Introduction to Satellite Technology

Satellite Technology and Telecom Laws

PG Diploma in RS & GIS

NALSAR UNIVERSITY OF LAW, HYDERABAD

Satellites - Technological challenges

- Harsh operational environment- Thermal, Vacuum and Radiation; Debris
- Weight, power , volume constraints
- No access to repairs, auto reconfiguration demands
- Reliability demands, Fail safe operations
- Long life expectation
- Dual use potential

Different types of spacecraft

- Orbiter
- Fly-by
- Landers
- Rovers
- Space stations
- Probes (Deep space)
- Remote Sensing
- Communications
- Navigation
- Geodesy
- Scientific Satellites

Satellite technology trends

- High throughput satellites
- Small satellite constellations
- Inter satellite links for mega constellations
- Docking and in-orbit servicing using small satellites
- Use of AI for onboard processing and managing constellations
- Higher frequency bands (Ku, Ka..) for data communications in Small sats

Typical CubeSat configuration

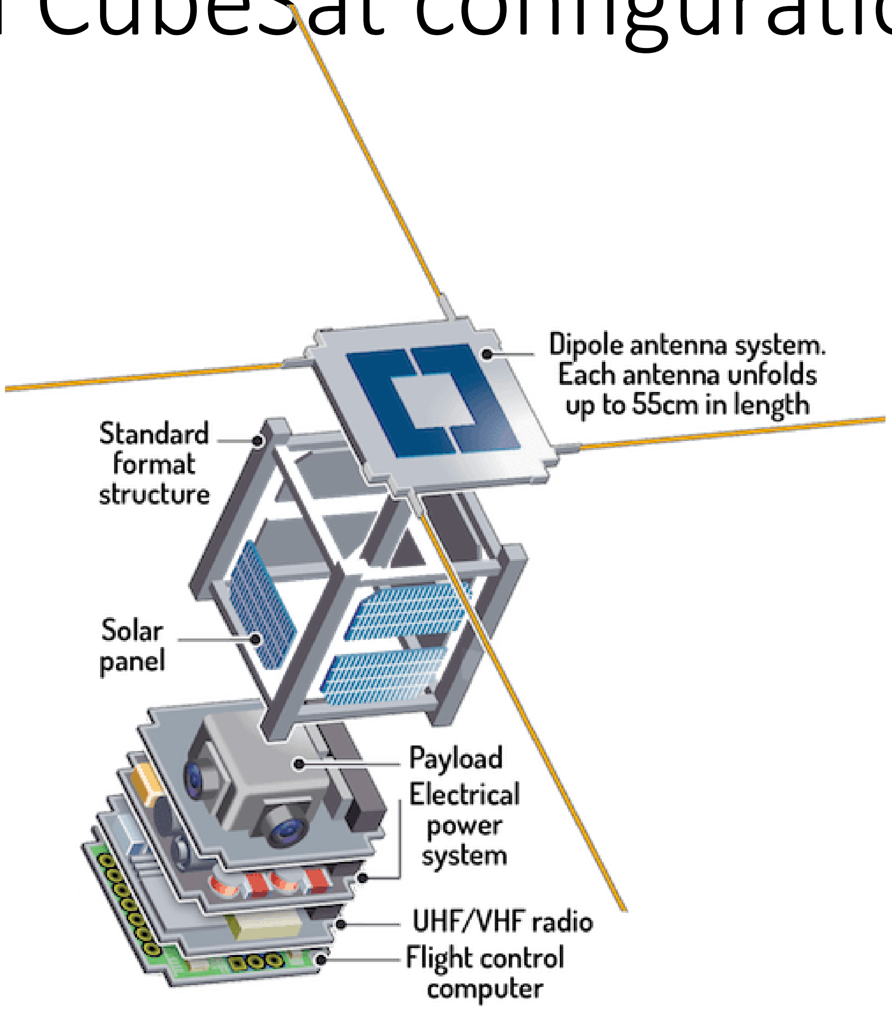
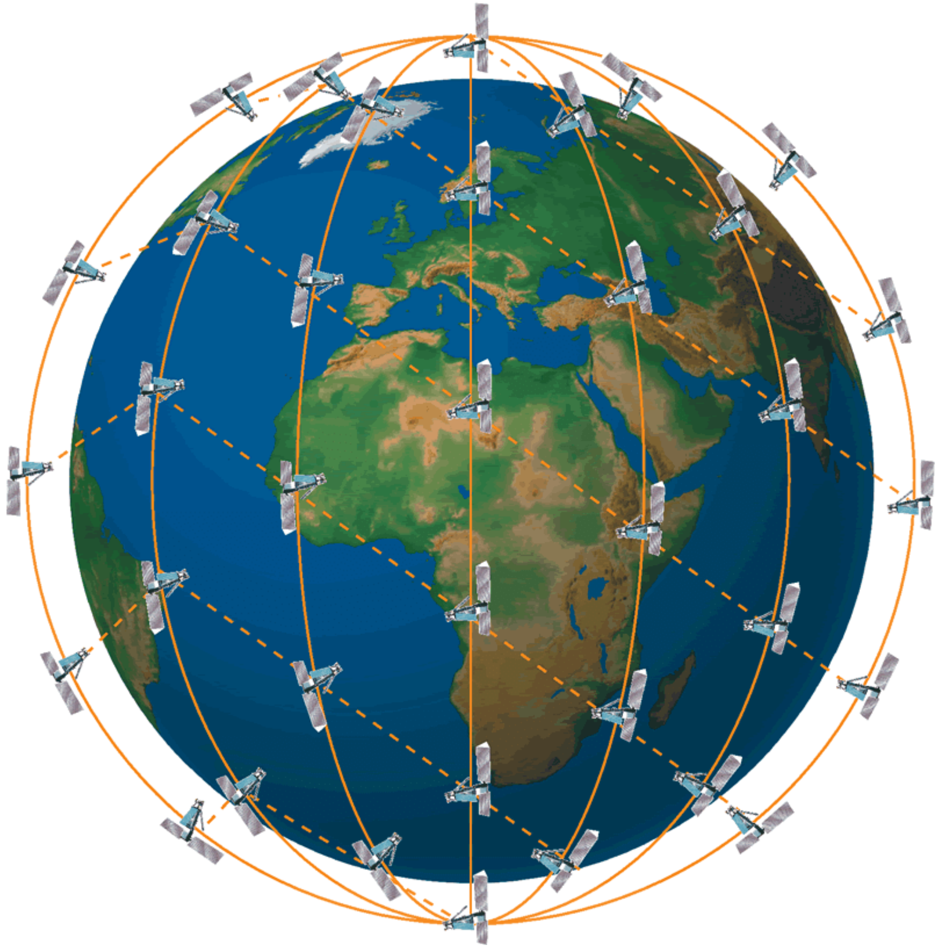


