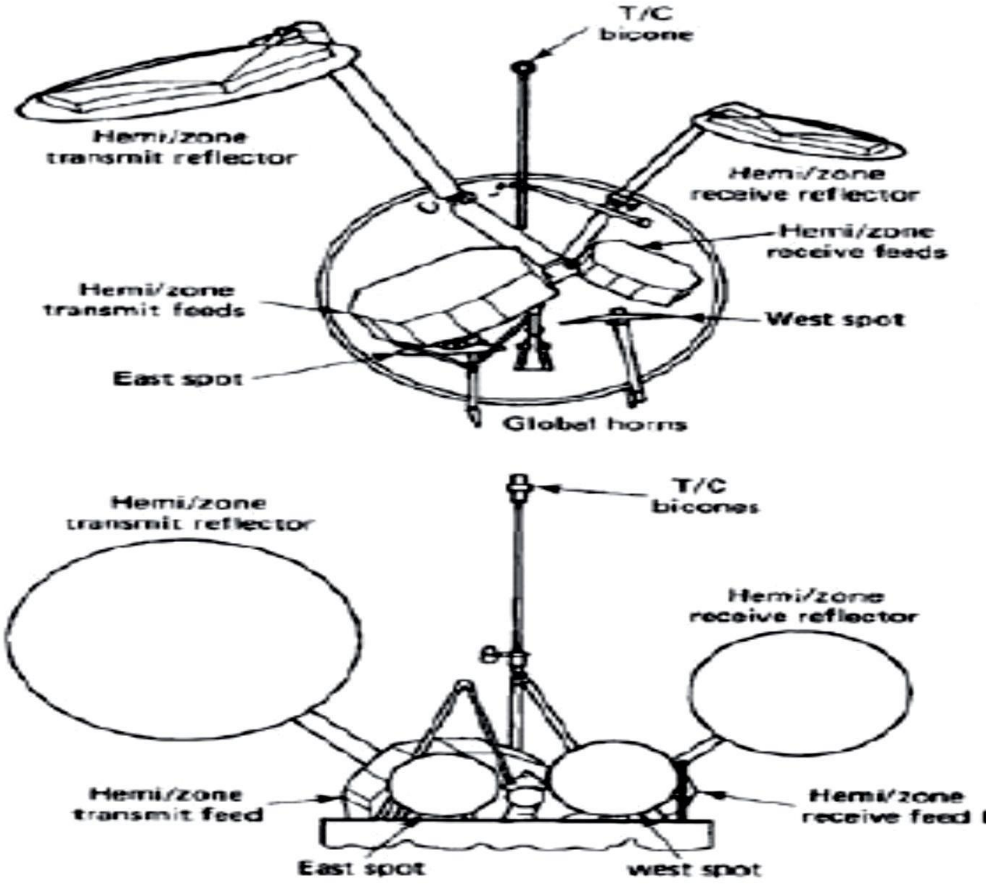
Antenna Subsystem

The ratio D/λ is seen to be the key factor in these equations, the gain being directly proportional to $(D/\lambda)^2$ and the beamwidth inversely proportional to D/λ. Hence the gain can be increased and the beamwidth made narrower by increasing the reflector size or decreasing the wavelength. In comparing C-band and Ku-band, the largest reflectors are those for the 6/4-GHz band. Comparable performance can be obtained with considerably smaller reflectors in the 14/12-GHz band. Satellites used for mobile services in the L-band employ much larger antennas

- The polarization separation takes place in a device known as an ortho coupler, or orthogonal mode transducer (OMT).
- Separate horns also may be used for the transmit and receive functions, with both horns using the same reflector.

Antenna Subsystem

- The transmit and receive signals are separated in a device known as a *diplexer*



Satellite Link Design

Content

- Design of the Satellite Links
- Link Budget and their Interpretation

Introduction

- A satellite link is defined as an Earth station - satellite - Earth station connection.
- The Earth station - satellite segment is called the uplink
- The satellite - Earth station segment is called the downlink

Introduction

The Earth station design consists of,

✓The Transmission Link Design or the Link Budget,

✓the Transmission System Design.

- The Link Budget establishes the resources needed for a given service to achieve the performance objectives

Design of the Satellite Link

- The satellite link is probably the most basic in microwave communications since a line-of-sight path typically exists between the Earth and space.
- This means that an imaginary line extending between the transmitting or receiving Earth station and the satellite antenna passes only through the atmosphere and not ground obstacles.

Design of the Satellite Link

- Free-space attenuation is determined by the inverse square law, which states that the power received is inversely proportional to the square of the distance.
- There are, however, a number of additional effects that produce a significant amount of degradation and time variation.
- These include rain, terrain effects such as absorption by trees and walls, and some less-obvious impairment produced by unstable conditions of the air and ionosphere.

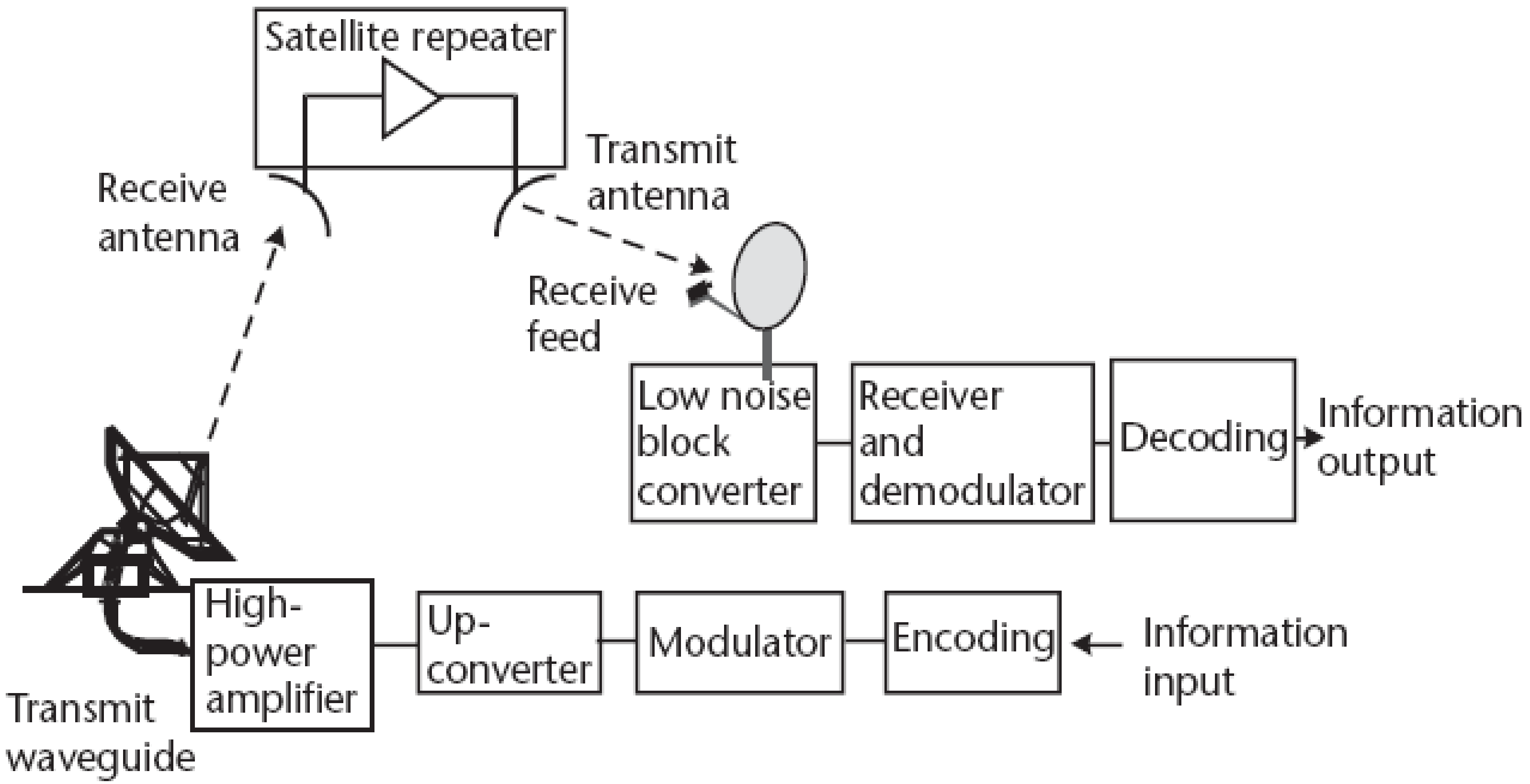
Design of the Satellite Link

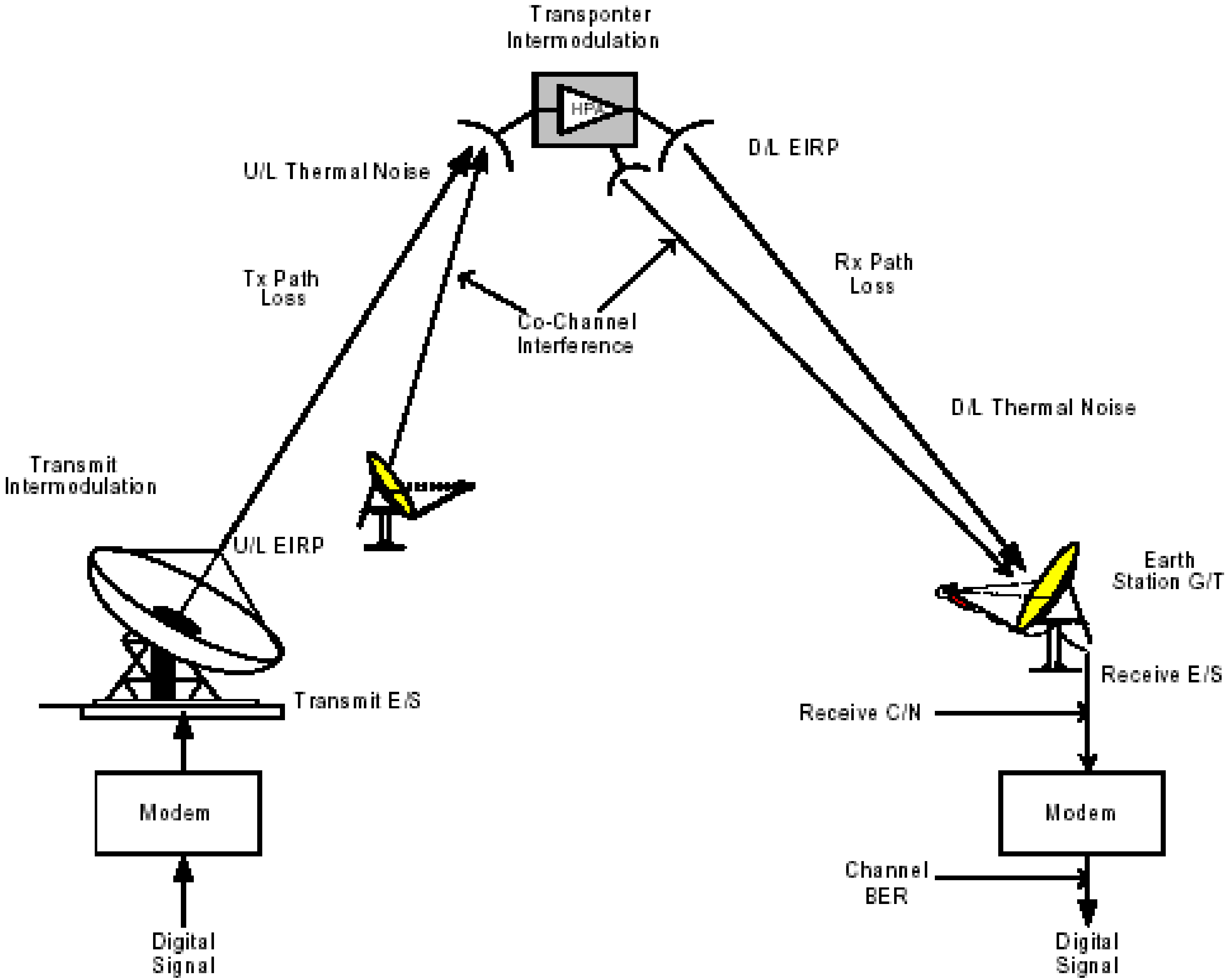
- It is the job of the communication engineer to identify all of the significant contributions to performance and make sure that they are properly taken into account.
- The required factors include the performance of the satellite itself,
- The configuration and performance of the uplink and downlink Earth stations, and
- The impact of the propagation medium in the frequency band of interest.

Design of the Satellite Link

- The RF carrier in any microwave communications link begins at the transmitting electronics and propagates from the transmitting antenna through the medium of free space and absorptive atmosphere to the receiving antenna, where it is recovered by the receiving electronics.
- The carrier is modulated by a baseband signal that transfers information for the particular application.
- The first step in designing the microwave link is to identify the overall requirements and the critical components that determine performance.
- For this purpose, we use the basic arrangement of the link shown in Figure.

Design of the Satellite Link




Transponter
Intermodulation
HPA
U/L Thermal Noise
D/L EIRP
Tx Path
Loss
Rx Path
Loss
Co-Channel
Interference
D/L Thermal Noise
Transmit
Intermodulation
U/L EIRP
Earth
Station G/T
Transmit E/S
Receive E/S
Receive C/N
Modem
Modem
Channel
BER
Digital
Signal
Digital
Signal

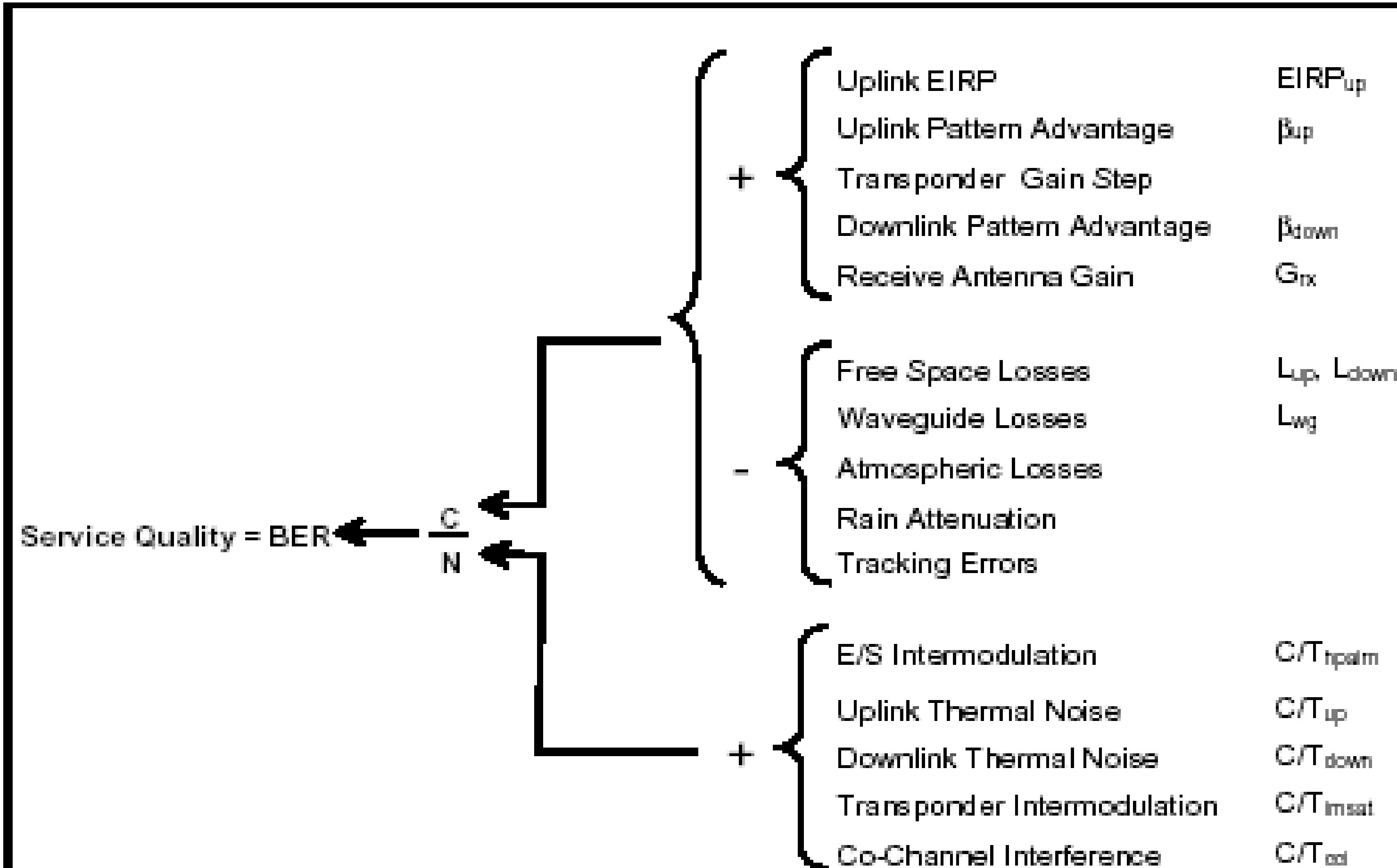
Design of the Satellite Link

- Bidirectional (duplex) communication occurs with a separate transmission from each Earth station.
- Due to the analog nature of the radio frequency link, each element contributes a gain or loss to the link and may add noise and interference as well.

Design of the Satellite Link

- The result in the overall performance is presented in terms of the ratio of carrier power to noise and, ultimately, information quality
- Any uncertainty can be covered by providing an appropriate amount of link margin, which is over and above the C/N needed to deal with propagation effects and nonlinearity in the Earth stations and satellite repeater.

Link Parameters' Impact on Service Quality



Satellite Link Design

The four factors related to satellite system design:

1.The weight of satellite

2.The choice frequency band

3.Atmospheric propagation effects

4.Multiple access technique

- The major frequency bands are 6/4 GHz, 14/11 GHz and 30/20 GHz (Uplink/Downlink)
- At geostationary orbit there is already satellites using both 6/4 and 14/11 GHz every 2˚(minimum space to avoid interference from uplink earth stations)

LINK BUDGET

The link budget determines the antenna size to deploy,

- ✓ Power requirements,
- ✓ link availability,
- ✓ bit error rate,
- ✓ overall customer satisfaction with the satellite service.

- A link budget is a tabular method for evaluating the power received and the noise ratio in a radio link .
- It simplifies C/N ratio calculations
- The link budget must be calculated for an individual

transponder, and must be recalculated for each of the

individual links

LINK BUDGET

The satellite link is composed primarily of three segments:

(i) the transmitting Earth station and the uplink media;

(ii) the satellite; and

(iii) the downlink media and the receiving Earth station.

- The carrier level received at the end of the link is a straightforward addition of the losses and gains in the path between transmitting and receiving Earth stations.

LINK BUDGETS

- C/N ratio calculation is simplified by the use of link budgets
- Evaluation of the received power and noise power in radio link
- the link budget must be calculated for individual transponder and for each link
- When a bent pipe transponder is used the uplink and down link C/N ratios must be combined to give an overall C/N

Link Budget Example

- Satellite application engineers need to assess and allocate performance for each source of gain and loss.
- The link budget is the most effective means since it can address and display all of the components of the power balance equation, expressed in decibels.
- In the past, each engineer was free to create a personalized methodology and format for their own link budgets.
- This worked adequately as long as the same person continued to do the work.
- Problems arose, however, when link budgets were exchanged between engineers, as formats and assumptions can vary.
- A standardized link budget software tool should be used that performs all of the relevant calculations and presents the results in a clear and complete manner.

Link Budget Example

- We will now evaluate a specific example using a simplified link budget containing the primary contributors.
- This will provide a typical format and some guidelines for a practical approach.
- Separate uplink and downlink budgets are provided; our evaluation of the total end-to-end link presumes the use of a bent-pipe repeater.
- This is one that transfers both carrier and noise from the uplink to the downlink, with only a frequency translation and amplification.
- The three constituents are often shown in a single table, but dividing them should make the development of the process clearer for readers.
- The detailed engineering comes into play with the development of each entry of the table.
- Several of the entries are calculated using straightforward mathematical equations; others must be obtained through actual measurements or at least estimates thereof.

Link Budget Example

- This particular example is for a C-band digital video link at 40 Mbps, which is capable of transmitting 8 to 12 TV channels using the Motion Picture Experts Group 2 (MPEG 2) standard.

Link Budget Example: Downlink Budget

The following Table 2.3 presents the downlink budget in a manner that identifies

- the characteristics of the satellite transmitter
- and antenna,
- the path,
- the receiving antenna,
- and the expected performance of the Earth station receiver.
- It contains the elements that select the desired radio signal (i.e., the carrier) and demodulates the useful information (i.e., the digital baseband containing the MPEG 2 “transport” bit stream).
- Once converted back to baseband, the transmission can be applied to other processes, such as de-multiplexing, decryption, and digital-to-analog conversion (D/A conversion).

Link Budget Example: Downlink Budget

Table 2.3 Link Budget Analysis for the Downlink (3.95 GHz, C-Band)

Item	*Link Parameter*	*Value*	*Unit*	*Computation*
1	Transmit power (10W)	10.0	dBW	Assumption
2	Transmit waveguide losses	1.5	dB	Assumption
3	Transmit antenna gain	27.0	dBi	U.S. Continental coverage
4	Satellite EIRP (toward LS)	35.5	dBW	1–2+3
5	Free-space loss	196.0	dB	(2.4)
6	Atmospheric absorption (clean air)	0.1	dB	Typical
7	Receive antenna gain(3.2m)	40.2	dBi	
8	Receive waveguide loss	0.5	dB	
9	Received carrier power	–121.7	dBW	4-5-6+7-8
10	System noise temperature (140K)	21.5	dBK	
11	Earth station *G/T*	18.2	dB/K	7–8–10
12	Boltzmann's constant	–228.6	dBW/Hz/K	
13	Bandwidth (25 MHz)	74.0	dB Hz	
14	Noise power	–133.1	dBW	10+12+13
15	Carrier-to-noise ratio	11.4	dB	9–14

Link Budget Example: Downlink Budget

- Each of the link parameters relates to a specific piece of hardware or some property of the microwave path between space and ground.
- A good way to develop the link budget is to prepare it with a spreadsheet program.
- This permits the designer to include the various formulas directly in the budget, thus avoiding the problem of external calculation or the potential for arithmetic error
- Commercial link budget software, such as SatMaster Pro from Arrowe Technical Services, does the same job but in a standardized fashion.

