Introduction to Space Technology

Space Technology and Law, Semester 1

MA(STL)

NALSAR UNIVERSITY OF LAW, HYDERABAD

What is Outerspace ?

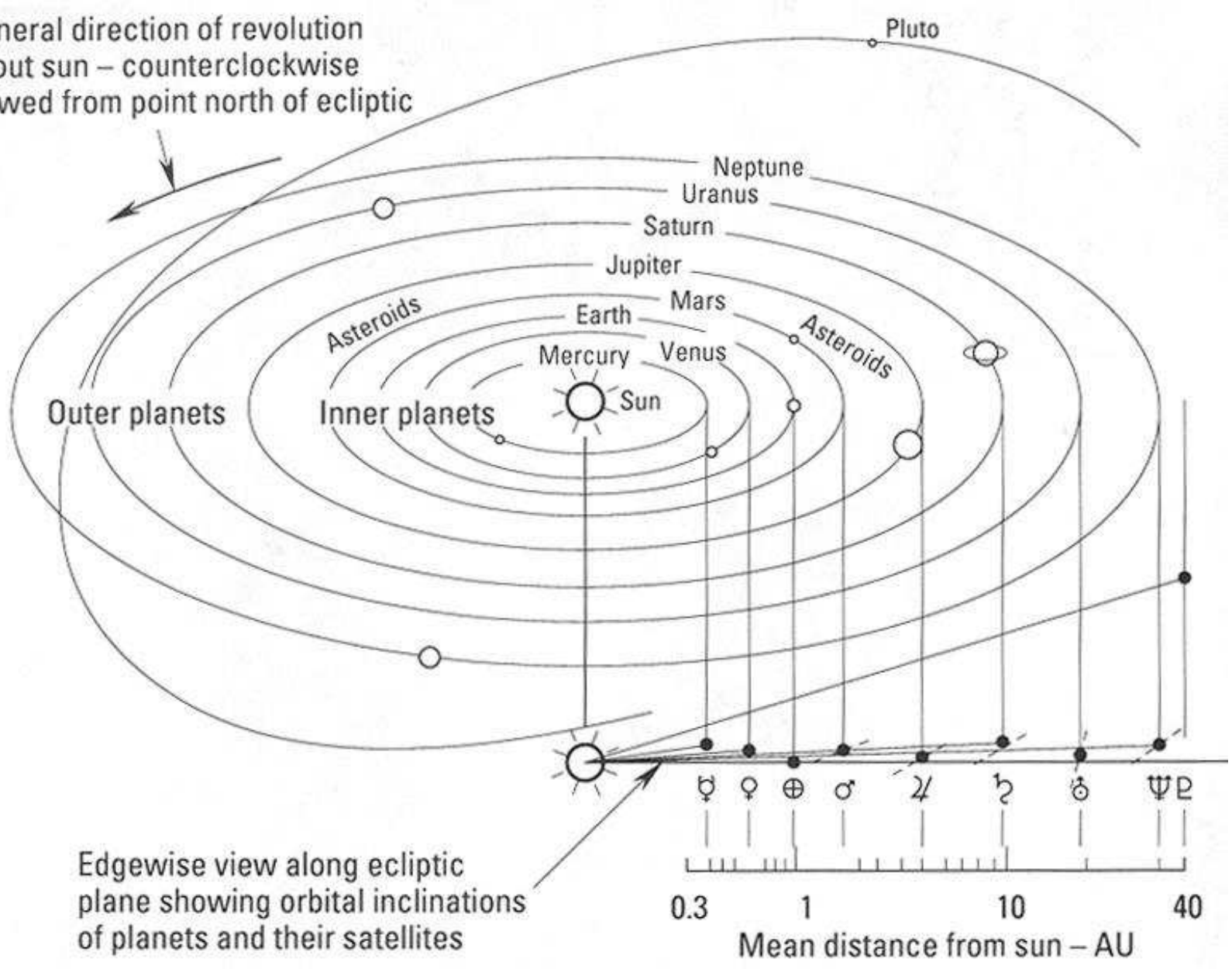
- Outerspace is the space beyond the earth's atmosphere
- There is no clear definition of the lower boundary of outerspace
- It is beyond the airspace, which extends upto the heights that aircrafts can fly
- Modern aircraft fly upto 65km, using forces of air for lifting
- 99% of gases in atmosphere- concentrated in the region upto 30-35 km from earth surface
- Near earth space.. 150-1000 km
- Deep space .. Above 1000 km altitudes

What is space technology and how it is distinguished?

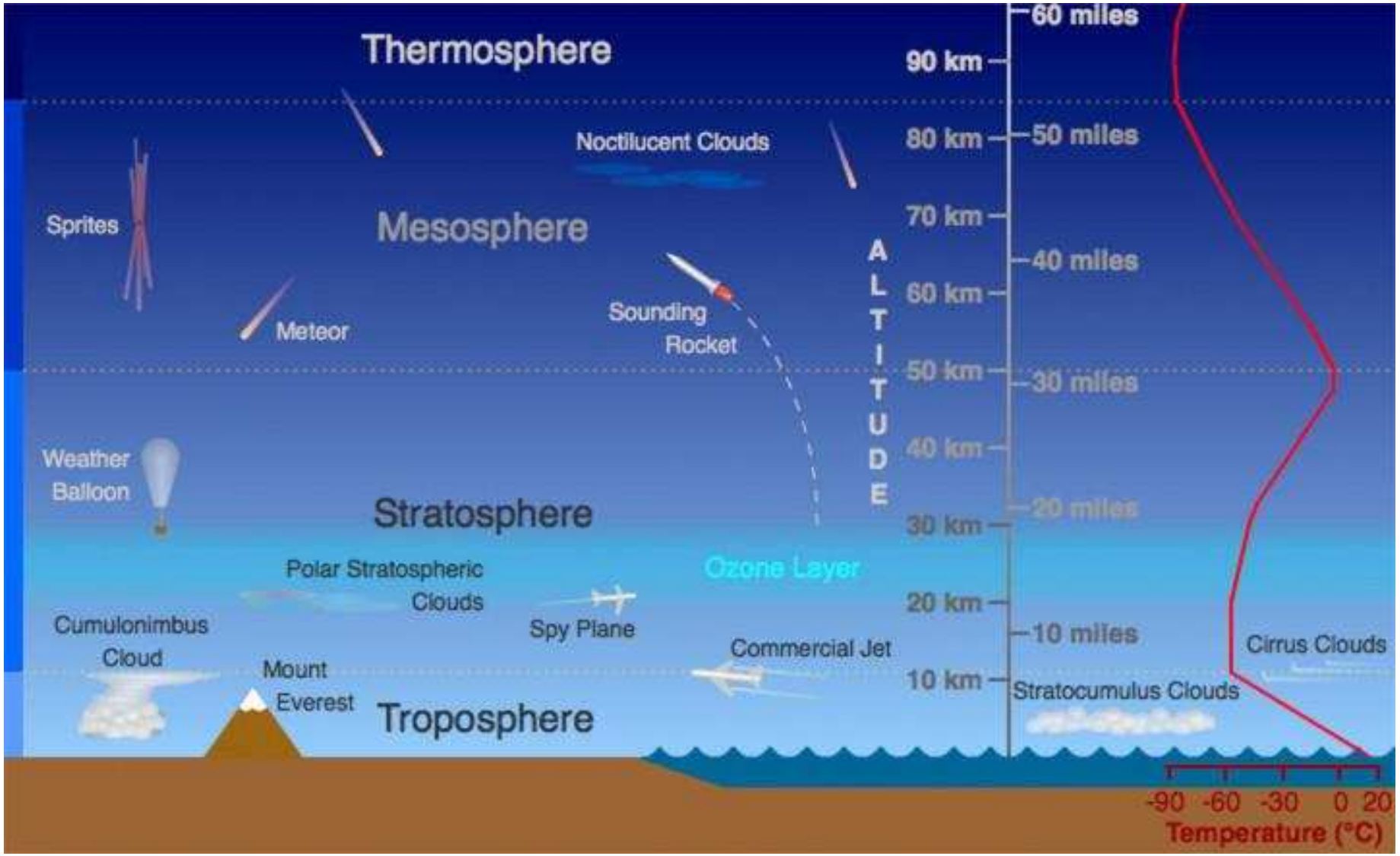
- Multidisciplinary application of scientific principles to build and operate systems that can be delivered and operated in space for the exploration and diverse uses
- Distinct capabilities/ characteristics of space technologies:
  - Very high speeds and accelerations of travel
  - Synoptic/ repetitive coverage
  - Resilience to disasters
  - Operation in special environments- micro-gravity, vacuum, radiation, thermal shock
  - Intercontinental connectivity
  - Optimised size, weight and power considerations

Solar System

SUN's INFLUENCE
Solar Activity
Solar wind
Solar Flares
Energy source
Impact on Earth's magnetic field
Atmospheric impacts



Earth's Atmospheric Layers



IONOSPHERE

SOURCE:
https://scied.ucar.edu/sites/default/files/images/large_image_for_image_content/atmosphere_layers_diagram_720x440.jpg

Atmospheric regions

Tropo sphere

Area of unstable air where weather phenomena takes place

Turbulent convection of the air heated at the surface by earth's IR emission

Temp decreases linearly upto tropo pause

At tropo pause temp. Does not vary (transition region)

Strato sphere (~ 10 -40 km)

Relatively non turbulent

Temp. increases with altitude because of absorption of IR by H_2O and CO_2 molecules. Ozone concentration 10 parts per million.

Ozone absorbs harmful UV (solar). CFCs emission deplete Ozone.

Meso sphere (~40 – 70 km)

Temp falls with height due to reradiation

Thermosphere

After meso pause, (Iso thermal layer), temp increases rapidly with height due to direct absorption of solar radiation by atmospheric constituents.

