Sources for Future African Multipurpose GEO Satellites (FAMGS)

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Space Science Centre (SSC)

Radio and

Satellite Communication,

Navigation and Surveillance (CNS)

Durban University of Technology (DUT)

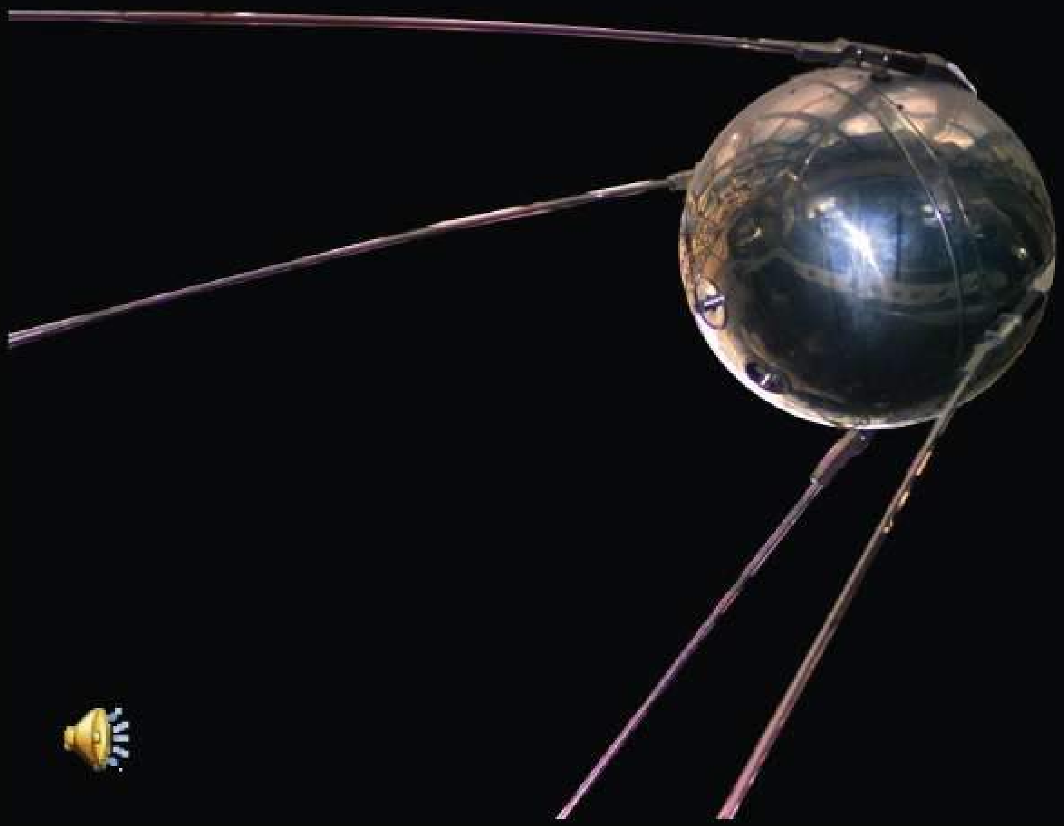
Space Science Centre