Satellite link design -Uplink

- Uplink design is easier than the down link in many cases
  - ✓earth station could use higher power transmitters
- Earth station transmitter power is set by the power level required at the input to the transporter, either
  - ✓a specific flux density is required at the satellite
  - ✓a specific power level is required at the input to the transporter
- analysis of the uplink requires calculation of the power level at the input to the transponder so that uplink C/N ratio can be found
- With small-diameter earth stations, a higher power earth station transmitter is required to achieve a similar satellite EIRP.
  - ✓interference to other satellites rises due to wider beam of small antenna
- Uplink power control can be used against uplink rain attenuation

Link Budget Example: Uplink Budget

Table 2.4 Link Budget Analysis for the Uplink (6.175 GHz, C-band)

Item	*Link Parameter*	*Value*	*Units*	*Computation*
16	Transmit power (850W)	29.3	dBW	
17	Transmit waveguide losses	2.0	dB	
18	Transmit antenna gain (7m)	50.6	dBi	
19	Uplink EIRP from Boston	77.9	dBW	16 – 17 + 18
20	Spreading loss	162.2	dB(m^2)	
21	Atmospheric attenuation	0.1	dB	
22	Flux density at the spacecraft	–84.4	dBW/m^2	19 – 20 – 21
23	Free-space loss	200.4	dB	
24	Receive antenna gain	26.3	dBi	
25	Receive waveguide loss	0.5	dB	
26	System noise temperature (450K)	26.5	dB(K)	
27	Spacecraft *G/T*	–0.7	dB/K	24 – 25 – 26
28	Received *C/T*	–122.9	dBW/K	19 – 23 – 21 + 27
29	Boltmann's constant	–228.6	dBW/Hz/K	
30	Bandwidth (25 MHz)	74.0	dB Hz	
31	Carrier-to-noise ratio	31.7	dB	28 – 29 – 30

C/N

$[C/N_0]_D = [EIRP]_D + [G/T]_D - [LOSSES]_D – [k]$ $[C/N_0]_U = [EIRP]_U + [G/T]_U - [LOSSES]_U – [k]$

Link Budget Example: Overall Link Budget

- The last step in link budgeting for a bent-pipe repeater is to combine the two link performances and compare the result against a minimum requirement—also called the threshold.
- Table 2.5 presents a detailed evaluation of the overall link under the conditions of line-of-sight propagation in clear sky.
- We have included an allocation for interference coming from sources such as a cross-polarized transponder and adjacent satellites.
- This type of entry is necessary because all operating satellite networks are exposed to one or more sources of interference.
- The bottom line represents the margin that is available to counter rain attenuation and any other losses that were not included in the link budgets.
- Alternatively, rain margin can be allocated separately to the uplink and downlink, with the combined availability value being the arithmetic product of the two as a decimal value (e.g., if the uplink and downlink were each 99.9%, then the combined availability is 0.999 × 0.999 = 0.998 or 99.8%).

Link Budget Example: Overall Link Budget

Table 2.5 Combining the Uplink and the Downlink to Estimate Overall Link Performance

Item	*Link Parameter*	*Value*	*Units*	*Computation*
32	Uplink C/N (31.7 dB)	1,479.1	Ratio	31
33	N_u/C	0.000676	Ratio	
34	Downlink C/N (11.4 dB)	13.8	Ratio	15
35	N_d/C	0.0724	Ratio	
36	Total thermal noise (N_{th}/C)	0.0731	Ratio	33 + 35
37	Total thermal C/N_{th}	13.7	Ratio	
38	Total thermal C/N_{th}	11.4	dB	
39	Interference C/I (18.0 dB)	63.1	Ratio	Assumption
40	I/C	0.015848	Ratio	
41	Total noise ($N_{th} + I$)/C	0.0889	Ratio	36 + 40
42	Total $C/(N_{th} + I)$	11.2	Ratio	
43	Total $C/(N_{th} + I)$	10.5	dB	
44	Required C/N	8.0	dB	Equipment

SATELLITE LINK DESIGN METHODOLOGY

The design methodology for a one-way satellite communication link can be summarized into the following steps.

The return link follows the same procedure.

- Step 1. Frequency band determination.
- Step 2. Satellite communication parameters determination. Make informed guesses for unknown values.
- Step 3. Earth station parameter determination; both uplink and downlink.
- Step 4. Establish uplink budget and a transponder noise power budget to find (C/N)up in the transponder
- Step 5. Determine transponder output power from its gain or output backoff.

SATELLITE LINK DESIGN METHODOLOGY

- Step 6. Establish a downlink power and noise budget for the receiving earth station
- Step 7. Calculate (C/N)down and (C/N)u for a station at the outermost contour of the satellite footprint.
- Step 8. Calculate SNR/BER in the baseband channel.
- Step 9. Determine the link margin.
- Step 10. Do a comparative analysis of the result vis-à-vis the specification requirements.

SATELLITE LINK DESIGN METHODOLOGY

- Step 11. Tweak system parameters to obtain acceptable (C/N)0 /SNR/BER values.
- Step 12. Propagation condition determination.
- Step 13. Uplink and downlink unavailability estimation.
- Step 14. Redesign system by changing some parameters if the link margins are inadequate.
- Step 15. Are gotten parameters reasonable? Is design financially feasible?
- Step 16. If YES on both counts in step 15, then satellite link design is successful – Stop.
- Step 17. If NO on either (or both) counts in step 15, then satellite link design is unsuccessful – Go to step 1.

SATELLITE ACCESS

Multiple Access System

- Applications employ multiple-access systems to allow two or more Earth stations to simultaneously share the resources of the same transponder or frequency channel.
- These include the three familiar methods:
  - FDMA,
  - TDMA, and
  - CDMA.
- Another multiple access system called space division multiple access (SDMA) has been suggested in the past. In practice, SDMA is not really a multiple access method but rather a technique to reuse frequency spectrum through multiple spot beams on the satellite.
- Because every satellite provides some form of frequency reuse (cross-polarization being included), SDMA is an inherent feature in all applications.

Multiple Access System

- TDMA and FDMA require a degree of coordination among users:
  - FDMA users cannot transmit on the same frequency and
  - TDMA users can transmit on the same frequency but not at the same time.
- Capacity in either case can be calculated based on the total bandwidth and power available within the transponder or slice of a transponder.
- CDMA is unique in that multiple users transmit on the same frequency at the same time (and in the same beam or polarization).
- This is allowed because the transmissions use a different code either in terms of high-speed spreading sequence or frequency hopping sequence.

Multiple Access System

- The capacity of a CDMA network is not unlimited, however, because at some point the channel becomes overloaded by self-interference from the multiple users who occupy it.

- Furthermore, power level control is critical because a given CDMA carrier that is elevated in power will raise the noise level for all others carriers by a like amount.

Multiple Access System

- Multiple access is always required in networks that involve two-way communications among multiple Earth stations.
- The selection of the particular method depends heavily on the specific communication requirements, the types of Earth stations employed, and the experience base of the provider of the technology.
- All three methods are now used for digital communications because this is the basis of a majority of satellite networks.

Multiple Access System

- The digital form of a signal is easier to transmit and is less susceptible to the degrading effects of the noise, distortion from amplifiers and filters, and interference.
- Once in digital form, the information can be compressed to reduce the bit rate, and FEC is usually provided to reduce the required carrier power even further.
- The specific details of multiple access, modulation, and coding are often preselected as part of the application system and the equipment available on a commercial off-the-shelf (COTS) basis.

Multiple Access System

- The only significant analog application at this time is the transmission of cable TV and broadcast TV.
- These networks are undergoing a slow conversion to digital as well, which may in fact be complete within a few years.

FDMA

- Nearly every terrestrial or satellite radio communications system employs some form of FDMA to divide up the available spectrum.
- The areas where it has the strongest hold are in single channel per carrier (SCPC), intermediate data rate (IDR) links, voice telephone systems, VSAT data networks, and some video networking schemes.
- Any of these networks can operate alongside other networks within the same transponder.
- Users need only acquire the amount of bandwidth and power that they require to provide the needed connectivity and throughput.
- Also, equipment operation is simplified since no coordination is needed other than assuring that each Earth station remains on its assigned frequency and that power levels are properly regulated.
- However, inter-modulation distortion (IMD) present with multiple carriers in the same amplifier must be assessed and managed as well.

FDMA

- The satellite operator divides up the power and bandwidth of the transponder and sells off the capacity in attractively priced segments.
- Users pay for only the amount that they need. If the requirements increase, additional FDMA channels can be purchased.
- The IMD that FDMA produces within a transponder must be accounted for in the link budget; otherwise, service quality and capacity will degrade rapidly as users attempt to compensate by increasing uplink power further.
- The big advantage, however, is that each Earth station has its own independent frequency on which to operate.
- A bandwidth segment can be assigned to a particular network of users, who subdivide the spectrum further based on individual needs.
- Another feature, is to assign carrier frequencies when they are needed to satisfy a traffic requirement. This is the general class of demand assigned networks, also called demand-assigned multiple access (DAMA).
- In general, DAMA can be applied to all three multiple access schemes previously described; however, the term is most often associated with FDMA.

Time Division Multiple Access and ALOHA

- TDMA is a truly digital technology, requiring that all information be converted into bit streams or data packets before transmission to the satellite. (An analog form of TDMA is technically feasible but never reached the market due to the rapid acceptance of the digital form.)
- Contrary to most other communication technologies, TDMA started out as a high-speed system for large Earth stations.
- Systems that provided a total throughput of 60 to 250 Mbps were developed and fielded over the past 25 years.
- However, it is the low-rate TDMA systems, operating at less than 10 Mbps, which provide the foundation of most VSAT networks.
- As the cost and size of digital electronics came down, it became practical to build a TDMA Earth station into a compact package.

Time Division Multiple Access and ALOHA

- Lower speed means that less power and bandwidth need to be acquired (e.g., a fraction of a transponder will suffice) with the following benefits:
  - The uplink power from small terminals is reduced, saving on the cost of transmitters.
  - The network capacity and quantity of equipment can grow incrementally, as demand grows.

Time Division Multiple Access and ALOHA

- TDMA signals are restricted to assigned time slots and therefore must be transmitted in bursts.
- The time frame is periodic, allowing stations to transfer a continuous stream of information on average.
- Reference timing for start-of-frame is needed to synchronize the network and provide control and coordination information.
- This can be provided either as an initial burst transmitted by a reference Earth station, or on a continuous basis from a central hub.
- The Earth station equipment takes one or more continuous streams of data, stores them in a buffer memory, and then transfers the output toward the satellite in a burst at a higher compression speed.

Time Division Multiple Access and ALOHA

- At the receiving Earth station, bursts from Earth stations are received in sequence, selected for recovery if addressed for this station, and then spread back out in time in an output expansion buffer.
- It is vital that all bursts be synchronized to prevent overlap at the satellite; this is accomplished either with the synchronization burst (as shown) or externally using a separate carrier.
- Individual time slots may be pre-assigned to particular stations or provided as a reservation, with both actions under control by a master station.
- For traffic that requires consistent or constant timing (e.g., voice and TV), the time slots repeat at a constant rate.

Time Division Multiple Access and ALOHA

- Computer data and other forms of packetized information can use dynamic assignment of bursts in a scheme much like a DAMA network.
- There is an adaptation for data, called ALOHA, that uses burst transmission but eliminates the assignment function of a master control.
- ALOHA is a powerful technique for low cost data networks that need minimum response time. Throughput must be less than 20% if the bursts come from stations that are completely uncoordinated because there is the potential for time overlap (called a collision).

Time Division Multiple Access and ALOHA

- The most common implementation of ALOHA employs a hub station that receives all of these bursts and provides a positive acknowledgement to the sender if the particular burst is good.
- If the sending station does not receive acknowledgment within a set "time window," the packet is re-sent after a randomly selected period is added to prevent another collision.
- This combined process of the window plus added random wait introduces time delay, but only in the case of a collision.
- Throughput greater than 20% brings a high percentage of collisions and resulting retransmissions, introducing delay that is unacceptable to the application.

Time Division Multiple Access and ALOHA

- An optimally and fully loaded TDMA network can achieve 90% throughput, the only reductions required for guard time between bursts and other burst overhead for synchronization and network management.
- The corresponding time delay is approximately equal to one-half of the frame time, which is proportional to the number of stations sharing the same channel.
- This is because each station must wait its turn to use the shared channel.
- ALOHA, on the other hand, allows stations to transmit immediately upon need. Time delay is minimum, except when you consider the effect of collisions and the resulting retransmission times.

Time Division Multiple Access and ALOHA

- TDMA is a good fit for all forms of digital communications and should be considered as one option during the design of a satellite application.
- The complexity of maintaining synchronization and control has been overcome through miniaturization of the electronics and by way of improvements in network management systems.
- With the rapid introduction of TDMA in terrestrial radio networks like the GSM standard, we will see greater economies of scale and corresponding price reductions in satellite TDMA equipment.

Code Division Multiple Access

- CDMA, also called spread spectrum communication, differs from FDMA and TDMA because it allows users to literally transmit on top of each other.
- This feature has allowed CDMA to gain attention in commercial satellite communication.
- It was originally developed for use in military satellite communication where its inherent anti-jam and security features are highly desirable.
- CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems.

Code Division Multiple Access

- It has not been proven that CDMA is universally superior as this depends on the specific requirements.
- For example, an effective CDMA system requires contiguous bandwidth equal to at least the spread bandwidth.
- Two forms of CDMA are applied in practice:
  (1) direct sequence spread spectrum (DSSS) and
  (2) frequency hopping spread spectrum (FHSS).
- FHSS has been used by the OmniTracs and Eutel-Tracs mobile messaging systems for more than 10 years now, and only recently has it been applied in the consumer's commercial world in the form of the Bluetooth wireless LAN standard. However, most CDMA applications over commercial satellites employ DSSS (as do the cellular networks developed by Qualcomm).

Code Division Multiple Access

- Consider the following summary of the features of spread spectrum technology (whether DSSS or FHSS):
  - Simplified multiple access: no requirement for coordination among users;
  - Selective addressing capability if each station has a unique chip code sequence—provides authentication: alternatively, a common code may still perform the CDMA function adequately since the probability of stations happening to be in synch is approximately 1/n;
  - Relative security from eavesdroppers: the low spread power and relatively fast direct sequence modulation by the pseudorandom code make detection difficult;
  - Interference rejection: the spread-spectrum receiver treats the other DSSS signals as thermal noise and suppresses narrowband interference.

Code Division Multiple Access

- A typical CDMA receiver must carry out the following functions in order to acquire the signal, maintain synchronization, and reliably recover the data:
  - Synchronization with the incoming code through the technique of correlation detection;
  - De-spreading of the carrier;
  - Tracking the spreading signal to maintain synchronization;
  - Demodulation of the basic data stream;
  - Timing and bit detection;
  - Forward error correction to reduce the effective error rate;

Code Division Multiple Access

- The first three functions are needed to extract the signal from the clutter of noise and other signals.
- The processes of demodulation, bit timing and detection, and FEC are standard for a digital receiver, regardless of the multiple access method.

Multiple Access Summary

- The bottom line in multiple access is that there is no single system that provides a universal answer.
- FDMA, TDMA, and CDMA will each continue to have a place in building the applications of the future.
- They can all be applied to digital communications and satellite links.
- When a specific application is considered, it is recommended to perform the comparison to make the most intelligent selection.

Frequency Band Trade-Offs

- Satellite communication is a form of radio or wireless communication and therefore must compete with other existing and potential uses of the radio spectrum.
- During the initial 10 years of development of these applications, there appeared to be more or less ample bandwidth, limited only by what was physically or economically justified by the rather small and low powered satellites of the time.
- In later years, as satellites grew in capability, the allocation of spectrum has become a domestic and international battlefield as service providers fight among themselves, joined by their respective governments when the battle extends across borders.
- So, we must consider all of the factors when selecting a band for a particular application.

Frequency Band Trade-Offs

- The most attractive portion of the radio spectrum for satellite communication lies between 1 and 30 GHz.
- The relationship of frequency, bandwidth, and application are shown in Figure 2.9.
- The scale along the x-axis is logarithmic in order to show all of the satellite bands; however, observe that the bandwidth available for applications increases in real terms as one moves toward the right (i.e., frequencies above 3 GHz).
- Also, the precise amount of spectrum that is available for services in a given region or country is usually less than Figure 2.9 indicates.

Operation of Multiple Access Protocols - TDMA

- An example of a TDMA burst time frame lasting about 45 ms is provided in Figure 9.4.
- As applied to the inbound channel, the transmissions from the VSATs are coordinated and highly synchronized so as to prevent overlap and a resulting loss of information.
- Each station (numbered 1 through 10) is allotted a fixed interval of time in which to transmit data.
- The frame repeats every 45 ms, producing an average delay per inbound channel burst due to multiple access of 45/2 = 22.5ms.
- Obviously, the shorter the frame, the less the average delay.

Operation of Multiple Access Protocols - TDMA

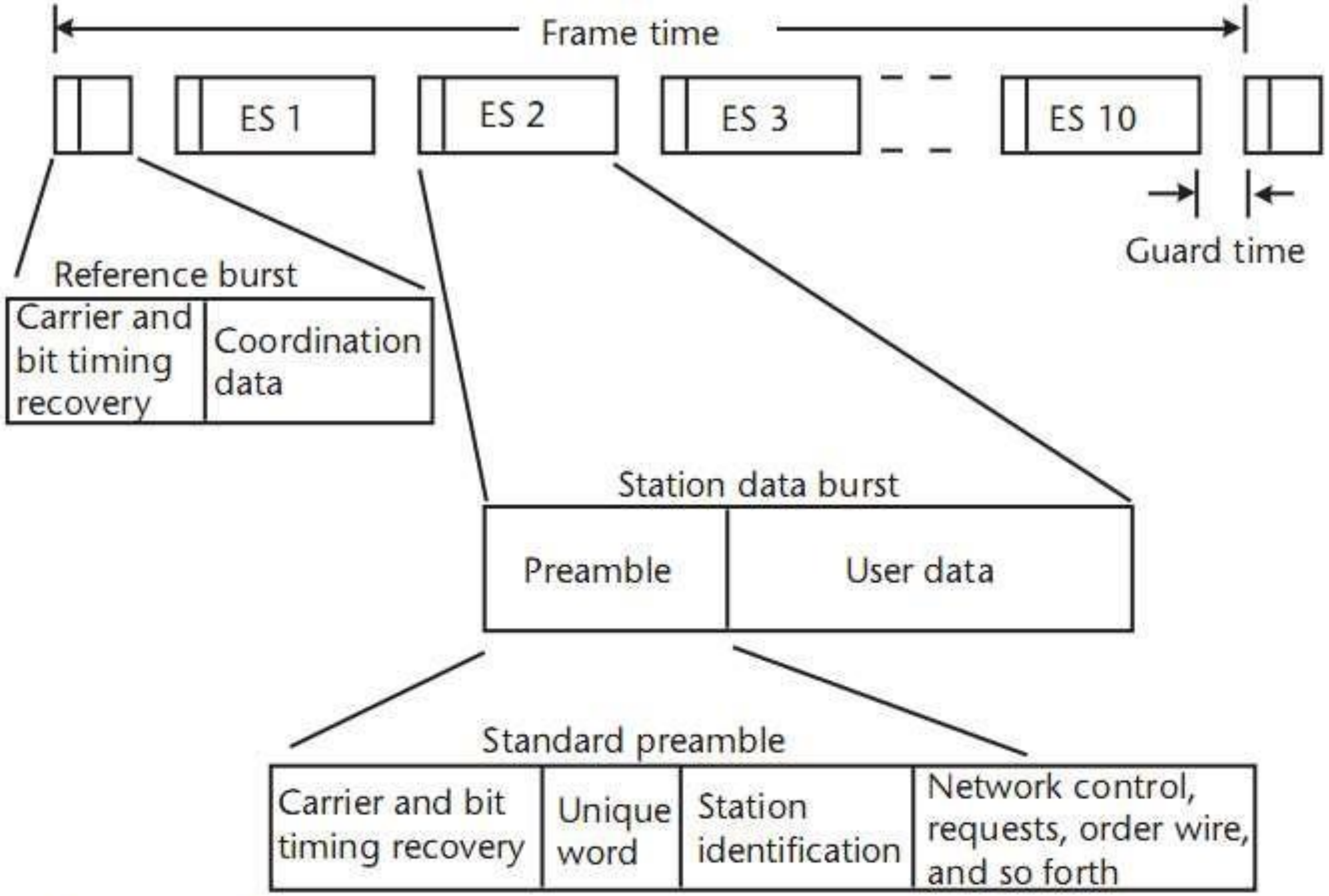


Figure 9.4 An example of a TDMA time frame format, indicating burst transmissions from 10 different VSATs on the same frequency. Stations synchronize their bursts to a reference transmitted by the hub (which may in fact be sent over the outbound broadcast carrier rather than within the TDMA time frame).

Operation of Multiple Access Protocols - ALOHA

- Another approach for separating the inbound channel transmissions in time is the ALOHA protocol.
- The scheme is simpler in that the transmissions are uncoordinated; however, the complexity occurs because there are occasional overlaps that result in lost communication.
- This is overcome by retransmissions from the affected VSATs.
- For example, a slotted ALOHA channel with three users is shown in Figure 9.5.
- Slotting refers to requiring that the ALOHA packets fall within timed periods, indicated by the vertical lines.
- The upper three horizontal lines represent three VSAT uplinks; the bottom timeline depicts the downlink showing how the ALOHA packets appear after passing through the satellite repeater.