Image credit: https://alen.space/basic-guide-nanosatellites/

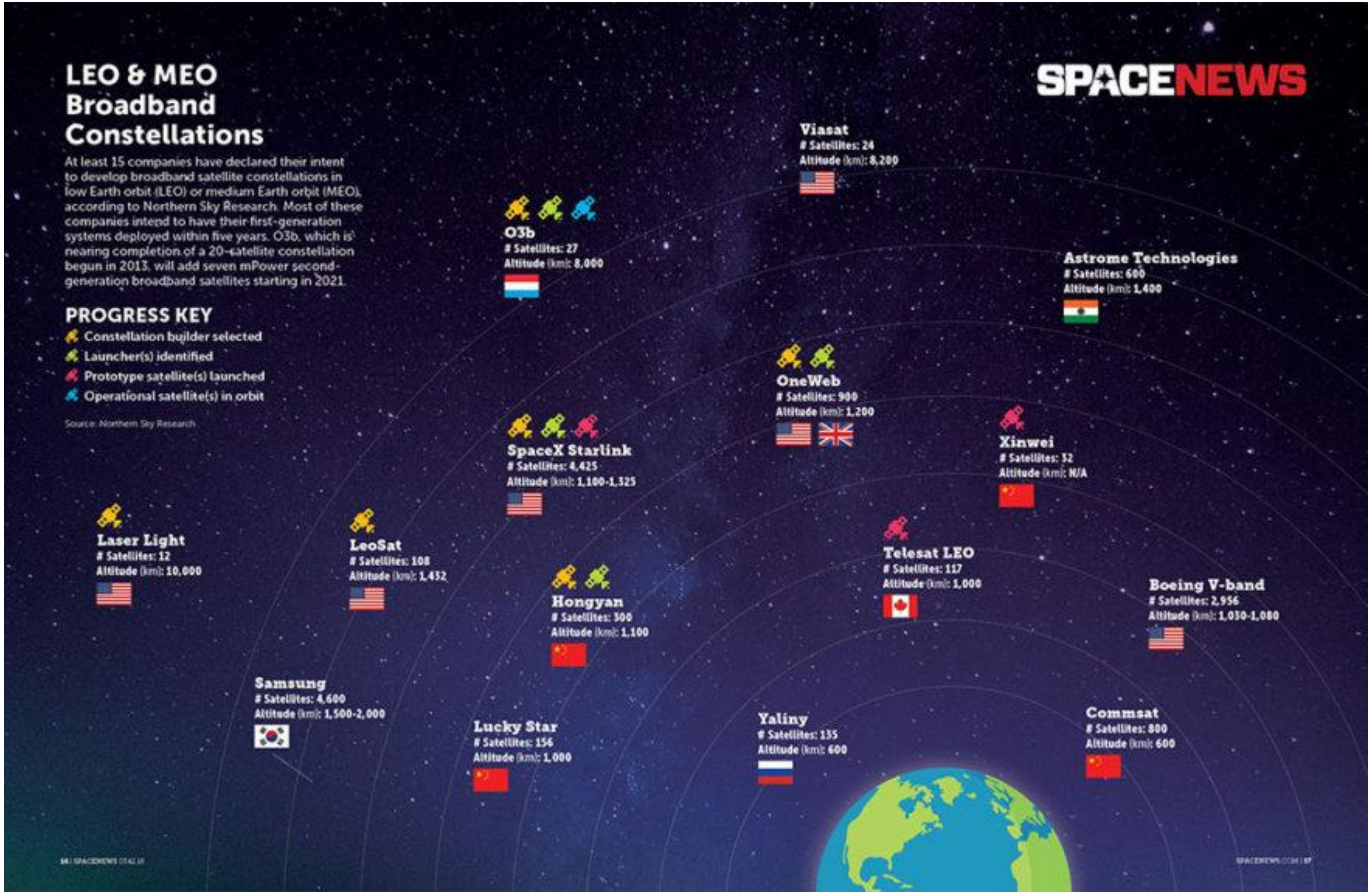
Low earth orbit constellation concept



Reference/ credits:

Modelling and Performance Analysis of 2.5 Gbps Inter-satellite Optical Wireless Communication (IsOWC) System in LEO Constellation - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Low-Earth-Orbit-LEO-satellite-constellation_fig1_328133212 [accessed 18 Feb, 2021]

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

APPLICATION SEGMENTS OF CUBESATs

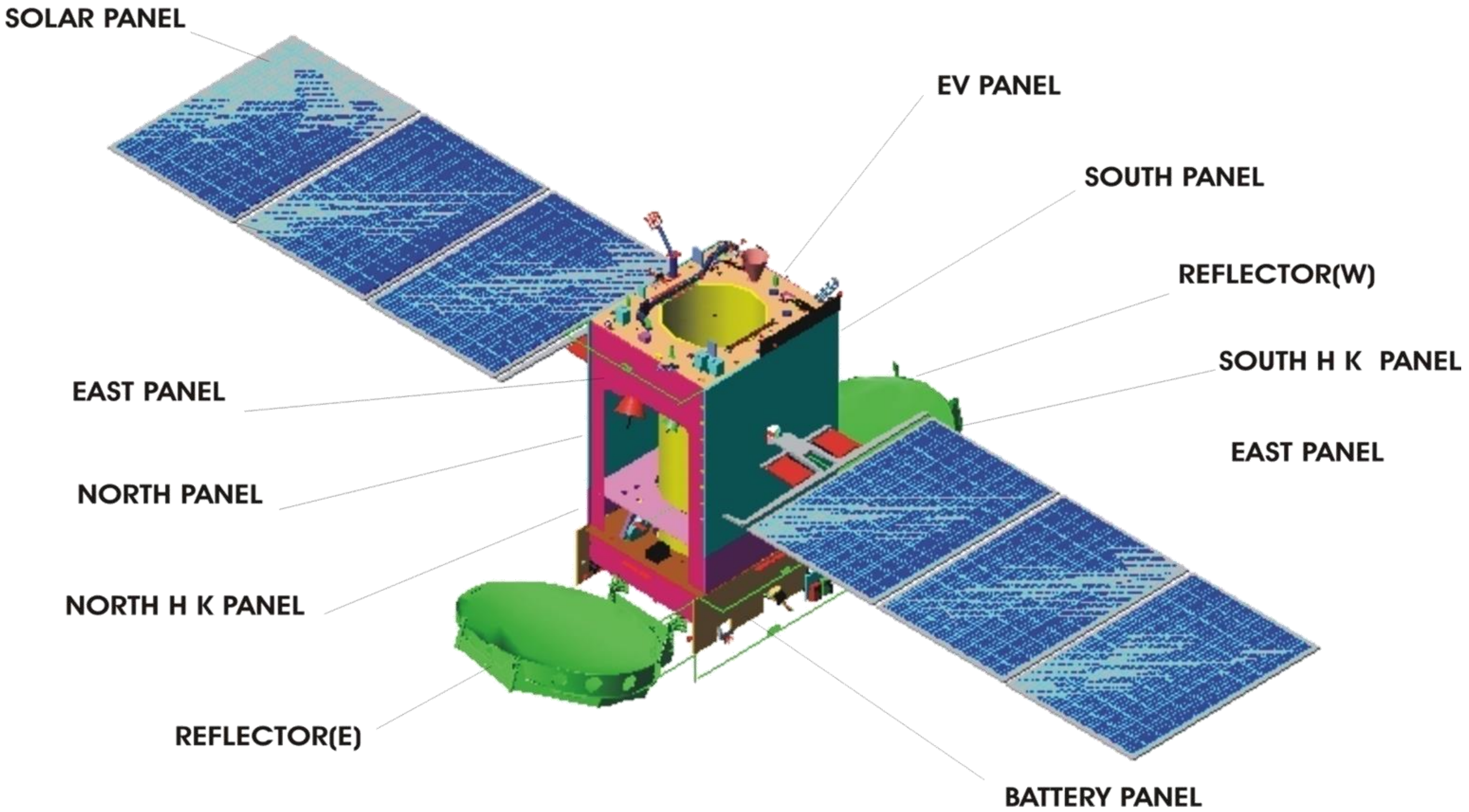
- Remote sensing
  - Mapping
  - Urban planning
  - Crop yield forecasting
  - Hyper spectral imaging
  - RADAR data
  - Video imaging
- Science
  - Astronomical mapping
  - Auroral plasma
  - Education/ capacity building
- Disaster support
  - Disaster Monitoring
  - Flood mapping
  - Fire detection
  - Space Debris monitoring
- Communications
  - IoT and Machine to Machine data exchange
  - Data store &forward (Global)
  - Mobile communications
  - Communications relay, Internet Access
- Security
  - ELINT/SIGINT
  - Reconnaissance
  - Technology validation
- Mobile Assets
  - Tracking of ships (AIS)
  - Tracking aircraft in flight using ADS-B
  - Remote monitoring & control