Aeronautical Communication, Navigation and Surveillance (CNS) via Spacecraft

Soviet First Artificial Satellite Sputnik 1

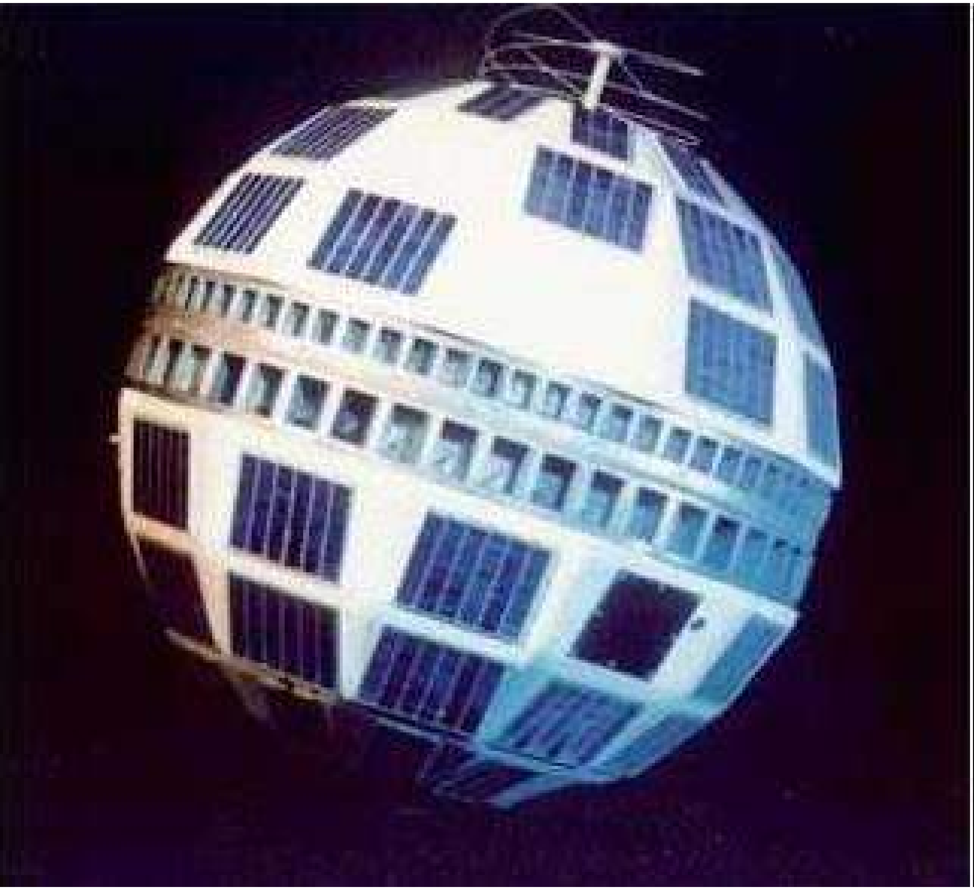
Integrated Payloads Sputnik

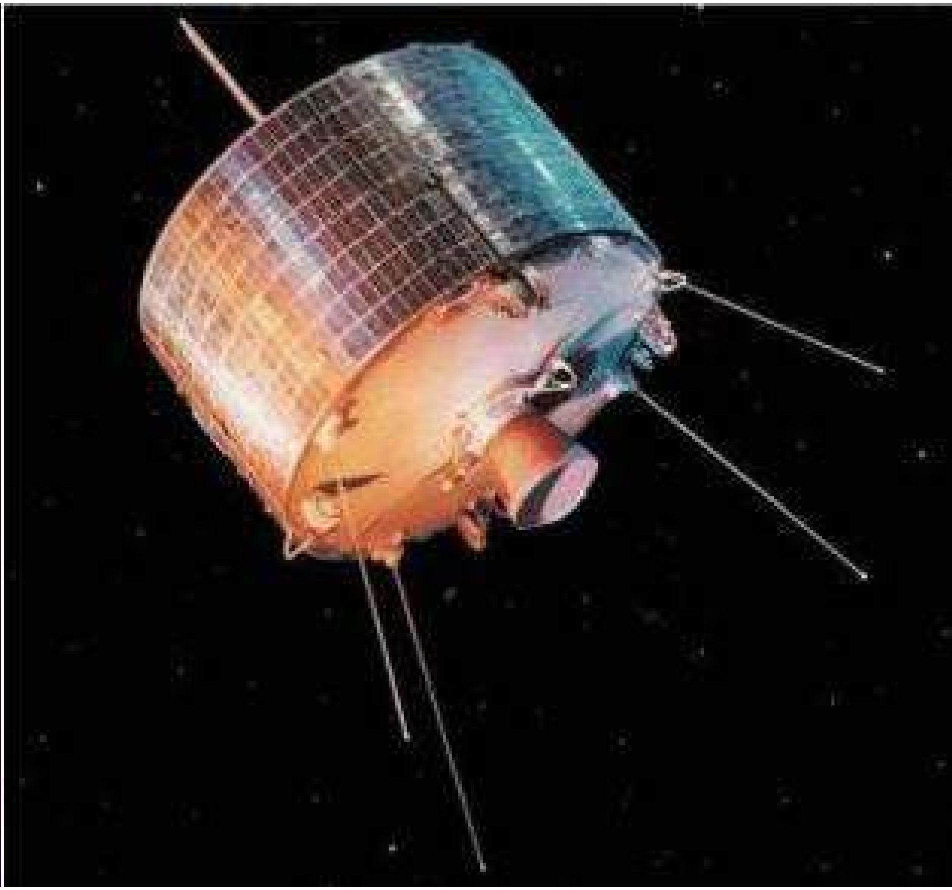
- 4-26 October 1957
- Flying radio transmitter
- 20 and 40 MHz
- Battery powered