Operation of Multiple Access Protocols - ALOHA

- Each VSAT remains in an idle state until there is data to be transmitted.
- Lets assume that VSAT 1 is the first to need the channel and so transmits the block of data without waiting.
- VSAT 2 transmits next, independently of what happens at users 1 and 3.
- From the downlink timeline, we see that VSAT 1 and VSAT 2 do not overlap and hence get through in the clear.
- The next packets from VSATs 1 and 3 have reached the satellite at approximately the same time and so have produced a collision.
- In the event of such a time overlap, the signals jameach other and the information is lost (indicated by the presence of a dark block in the downlink).
- Neither packet is received at the hub—a condition that is inferred by these VSATs because of non-acknowledgment by the hub over the outbound channel.

Operation of Multiple Access Protocols - ALOHA

- The way that packets are ultimately transferred is through automatic retransmissions, as shown at the ends of the curved arrows in Figure 9.5.
- The delay between the original and retransmitted packets is selected randomly by each VSAT to reduce the possibility of a second collision.
- The result of this protocol is that the delay is as small as it can possibly be for a packet that does not experience a collision.
- For one that does, the delay is lengthy since it includes at least two round-trip delays plus the delays of the random offset as well as from processing within the hub and VSAT.
- In an acceptable operating situation, only 1 in 10 ALOHA packets will experience a collision.

Operation of Multiple Access Protocols - ALOHA

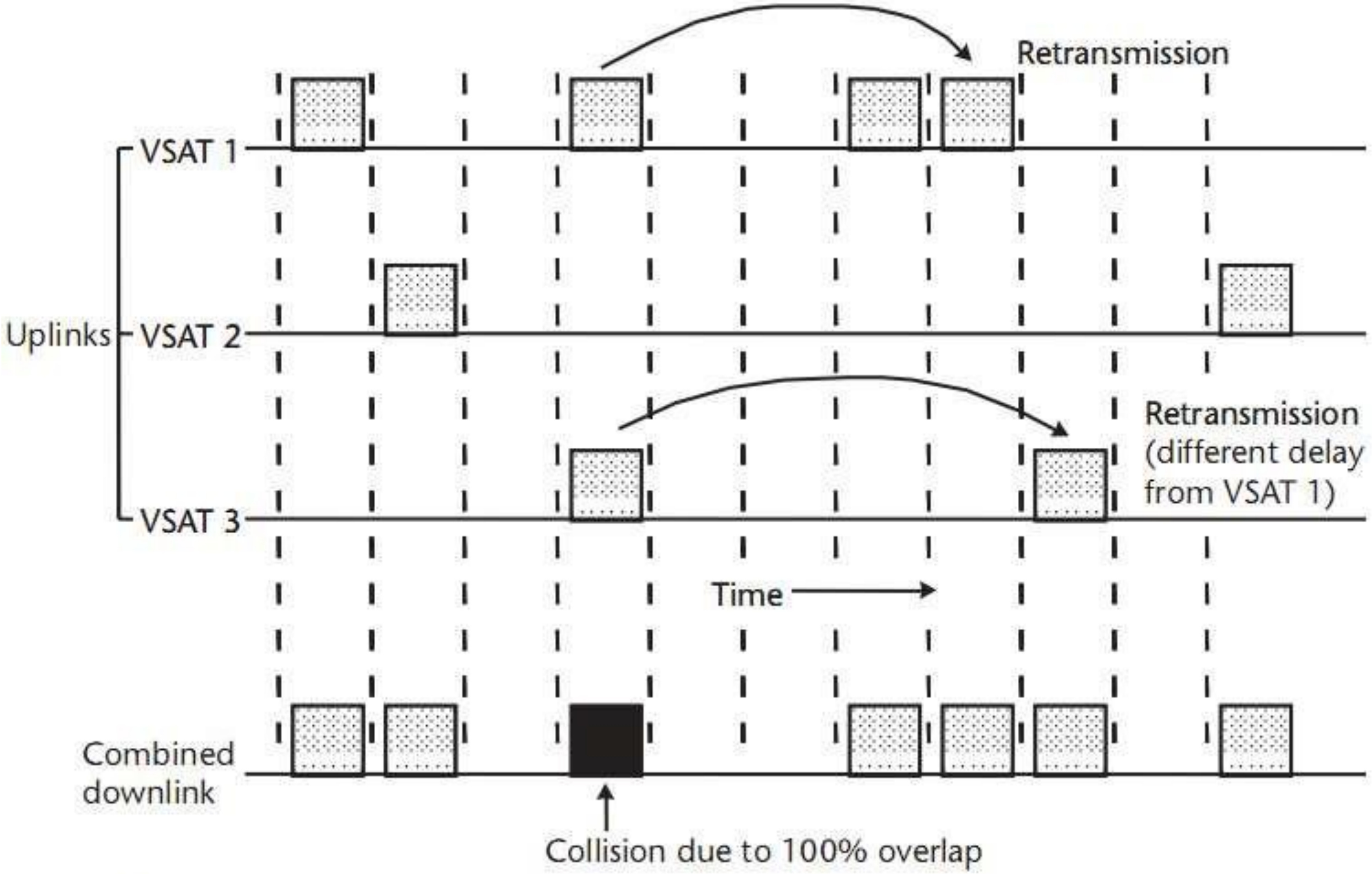


Figure 9.5 The operation of the slotted ALOHA channel with three VSATs. The collision occurs when packets from two users overlap at the satellite. The vertical dashed lines represent reference times to reduce the potential collision to times of 100% coincidence of VSAT transmission.

UNIT V
SATELLITE APPLICATIONS

INTELSAT Series :

- ✓INTELSAT stands for *International Telecommunications Satellite.*
- ✓The organization was created in 1964 and currently has over 140 member countries and more than 40 investing entities.
- ✓July 2001 INTELSAT became a private company and in May 2002 the company began providing end-to-end solutions through a network of teleports, leased fiber, and *points of presence* (PoPs) around the globe.

INSAT

- INSAT or the Indian National Satellite System is a series of multipurpose geo-stationary satellites launched by ISRO to satisfy the telecommunications, broadcasting, meteorology, and search and rescue operations.

- Commissioned in 1983, INSAT is the largest domestic communication system in the Asia Pacific Region.

- It is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. The overall coordination and management of INSAT system rests with the Secretary-level INSAT Coordination Committee.

- INSAT satellites provide transponders in various bands (C, S, Extended C and Ku) to serve the television and communication needs of India. Some of the satellites also have the Very High Resolution Radiometer (VHRR), CCD cameras for metrological imaging.

- The satellites also incorporate transponder(s) for receiving distress alert signals for search and rescue missions in the South Asian and Indian Ocean Region, as ISRO is a member of the Cospas-Sarsat programme.

INSAT System

- The Indian National Satellite (INSAT) System Was Commissioned With The Launch Of INSAT-1B In August 1983
- INSAT-1A, The First Satellite Was Launched In April 1982 But Could Not Fulfil The Mission.
- INSAT System Ushered In A Revolution In India's Television And Radio Broadcasting, Telecommunications And Meteorological Sectors.
- It Enabled The Rapid Expansion Of TV And Modern Telecommunication Facilities To Even The Remote Areas And Off-Shore Islands.

Satellites In Service

- Of The 24 Satellites Launched In The Course Of The INSAT Program, 10 Are Still In Operation.
- INSAT-2 E It Is The Last Of The Five Satellites In INSAT-2 Series{Prateek }.
- It Carries Seventeen C-Band And Lower Extended C-Band Transponders Providing Zonal And Global Coverage With An Effective Isotropic Radiated Power (EIRP) Of 36 Dbw.
- It Also Carries A Very High Resolution Radiometer (VHRR) With Imaging Capacity
- In The Visible (0.55-0.75 μm),
- Thermal Infrared (10.5-12.5 μm) And Water Vapour (5.7-7.1 μm) Channels
- Provides 2x2 Km, 8x8 Km And 8x8 Km Ground Resolution Respectively.

INSAT-3 A

- The Multipurpose Satellite, INSAT-3A, Was Launched By Ariane In April 2003.
- It Is Located At 93.5 Degree East Longitude.
- The Payloads On INSAT-3 A Are As Follows:
- 12 Normal C-Band Transponders (9 Channels Provide Expanded Coverage From Middle East To South East Asia With An EIRP Of 38 Dbw, 3 Channels Provide India Coverage With An EIRP Of 36 Dbw And 6 Extended C-Band Transponders Provide India Coverage With An EIRP Of 36 Dbw).
- A CCD Camera Provides 1x1 Km Ground Resolution, In The Visible (0.630.69 µm), Near Infrared (0.77-0.86 µm) And Shortwave Infrared (1.55-1.70 µm) Bands.

INSAT-3 D

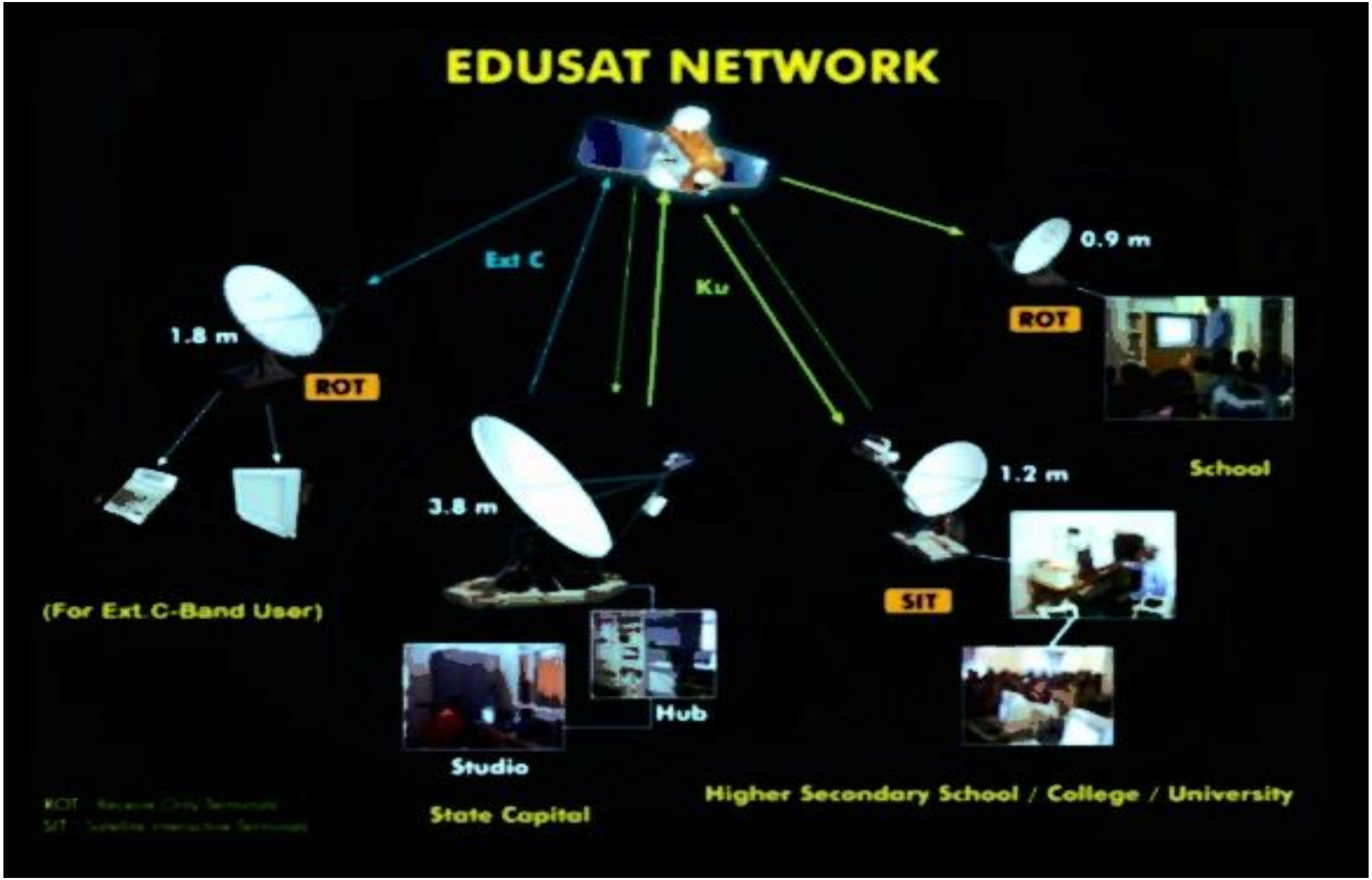
- Launched In July 2013
- INSAT-3D Is Positioned At 82 Degree East Longitude.
- INSAT-3D Payloads Include Imager, Sounder, Data Relay Transponder And Search & Rescue Transponder.
- All The Transponders Provide Coverage Over Large Part Of The Indian Ocean Region Covering India,Bangladesh, Bhutan,Maldives, Nepal, Seychelles, Sri Lanka And Tanzania For Rendering Distress Alert Services

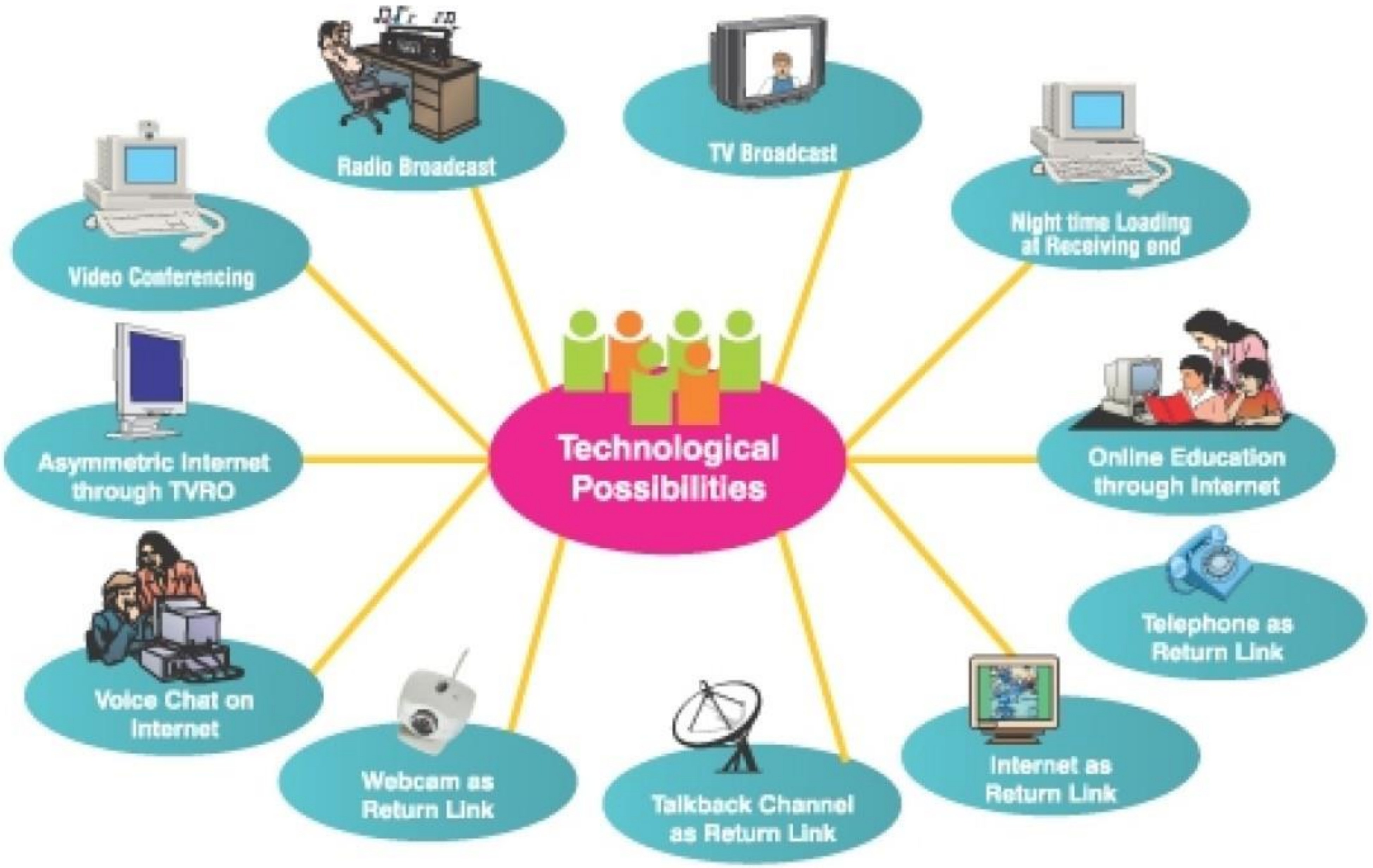
- INSAT-3 E
- Launched In September 2003
- INSAT-3E Is Positioned At 55 Degree East Longitude And Carries 24 Normal C-Band Transponders Provide An Edge Of Coverage EIRP Of 37 Dbw Over India And 12 Extended C-Band Transponders Provide An Edge Of Coverage EIRP Of 38 Dbw Over India.
- KALPANA-1
- KALPANA-1 Is An Exclusive Meteorological Satellite Launched By PSLV In September 2002.
- It Carries Very High Resolution Radiometer And DRT Payloads To Provide Meteorological Services.
- It Is Located At 74 Degree East Longitude. Its First Name Was METSAT.
- It Was Later Renamed As KALPANA1 To Commemorate Kalpana Chawla.

Edusat

- Configured For Audio-Visual Medium Employing Digital Interactive Classroom Lessons And Multimedia Content, EDUSAT Was Launched By GSLV In September 2004.
- Its Transponders And Their Ground Coverage Are Specially Configured To Cater To The Educational Requirements.
- GSAT-2

Launched By The Second Flight Of GSLV In May 2003, GSAT-2 Is Located At 48 Degree East Longitude And Carries Four Normal C-Band Transponders To Provide 36 Dbw EIRP With India Coverage, Two Ku Band Transponders With 42 Dbw EIRP Over India And An MSS Payload Similar To Those On INSAT-3B And INSAT-3 C.


EDUSAT NETWORK
Ext C
Ku
0.9 m
ROT
1.8 m
ROT
3.8 m
1.2 m
School
SIT
(For Ext.C-Band User)
Hub
Studio
State Capital
Higher Secondary School / College / University



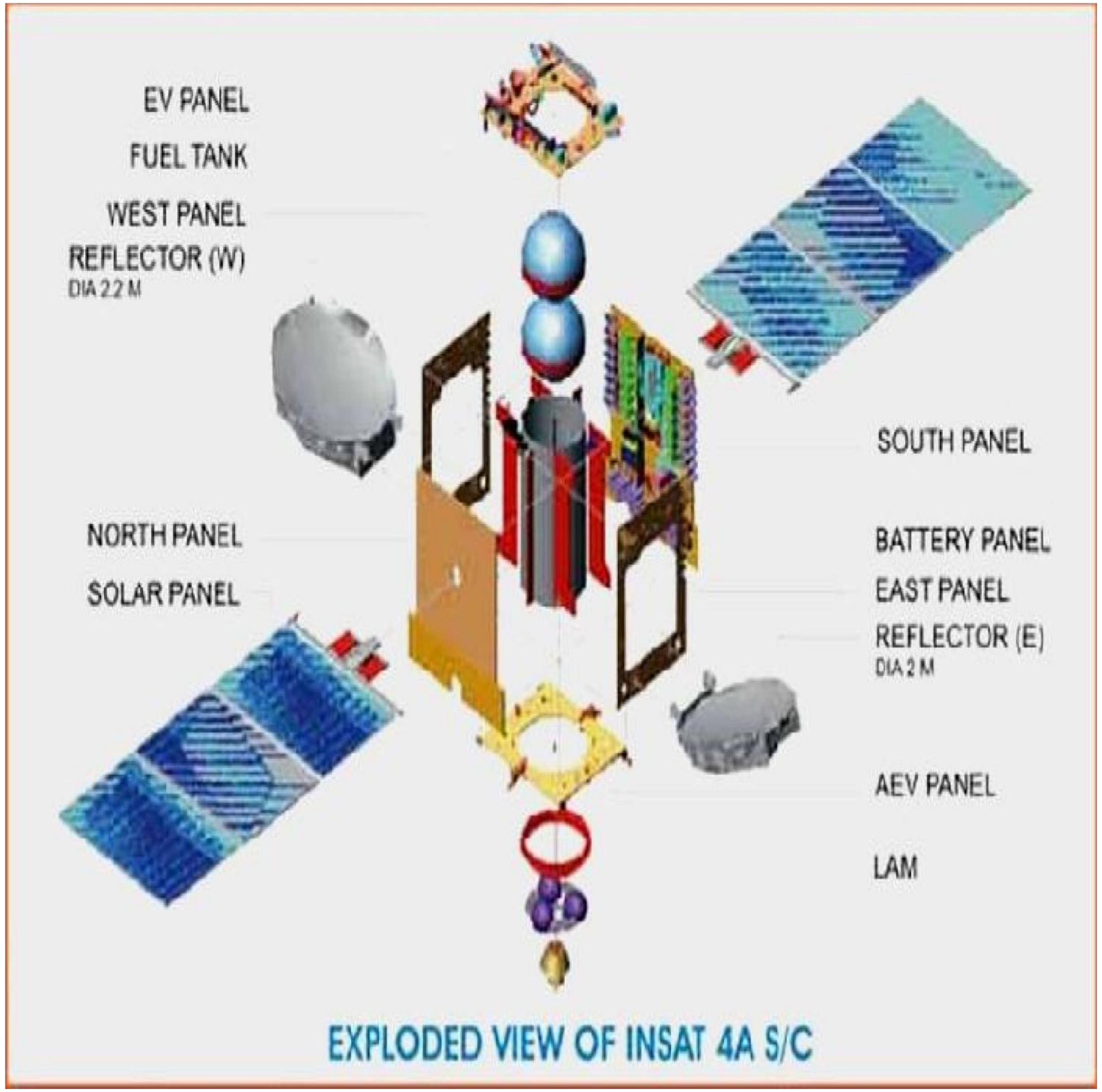
Potential uses of EDUSAT

INSAT-4 Series

- ✓ INSAT-4A is positioned at 83 degree East longitude along with INSAT-2 E and INSAT-3B.