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

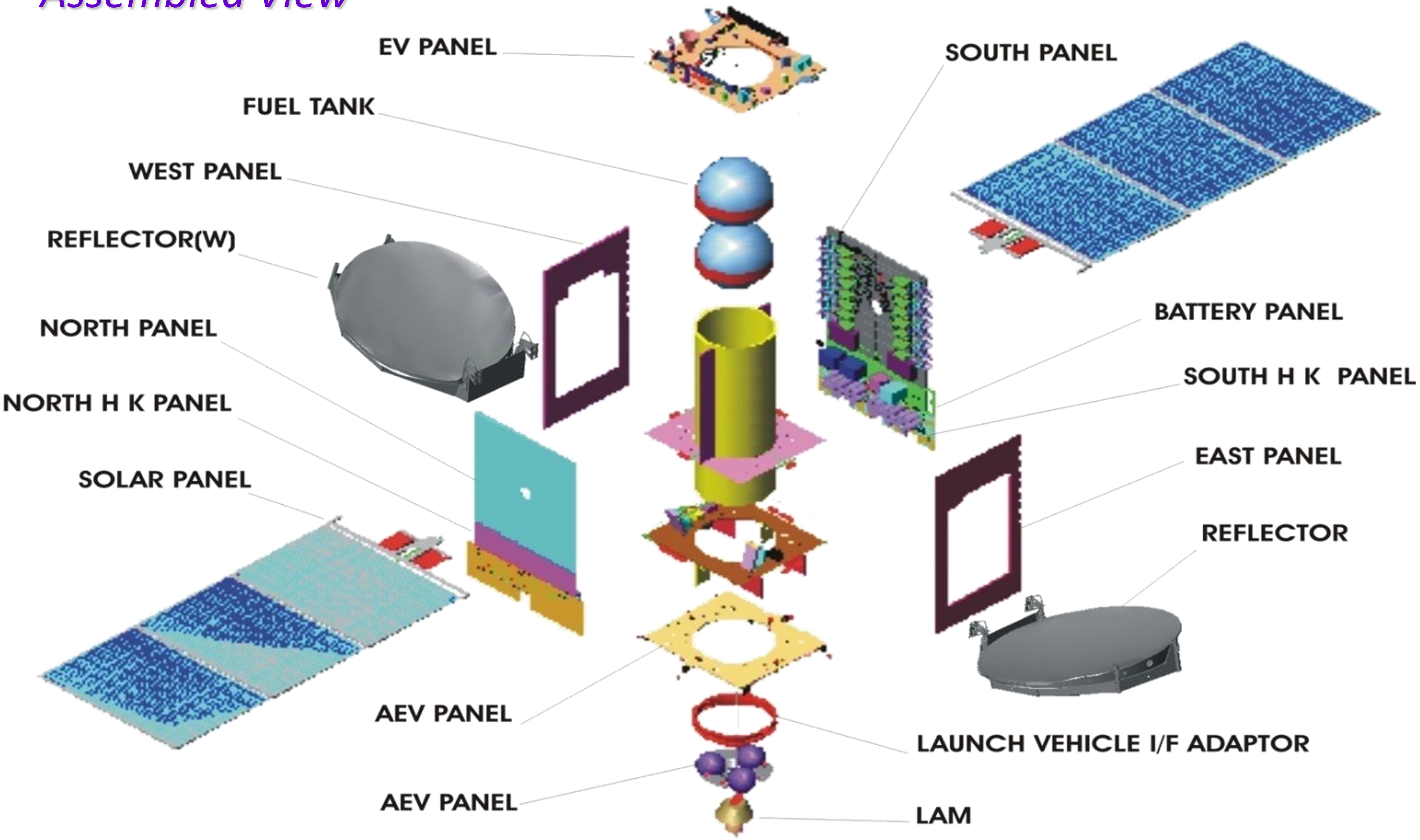
I-3K Bus

Typical Communication Satellite

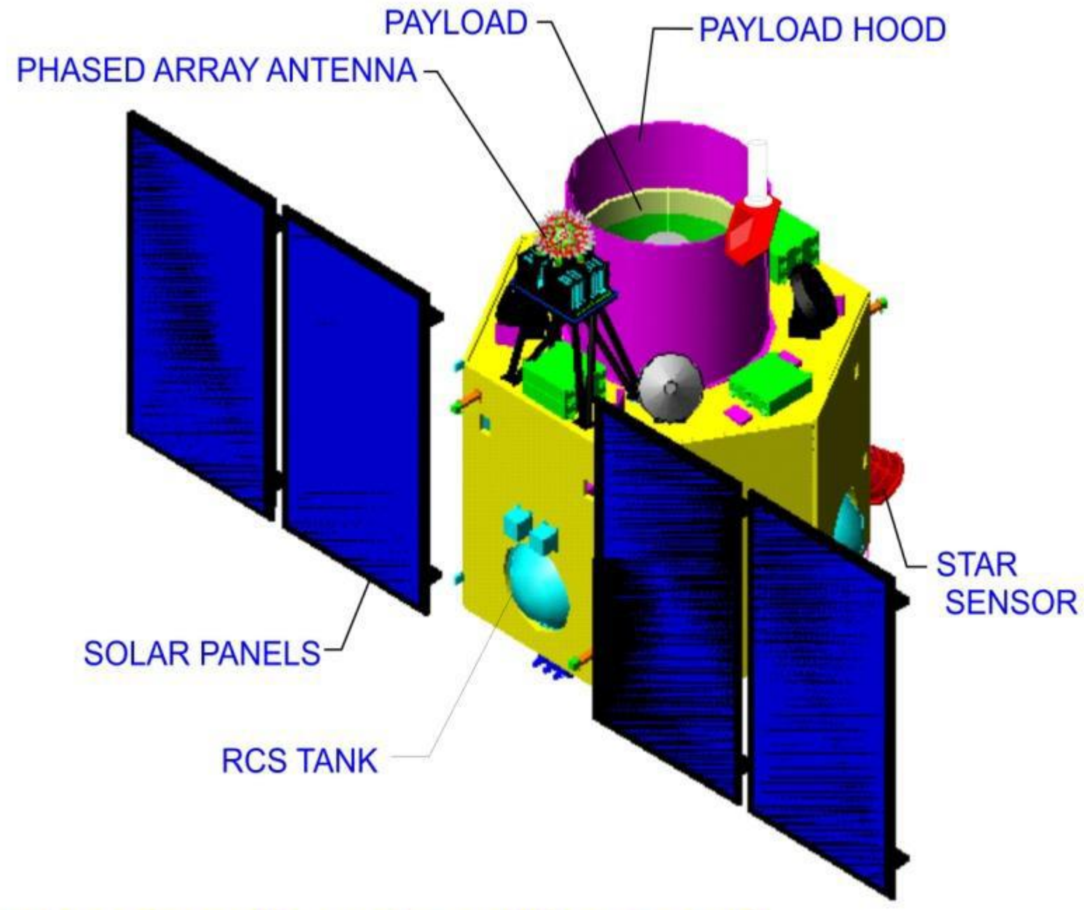


I-3K Bus

I-3K Bus Spacecraft Dis-Assembled View



Remote Sensing satellite (Cartosat continuation)



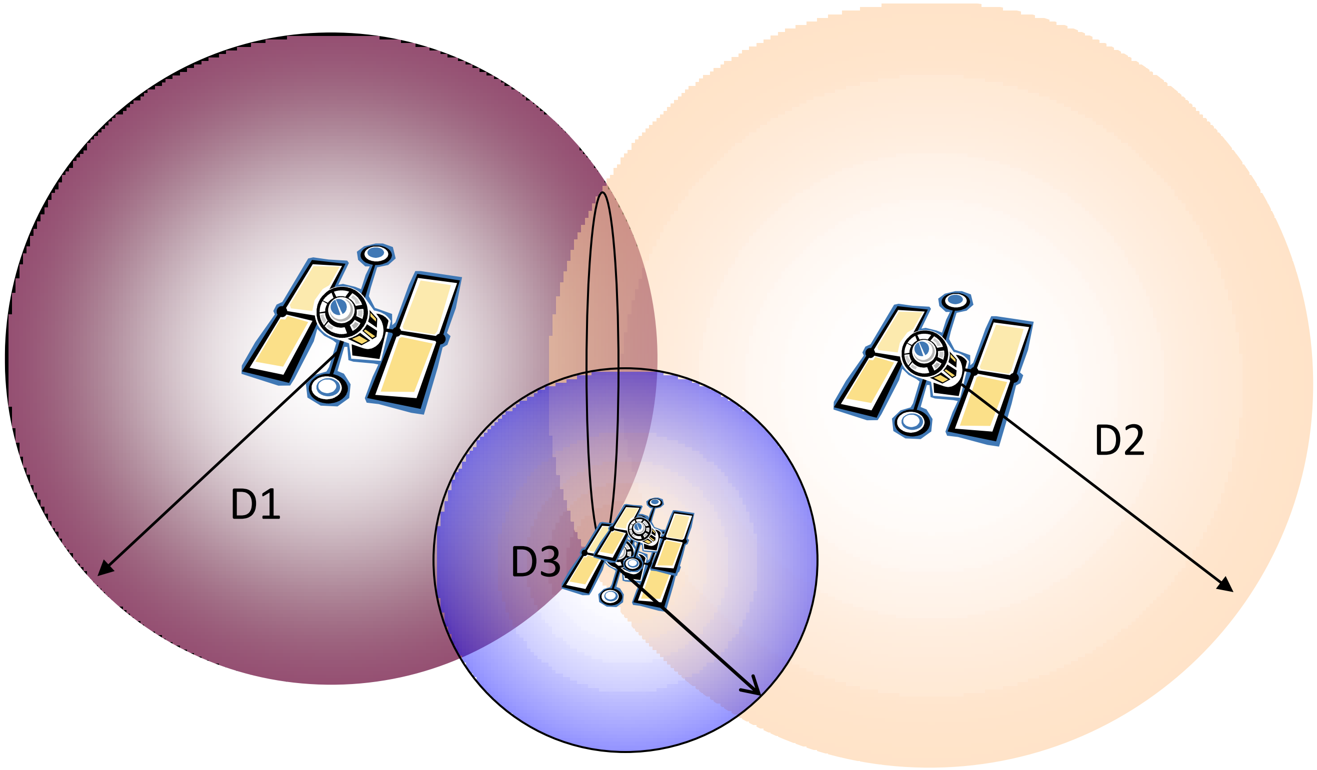
Deployed configuration of Spacecraft

Payloads:

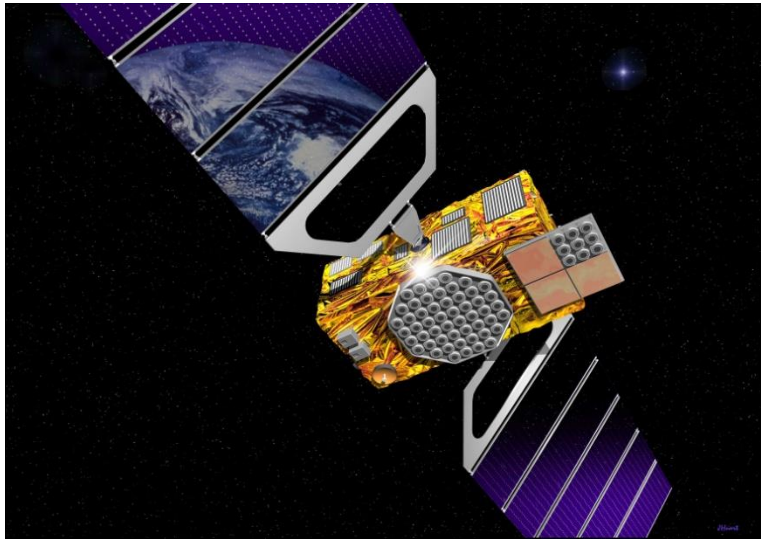
- PAN: 0.6m Resolution,
- 7.2 Km SWATH
- **MX: 2.4m Resolution, 30km SWATH**
- **S/C BUS similar to Carto-2**

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.