First Russian Cosmonaut Yuri Gagarin Lifted in Orbit by Vostok 1 on 12 April 1961

First Commercail Communication Satellites Telstar 1 (Left) Launched by US in 1962 and Intelsat 1 (Right) in 1964





Introduction of Multipurpose GEO Satellite

The South African company CNS Systems (Pty) Ltd and Space Science Centre (SSC) are potential and main designers of novel Multipurpose GEO Satellite constellation for full coverage of the entire African Continent and Middle East.

The SSC Group at Durban University of Technology (DUT) may collaborate with similar institutes in the Country or Continent and provide essential project of first Multipurpose GEO Satellite by Africans for Africa. What is Multipurpose GEO Satellite?

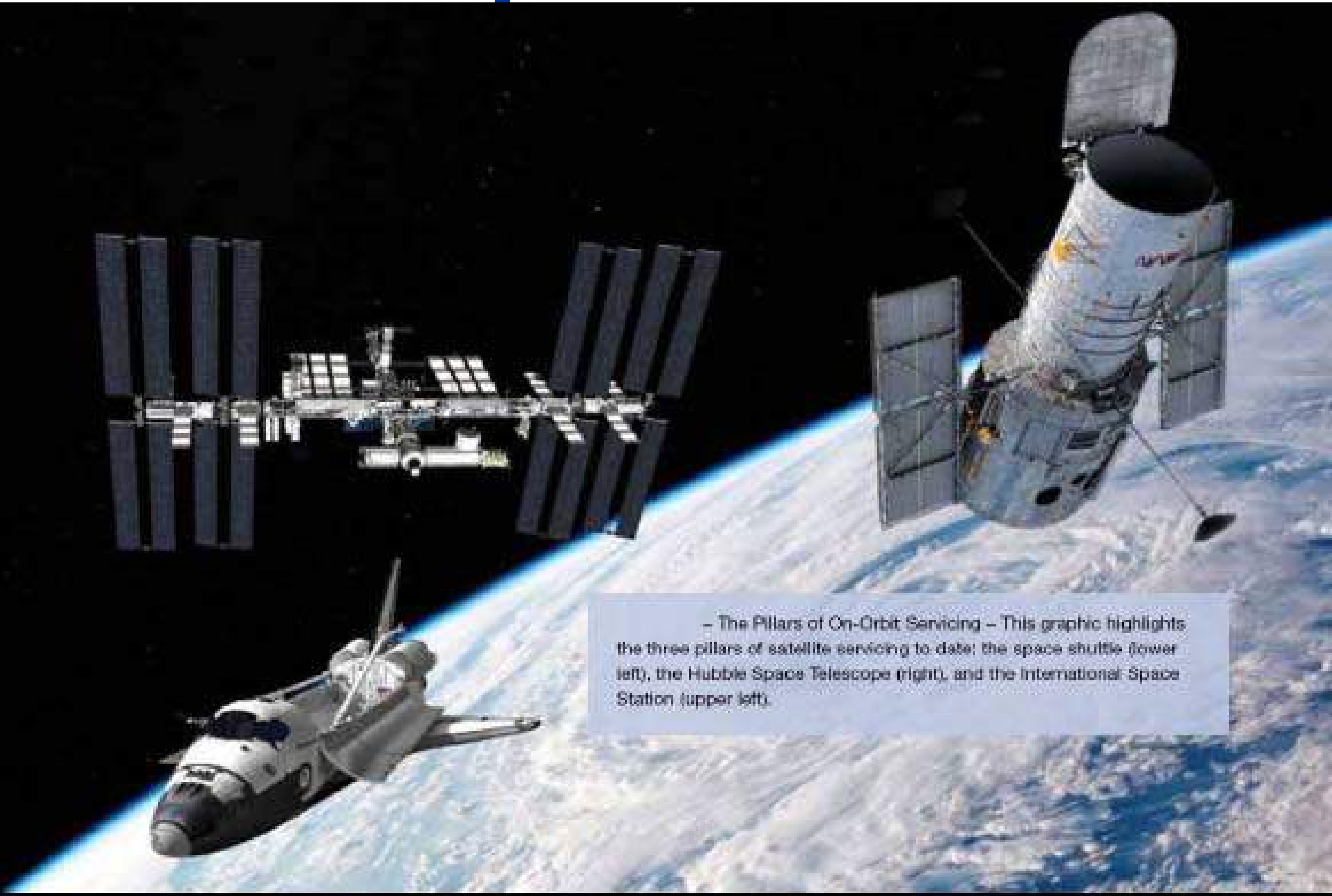
This is an integration of GEO Communication with GNSS (Navigation) Payloads in a modern satellite configuration for CNS Solutions.