Atmospheric regions

Exo sphere

Temp relatively constant with altitude (due to large mean free path between molecules)

Energetic molecules may actually escape earth's gravity and be lost into space

Green house effect

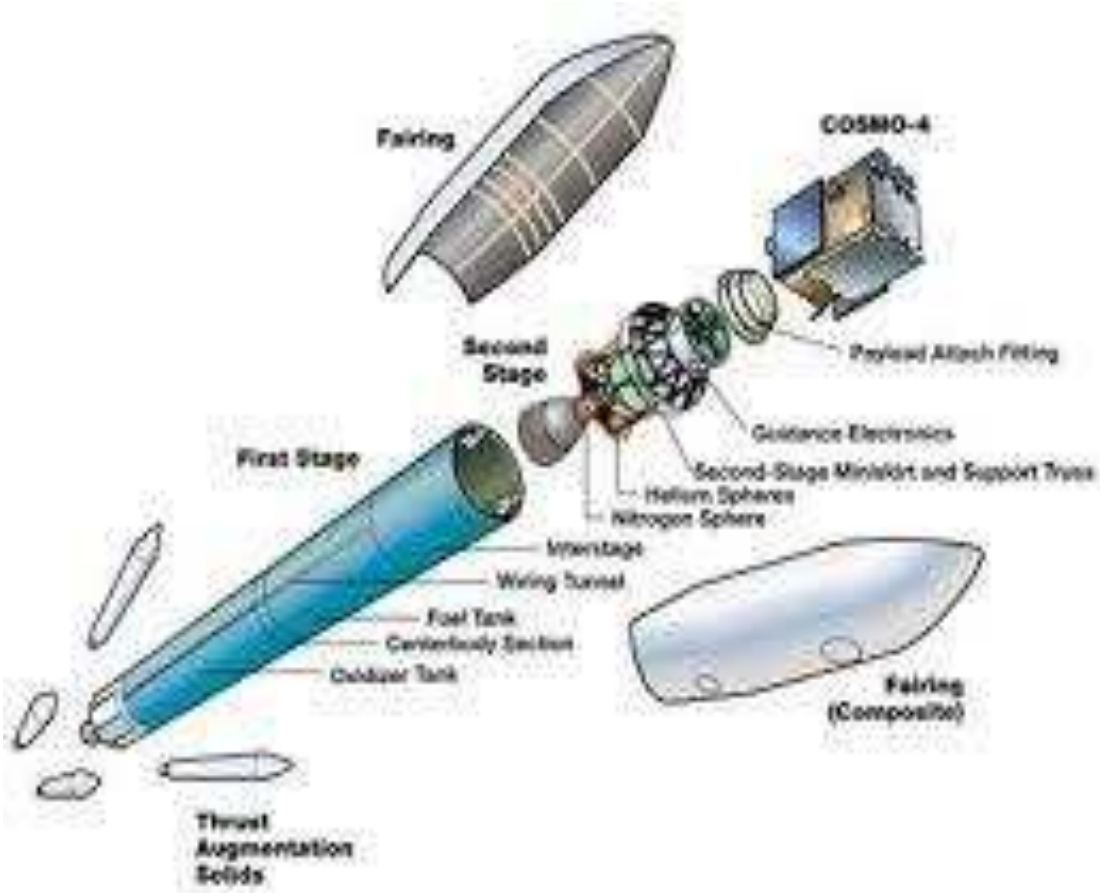
Due to high IR absorption property of CO_2 and H_2O molecules

Sun radiation (in visible) pass through clear atmosphere

Outgoing emission from earth in IR is trapped by CO_2

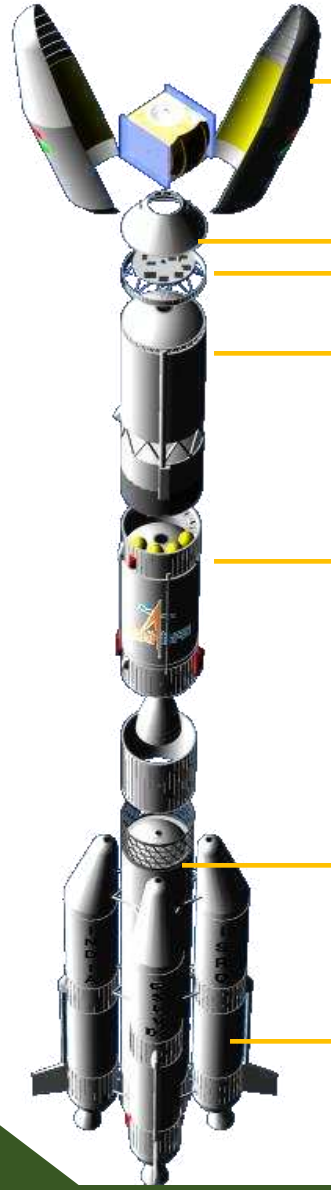
Space transportation systems

- Expendable Rockets
- Reusable Rockets
- Examples



- See http://history.nasa.gov/SP-4402/ch1.htm

GSLV Configuration



PAYLOAD FAIRING: 3.4 m/4 m DIAMETER

PAYLOAD ADAPTER: 937 IF / 1194 IF

EQUIPMENT BAY

GS3 STAGE: C12 / C15

Propellant: LOX, LH2

GS2 STAGE : L37.5H / GL40H

Propellant : N2O4, UH25

GS1 STAGE : (4L40H & S139)

S139 STAGE: Solid propellant

L40 Stage: Propellant : N2O4, UH25

Rocket Parts Definitions

Aerodynamic nose cap - The top part of the rocket designed for flight in the atmosphere.

Avionics - The electrical systems that control the rocket during flight.

Fuel tank - The tank containing chemicals that combine with an oxidizer to burn and produce thrust.

Interstage - Section that connects stages.

Oxidizer tank - A tank containing oxygen compounds that permit rocket fuel to burn both in the atmosphere and in the vacuum of space.

Rocket parts

- **Parachute** - A folding, umbrella-like fabric device with cords supporting a harness or straps that decreases the terminal velocity of an object by increasing the drag on the object.

  Payload - The cargo carried by a rocket.

  Rocket engine - A machine with moving parts that converts stored propellant into hot gases to produce thrust.

  Solid fuel motor - A simple device that converts stored propellant into hot gases to produce thrust.

  Stabilizing fins - Lengthwise fixed attachments to rockets to provide a stabilizing effect.

  Stage - Two or more rockets stacked on top of each other to reach higher altitudes or have a greater payload capacity.

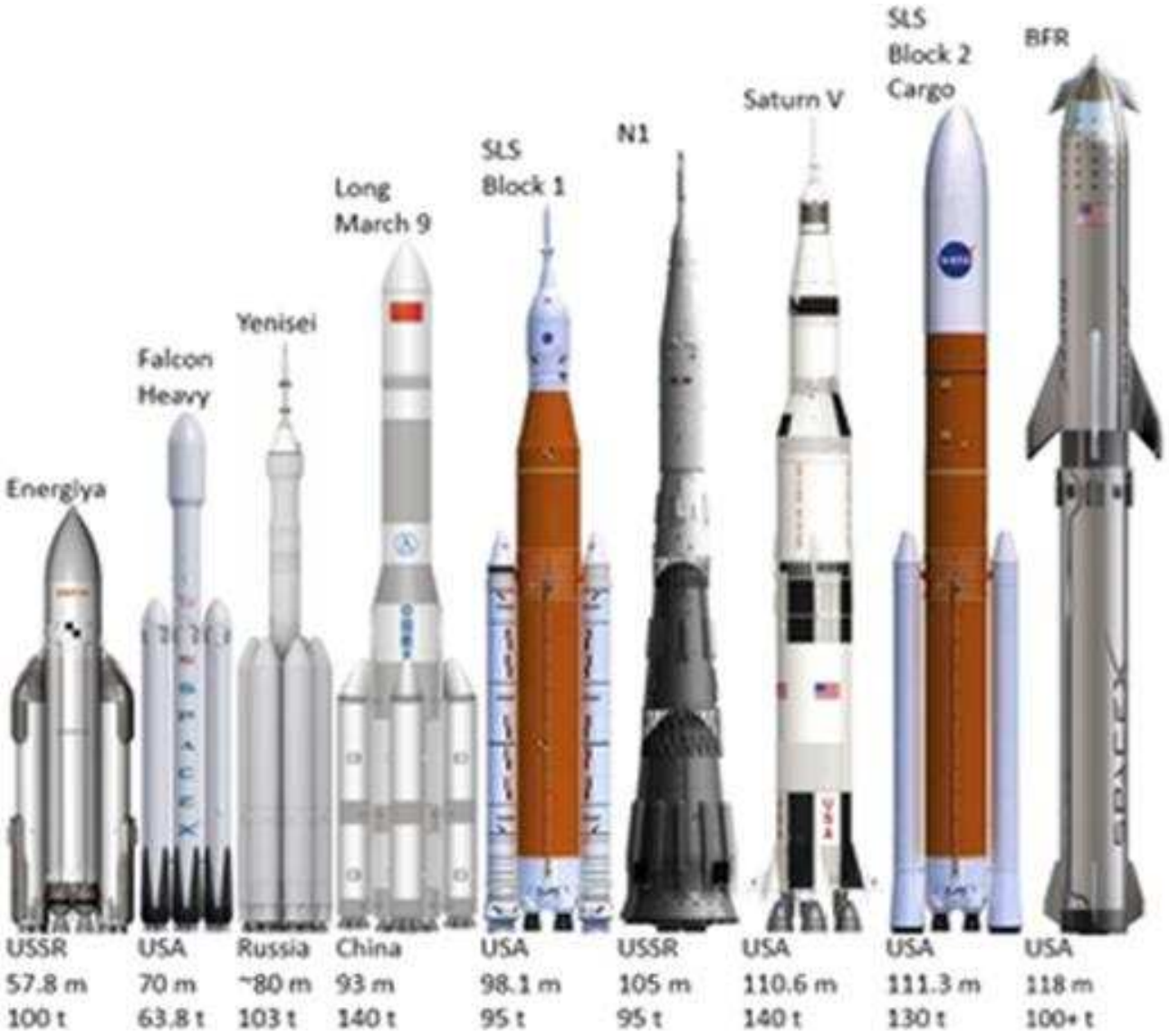
Launch Services

- US Systems: Delta IV, Atlas V , Pegasus/Taurus, Falcon 1& 9 ,Zenit - 3SL…(13t in GTO/23t LEO)
- Europe- Ariane V, Soyuz, Vega (10.5t &17.25 t)
- Russia: Kosmos, Molniya, Dnepr, Soyuz, Zenit 2M, Proton M (5.5t/ 21t)
- China: long March series (4.5t, 13.5t [3B])
- India: PSLV, GSLV (2.5t/5t)
- Japan: H-IIA (5.8t/11.7t)

Maximum capacity for GTO & LEO indicated respectively in parenthesis

- BUSINESS CHALLENGES –Entry barriers, uneven competition, high risks

Heavy lift Launch Vehicles



Big Falcon Rocket (BFR)
106m, 9 m dia, 150t in LEO

SLS (Block 2) Cargo, USA
111m, 130t LEO

Long March -9 (China)
93m, 140t

Yenisei (Russia)
80m, 103 t.