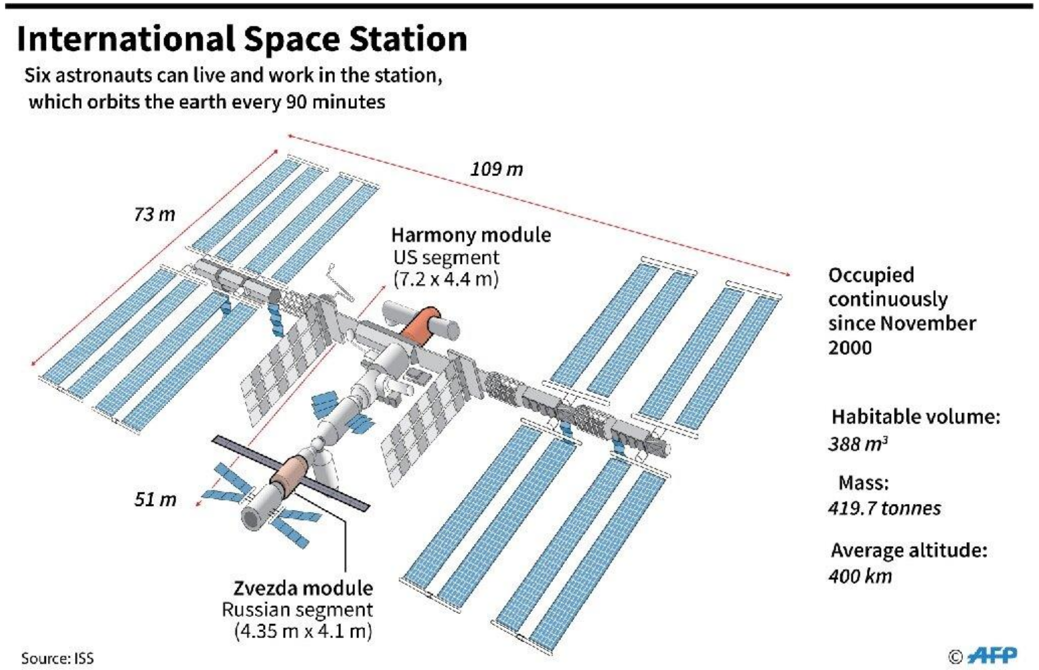
Human Space Flight

- 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)

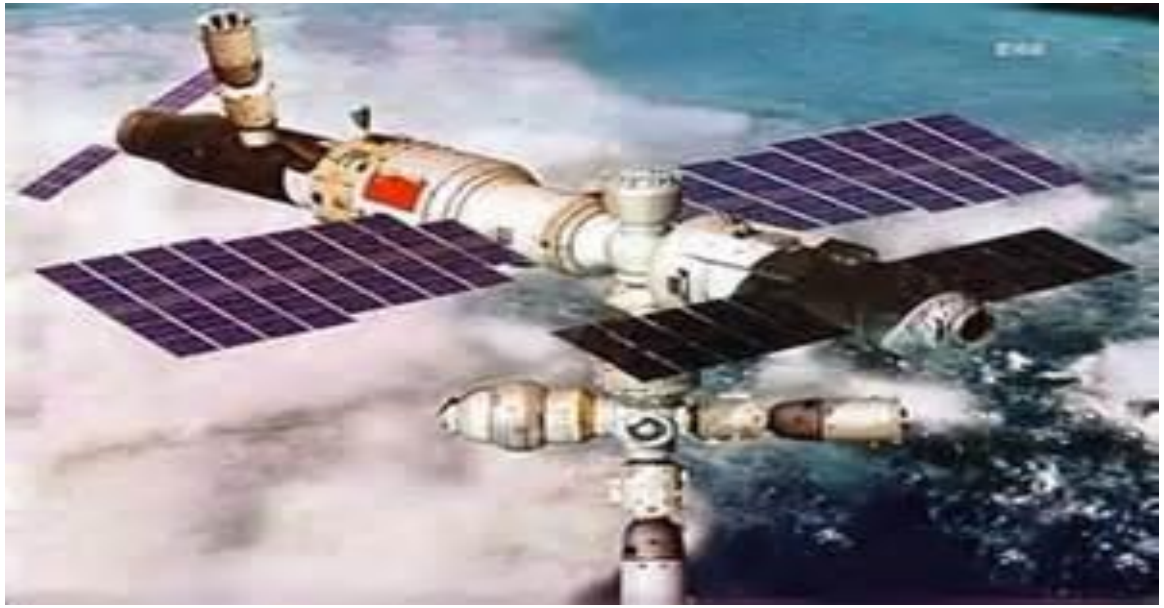
MIR STATION (RUSSIA)



CHINESE SPACE STATION

Tiangong

Manned module (Shenzhou)

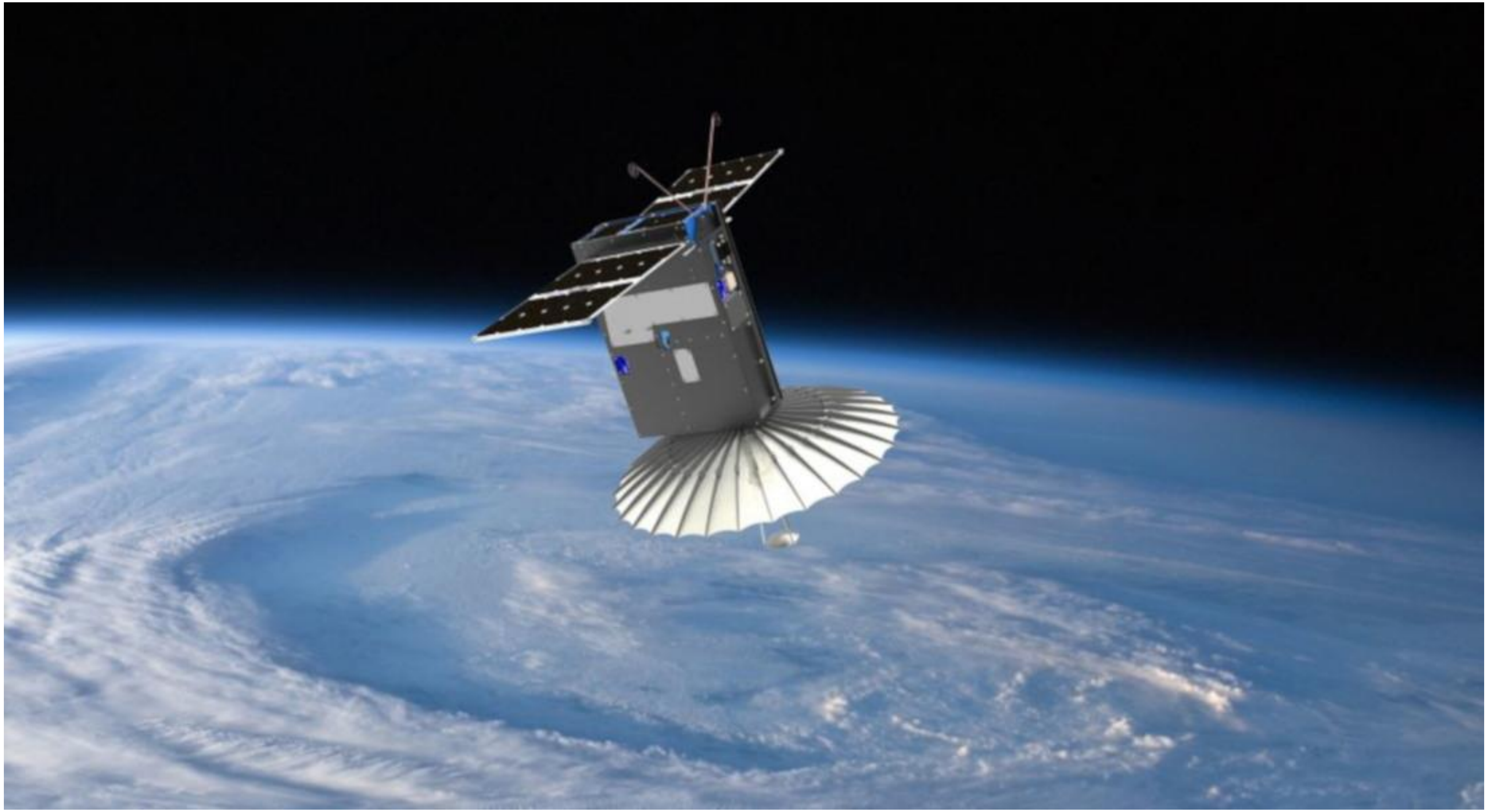


ORION CAPSULE

- 

NASA

RainCube’s deployable antenna

- 

RainCube’s deployable antenna / Image: Tyvak-Jonathan Sauder-NASA-JPL Caltech via Space.com.