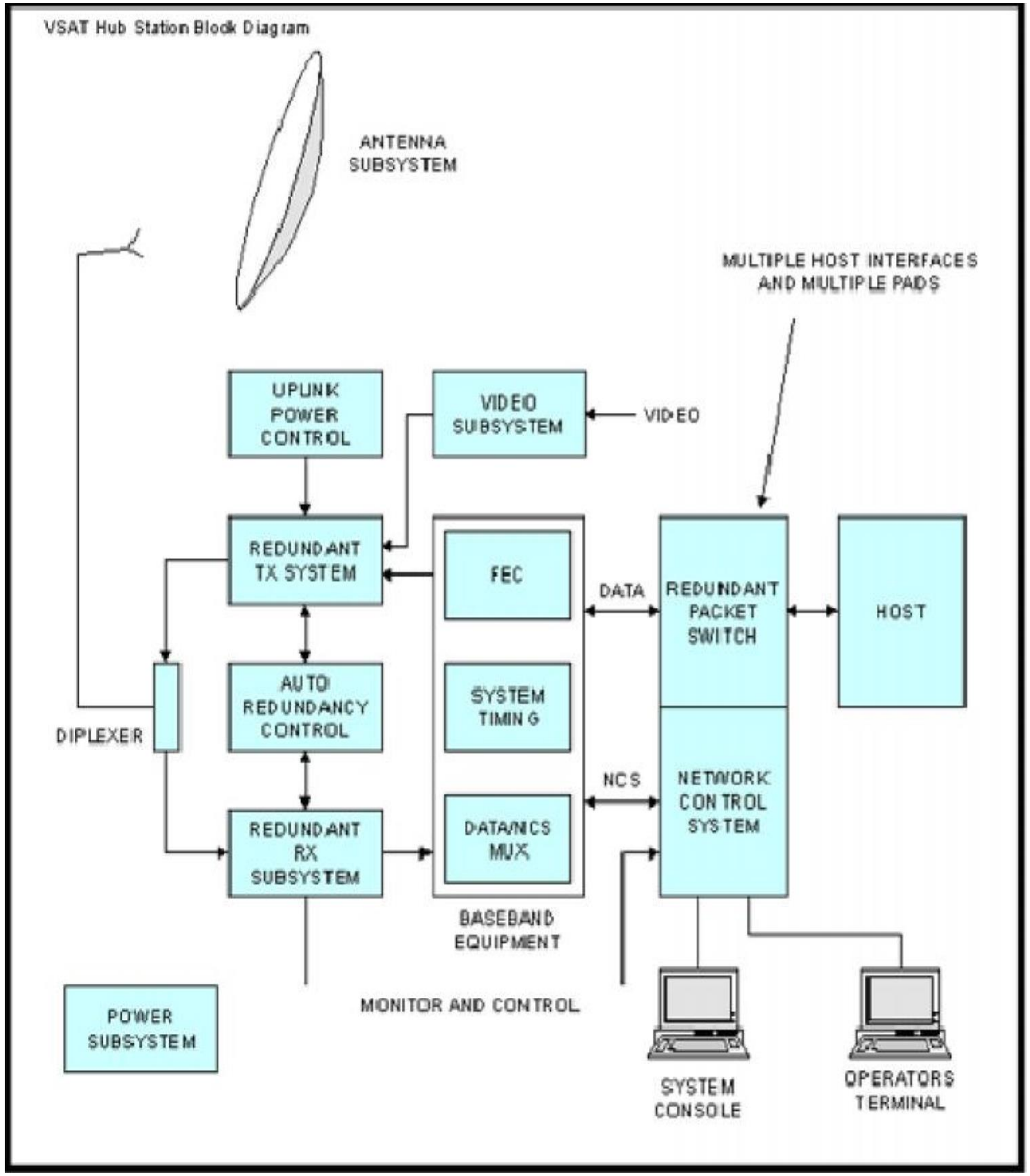
- ✓ It carries 12 Ku band 36 MHz bandwidth transponders employing 140 W TWTAs to provide an EIRP of 52 dBW at the edge of coverage polygon with footprint covering Indian main land and 12 C-band 36 MHz bandwidth transponders provide an EIRP of 39 dBW at the edge of coverage with expanded radiation patterns encompassing Indian geographical boundary, area beyond India in southeast and northwest regions.
- ✓ Tata Sky, a joint venture between the TATA Group and STAR uses INSAT-4A for distributing their DTH service.

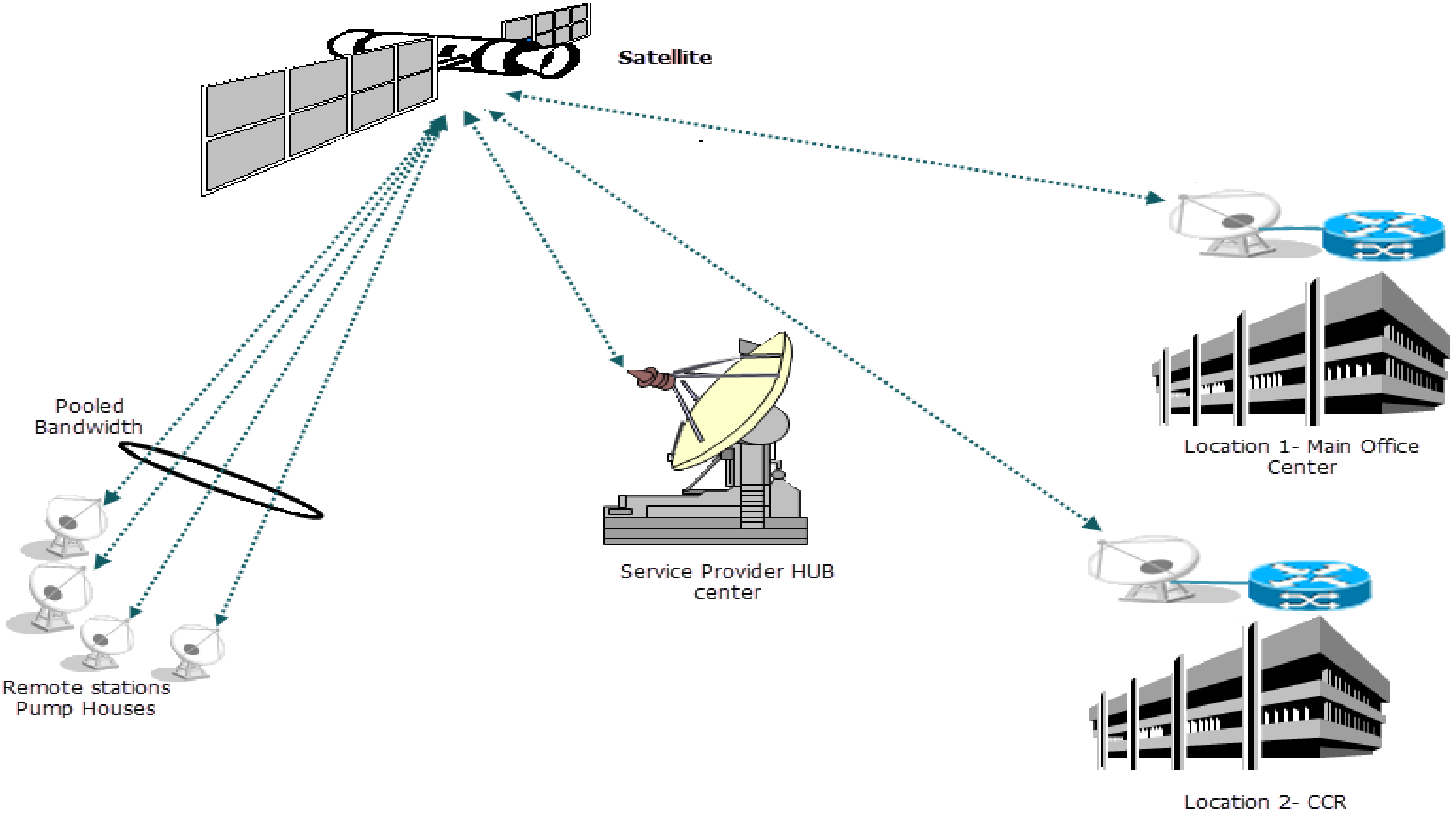
    INSAT-4 A
    INSAT-4 B
    Glitch In INSAT 4B
    China-Stuxnet Connection
    INSAT-4 CR
    GSAT-8 / INSAT-4 G
    GSAT-12 /GSAT-10

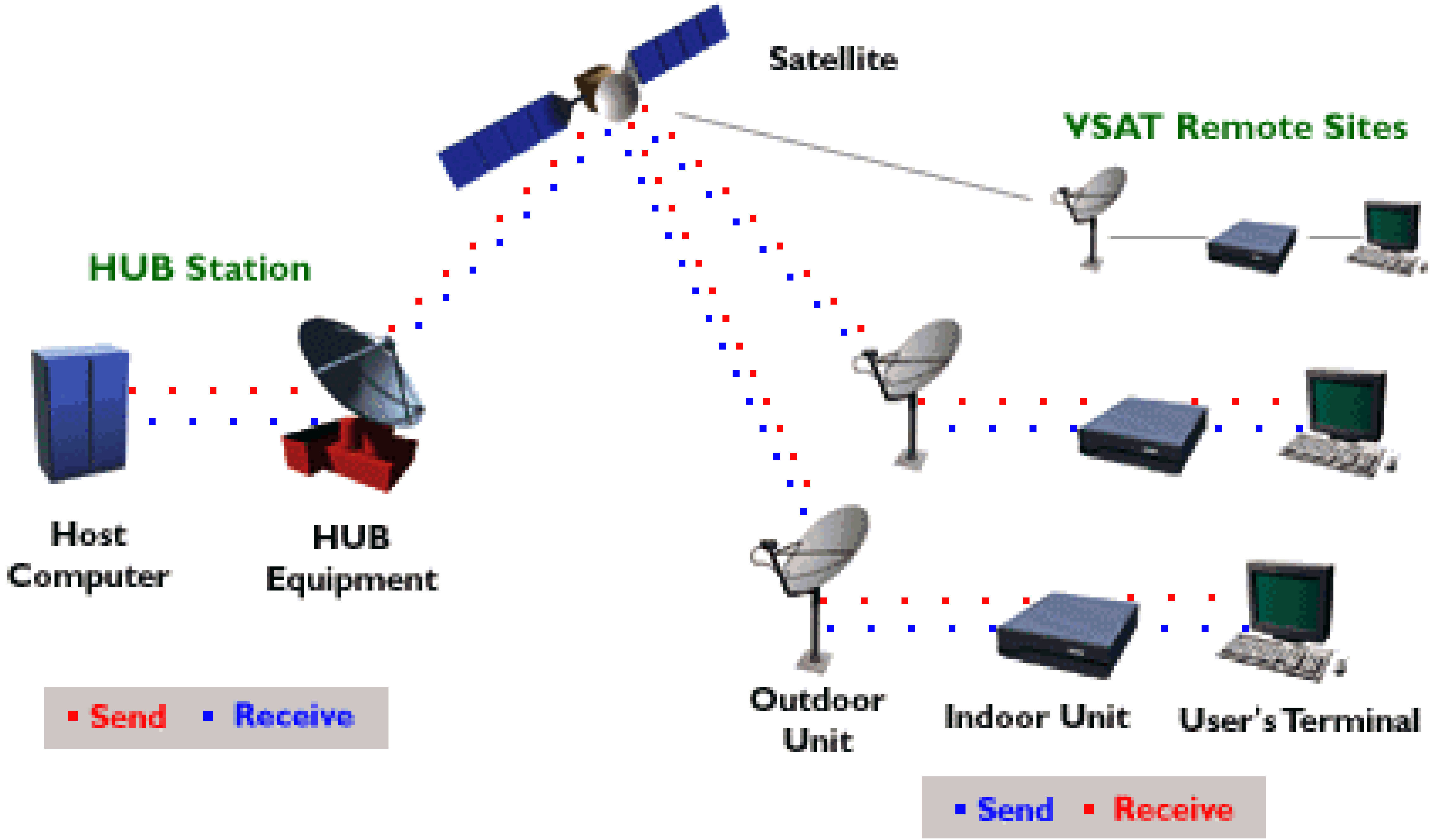


VSAT

- VSAT stands for very small aperture terminal system.
- This is the distinguishing feature of a VSAT system, the earth-station antennas being typically less than 2.4 m in diameter (Rana et al., 1990).
- The trend is toward even smaller dishes, not more than 1.5 m in diameter (Hughes et al., 1993).
- In this sense, the small TVRO terminals for direct broadcast satellites could be labeled as VSATs, but the appellation is usually reserved for private networks, mostly providing two-way communications facilities.
- Typical user groups include banking and financial institutions, airline and hotel booking agencies, and large retail stores with geographically dispersed outlets.




Satellite
Pooled Bandwidth
Service Provider HUB center
Location 1- Main Office Center
Remote stations Pump Houses
Location 2- CCR


Satellite
VSAT Remote Sites
HUB Station
Host Computer
HUB Equipment
Outdoor Unit
Indoor Unit
User's Terminal
Send
Receive
Send
Receive

VSAT network

- ✓The basic structure of a VSAT network consists of a hub station which provides a broadcast facility to all the VSATs in the network and the VSATs themselves which access the satellite in some form of multiple- access mode.
- ✓The hub station is operated by the service provider, and it may be shared among a number of users, but of course, each user organization has exclusive access to its own VSAT network.
- ✓Time division multiplex is the normal downlink mode of transmission from hub to the VSATs, and the transmission can be broadcast for reception by all the VSATs in a network, or address coding can be used to direct messages to selected VSATs.
- ✓A form of *demand assigned multiple access* (DAMA) is employed in some systems in which channel capacity is assigned in response to the fluctuating demands of the VSATs in the network.
- ✓Most VSAT systems operate in the Ku band, although there are some C band systems in existence (Rana et al., 1990).

Applications

- ✓Supermarket shops (tills, ATM machines, stock sale updates and stock ordering).
- ✓Chemist shops - Shoppers Drug Mart - Pharmaprix.
- ✓Broadband direct to the home. e.g. Downloading MP3 audio to audio players.
- ✓Broadband direct small business, office etc, sharing local use with many PCs.
- ✓Internet access from on board ship Cruise ships with internet cafes, commercial shipping communications

Mobile satellite services: GSM

Services and Architecture :

- ✓If your work involves (or is likely to involve) some form of wireless public communications, you are likely to encounter the GSM standards.
- ✓Initially developed to support a standardized approach to digital cellular communications in Europe, the "Global System for Mobile Communications" (GSM) protocols are rapidly being adopted to the next generation of wireless telecommunications systems.
- ✓In the US, its main competition appears to be the cellular TDMA systems based on the IS-54 standards. Since the GSM systems consist of a wide range of components, standards, and protocols.

- ✓The GSM and its companion standard DCS1800 (for the UK, where the 900 MHz frequencies are not available for GSM) have been developed over the last decade to allow cellular communications systems to move beyond the limitations posed by the older analog systems.
- ✓Analog system capacities are being stressed with more users that can be effectively supported by the available frequency allocations
- ✓. Compatibility between types of systems had been limited, if non-existent.
- ✓By using digital encoding techniques, more users can share the same frequencies than had been available in the analog systems.
- ✓As compared to the digital cellular systems in the US (CDMA [IS-95] and TDMA [IS-54]) , the GSM market has had impressive success.
- ✓Estimates of the numbers of telephones run from 7.5 million GSM phones to .5 million IS54 phones to .3 million for IS95.

- ✓GSM has gained in acceptance from its initial beginnings in Europe to other parts of the world including Australia, New Zealand, countries in the Middle East and the far east.

- ✓ Beyond its use in cellular frequencies (900 MHz for GSM, 1800 MHz for DCS1800), portions of the GSM signaling protocols are finding their way into the newly developing PCS and LEO Satellite communications systems.

- ✓While the frequencies and link characteristics of these systems differ from the standard GSM air interface.

- ✓ all of these systems must deal with users roaming from one cell (or satellite beam) to another, and bridge services to public communication networks including the Public Switched Telephone Network (PSTN), and public data networks (PDN).

GSM architecture includes several subsystems

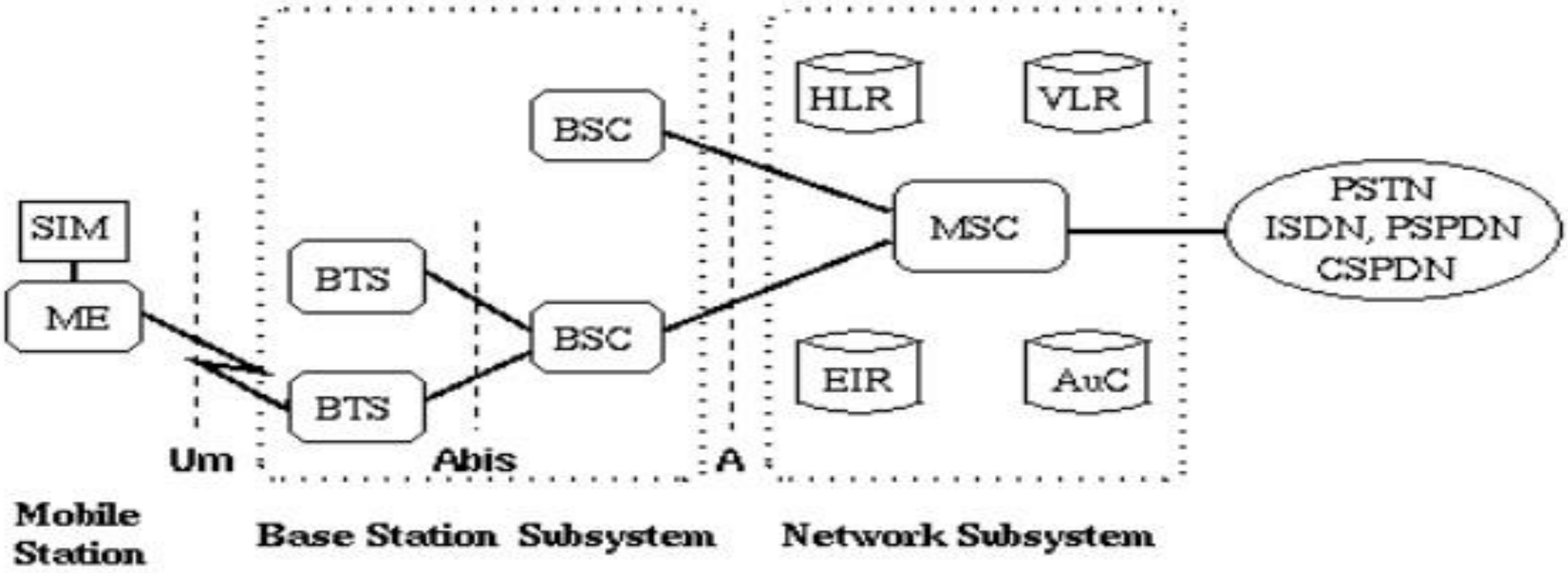
✓The Mobile Station (MS)

- These digital telephones include vehicle, portable and hand-held terminals.
- A device called the Subscriber Identity Module (SIM) that is basically a smart-card provides custom information about users such as the services they've subscribed to and their identification in the network

✓The Base Station Sub-System (BSS)

- The BSS is the collection of devices that support the switching networks radio interface.
- Major components of the BSS include the Base Transceiver Station (BTS) that consists of the radio modems and antenna equipment.
- In OSI terms, the BTS provides the physical interface to the MS where the BSC is responsible for the link layer services to the MS.
- Logically the transcoding equipment is in the BTS, however, an additional component

GSM System Architecture



SIM Subscriber Identity Module
ME Mobile Equipment
BTS Base Transceiver Station
BSC Base Station Controller
HLR Home Location Register
VLR Visitor Location Register
MSC Mobile services Switching Center
EIR Equipment Identity Register
AuC Authentication Center

- The Network and Switching Sub-System (NSS) T

❖The NSS provides the switching between the GSM subsystem and external networks along with the databases used for additional subscriber and mobility management.