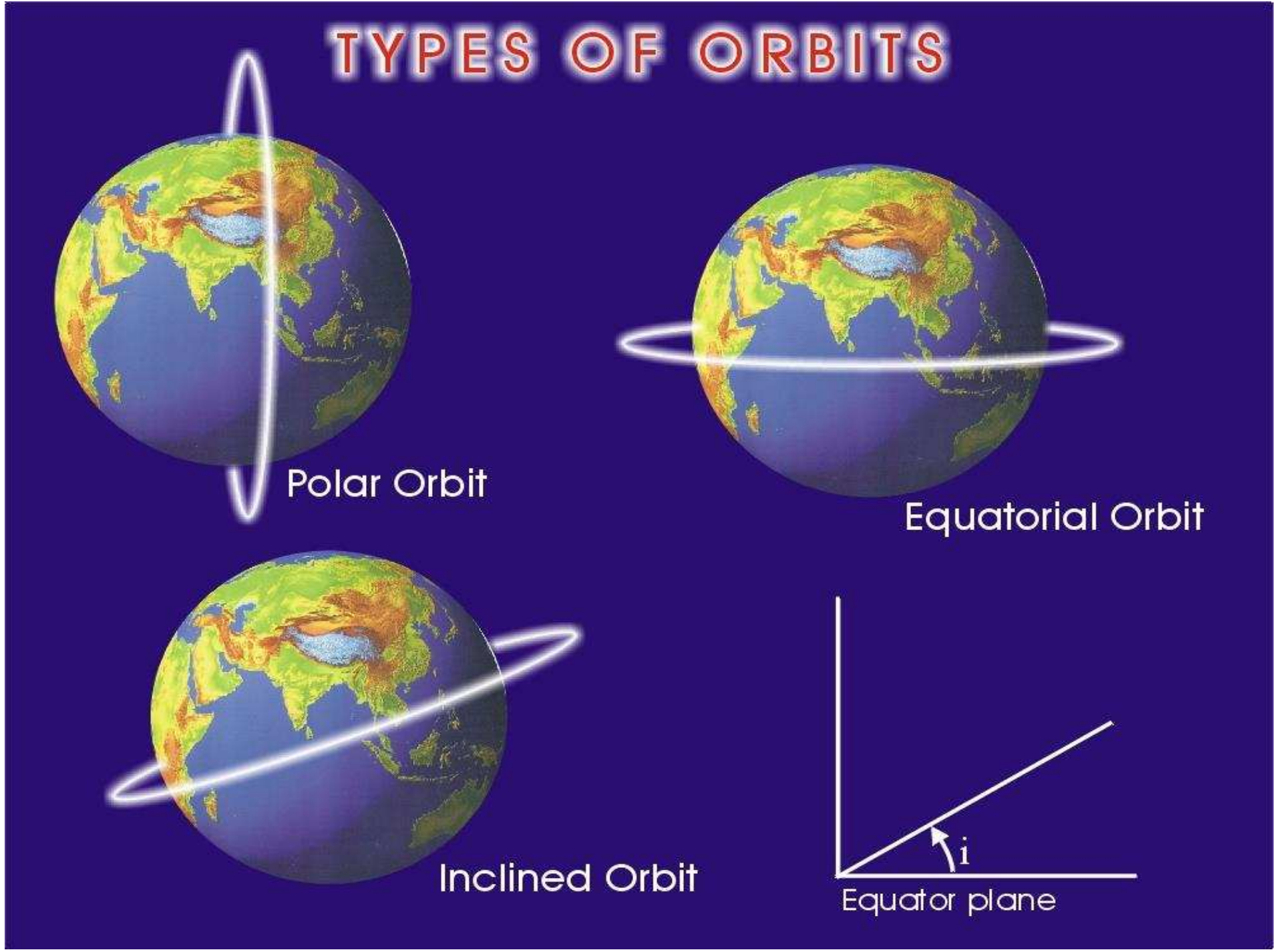
Launch sites

Nations having launch sites:

- Australia, Brazil, Canada,
- China (3), Europe, France (2),
- UK, India, Iraq, Israel,
- Italy, Japan (2), Morocco,
- Norway, Pakistan, Russia (4),
- Senegal, South Africa, Spain,
- USA (14)

Busiest space ports:

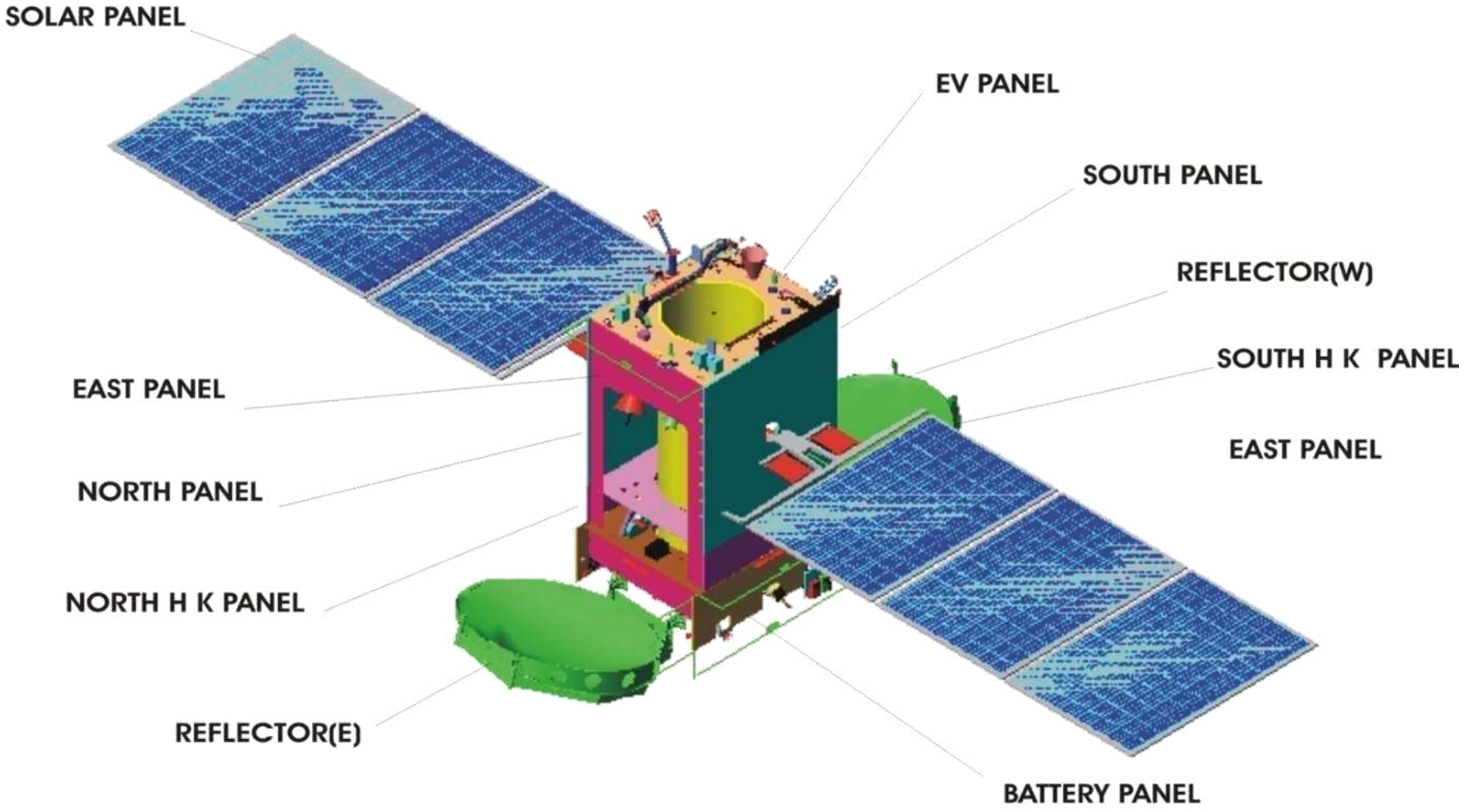
- Cape Canaveral,
- Vandenberg
- Baikonur
- Plesetsk
- Kourou
- Tanegashima
- Juiquan
- Xichang
- Sriharikota