IMPACT OF "COTS " APPROACH TO CAMERA

LISS III SENSOR (RESOURCESAT)

Medium Resolution
4 bands
23 meter spatial res.
70W power
140 km swath
106 Kg

CUBESAT Camera

High resolution image & video
5m spatial resolution
3388 x 2712 pixel frame (9MP)
5.1 w power, 398 gram
Model: Imperx B 3412 DX Mirror
Optics SY: 500mm f/6.3

Satellite design steps - flow diagram

Mission
- Altitude
- Inclination
- Launch year
- Life span

Payload
- Mass
- Power
- Data rate
- Pointing requirements

Satellite subsystems

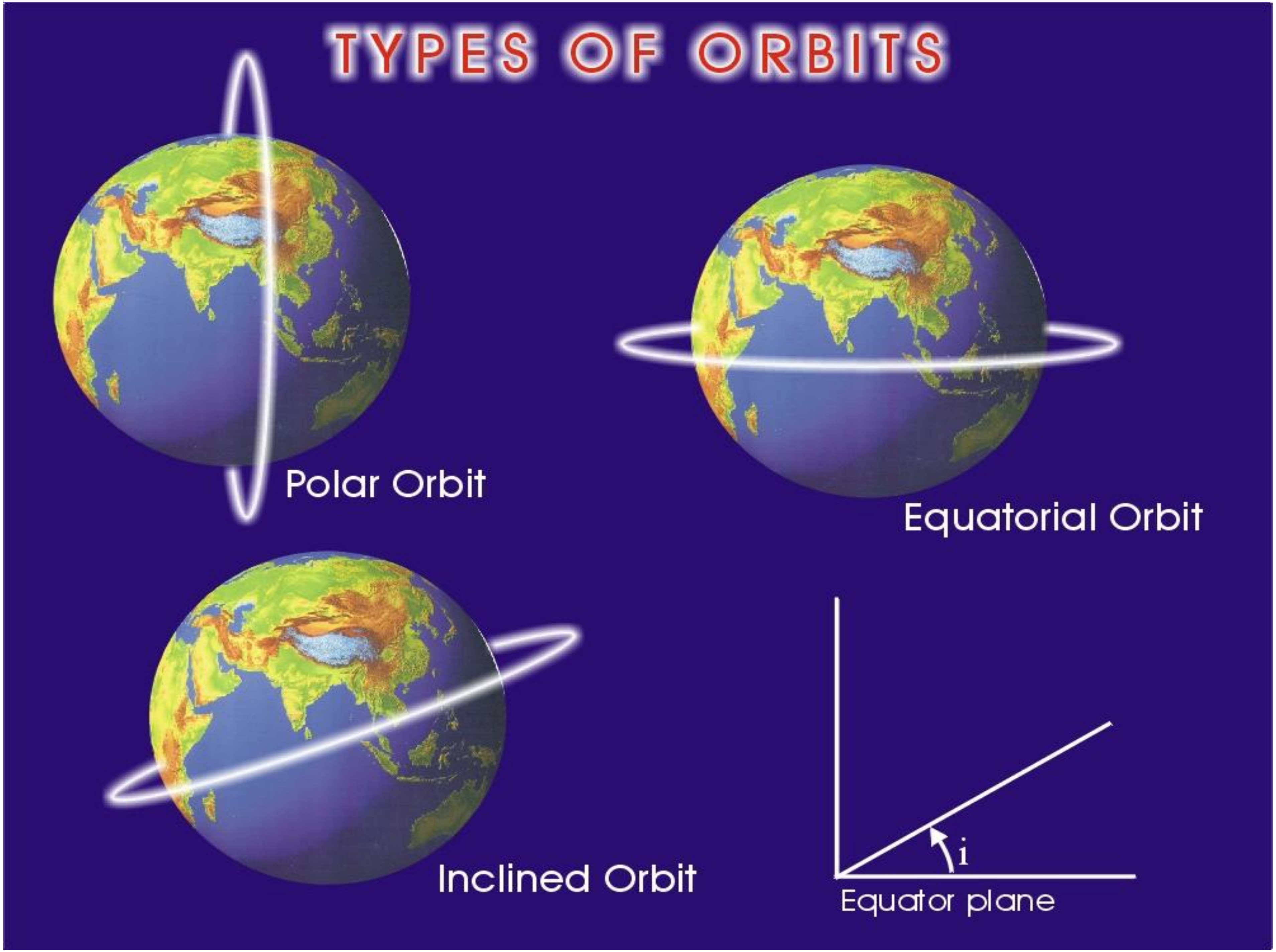
AOCS
Power
Thermal
Data handling
TTC
Propulsion
Onboard computer
Structure

References:

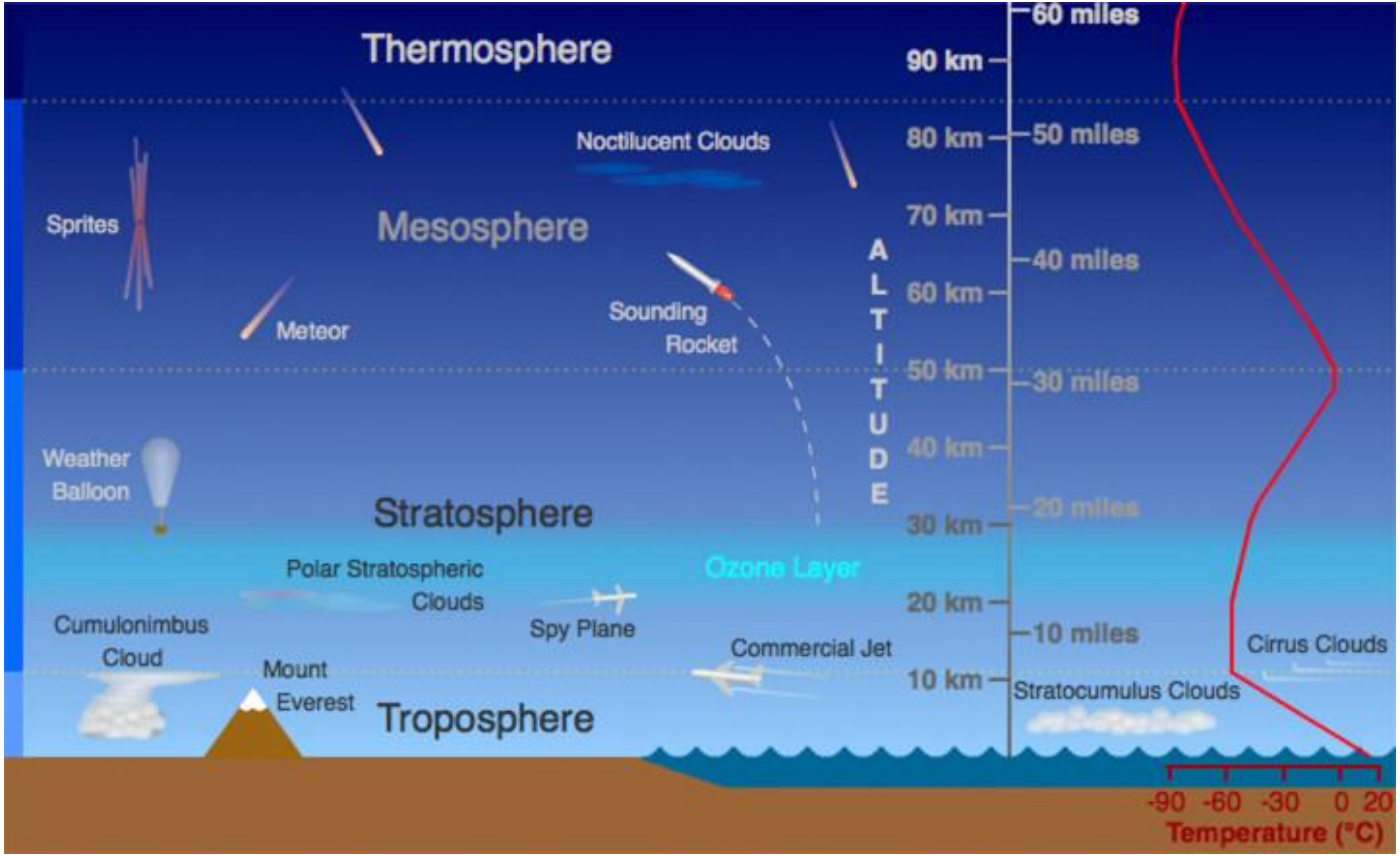
1. Basics of Spaceflight: Learner’s workbook-NASA
Chapters 11-12
https://www.jpl.nasa.gov/seh/spacecraft.pdf