✓Major components in the NSS include

➢the Mobile Services Switching Center (MSC),

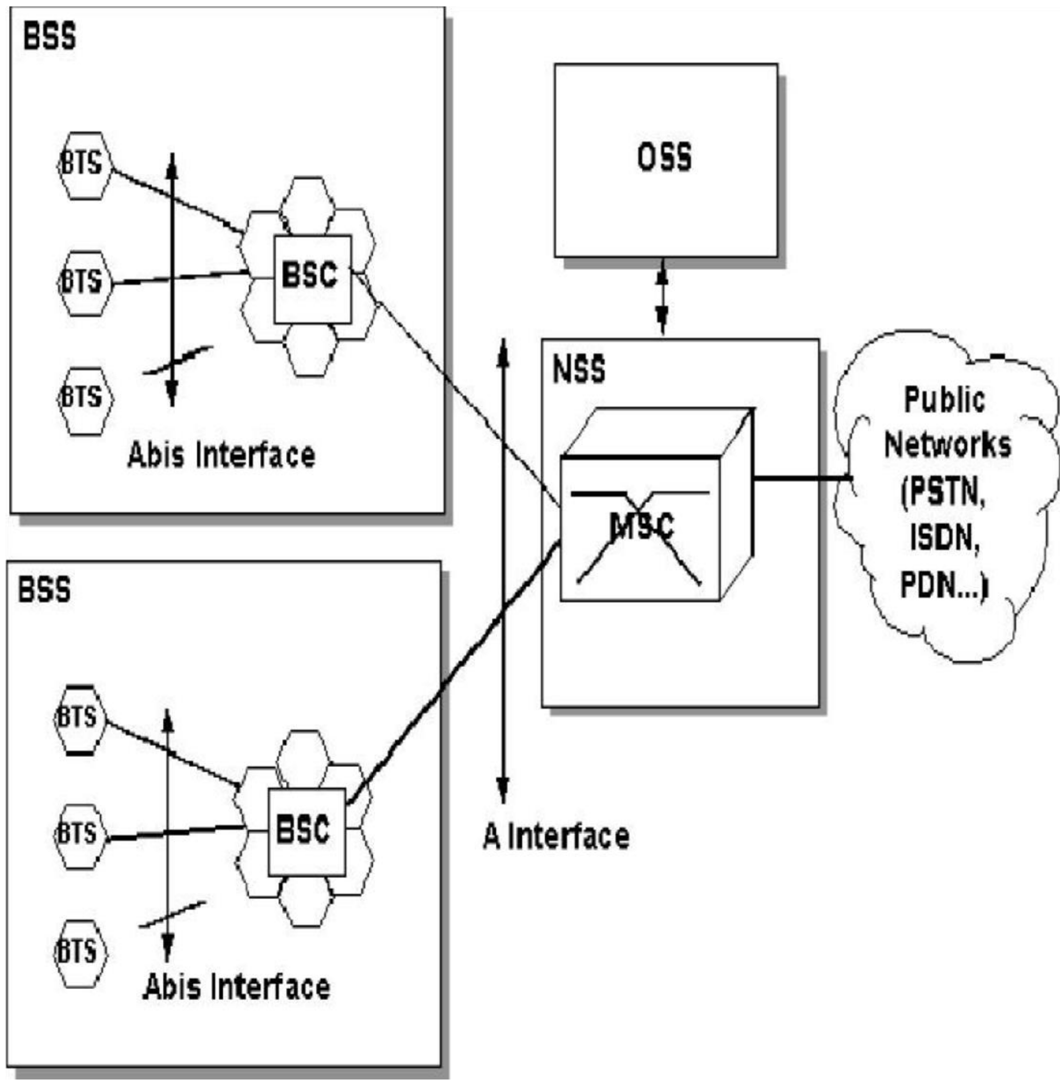
➢Home and Visiting Location Registers (HLR, VLR).

➢ The HLR and VLR databases are interconnected through the telecomm standard Signaling System 7 (SS7) control network.

✓The Operation Sub-System (OSS)

✓The OSS provides the support functions responsible for the management of network maintenance and services.

✓Components of the OSS are responsible for network operation and maintenance, mobile equipment management, and subscription management and charging.



Several channels are used in the air interface

- ✓ **FCCH** - the frequency correction channel - provides frequency synchronization information in a burst
- ✓ **SCH** - Synchronization Channel - shortly following the FCCH burst (8 bits later), provides a reference to all slots on a given frequency
- ✓ **PAGCH** - Paging and Access Grant Channel -used for the transmission of paging information requesting the setup of a call to a MS.
- ✓ **RACH** - Random Access Channel - an inbound channel used by the MS to request connections from the ground network. Since this is used for the first access attempt by users of the network, a random access scheme is used to aid in avoiding collisions.
- ✓ **CBCH -** Cell Broadcast Channel - used for infrequent transmission of broadcasts by the ground network.
- ✓ **BCCH** - Broadcast Control Channel - provides access status information to the MS. The information provided on this channel is used by the MS to determine whether or not to request a transition to a new cell
- ✓ **FACCH -** Fast Associated Control Channel for the control of handovers
- ✓ **TCH/F** - Traffic Channel, Full Rate for speech at 13 kbps or data at 12, 6, or 3.6 kbps
- ✓ **TCH/H** - Traffic Channel, Half Rate for speech at 7 kbps, or data at 6 or 3.6 kbps

GSM service security

- GSM was designed with a moderate level of service security.
- GSM uses several cryptographic algorithms for security.
- The A5/1, A5/2, and A5/3 stream ciphers are used for ensuring over-the-air voice privacy.
- GSM uses General Packet Radio Service (GPRS) for data transmissions like browsing the web.
- The most commonly deployed GPRS ciphers were publicly broken in 2011The researchers revealed flaws in the commonly used GEA/1.

Global Positioning System (GPS)

- ✓ The Global Positioning System (GPS) is a satellite based navigation system that can be used to locate positions anywhere on earth.
- ✓ Operated by the U.S. Department of Defense
- ✓ it consists of satellites, control and monitor stations, and receivers.
- ✓ GPS receivers take information transmitted from the satellites and uses triangulation to calculate a user's exact location.
- ✓ GPS is used on incidents in a variety of ways

- To determine position locations

  for example, you need to radio a helicopter pilot the coordinates of your position location so the pilot can pick you up.

- To navigate from one location to another

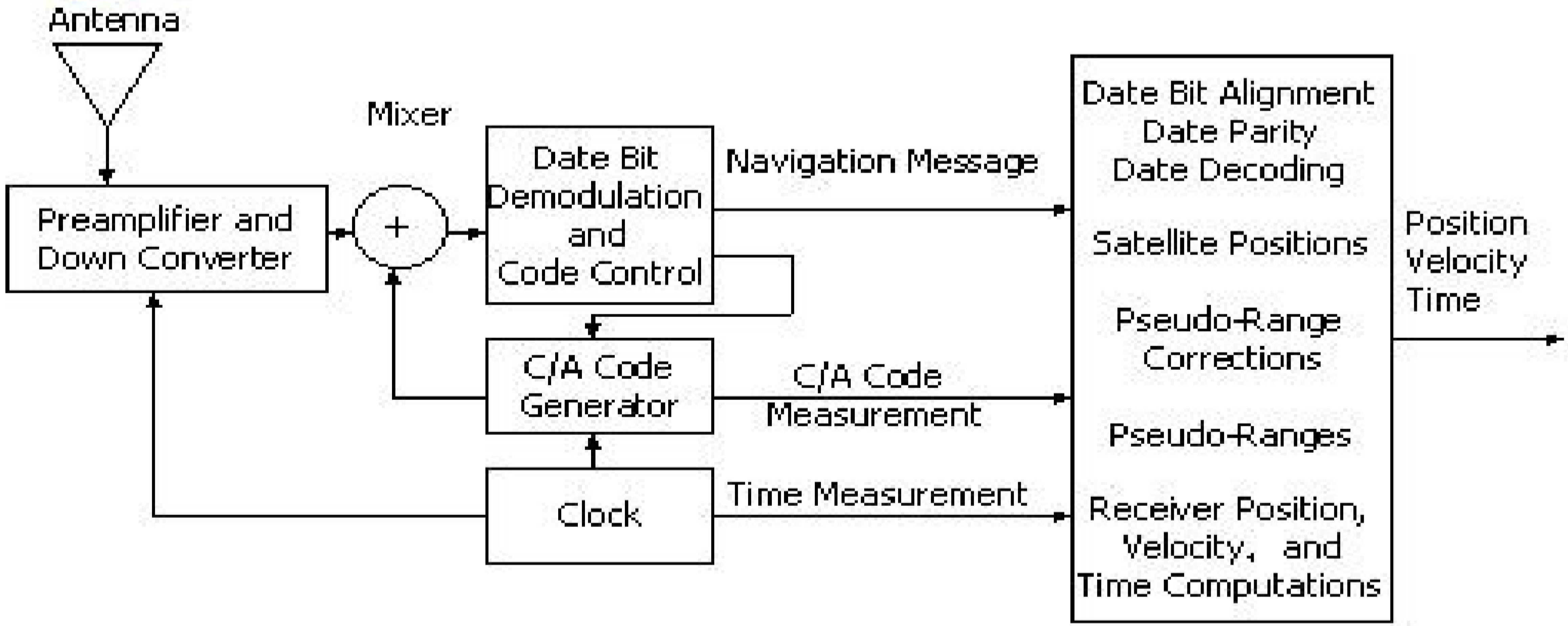
  for example, you need to travel from a lookout to the fire perimeter.

- To create digitized maps

  for example, you are assigned to plot the fire perimeter and hot spots.

- To determine distance between two points or how far you are from another location.

Simplified GPS Receiver Block Diagram



Three Segments of GPS:

Space Segment — Satellites orbiting the earth

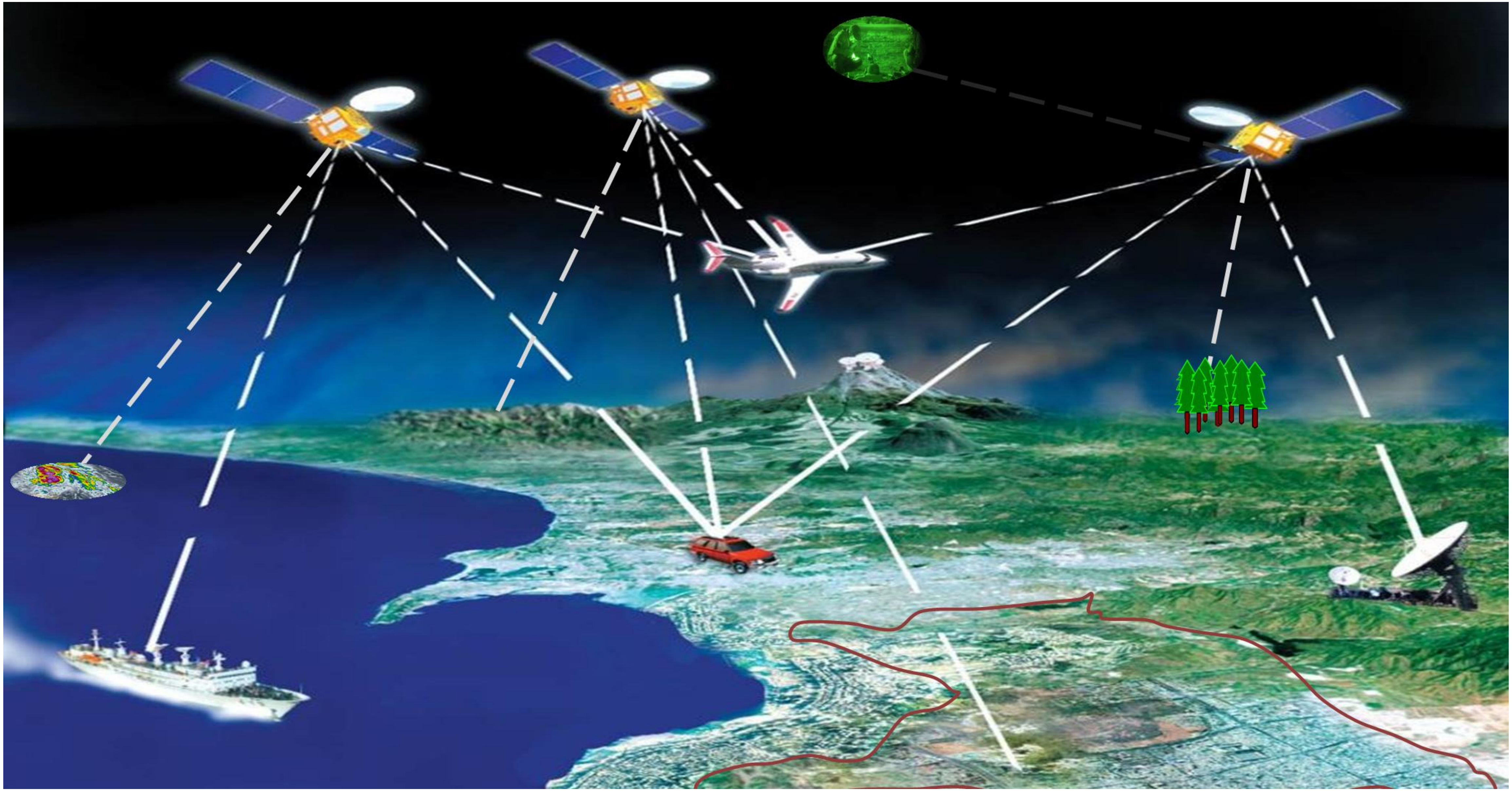
- ✓ consists of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude.
- ✓ This high altitude allows the signals to cover a greater area.
- ✓ The satellites are arranged in their orbits so a GPS receiver on earth can receive a signal from at least four satellites at any given time.
- ✓ Each satellite contains several atomic clocks.

Control Segment — The control and monitoring stations

- ✓ Tracks the satellites and then provides them with corrected orbital and time information.
- ✓ consists of five unmanned monitor stations and one Master Control Station.
- ✓ The five unmanned stations monitor GPS satellite signals and then send that information to the Master Control Station where anomalies are corrected and sent back to the GPS satellites through ground antennas.

User Segment — The GPS receivers owned by civilians and military

- ✓ The user segment consists of the users and their GPS receivers.
- ✓ The number of simultaneous users is limitless.



How GPS Determines a Position

- The GPS receiver uses the following information to determine a position.

❖ Precise location of satellites

- When a GPS receiver is first turned on, it downloads orbit information from all the satellites called an almanac.
- This process, the first time, can take as long as 12 minutes; but once this information is downloaded, it is stored in the receiver's memory for future use.

❖ Distance from each satellite

- The GPS receiver calculates the distance from each satellite to the receiver by using the distance formula: distance = velocity x time.
- The receiver already knows the velocity, which is the speed of a radio wave or 186,000 miles per second (the speed of light).

❖ Triangulation to determine position

- The receiver determines position by using triangulation.
- When it receives signals from at least three satellites the receiver should be able to calculate its approximate position (a 2D position).
- The receiver needs at least four or more satellites to calculate a more accurate 3D position.

Using a GPS Receiver

❖ There are several different models and types of GPS receivers.

- Refer to the owner's manual for your GPS receiver and practice using it to become proficient.

❖ When working on an incident with a GPS receiver it is important to:

✓ Always have a compass and a map.

✓ Have a GPS download cable.

✓ Have extra batteries.

✓ Know memory capacity of the GPS receiver to prevent loss of data, decrease in accuracy of data,or other problems.

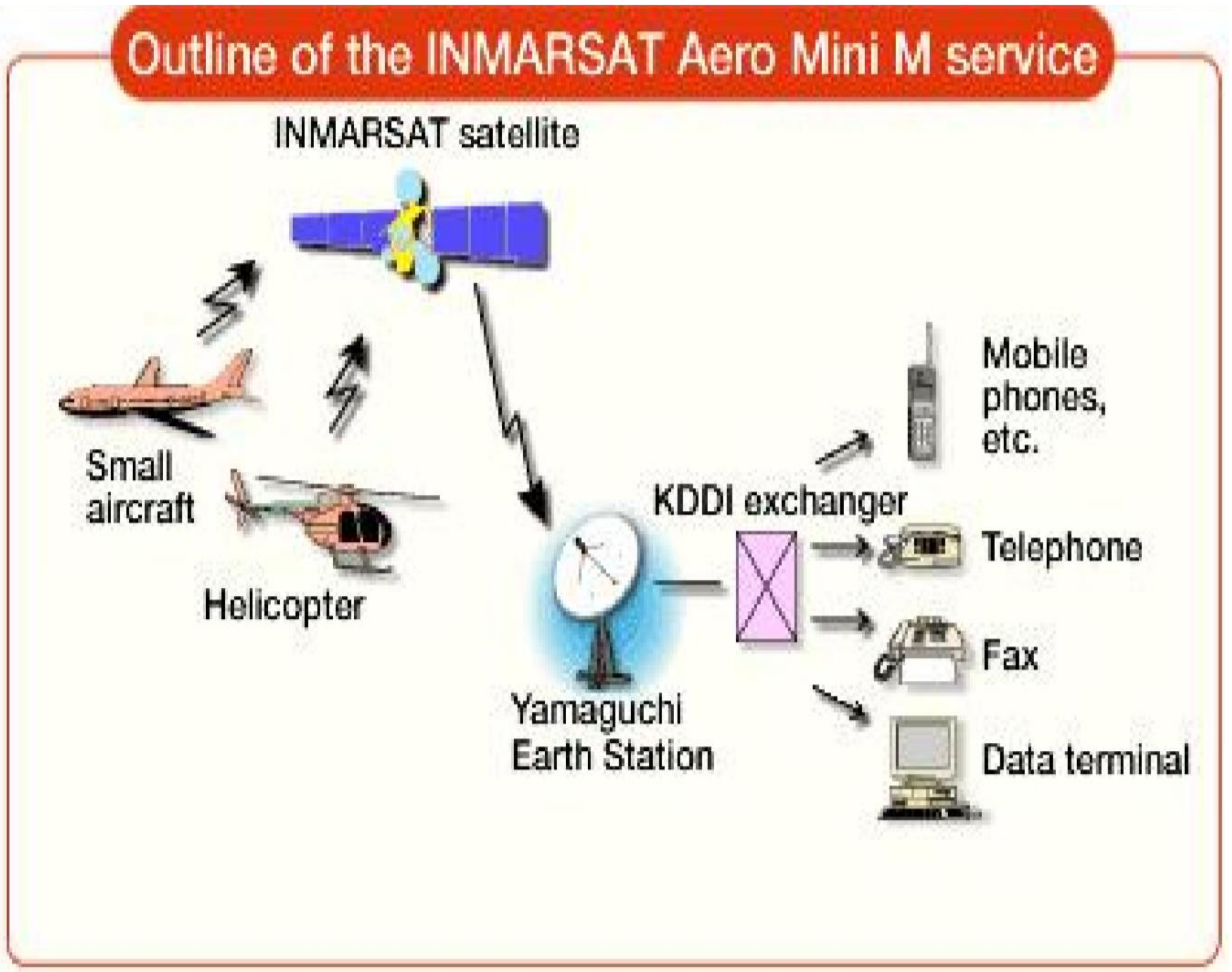
✓ Use an external antennae whenever possible, especially under tree canopy, in canyons, or while flying or driving.

✓ Set up GPS receiver according to incident or agency standard regulation; coordinate system.

✓ Take notes that describe what you are saving in the receiver.

INMARSAT

- Inmarsat-Indian Maritime SATellite
- sole IMO-mandated provider of satellite communications for the GMDSS
- Global Maritime Distress and Safety System (GMDSS)
- Availability for GMDSS is a minimum of 99.9%
- Inmarsat has constantly and consistently exceeded this figure & Independently audited by IMSO and reported on to IMO.
- Now Inmarsat commercial services use the same satellites and network
- Inmarsat A closes at midnight on 31 December 2007 Agreed by IMO – MSC/Circ.1076.
- Successful closure programme almost concluded Overseen throughout by IMSO.

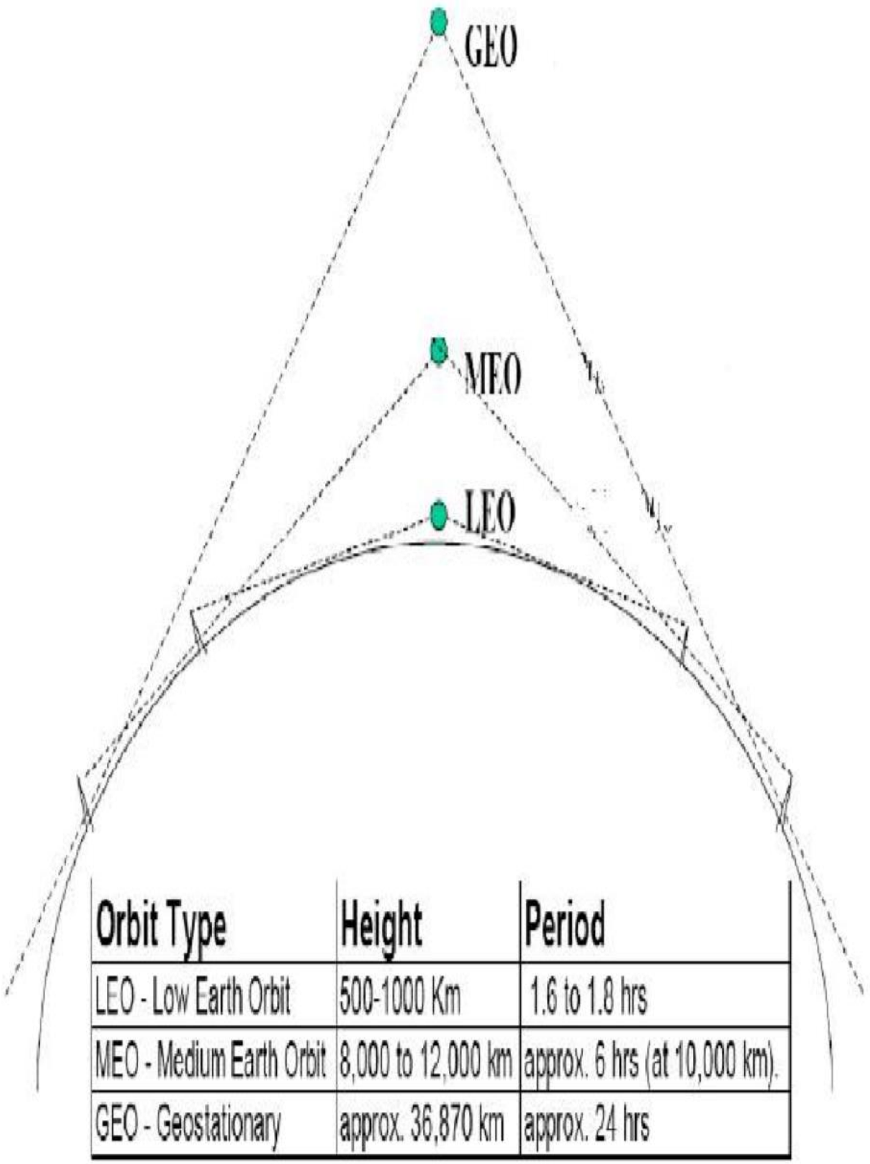


GMDSS services continue to be provided by

- ✓Inmarsat B, Inmarsat C/mini-C and Inmarsat Fleet F77
- ✓ Potential for GMDSS on Fleet Broadband being assessed
- ✓ The IMO Criteria for the Provision of Mobile Satellite Communications Systems in the Global Maritime Distress and Safety System (GMDSS)
- ✓ Amendments were proposed; potentially to make it simpler for other satellite systems to be approved
- ✓ The original requirements remain and were approved by MSC 83
- ✓ No dilution of standards
- ✓ Minor amendments only; replacement Resolution expected to be approved by the IMO 25th Assembly
- ✓ Inmarsat remains the sole, approved satcom provider for the GMDSS

LEO

- ❖ Low Earth Orbit satellites have a small area of coverage.
- ❖ They are positioned in an orbit approximately 3000km from the surface of the earth
  - ✓ They complete one orbit every 90 minutes
  - ✓ The large majority of satellites are in low earth orbit
  - ✓ The Iridium system utilizes LEO satellites (780km high)
  - ✓ The satellite in LEO orbit is visible to a point on the earth for a very short time



Orbit Type	Height	Period
LEO - Low Earth Orbit	500-1000 Km	1.6 to 1.8 hrs
MEO - Medium Earth Orbit	8,000 to 12,000 km	approx. 6 hrs (at 10,000 km).
GEO - Geostationary	approx. 36,870 km	approx. 24 hrs

MEO

- ✓ *Medium Earth Orbit* satellites have orbital altitudes between 3,000 and 30 ,000 km.