TYPES OF ORBITS
Polar Orbit
Equatorial Orbit
Inclined Orbit
i
Equator plane

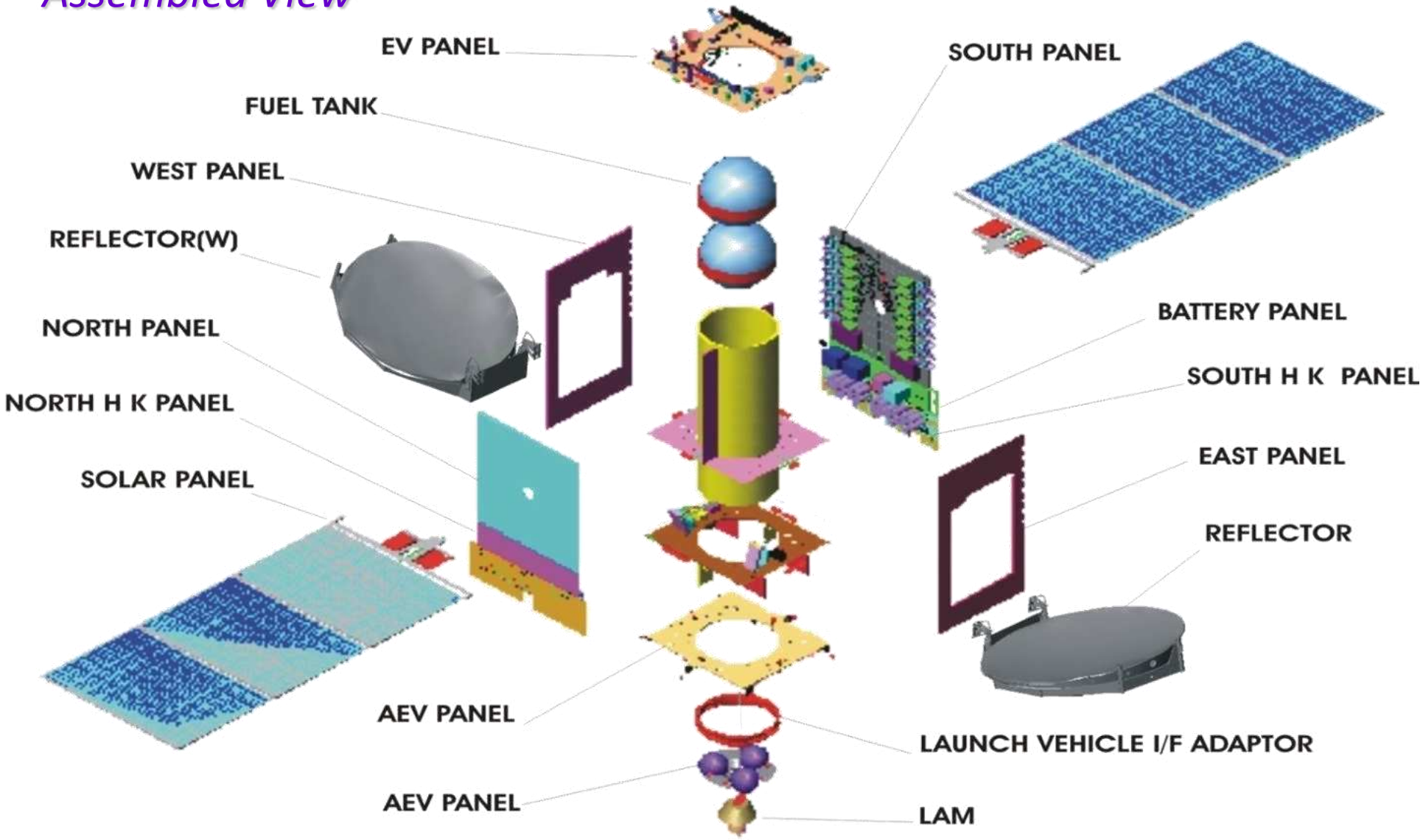
Different types of satellites

- Remote Sensing
- Communications
- Navigation
- Geodesy
- Scientific Satellites

I-3K Bus Spacecraft Deployed View



I-3K Bus Spacecraft Dis-Assembled View

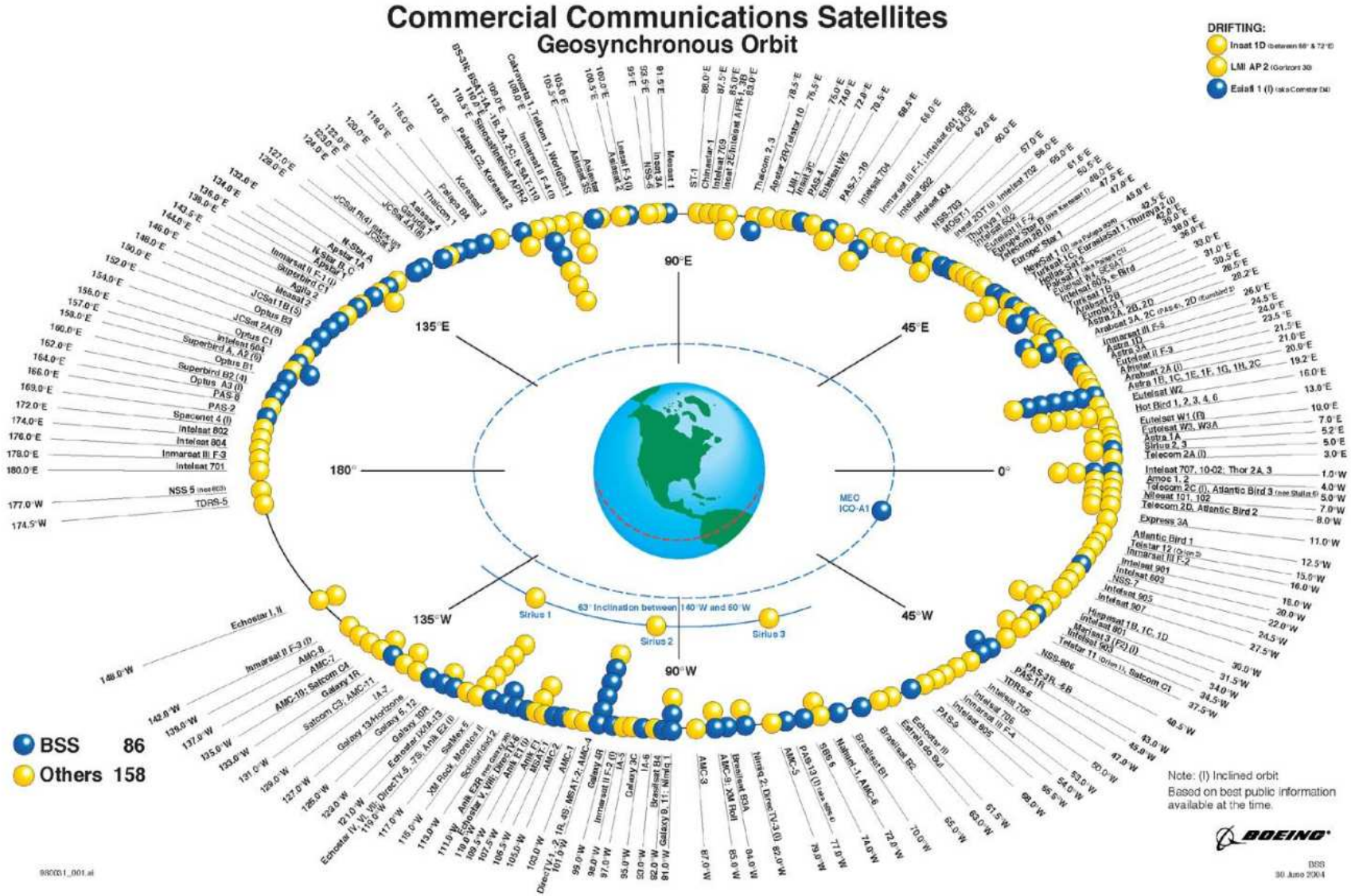


Satellite Communications
Great opportunity but toughest competition

- Worldwide 1.4 billion homes have TV but DTH homes are about 150 million
- HD channels are growing rapidly- 3853 channels in May2011 (42% growth over previous year)
- 113 satellite operators compete
- 4 operators dominate FSS market (share 75%)

  (Intelsat, SES, Telesat and Eutelsat)

Broadband, increased mobile use create new opportunities

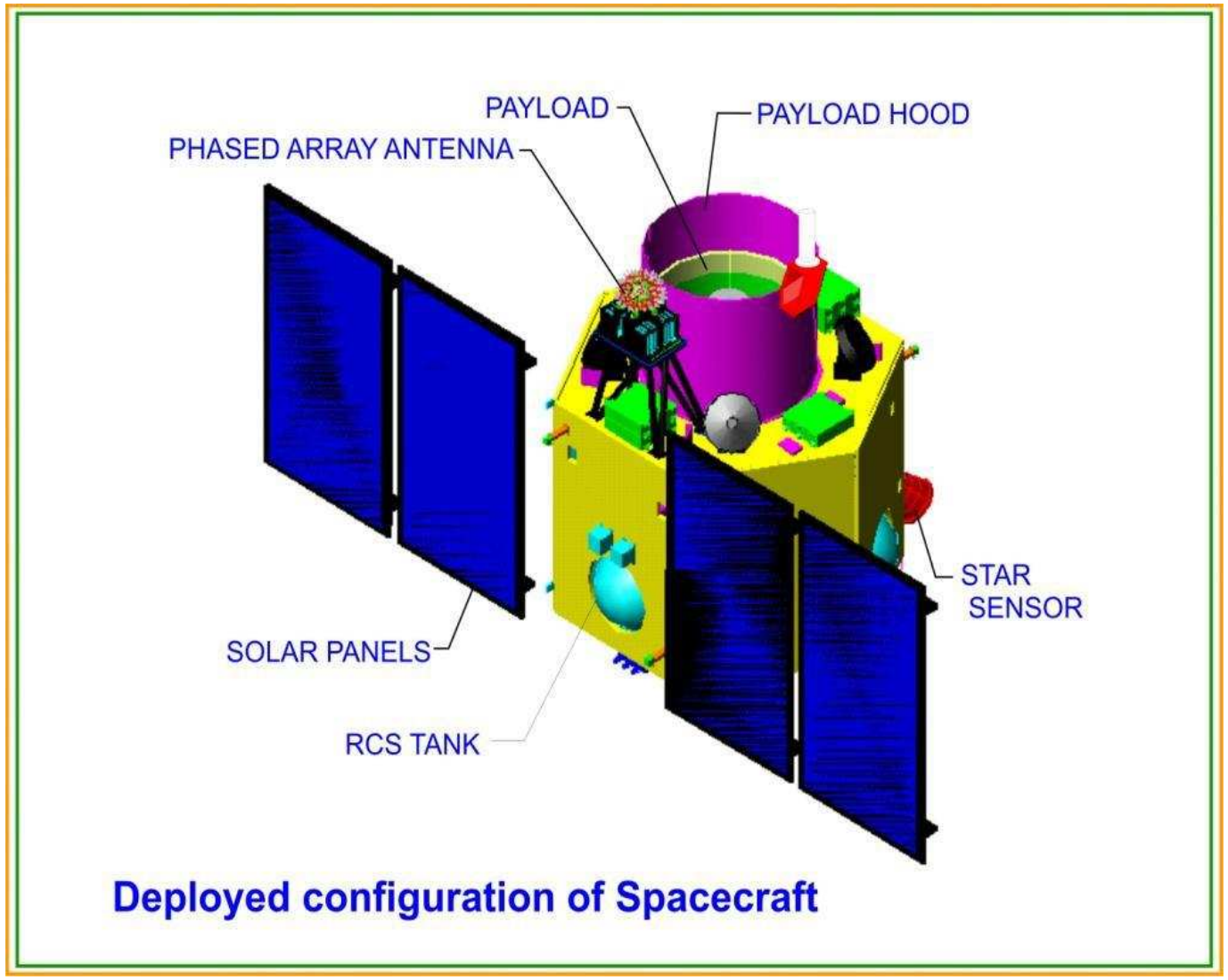

Commercial Communications Satellites
Geosynchronous Orbit
DRIFTING:
Insat 1D (between 66° & 72°E)
LMI AP 2 (Gorizont 38)
Eutelsat 1 (I) (aka Coronet 74)
90°E
135°E
45°E
180°
0°
135°W
45°W
90°W
MEO
ICO-A1
63° Inclination between 140°W and 60°W
Sirius 1
Sirius 2
Sirius 3
BSS 86
Others 158
Note: (I) Inclined orbit
Based on best public information available at the time.
BOEING
BSS
30 June 2004
980001_001.ai

REMOTE SENSING

Measurements by satellite earth observations

- ***Atmosphere:*** *Aerosol properties, atmospheric humidity fields (water vapour), atmospheric temperature fields (air* temperature), atmospheric winds, cloud properties, lightning detection, liquid water and precipitation rate, ozone, earth radiation budget (including solar irradiance), trace gases (carbon dioxide, methane and other greenhouse gases).
- ***Land:*** *Landscape topography (lake areas and levels), multi-purpose imagery (land cover, urban planning), soil moisture,* surface temperature (fire disturbance), vegetation (biomass, agricultural crop identification), albedo and reflectance.
- ***Ocean:*** *Ocean colour (for biological activity, including fisheries), ocean salinity, ocean surface winds, sea level,* currents, ocean wave height and spectrum, sea surface temperature.
- ***Snow and ice:*** *Ice sheet topography (glaciers and ice caps), sea ice cover, edge and thickness, snow cover, edge and depth.*
- ***Gravity, magnetic and geodynamic measurements:*** *Groundwater, sea level.*

Cartosat continuation satellite

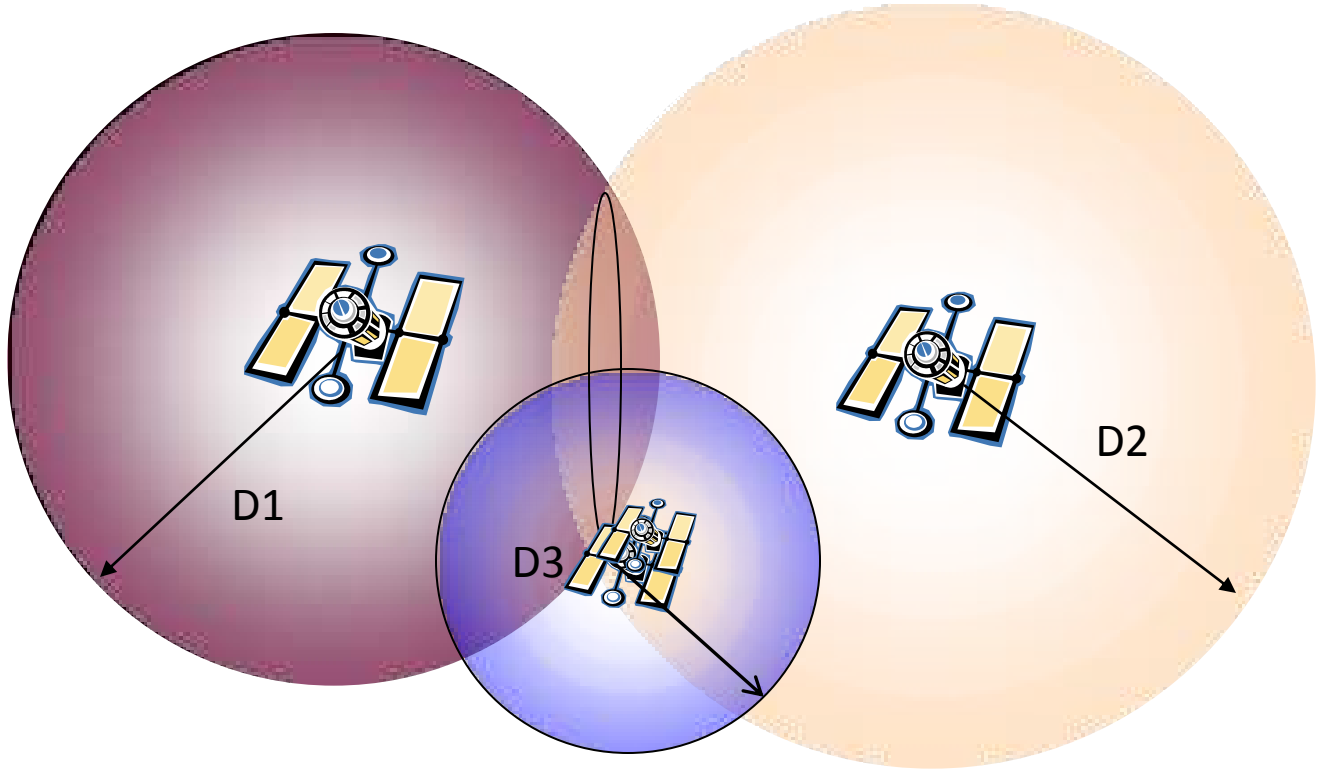


Payloads:

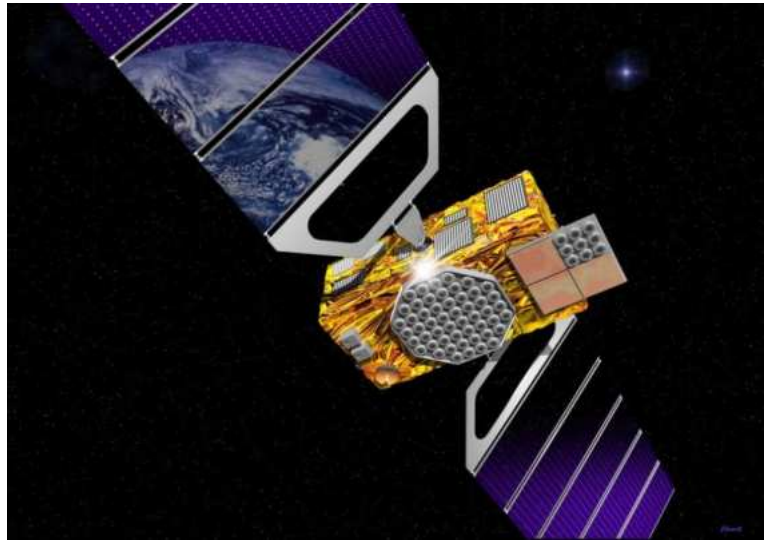
- PAN: 0.6m Resolution,
- 7.2 Km SWATH
- **MX: 2.4m Resolution, 30km SWATH**
- **S/C BUS similar to Carto-2**

Fixing position in 3D

- There are two common points of intersection for all 3 spheres, the centres of which are the 3 satellites and ranges measured are radius. One of those two points is on the earth.



Satellite positioning services



- Personal Navigation
- In- vehicle navigation Services

GPS, GLONAS, BEIDOU AND GALELIO CONSTELLATIONS
INDIA'S NAVIC REGIONAL SYSTEM
EQUIPMENT/ CHIP SET MARKET ~ 60 BI $

Science from space -

- Clear view beyond the haze of atmosphere
- Astronomy through Telescopes in earth's orbit
- Deep space probes
- Fly by spacecraft, orbiters, Robotic landers, around planets
- Living in space, astro- biology
- Materials experiments
- Space weather
- Major achievements: Farther view and Better understanding of Cosmos, origins and evolution, Van Allen Belts, Solar system, black holes, exoplanets, dark matter, planetary and earth science etc.

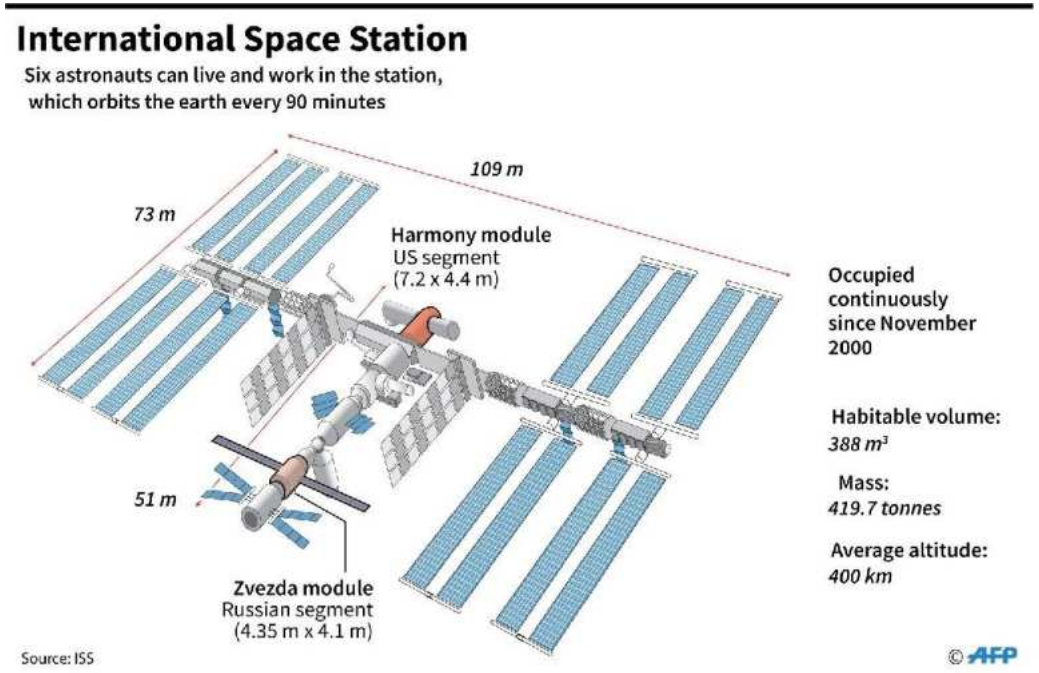
Human Space Flight

- Mercury, Gemini, Apollo programs of USA
- Voskhod, Soyuz programme of USSR
- Skylab
- Apollo – Soyuz
- Space Shuttle STS
- Space Stations- MIR, FREEDOM,
- Chinese human space flights (Shenzhou)

Space stations

- Permanent multipurpose manned facility orbiting in space for conducting research and space science experiments in microgravity environment
- MIR- the Russian station, International crew
- Freedom (356ft x 290ft), 220 miles alt. 470 tons, International.
- Chinese space station.. Tiangong-1 (20t)

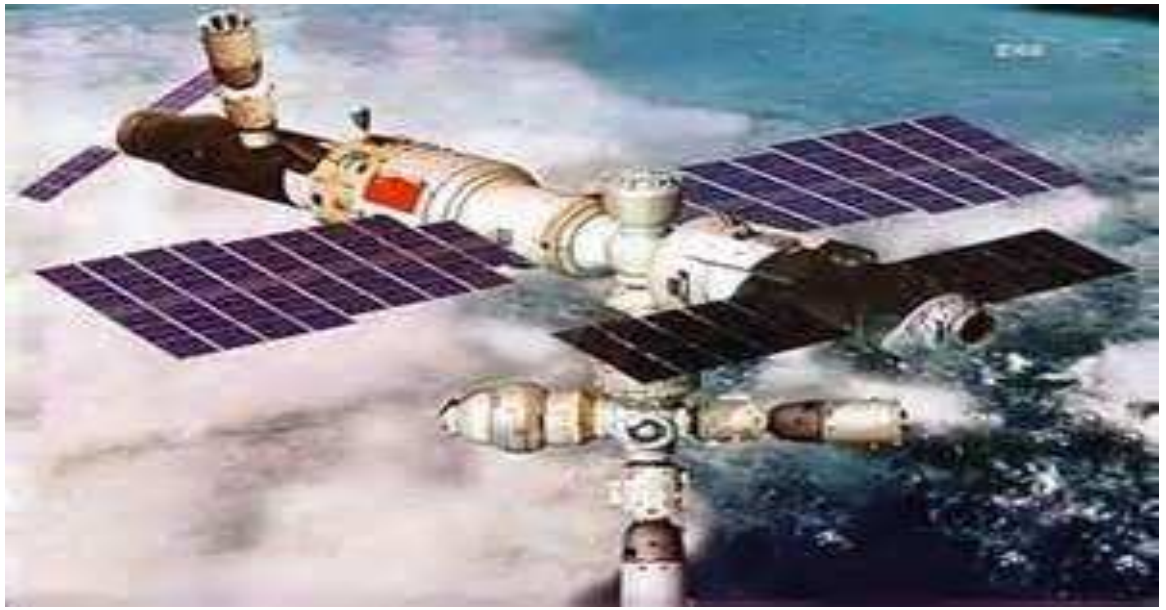
MIR STATION (RUSSIA)



CHINESE SPACE STATION

Tiangong

Manned module (Shenzhou)



Military and Security applications of Space

STRATEGIC ADVANTAGE OF SPACE SYSTEMS FOR SECURITY

- By very nature, space operations are global
- Advantage over potential adversaries due to use of specialized technologies and their integration
- Worldwide coverage and all weather day and night observing capability and high speed of travel
- Improved availability of critical data on weather, natural resources, infrastructure and their spatial distributions & non-invasive monitoring of changes
- Better response to users needs and amenability for integration with terrestrial systems

SPACE FOR SECURITY – GLOBAL SCENE

- Historical developments in use of Space as means for delivery of nuclear weapons & weapons of mass destruction .. Race for superiority, Doctrines of Balance of Power and Deterrence through Mutually assured Destruction
- Changed scenario in post cold war period
- Growing reliance on Space based assets for strategic advantage in security and military applications
- Weapons in space becoming a reality

SPACE FOR SECURITY- GLOBAL SCENARIO

- ~ 4900 military satellites launched so far
- Out of the above, 4800 by USA and USSR/ Russia
- Currently operational military satellites include 130 of USA, 60 of Russia and about 20 from rest of the world
- “Military space power provides means of support to terrestrial forces via instantaneously globe-spanning information/ Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance capabilities”

APPLICATIONS OF SPACE IN SECURITY

- Satellite Communication Services
- Space based earth observation services
- Space based signal intelligence
- Early warning of missile launches
- Space based position navigation and timing services

MILITARY COMMUNICATIONS - SATELLITES

- Secure connectivity
- Possibility of re-configuration
- Capability for high data rate to low data rate communications
- Flexibility to communicate with a variety of terminals including mobile terminals
- Ability to address better air traffic management
- Efficient networking

- TRENDS: Deployable laser-based communications capability
- Fully interoperable networks

MILITARY USES OF SPACE - BASED EARTH OBSERVATION

- Detection of changes over areas of interest
- Ability to capture topographic information
- Improved weather and sea state forecast
- Protection against jamming and deception
- Amenability for integration of various types of data and Worldwide coverage

SPACE BASED SIGNAL INTELLIGENCE

- Enables characterization and the location of telecommunications and radar systems
- Access to the content of the communications
- The monitoring of potentially hostile activities
- The detection and characterization of related human activity
- The support of counter-terrorism operations
- The detection of emitters with a high degree of accuracy

SPACE BASED EARLY WARNING SYSTEMS

- Alert the forces and national authorities of an incoming threat, providing impact prediction information (time and location) of the strike to enable defense and the use of protection measures
- Cue counterforce actions against the incoming missiles and counterforce actions against hostile launch capabilities
- Locate the launch site with a sufficient precision to allow the identification of the aggressor and provide evidence to high level decision makers.