2. Introduction to Satellite Communication technology for NREN
NAS technical report NAS-04-009

Addendum


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

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

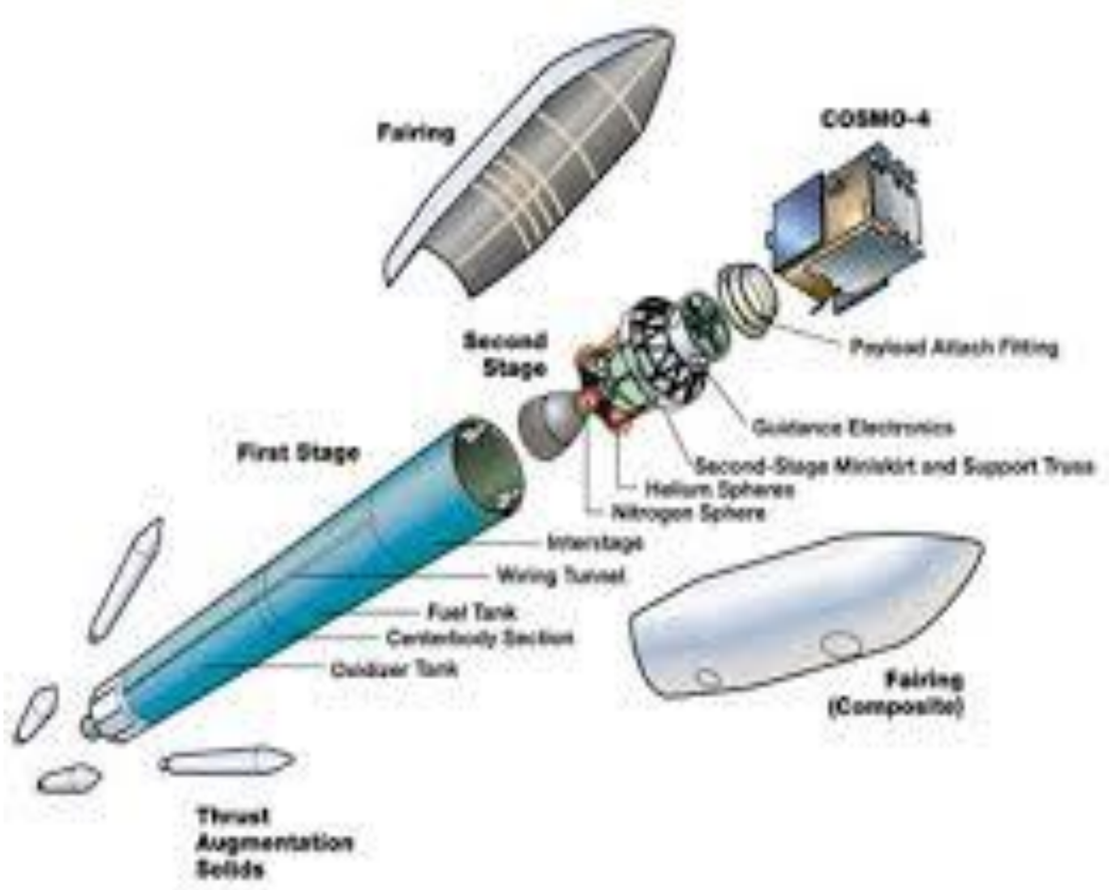
Due to high IR absorption property of CO_2 and H_2O molecules

Sun radiation (in visible) pass through clear atmosphere

Outgoing emission from earth in IR is trapped by CO_2

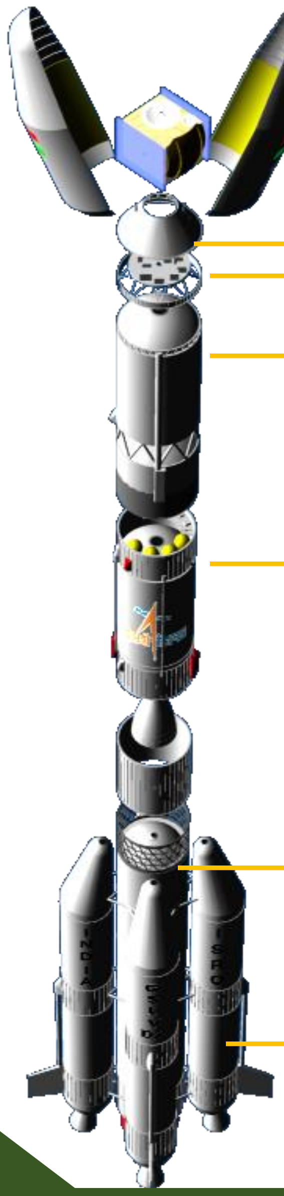
Space transportation systems

- 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

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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.

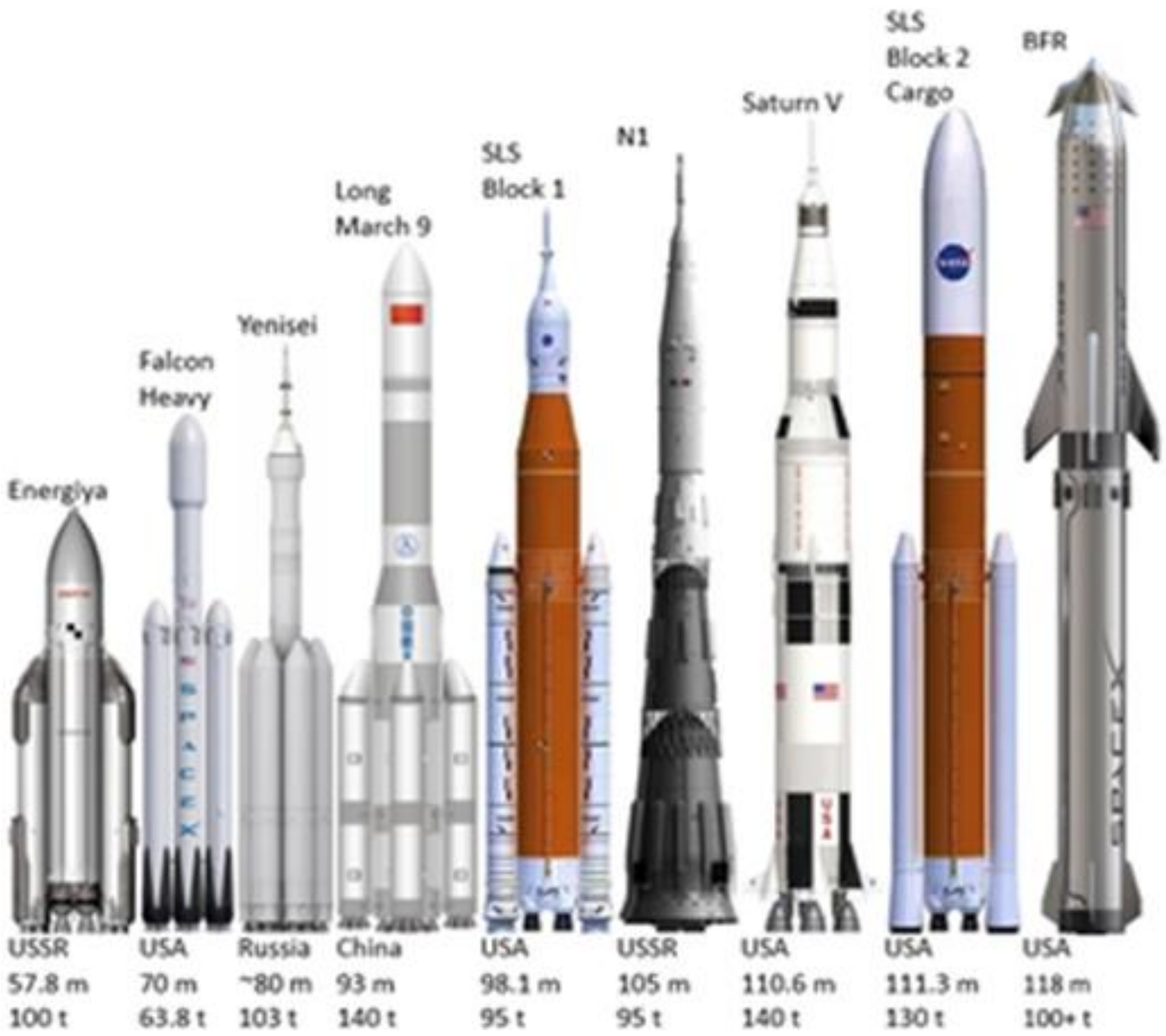
Launch Services

- 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

COMPARISON OF PROPULSION SYSTEMS

Type	Method of getting thrust	Exit vel. Km/s	Advantages	Limitations
Chemical	chemical energy of combustion	3	Readily available	Low spec.thrust; multiple units required
Free Radical	Recombination energy	5	Higher than conventional chemical system	Unstable; high operating temp.
Nuclear reactor 1	Heat transfer to propellent fluid	8	No expulsion of reaction products or Nucl fuel loss	Reactor temp higher than propellant's; heavy shielding
Nuclear reactor 2	Gaseous reaction products expelled	10	direct use of nucl energy to form jet	Large size; heavy sheilding; loss of nucl. Fuel
Plasma Jet	Nuetral plasma ejected by hydromagnetic forces	15	High specific thrust; no radiation hazard	Heavy auxillary power supply required
Ionic Jet	Electric or magnetic acceleration of charged particles	10000	very high thrust in comparision to mass expelled	heavy power handling equipment;high temp.
Photon Jet	complete conversion of matter to photons	300000	small prop mass for planetary operations	extreme heat dissipation problem

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

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 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

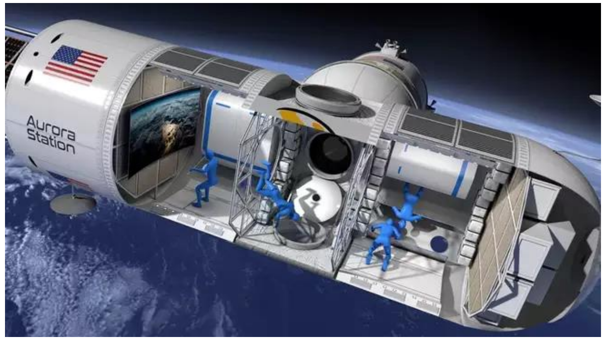
Space mining and living in space & on planets