- ✓They are commonly used in navigation systems such as GPS

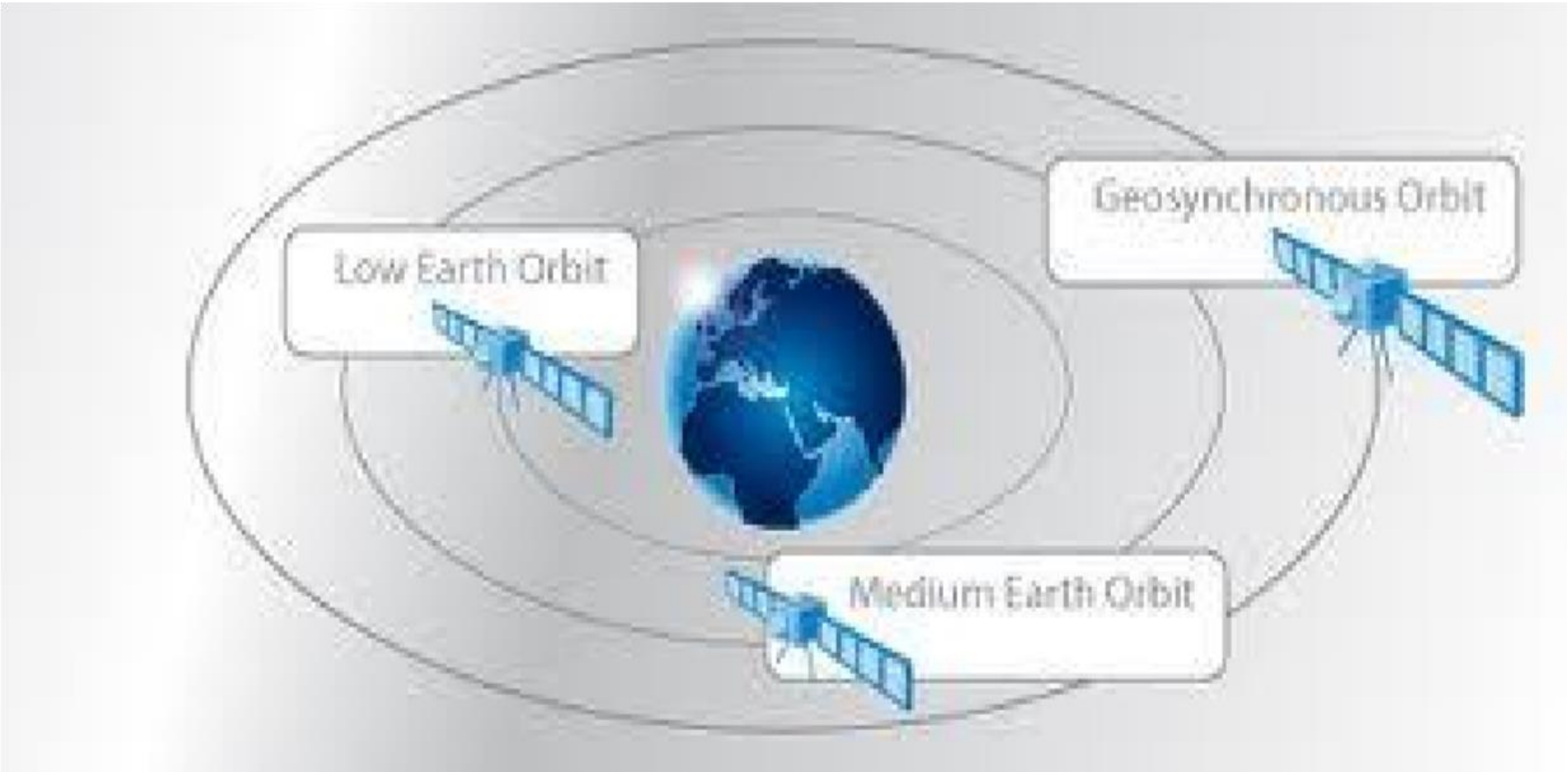
GEO

- *Geosynchronous (Geostationary) Earth Orbit* satellites are positioned over the equator.
- The orbital altitude is around 30,000-40 ,000 km
- There is only one geostationary orbit possible around the earth Lying on the earth’s equatorial plane.
  - ✓ The satellite orbiting at the same speed as the rotational speed of the earth on its axis.
  - ✓ They complete one orbit every 24 hours. This causes the satellite to appear stationary with respect to a point on the earth, allowing one satellite to provide continual coverage to a given area on the earth's surface
  - ✓ One GEO satellite can cover approximately 1/3 of the world’s surface
- They are commonly used in communication systems
- Advantages:
  - ✓ Simple ground station tracking.
  - ✓ Nearly constant range Very small frequency shift Disadvantages:
  - ✓ Transmission delay of the order of 250 msec. Large free space loss.
  - ✓ No polar coverage

Satellite orbits in terms of the orbital height

❖ According to distance from earth:

- ✓ Geosynchronous Earth Orbit (GEO) ,
- ✓ Medium Earth Orbit (MEO),
- ✓ Low Earth Orbit (LEO)



Satellite Navigational System

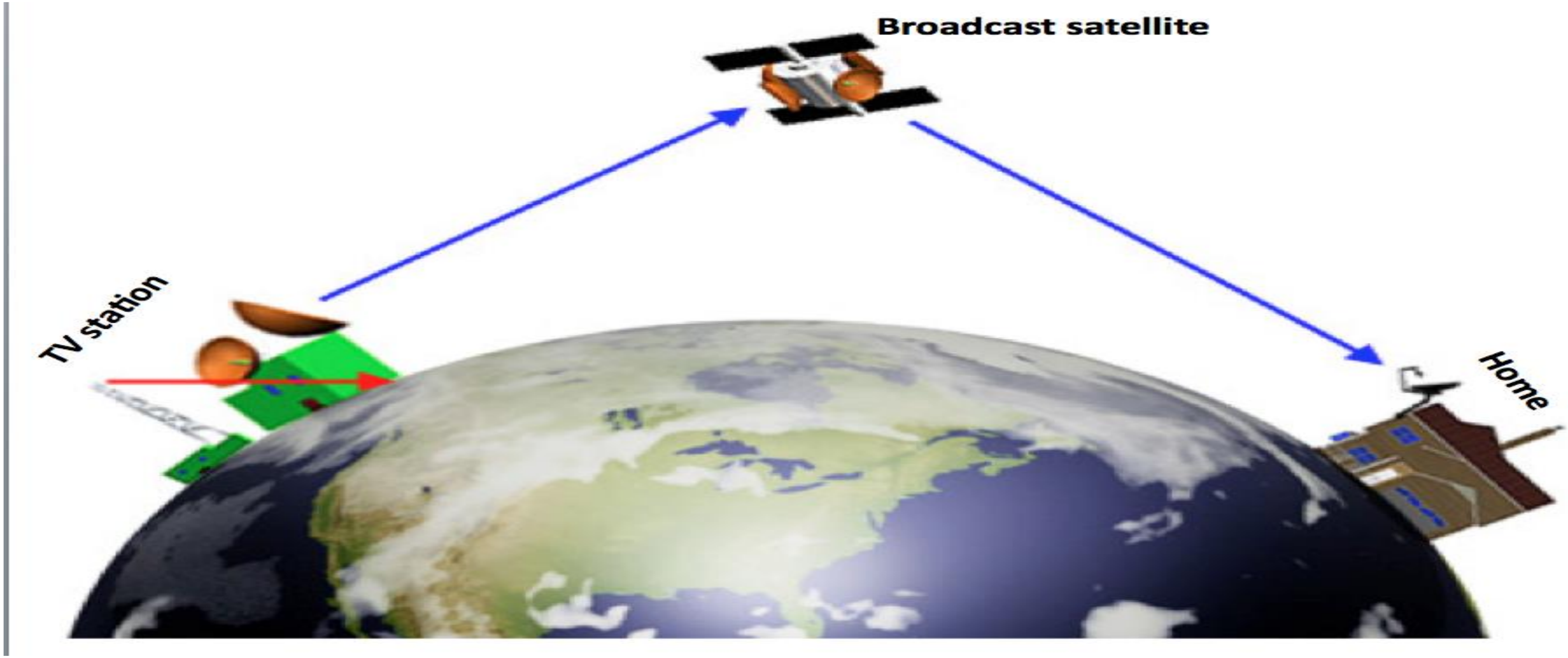
Benefits:

- Enhanced Safety
- Increased Capacity
- Reduced Delays

Advantage:

- Increased Flight Efficiencies
- Increased Schedule Predictability
- Environmentally Beneficial Procedures

Direct Broadcast satellites (DBS)

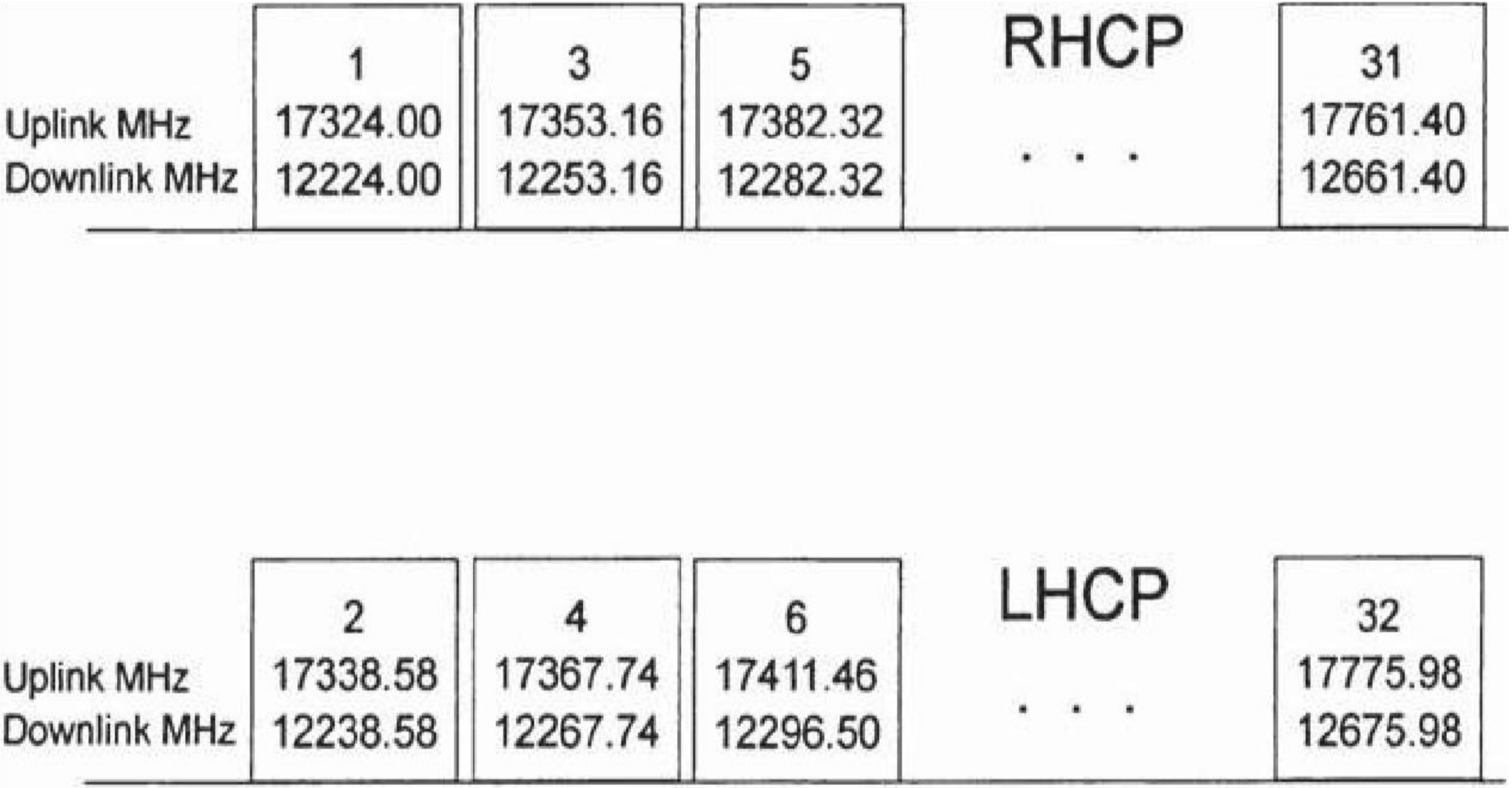


Direct Broadcast satellites (DBS)

- ✓Satellites provide *broadcast* transmissions in the fullest sense of the word, because antenna footprints can be made to cover large areas of the earth.
- ✓The idea of using satellites to provide direct transmissions into the home has been around for many years, and the services pro- vided are known generally as *direct broadcast satellite* (DBS) services.
- ✓Broadcast services include audio, television, and Internet services.

Power Rating and Number of Transponders

- satellite will be seen that satellites primarily intended for DBS have a higher [EIRP] than for the other categories, being in the range 51 to 60 dBW.
- At a *Regional Administrative Radio Council* (RARC) meeting in 1983, the value established for DBS was 57 dBW.
- Transponders are rated by the power output of their high-power amplifiers.
- Typically, a satellite may carry 32 transponders.
- If all 32 are in use, each will operate at the lower power rating of 120 W.
- The available bandwidth (uplink and downlink) is seen to be 500 MHz.
- A total number of 32 transponder channels, each of bandwidth 24 MHz, can be accommodated.
- The bandwidth is sometimes specified as 27 MHz, but this includes a 3MHz guardband allowance. Therefore, when calculating bit-rate capacity, the 24 MHz value is used.
- The total of 32 transponders requires the use of both *right- hand circular polarization* (RHCP) and *left-hand circular polarization* (LHCP) in order to permit frequency reuse, and guard bands are inserted between channels of a given polarization.

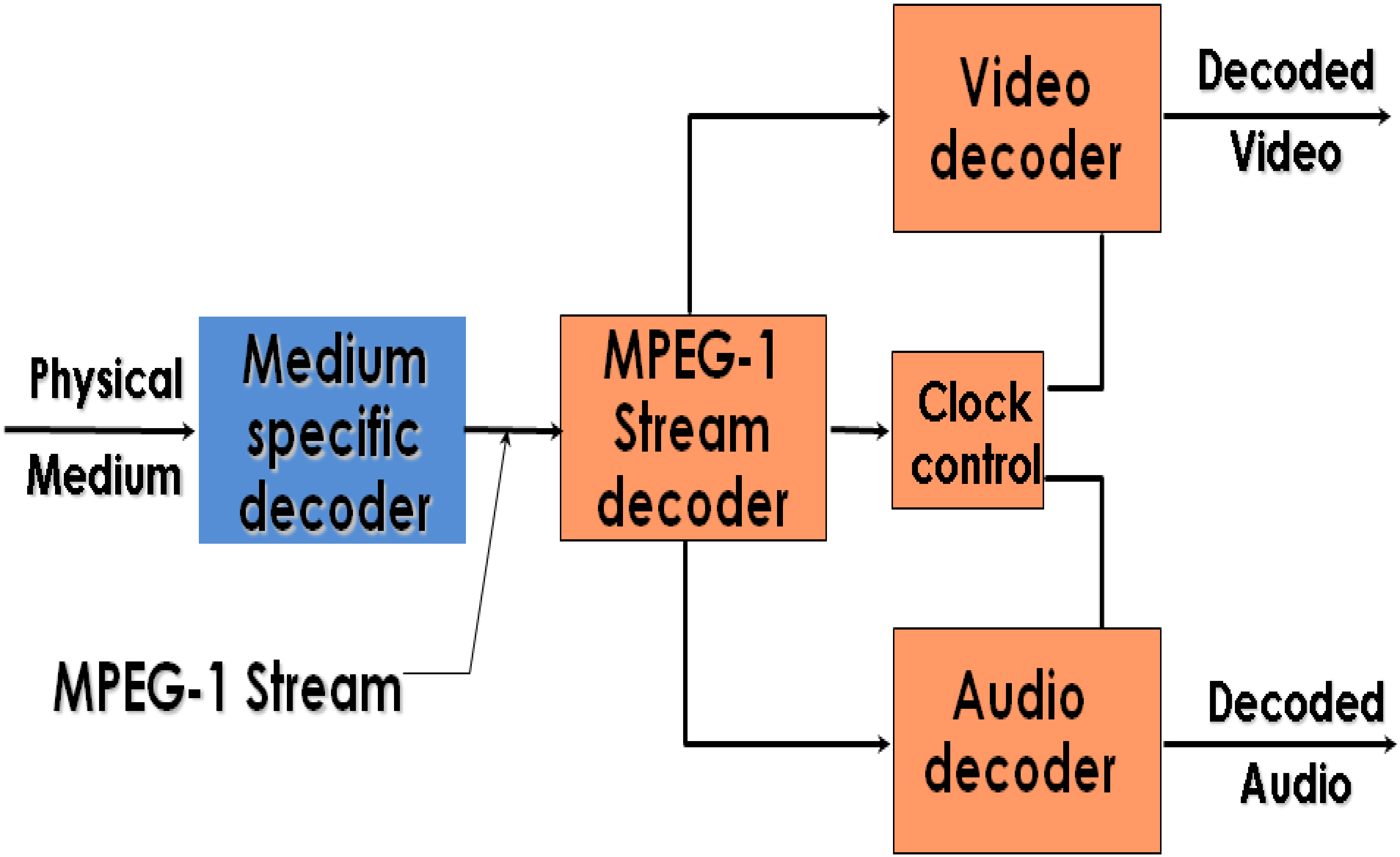

RHCP
Uplink MHz
Downlink MHz
1
17324.00
12224.00
3
17353.16
12253.16
5
17382.32
12282.32
31
17761.40
12661.40
LHCP
Uplink MHz
Downlink MHz
2
17338.58
12238.58
4
17367.74
12267.74
6
17411.46
12296.50
32
17775.98
12675.98