SPACE BASED WEAPONS

- Weapons stationed in space are conceived in the context of Ballistic Missile Defense (BMD) and in the context of negating the space capability of adversaries
- US withdrawal from the 1972 ABM Treaty and emphasis on BMD
- Weapons considered for BMD include Directed Energy weapons (like high energy lasers) and Kinetic Energy weapons

International organisations

- UN COPUOS
- Conference on Disarmament, UN Security Council
- ITU
- WMO
- IADC
- CEOS
- GEOS
- IAF
- IAA
- IISL
- COSPAR
- International Charter on Disaster Mitigation

Intergovernmental organizations

- EUMETSAT
- ESA (Govt)
- INTERSPUTNIK
- ARABSAT

- Now privatized organisations
  - INTELSAT
  - INMARSAT
  - EUTELSAT

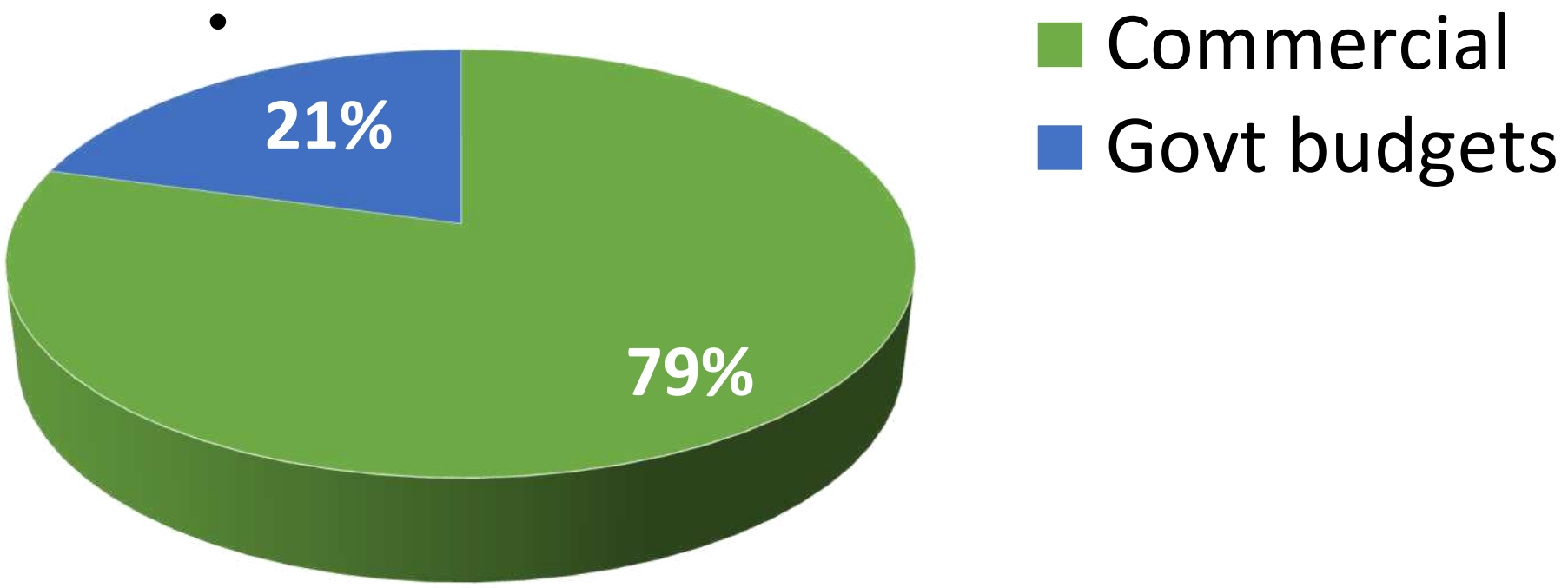
Space activities and actors

- 2,100 satellites operated by entities from 68 countries (some in regional consortia)
- Cumulatively, organizations from 86 countries have deployed at least one satellite since 1957
- 558 active satellites in GEO (27 more than in 2017, mostly providing communications services)
- Satellites launched 2014—2018 increased 243% over previous 5 years
- Average 210/year
- Due mostly to small/very small satellites in LEO (<1200kg)

SOURCE: SIA Report

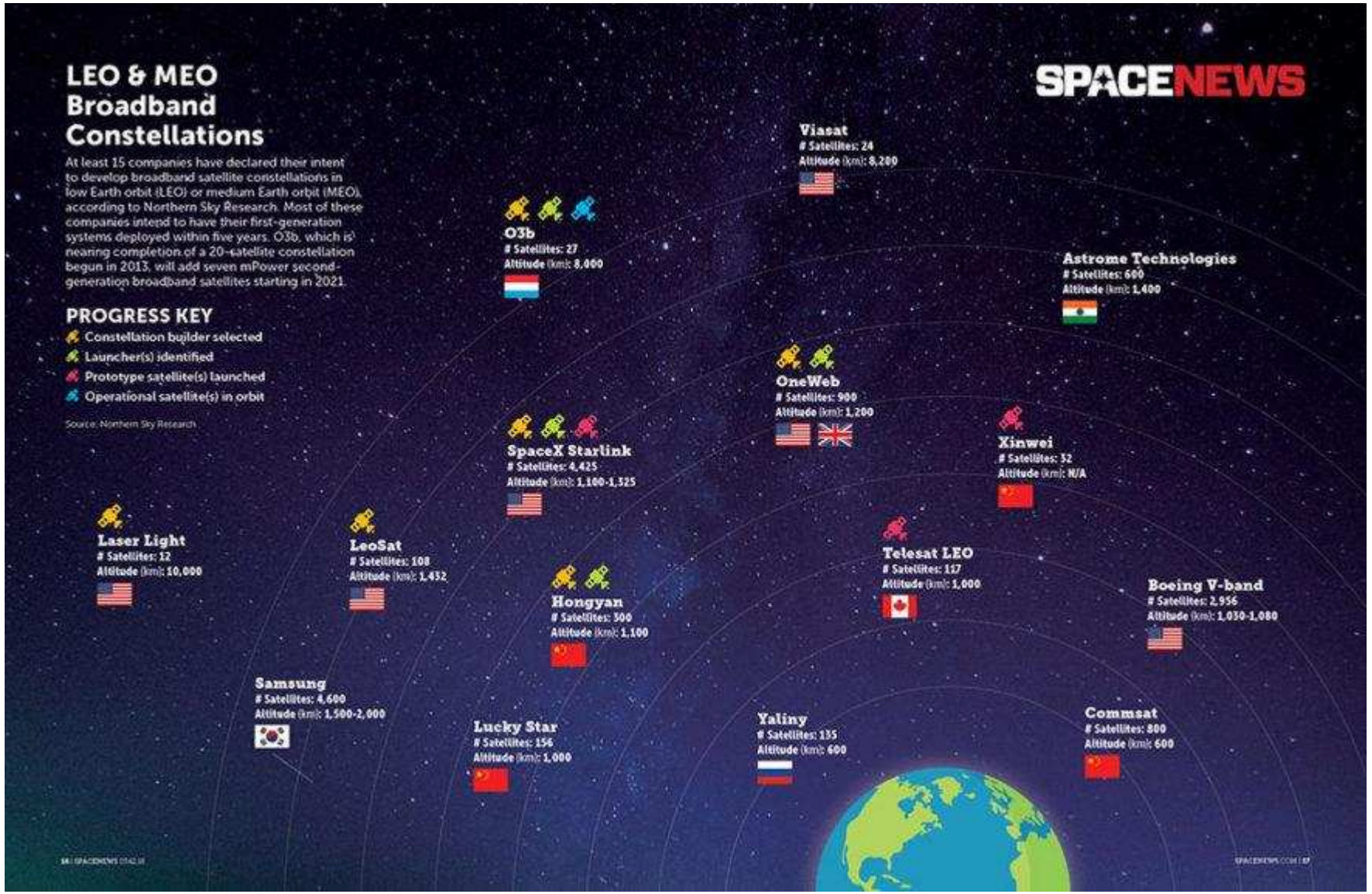
Commercialisation is the characteristic trend of the Global Space Economy

2019 Global Space Economy size $423.8 Bi.



- Increasing private investments, 'NewSpace' disruptions,
- Commercial revenues $ 336.89 Bi
- Governments are strong customers yet. Budgets $86.91 Bi

Large Constellations



Low cost , small sats.
Latency only 20ms against 280 of GEO

Mass production

Market: Backhauling
Consumer & enterprise
High speed INTERNET, M2M, Asset tracking

CREDIT:
SPACENEWS

Mega Constellations

	No of satellites	**Orbit, km**	**Frequency band**	**Remarks**
Star Link (SpaceX)	4425 (386kg)	1100 - 1325	Ku - V	23.7 Tbps, 2022, >100 G/Stn.
One web	900 (145 kg)	1200	Ku - V	1.5 Tbps, 2018 start, 71 G/stn.
Telesat	117	1000	Ka -V	2.66 Tbps 2017, 42 G/Stn.
Boeing	3000	1030-1080	V	26 TB capacity 2022
Leosat	103	1452	Ka	2018
SAMSUNG	4600	1500-2000	mm wave	
Hongyon	300	1100	-	-
Viasat	24	8200	Ka	2022

Mega constellations in LEO/MEO -Issues

- Will it be over build up of capacity :17000 satellites for >150 Tbps ??
- Competition from 5G and LTE networks??
- Will it be serving underserved, to bridge digital divide?
- Spectrum crowding and the challenges of ground segment development (going to V Band)
- Will the promise of lower cost be realised –
  - LEO constellation CAPEX…. 0.26 mi $ per 1GBPS
  - GEO large satellite CAPEX…….2 to 9 mi. USD per 1 GBPS
- Orbital debris contribution

International Space law- basic tenets

- Freedom to access and conduct of space activities as common province of mankind
- Prohibition of placement and use of Nuclear weapons or Weapons of Mass Destruction
- Non appropriation
- State responsibility
- Liability
- International cooperation
- Preservation of Space environment

Managing space traffic

Space Debris – *A Threatening Scenario*

- **Space Debris**
  - **About 22,000 tracked objects of size larger than 10 cm**
  - **More than 5,00,000 particles of size varying between 1 to 10 cm**
  - **Several millions particles of size less than 1 cm**

- **Sources**
  - **Mission related - Satellites, Rocket bodies**
  - **Accidental – Satellite break-ups, On-Orbit Collisions, Drop-outs from astronaut's extra-vehicular activities**
  - **Intentional – ASAT tests, Intentional Destructions, Abandonment of space objects in LEO, launching of Space Objects non-compliant to UN debris mitigation measures, micro and small satellites … …**

- **Remedial Measures**
  - **Strict compliance, Mitigation, Active Removal, On-Orbit Servicing**

Expert Group recommendations

- Implementation of mitigation measures
- Sharing debris monitoring information
- Improving accuracies of tracking
- Controlled reentry strategies
- Conjunction assessments in all phases of mission and prior to orbit maneuvers
- Information sharing procedures
- Cooperation in identifying space objects

Space tourism

Space mining and living in space & on planets

Space Tourism

- No scientific qualifications are needed, need for undergoing fitness tests and training ahead of flight
- **Key players:**
- Richard Branson’s Virgin Galactic;
- SpaceX – started by Elon Musk, co-founder of the Tesla electric car company –who has vowed to take two tourists on a trip around the moon.
- Blue Origin, which was founded by Amazon founder Jeff Bezos.