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

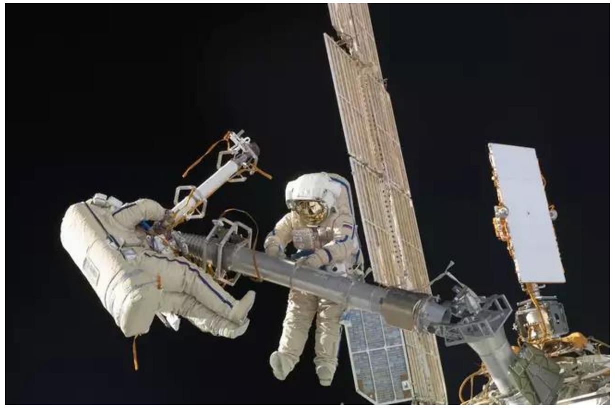
ORION SPAN



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

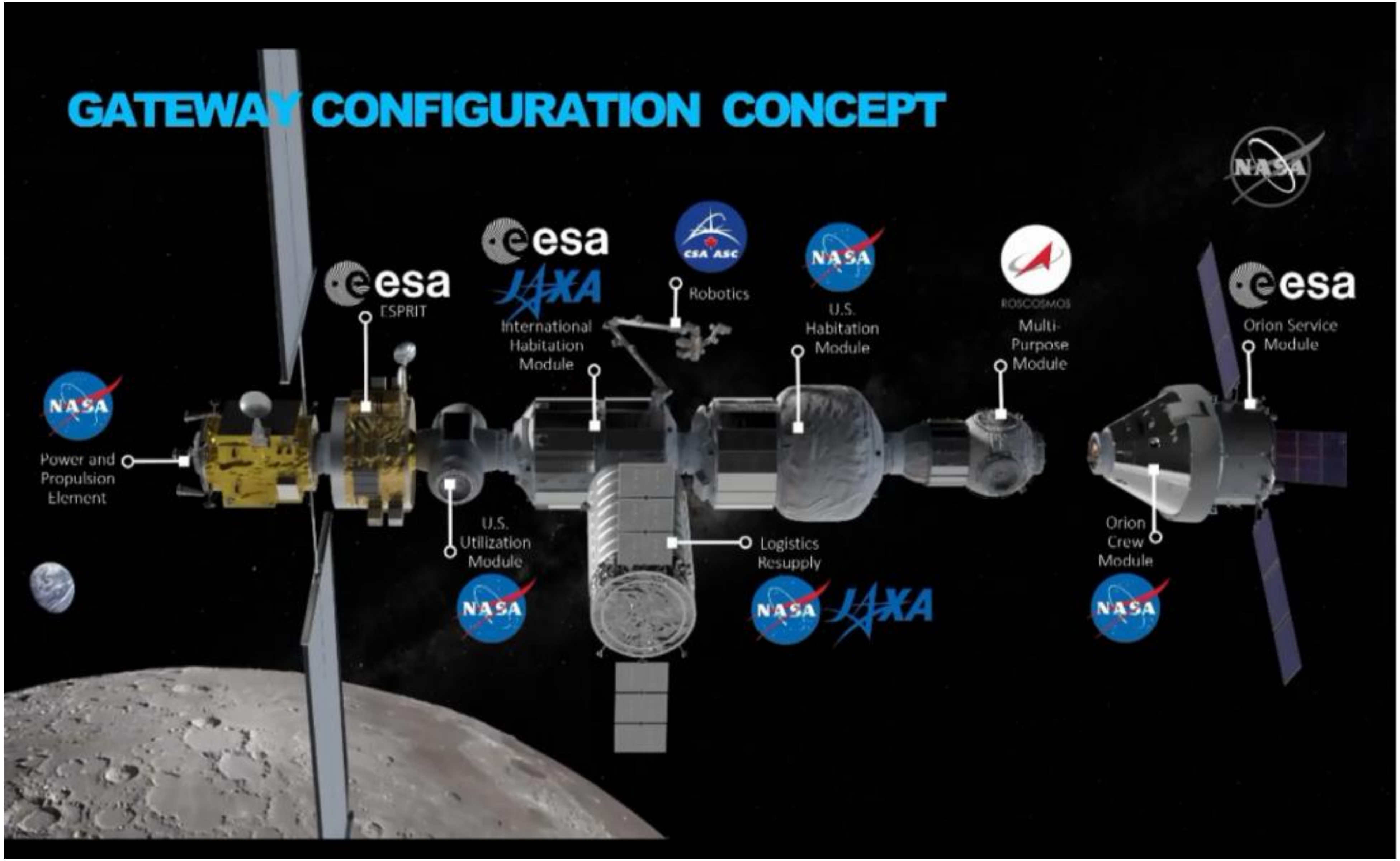
250,000/ person-trip

SPACEX

Blue Origin

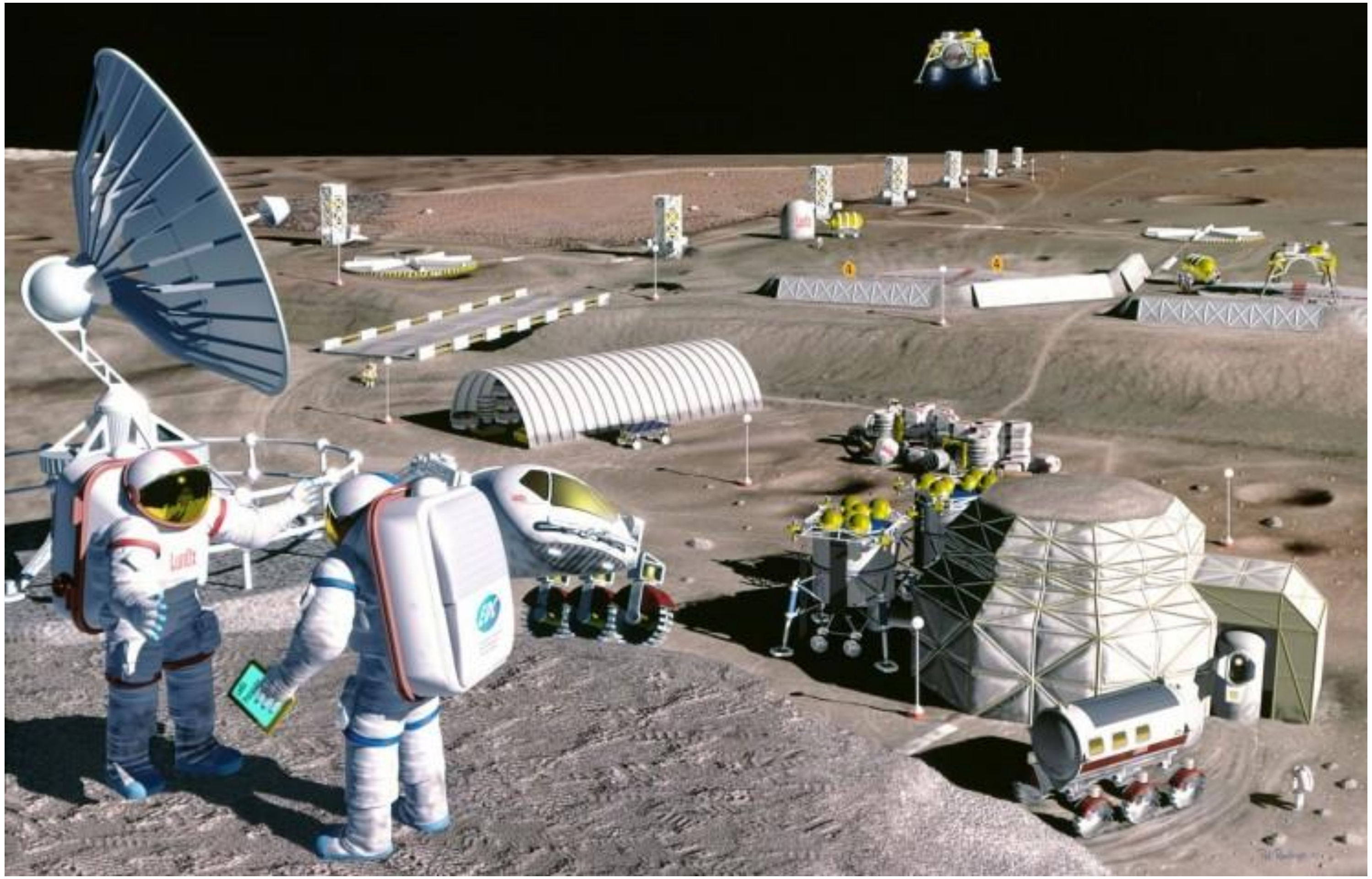
Photo credit: SpaceX, Blue Origin, Virgin Galactic