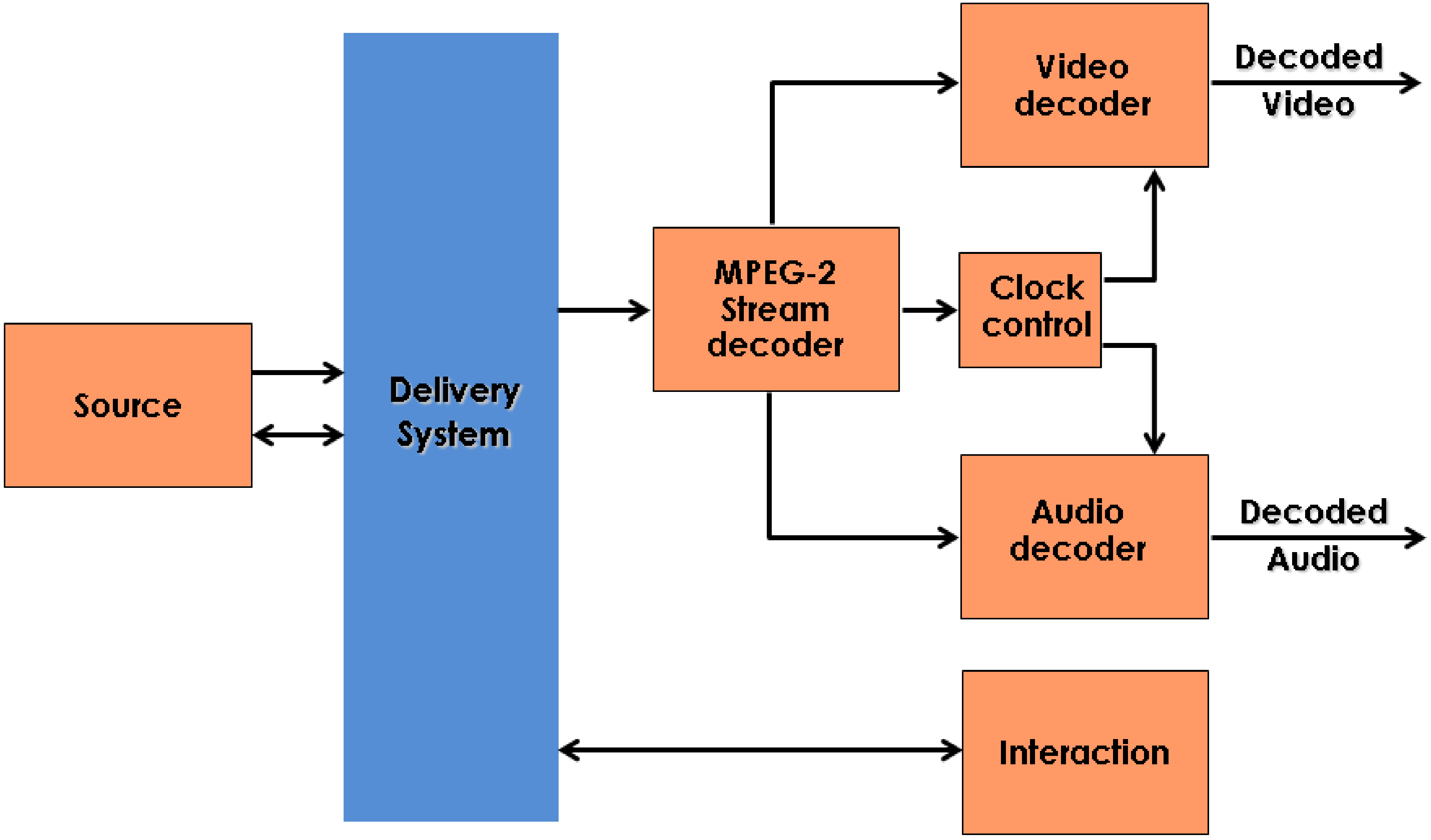
Bit Rates for Digital Television

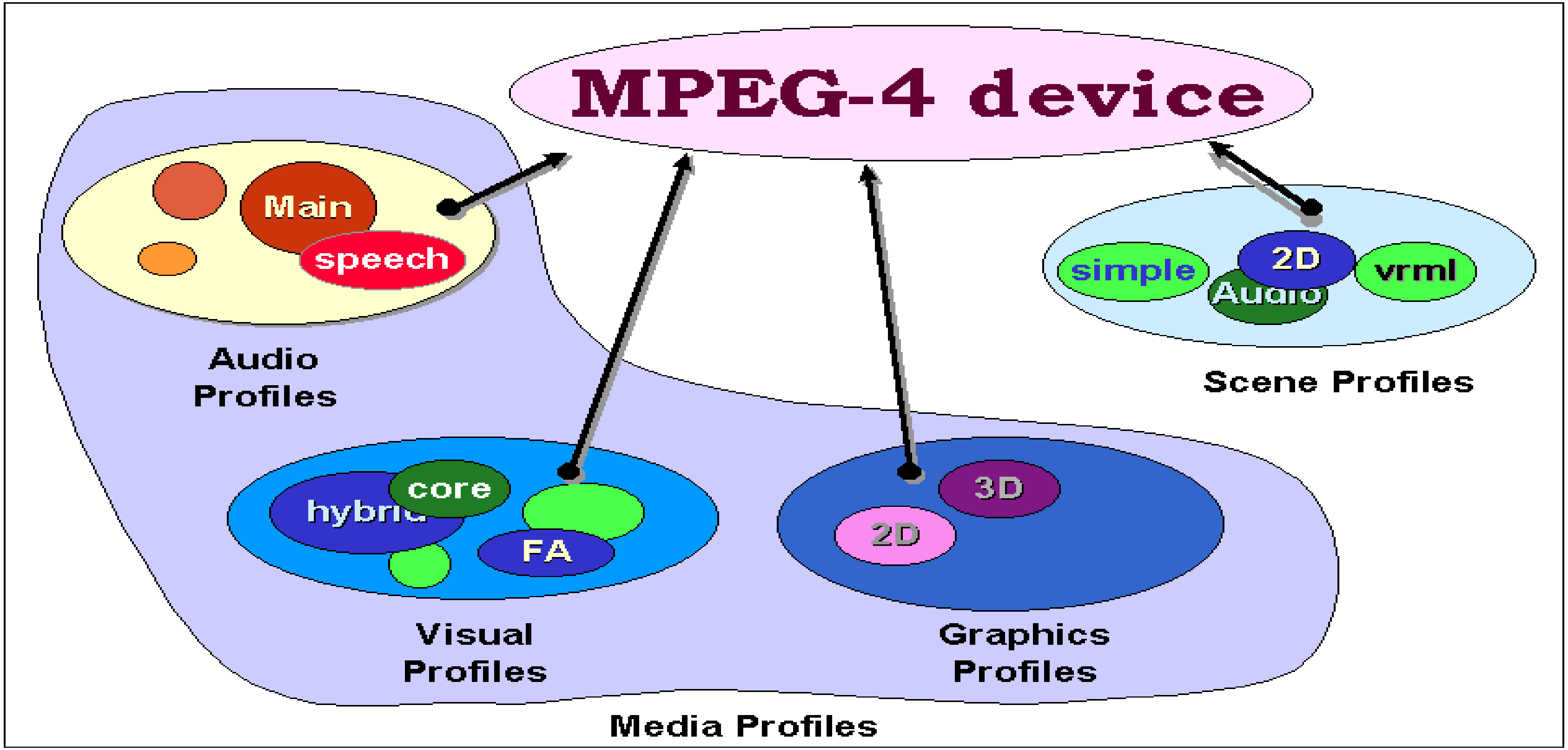
- The bit rate for digital television depends very much on the picture format.
- One way of estimating the uncompressed bit rate is to multiply the number of pixels in a frame by the number of frames per second, and multiply this by the number of bits used to encode each pixel.

MPEG Compression Standards

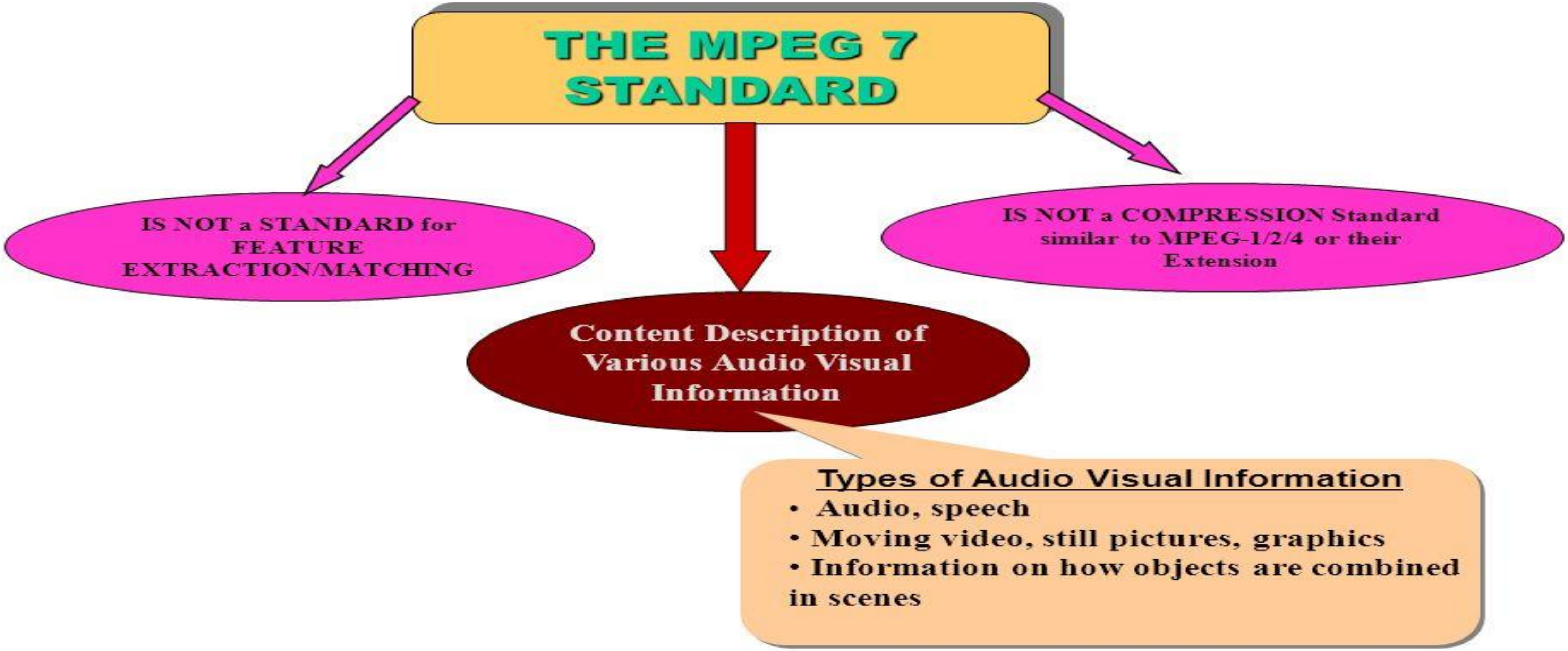
- MPEG is a group within the *International Standards Organization and the International Electrochemical Commission* (ISO/IEC) that undertook the job of defining standards for the transmission and storage of moving pictures and sound.
- The MPEG standards currently available are MPEG-1, MPEG-2, MPEG-4 , and MPEG-7.


Physical
Medium
Medium specific decoder
MPEG-1 Stream
MPEG-1 Stream decoder
Video decoder
Clock control
Audio decoder
Decoded
Video
Decoded
Audio


Source
Delivery System
MPEG-2 Stream decoder
Clock control
Video decoder
Decoded Video
Audio decoder
Decoded Audio
Interaction


MPEG-4 device
Main
speech
Audio Profiles
simple
2D
Audio
vrml
Scene Profiles
hybrid
core
FA
Visual Profiles
3D
2D
Graphics Profiles
Media Profiles

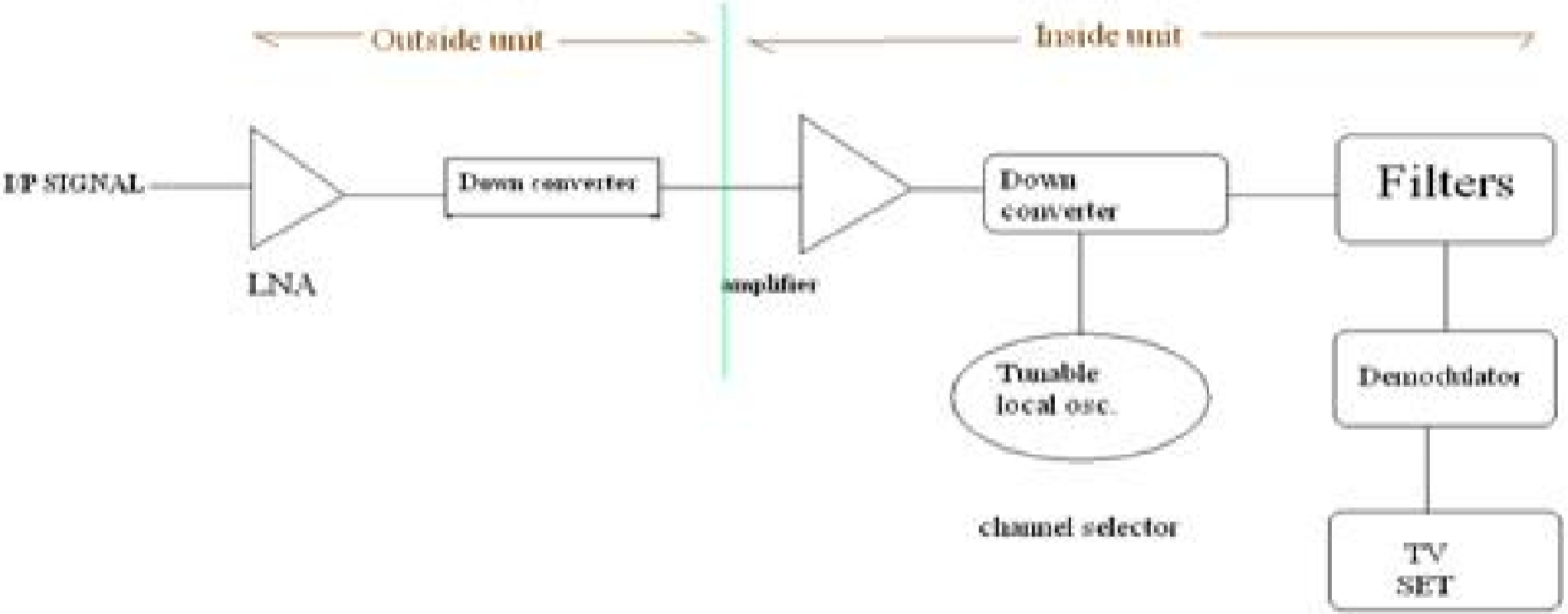
MPEG-7: What Is It ?

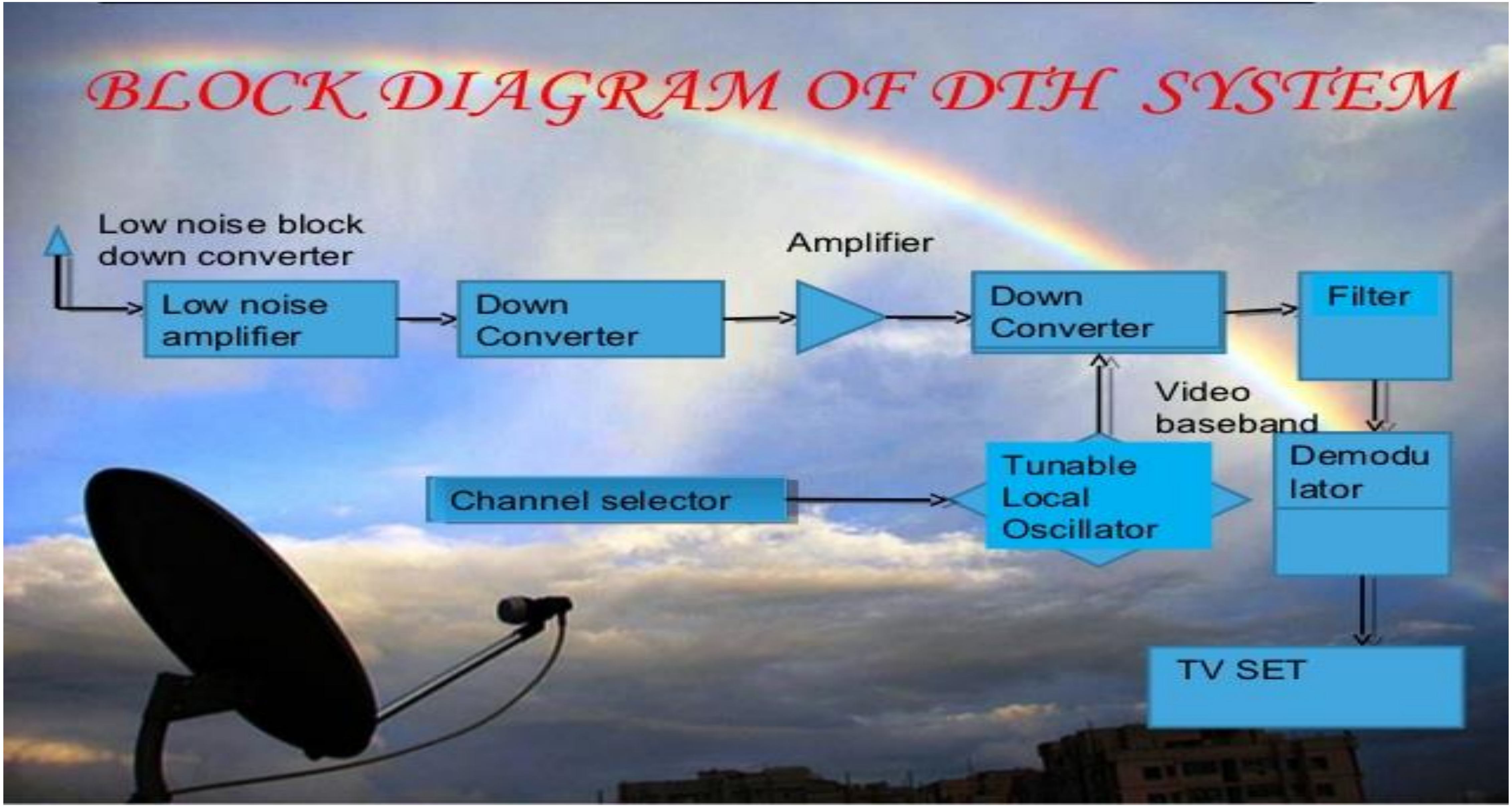


Direct to home Broadcast (DTH)

- ✓DTH stands for Direct-To-Home television. DTH is defined as the reception of satellite programmes with a personal dish in an individual home.
- ✓DTH Broadcasting to home TV receivers take place in the ku band(12 GHz).
- ✓This service is known as Direct To Home service.
- ✓DTH services were first proposed in India in 1996.
- ✓Finally in 2000, DTH was allowed.
- ✓The new policy requires all operators to set up earth stations in India
- ✓within 12 months of getting a license. DTH licenses in India will cost $2.14 million and will be valid for 10 years.
- ✓Working principal of DTH is the satellite communication. Broadcaster modulates the received signal and transmit it to the satellite in KU Band and from satellite one can receive signal by dish and set top box.

DTH Block Diagram





BLOCK DIAGRAM OF DTH SYSTEM
Low noise block
down converter
Low noise
amplifier
Down
Converter
Amplifier
Down
Converter
Filter
Video
baseband
Channel selector
Tunable
Local
Oscillator
Demodu
lator
TV SET

- ✓A DTH network consists of a broadcasting centre, satellites, encoders, multiplexers, modulators and DTH receivers
- ✓The encoder converts the audio, video and data signals into the digital format and the multiplexer mixes these signals.
- ✓It is used to provide the DTH service in high populated area A Multi Switch is basically a box that contains signal splitters and A/B switches.
- ✓ A outputs of group of DTH LNBs are connected to the A and B inputs of the Multi Switch.

DTH:Advantage

- ✓DTH also offers digital quality signals which do not degrade the picture or sound quality.
- ✓It also offers interactive channels and program guides with customers having the choice to block out programming which they consider undesirable
- ✓One of the great advantages of the cable industry has been the ability to provide local channels, but this handicap has been overcome by many DTH providers using other local channels or local feeds.
- ✓The other advantage of DTH is the availability of satellite broadcast in rural and semi-urban areas where cable is difficult to install.

DAB


Terrestrial broadcasting
involving both analogue AM/FM
and DAB transmission
Satellite
ON AIR
Radio
Studio
Satellite
Network
Internet
Cable
Internet

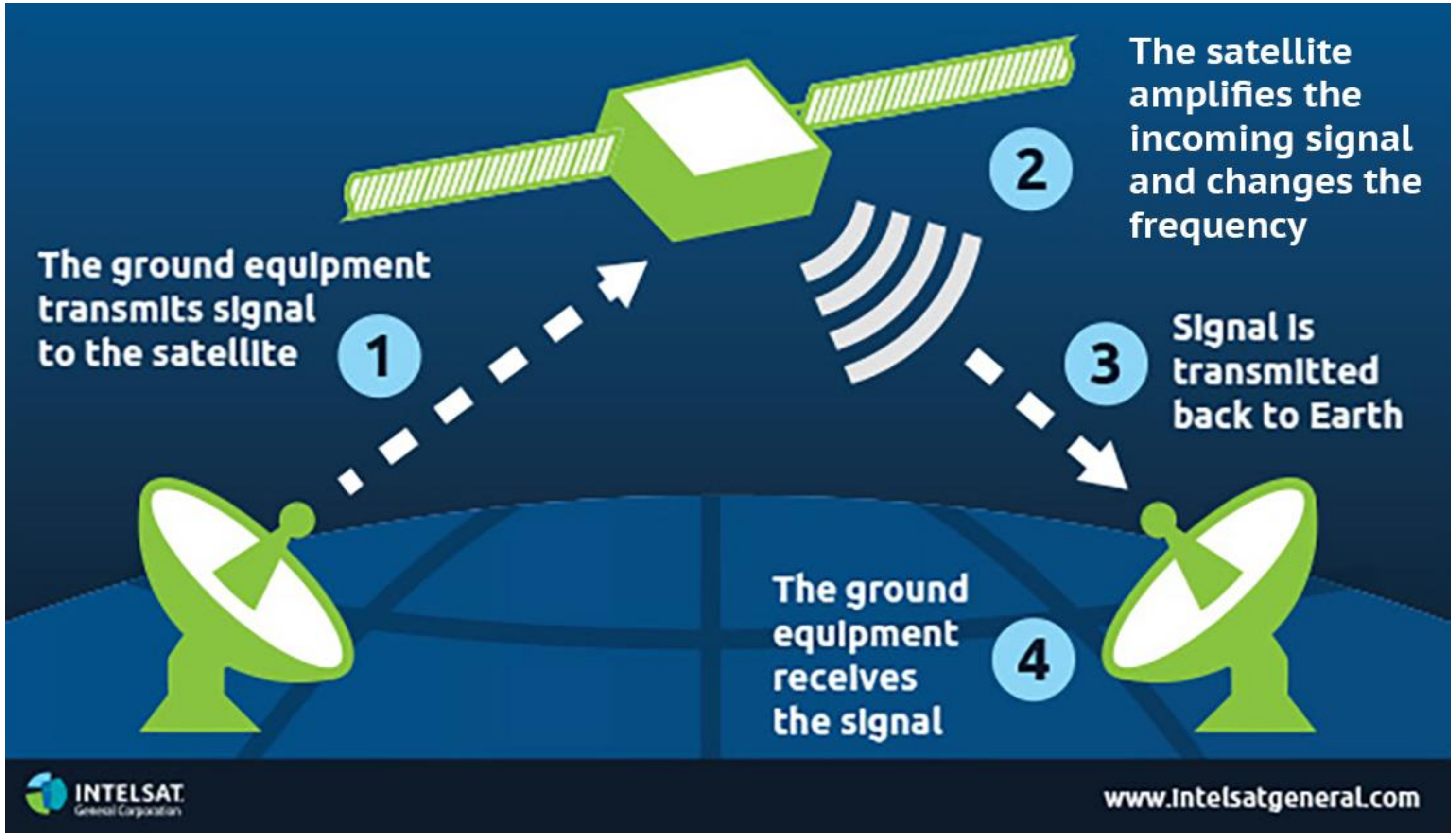
Digital audio broadcast (DAB)

- ✓DAB Project is an industry-led consortium of over 300 companies
- ✓The DAB Project was launched on 10th September, 1993
- ✓In 1995 it was basically finished and became operational
- ✓There are several sub-standards of the DAB standard o DAB-S (Satellite) – using QPSK – 40 Mb/s o DAB-T (Terrestrial) – using QAM – 50 Mb/s o DAB-C (Cable) – using OFDM – 24 Mb/s
- ✓These three sub-standards basically differ only in the specifications to the physical representation, modulation, transmission and reception of the signal.
- ✓The DAB stream consists of a series of fixed length packets which make up a Transport Stream (TS). The packets support 'streams' or 'data sections'.
- ✓Streams carry higher layer packets derived from an MPEG stream & Data sections are blocks of data carrying signaling and control data.
- ✓DAB is actually a support mechanism for MPEG.& One MPEG stream needing higher instantaneous data can 'steal' capacity from another with spare capacity.