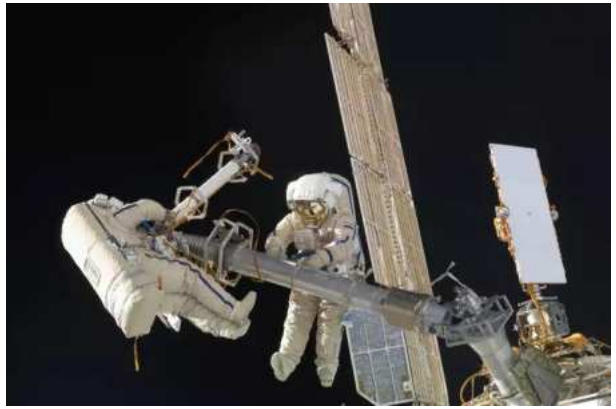
Space Tourism developments

ORION SPAN

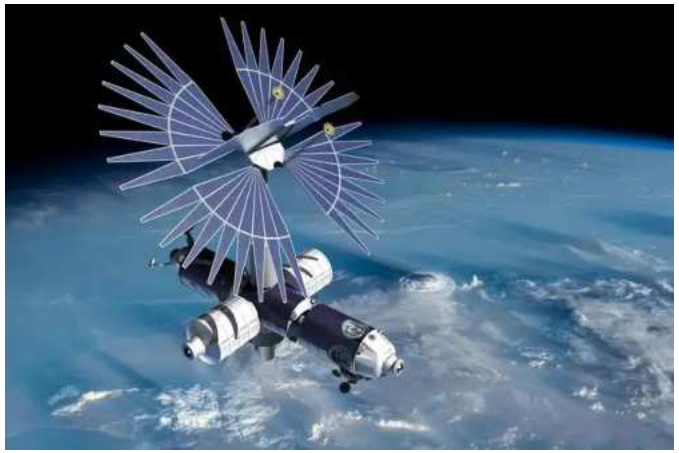
Four guests and
two crew per stay,
$9.5 mi. per person for
a 12-day mission

ROS COSMOS: 40-60 mil.$.
1 to 2 week on ISS

SPACE ADVENTURES



KOSMOKURS



15 min
$200,000 to $250,000 per person.

Space Tourism: Examples of actors

Virgin Galactic

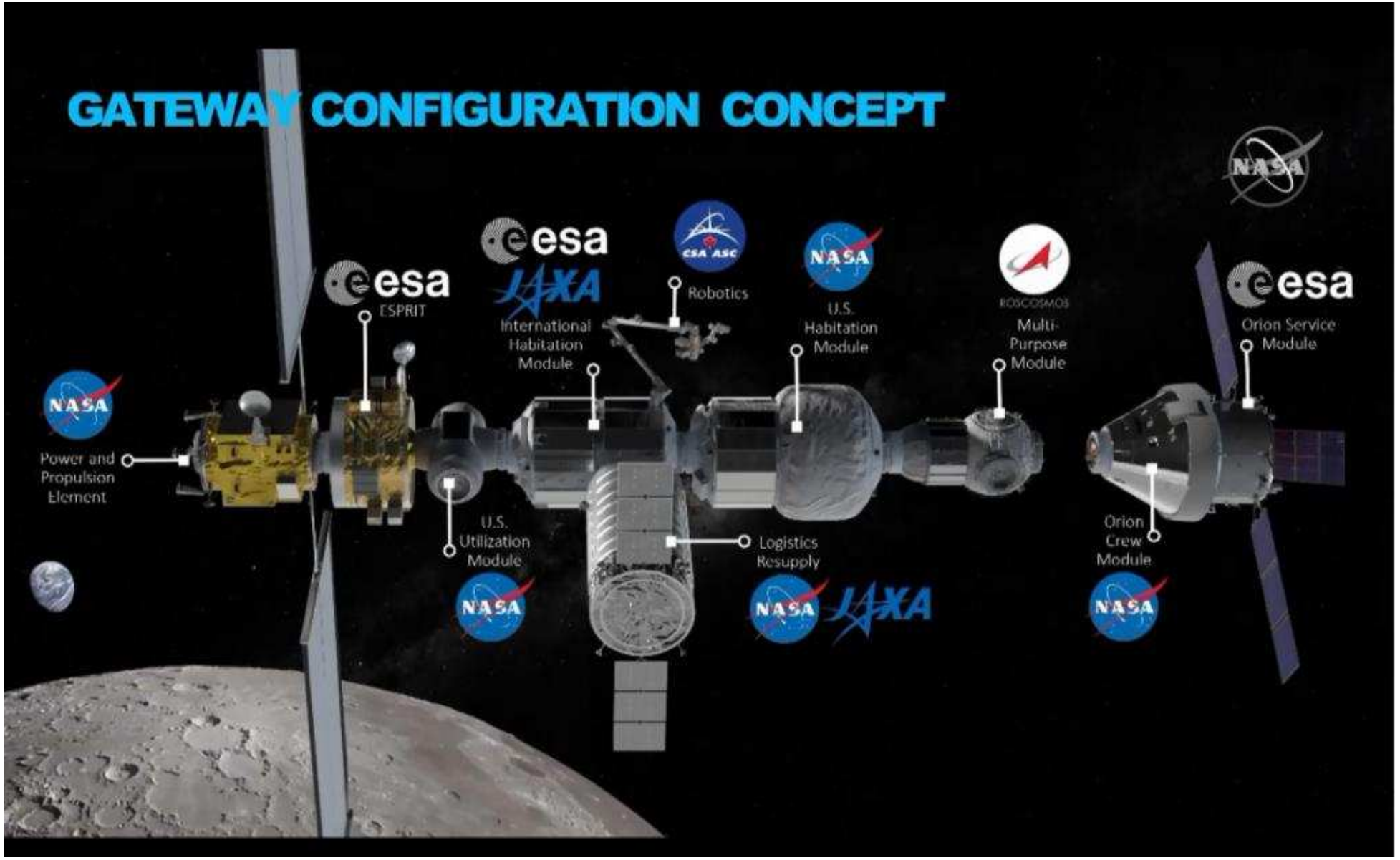
250,000/ person-trip

SPACEX

Blue Origin

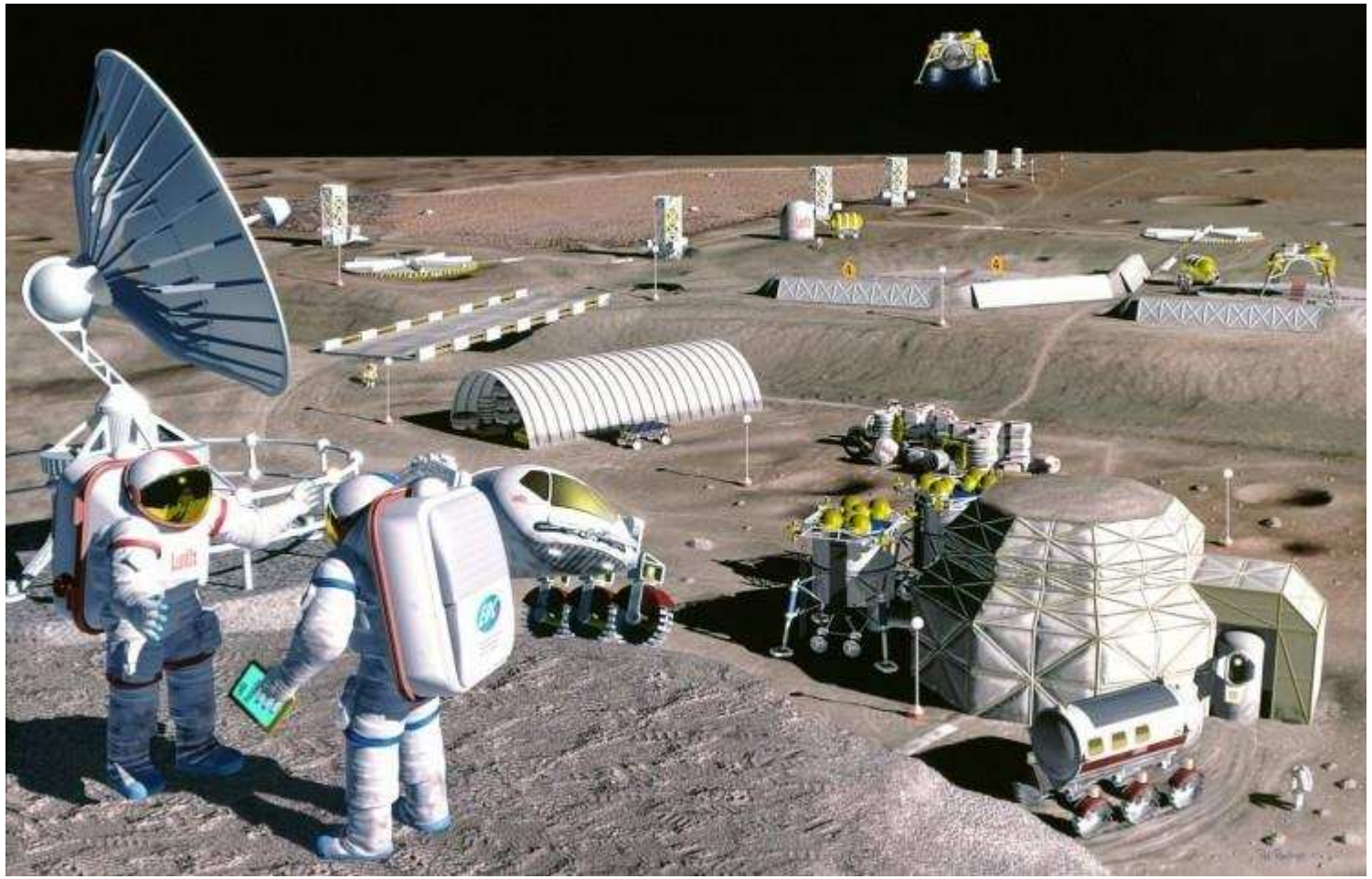
Photo credit: SpaceX, Blue Origin, Virgin Galactic