GATEWAY in near lunar space



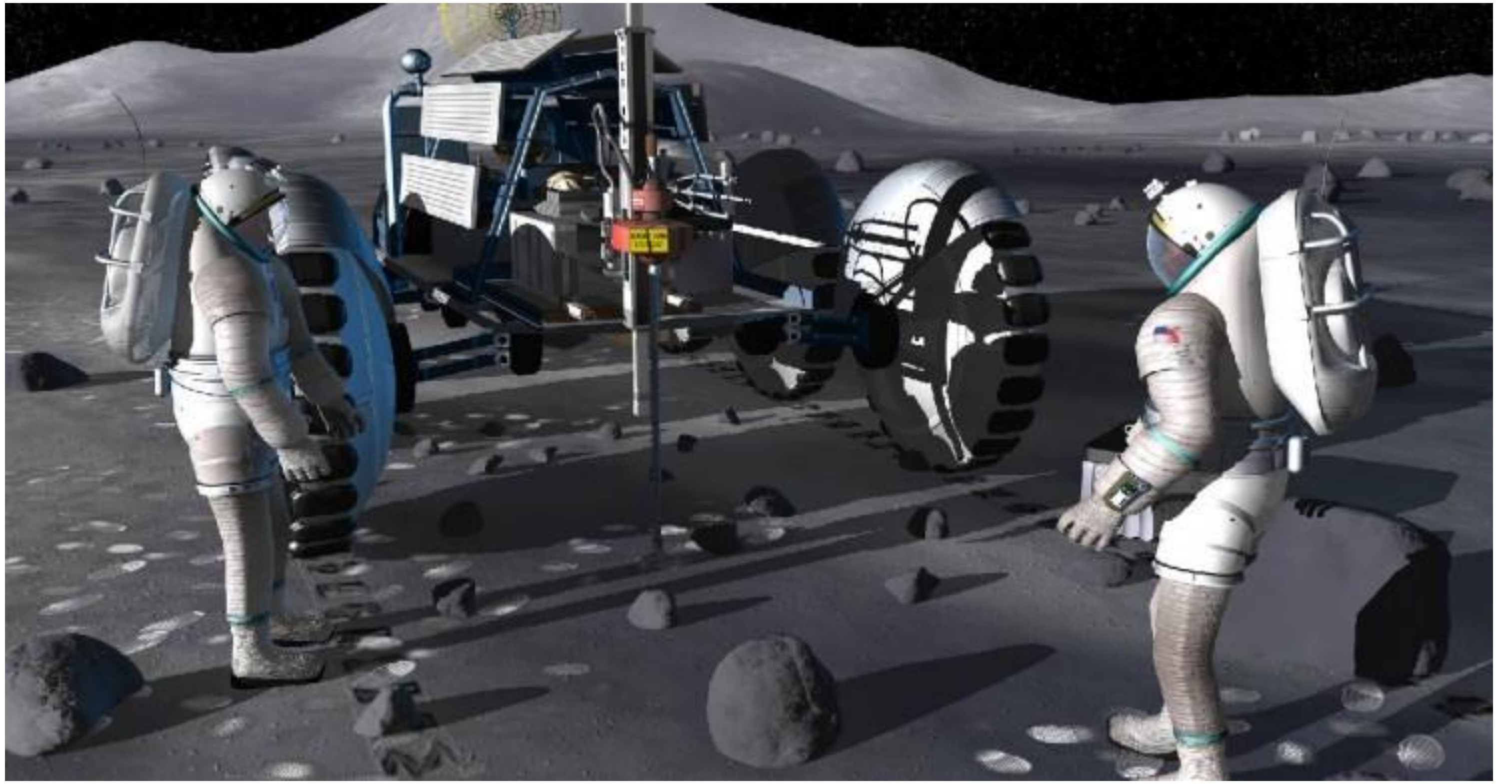
CREDIT: NASA

Moon Colony



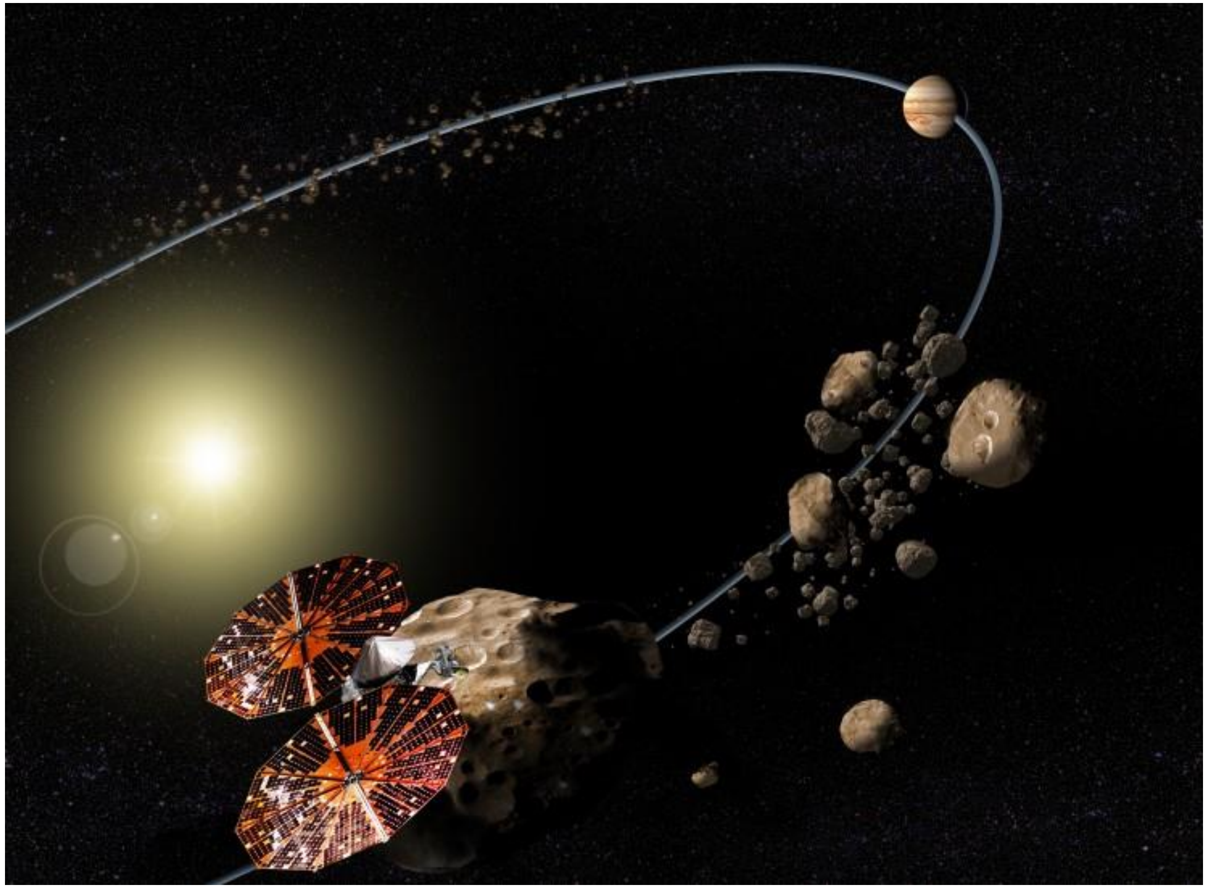
Source: [NASA/SAIC/Pat Rawlings/ Wikimedia Commons]

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

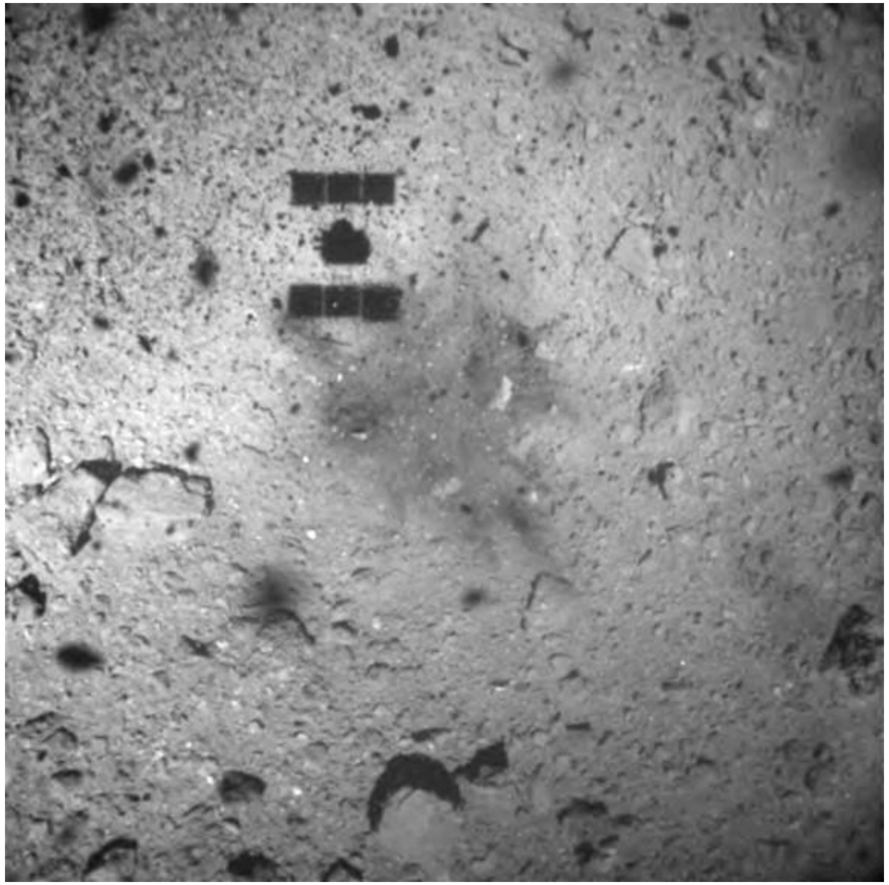


Image captured near the touchdown site immediately after touchdown. The photograph was taken with the Optical Navigation Camera – Wide angle (ONC-W1) on February 22, 2019 at an onboard time of around 07:30 JST.

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

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