World space services

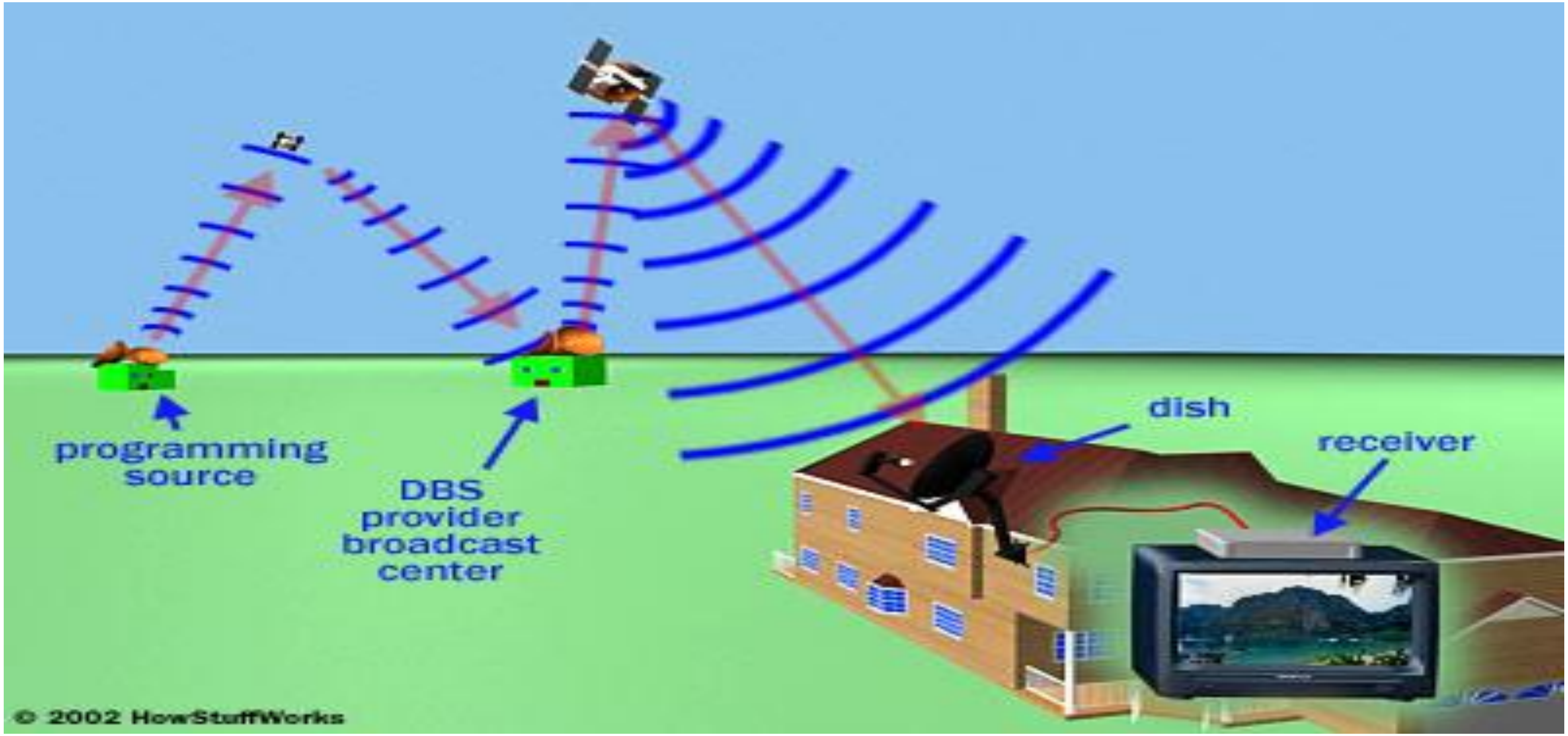
- ✓WorldSpace (Nasdaq: WRSP) is the world's only global media and entertainment company positioned to offer a satellite radio experience to consumers in more than 130 countries with five billion people, driving 300 million cars.
- ✓WorldSpace delivers the latest tunes, trends and information from around the world and around the corner.
- ✓WorldSpace subscribers benefit from a unique combination of local programming, original WorldSpace content and content from leading brands around the globe, including the BBC, CNN, Virgin Radio, NDTV and RFI. WorldSpace's satellites cover two-thirds of the globe with six beams.
- ✓Each beam is capable of delivering up to 80 channels of high quality digital audio and multimedia programming directly to WorldSpace Satellite Radios anytime and virtually anywhere in its coverage area.
- ✓ WorldSpace is a pioneer of satellite-based digital radio services (DARS) and was instrumental in the development of the technology infrastructure used today by FM Satellite Radio..

World space services



Business Television (BTV) - Adaptations for Education

- ✓ Business television (BTV) is the production and distribution, via satellite, of video programs for closed user group audiences.
- ✓ It often has two-way audio interaction component made through a simple telephone line. It is being used by many industries including brokerage firms, pizza houses, car dealers and delivery services.
- ✓ BTV is an increasingly popular method of information delivery for corporations and institutions.
- ✓ Private networks, account for about 70 percent of all BTV networks. It is estimated that by the mid-1990 s BTV has the potential to grow to a $1.6 billion market in North America with more and more Fortune 1 ,000 companies getting involved. The increase in use of BTV has been dramatic.
- ✓ Institution updates, news, training, meetings and other events can be broadcast live to multiple locations. The expertise of the best instructors can be delivered to thousands of people without requiring trainers to go to the site.
- ✓ Information can be disseminated to all employees at once, not just a few at a time. Delivery to the workplace at low cost provides the access to training that has been denied lower level employees. It may be the key to re-training America's work force.
- ✓ Television has been used to deliver training and information within businesses for more than 40 years.
- ✓ Its recent growth began with the introduction of the video cassette in the early 1970s. Even though most programming is produced for video cassette distribution, business is using BTV to provide efficient delivery of specialized programs via satellite.


programming source
DBS provider broadcast center
dish
receiver
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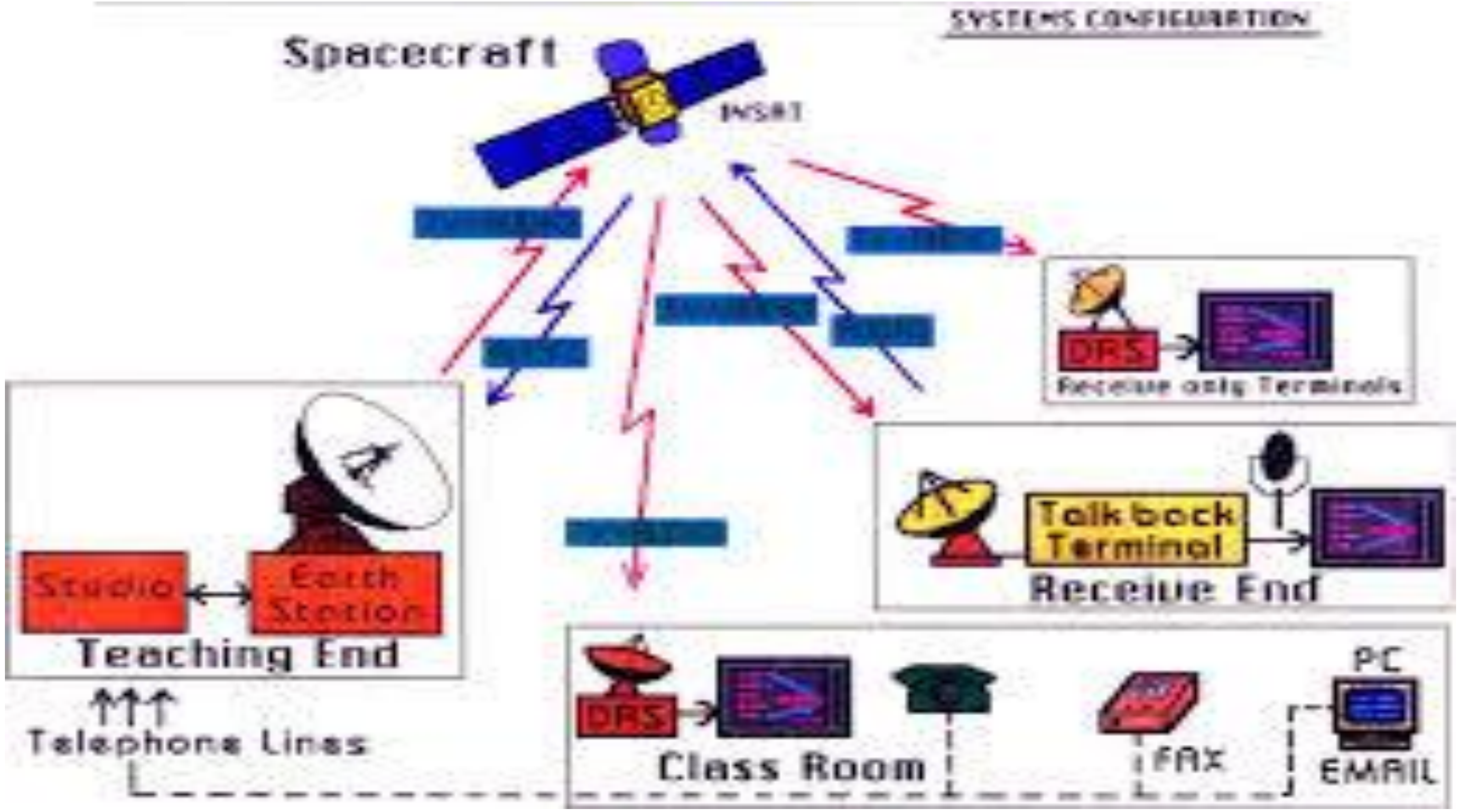
- ✓ The advent of smaller receiving stations - called very small aperture terminals (VSATs) has made private communication networks much more economical to operate.
- ✓ BTV has a number of tangible benefits, such as reducing travel, immediate delivery of time-critical messages, and eliminating cassette duplication and distribution hassles.
- ✓ The programming on BTV networks is extremely cost-effective compared to seminar fees and downtime for travel.
- ✓ It is an excellent way to get solid and current information very fast. Some people prefer to attend seminars and conferences where they can read, see, hear and ask questions in person.
- ✓ BTV provides yet another piece of the education menu and is another way to provide professional development.
- ✓ A key advantage is that its format allows viewers to interact with presenters by telephone, enabling viewers to become a part of the program. The satellite effectively places people in the same room, so that sales personnel in the field can learn about new products at the same time.
- ✓ Speed of transmission may well be the competitive edge which some firms need as they introduce new products and services.
- ✓ BTV enables employees in many locations to focus on common problems or issues that might develop into crises without quick communication and resolution.
- ✓ BTV networks transmit information every business day on a broad range of topics, and provide instructional courses on various products, market trends, selling and motivation. Networks give subscribers the tools to apply the information they have to real world situations.

GRAMSAT



SYSTEMS CONFIGURATION
Spacecraft
INSAT
DRS
Receive only Terminals
Talk back
Terminal
Receive End
Studio
Earth
Station
Teaching End
Telephone Lines
DRS
Class Room
FAX
PC
EMAIL

GRAMSAT

- ✓ISRO has come up with the concept of dedicated GRAMSAT satellites, keeping in mind the urgent need to eradicate illiteracy in the rural belt which is necessary for the all round development of the nation.
- ✓This Gramsat satellite is carrying six to eight high powered C-band transponders, which together with video compression techniques can disseminate regional and cultural specific audio-visual programmes of relevance in each of the regional languages through rebroadcast mode on an ordinary TV set.
- ✓The high power in C-band has enabled even remote area viewers outside the reach of the TV transmitters to receive programmers of their choice in a direct reception mode with a simple .dish antenna.

features of GRAMSAT

- Its communications networks are at the state level connecting the state
- capital to districts, blocks and enabling a reach to villages.
- It is also providing computer connectivity data broadcasting, TV-
- broadcasting facilities having applications like e- governance, development information, teleconferencing, helping disaster management.
- Providing rural-education broadcasting.
- However, the Gramsat projects have an appropriate combination of following activities.
- Interactive training at district and block levels employing suitable configuration
- Broadcasting services for rural development
- Computer interconnectivity and data exchange services
- Tele-health and tele-medicine services.

Specialized services

Satellite-email services:

- ✓The addition of Internet Access enables Astrium to act as an Internet Service Provider (ISP) capable of offering Inmarsat users a tailor-made Internet connection.
- ✓With Internet services added to our range of terrestrial networks, you will no longer need to subscribe to a third party for Internet access (available for Inmarsat A, B, M, mini-M, Fleet, GAN, Regional BGAN & SWIFT networks).
- ✓We treat Internet in the same way as the other terrestrial networks we provide, and thus offer unrestricted access to this service. There is no timeconsuming log-on procedure, as users are not required to submit a user-ID or password.

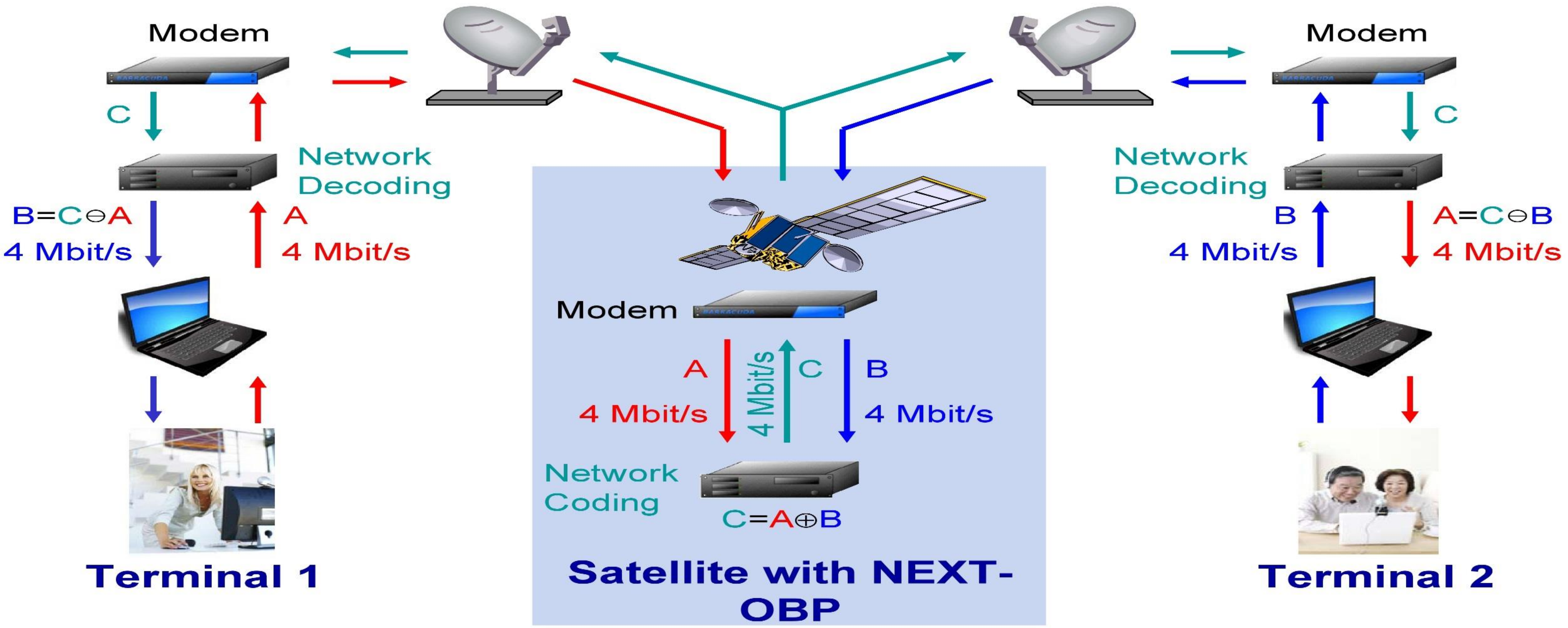
Description of E-mail Service:

- Astrium's E-Mail service allows Inmarsat users to send and receive e-mail directly through the Internet without accessing a public telephone network.

Features and Benefits

- No need to configure an e-mail client to access a Astrium e-mail account
- Service optimized for use with low bandwidth Inmarsat terminals
- Filter e-mail by previewing the Inbox and deleting any unwanted e-mails prior to downloading
- No surcharge or monthly subscription fees
- Service billed according to standard airtime prices for Inmarsat service used

Video Conferencing

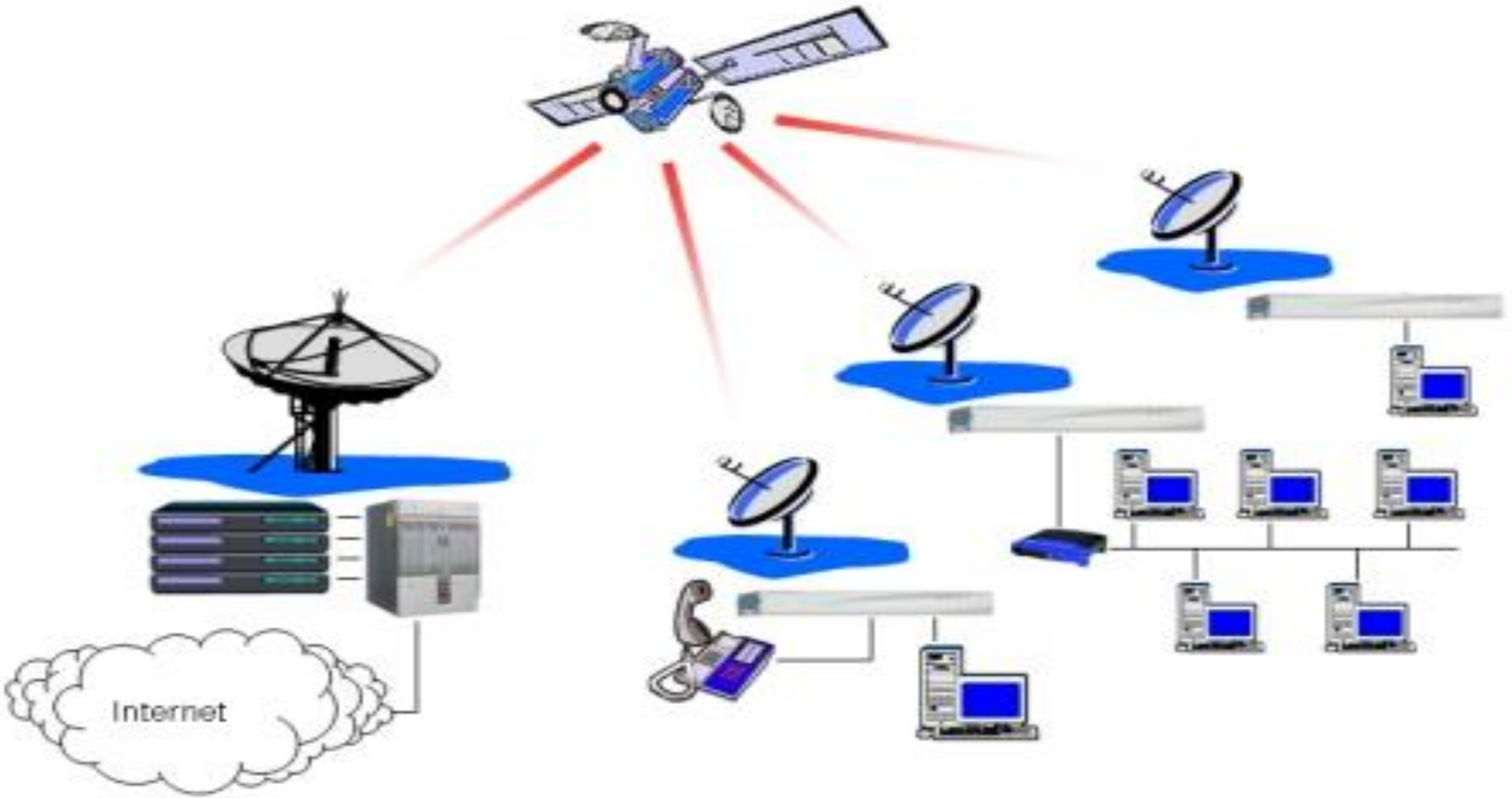


Video Conferencing (medium resolution)

- Video conferencing technology can be used to provide the same full, twoway interactivity of satellite broadcast at much lower cost.
- For Multi-Site meetings, video conferencing uses bridging systems to connect each site to the others.
- It is possible to configure a video conference bridge to show all sites at the same time on a projection screen or monitor.
- Or, as is more typical, a bridge can show just the site from which a person is speaking or making a presentation.
- The technology that makes interactive video conferencing possible, compresses video and audio signals, thus creating an image quality lower than that of satellite broadcasts.

Satellite Internet access

- ✓**Satellite Internet access** is Internet access provided through communications satellites.
- ✓ Modern satellite Internet service is typically provided to users through geostationary satellites that can offer high data speeds, with newer satellites using Ka band to achieve downstream data speeds up to 50 Mbps.
- ✓Satellite Internet generally relies on three primary components: a satellite in geostationary orbit (sometimes referred to as a geosynchronous Earth orbit, or GEO), a number of ground stations known as gateways that relay Internet data to and from the satellite via radio waves (microwave), and a VSAT (very-smallaperture terminal) dish antenna with a transceiver, located at the subscriber's premises.
- ✓Other components of a satellite Internet system include a modem at the user end which links the user's network with the transceiver, and a centralized network operations center (NOC) for monitoring the entire system


Internet