GATEWAY in near lunar space



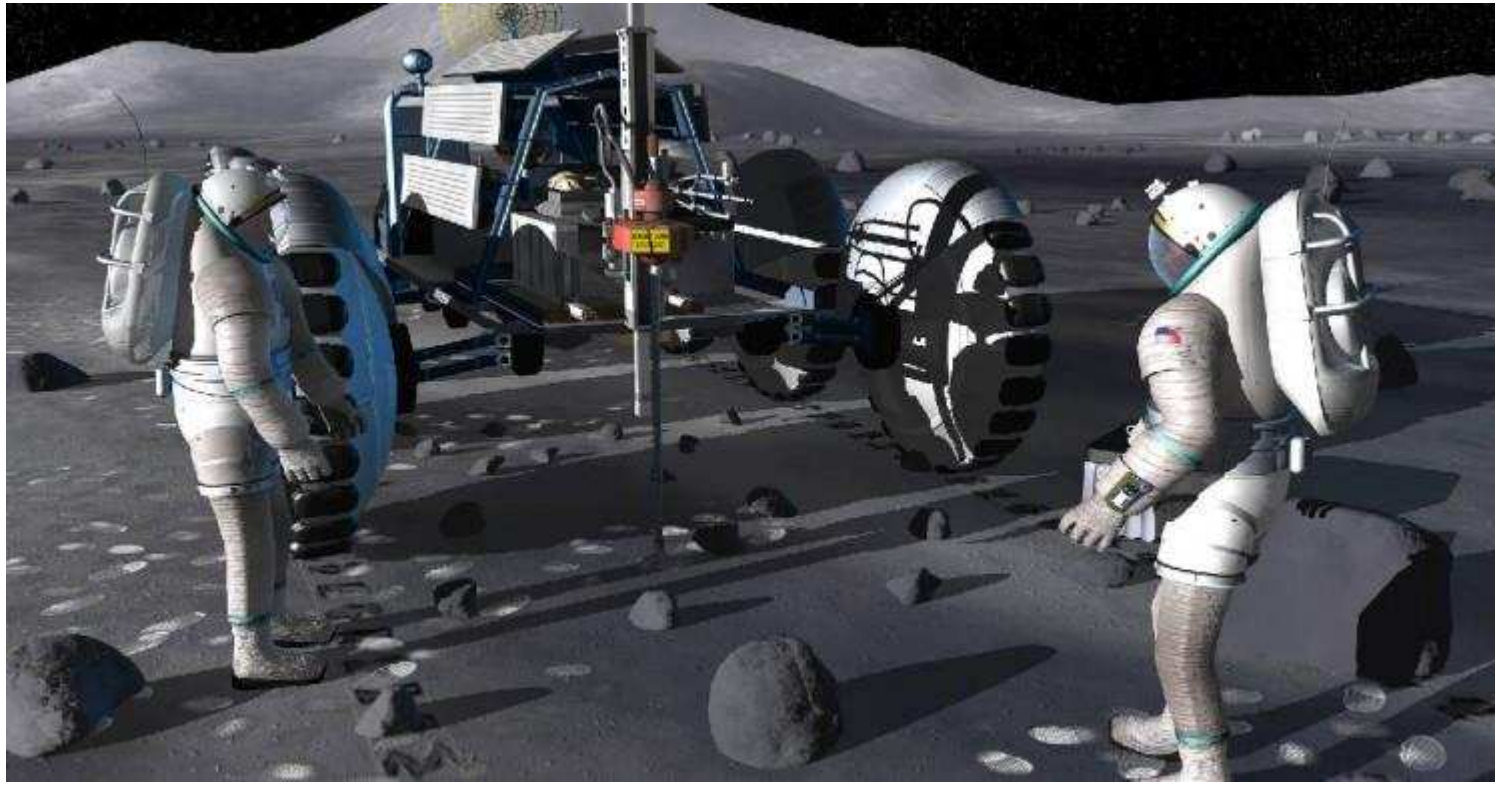
CREDIT: NASA

Moon Colony



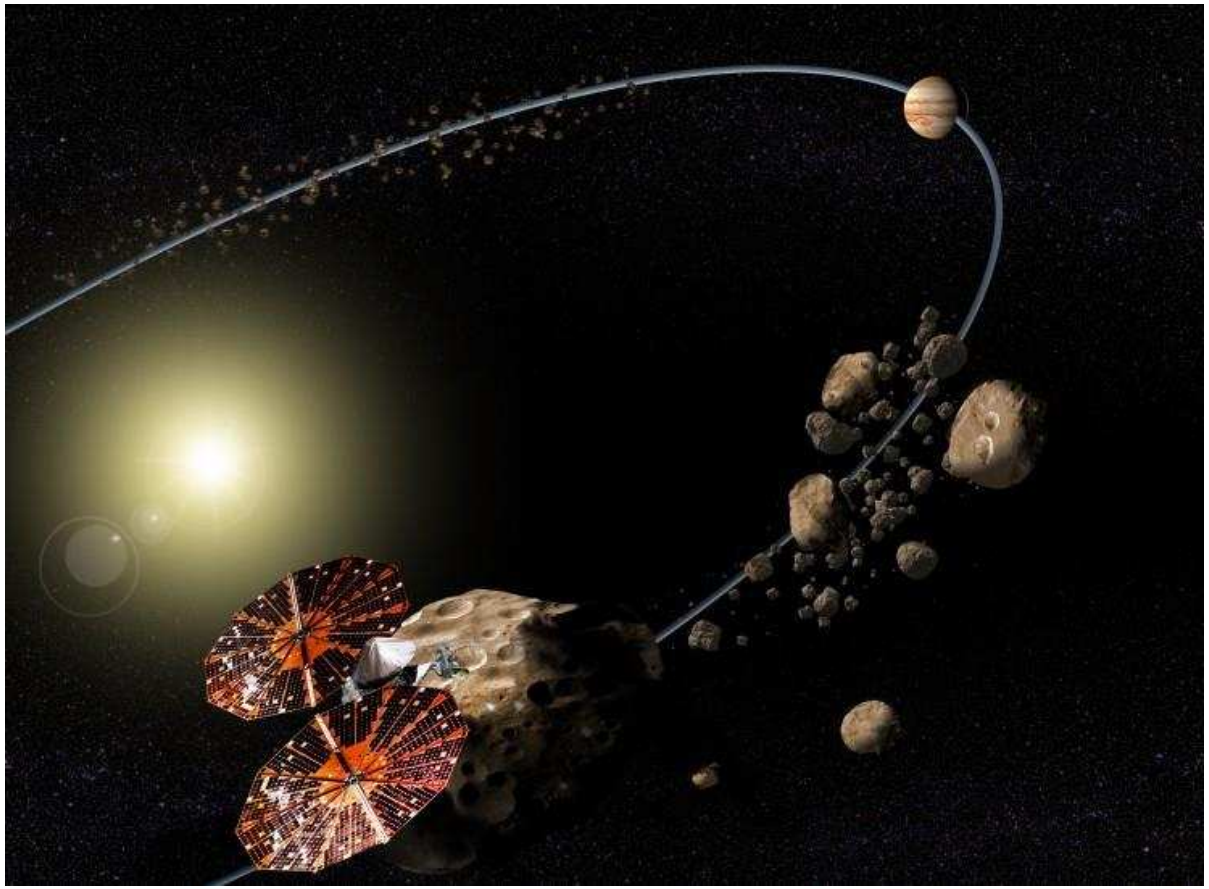
Source: *NASA/SAIC/Pat Rawlings/ Wikimedia Commons*

The mining of celestial bodies as well as the use of space resources



Candidates:
Near earth
Asteroids
Moon
Mars

Asteroid Exploration



There are about 12,000 asteroids that pass each year close to the earth, from large rocks to pieces several kilometres in diameter. Also, it would be easier to land on 10% of them than on the Moon.

Source: NASA/SwRI

Asteroid resources

- It is estimated that some asteroids could contain all the platinum obtained from landmines in all of history and have a market price of hundreds of billions of dollars.
- In fact, it is presumed that some contain iron, nickel or cobalt in sufficient quantity to cover the needs of the Earth for 3,000 years.
- Bernstein's Wall Street research firm says a large asteroid called 16 Psyche in the asteroid belt between Mars and Jupiter with an extension of 200 kilometers wide could contain enough nickel ore to cover the current human demand for millions of years.

HAYABUSA 2

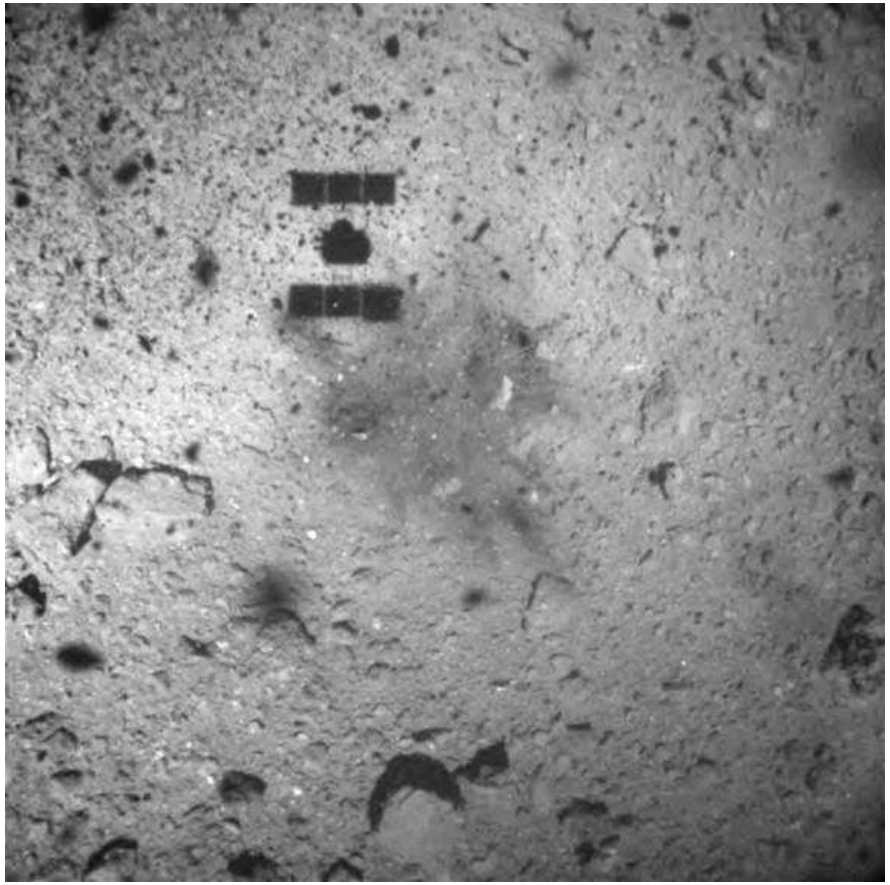


Image captured near the touchdown site immediately after touchdown. The photograph was taken with the Optical Navigation Camera – Wide angle (ONC-W1) on February 22, 2019 at an onboard time of around 07:30 JST.

Image credit : JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.

Space environment- technology impact

Impact of space environment on design of space craft

- Thermal control
- Spacecraft charging
- Radiation effect
- Vacuum/ corrosion (out gassing)
- Micrometeorites
- Debris
- Drag
- Sensors FOV constraints
- Manned presence constraints
- Micro gravity

Search for extra terrestrial life

- Discovery of Exoplanets – Hubble telescope to James Webb
- Kepler mission
- Main constituent elements of life on earth – Carbon, Nitrogen, Oxygen, Sulphur, Phosphorus, and Hydrogen
- Search for life on Mars (water) and Venus (presence of Phosphine)

A peek into the future

Future Space - Game Changers???

- Disruptive low cost access
- Constellations
- Space – a new domain for warfare
- Gateways for deep space exploration – Human & Robotic
- Space as source of energy and resources
- Alternate habitats

Thank you

Email: krsmurthy09@gmail.com