Advantages of Satellite Communications

- Wide Coverage Areas
- Broadcast DVB-RCS Capability
- Broadcast CNS Solutions
- Broadband, Multimedia and Internet Capability
- High Bandwidth
- Flexibility in Network Set-up
- Mobility and Availability
- Rapid Deployment
- Reliability and Safety
- Economic Solutions Available
- Backbone in Areas without Adequate Terrestrial Telecommunication and Cellular Infrastructures

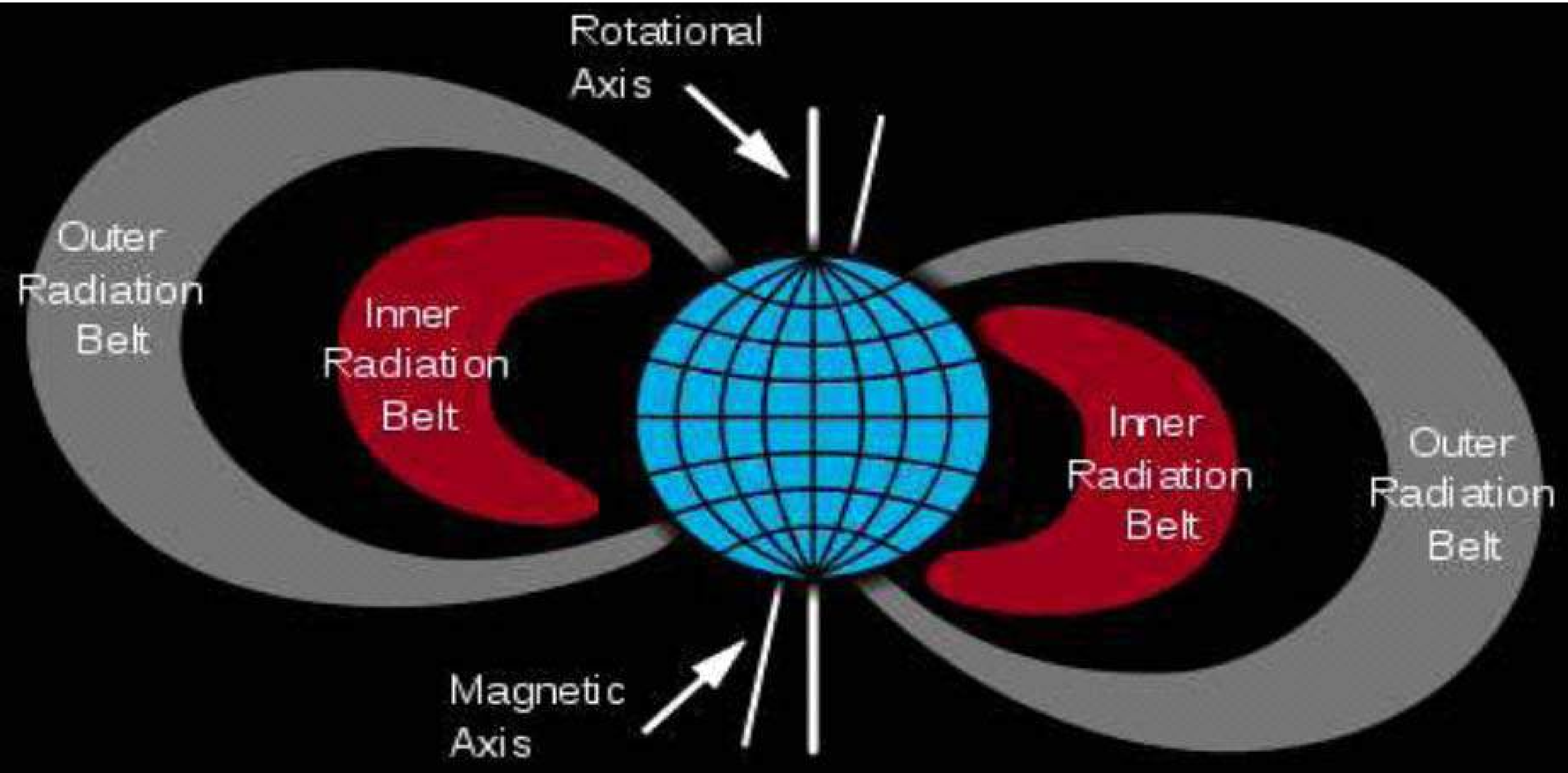
Russian Space Vision

US Space Vision



Negative Effects of Van Allen Radiation Belts

[Inner Belt is from 1000 to 5000 km and Outer Belt is from 16000 to 24000 km above the Earth Surface. In 2012, observations from the Van Allen Probes showed that a Third Belt may appear after each Sun eruption. Passing through these belts is very dangerous for the life of cosmonauts]



Platforms and Orbital Mechanics

The platform is an artificial object located in orbit around the Earth at a minimum altitude of about 20 to 25 km in the stratosphere and a maximum distance of about 36,000 km in the Space. In fact, a space platform is defined as an unattended object revolving about a larger one.

Orbital mechanics is a specific Space discipline describing planetary and satellite motion in the Solar system, which can solve the problems of calculating and determining the position, speed, path, perturbation and other orbital parameters of planets and satellites.

Kepler's Laws of Satellite Motion

A satellite is an artificial object located by rocket in space orbit following the same laws in its motion as the planets rotating around the Sun. In this sense, three so important laws for planetary motion were derived by scientists Johannes Kepler, as follows:

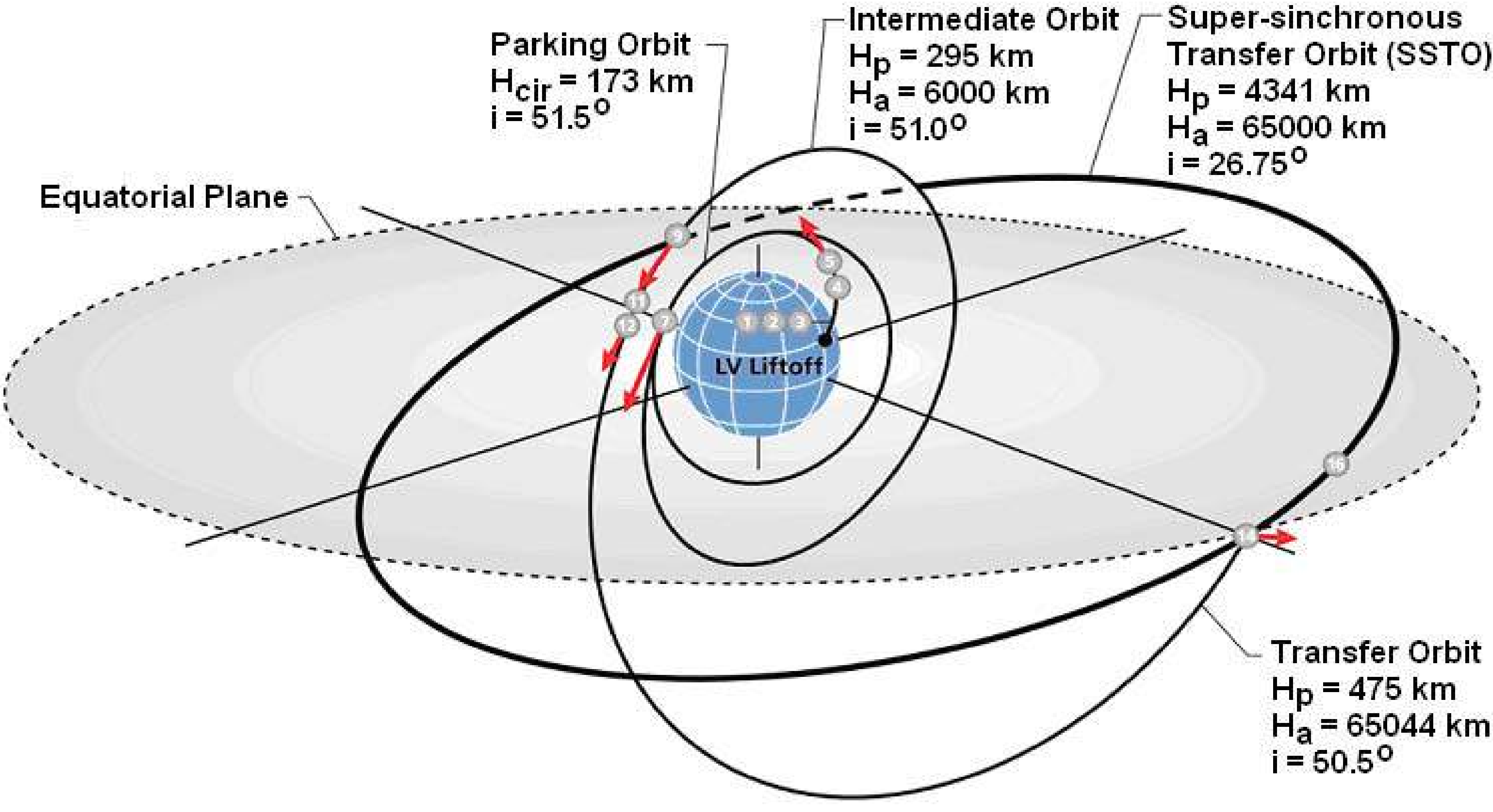
1. First Law – The orbit of each planet follows an elliptical path in space with the Sun in one focus. Motion lies in the plane around the Sun (1602).
2. Second Law – The line from the Sun to planet or radius vector (r) sweeps out equal areas in equal intervals of time. This is the Law of Areas (1605).
3. Third Law – The square of the planet's orbital period around the Sun (T) is proportional to the cube of the semi-major axis (a = distance from the Sun) of the ellipse for all planets in the Solar system (1618).

Principia Mathematica of Newton

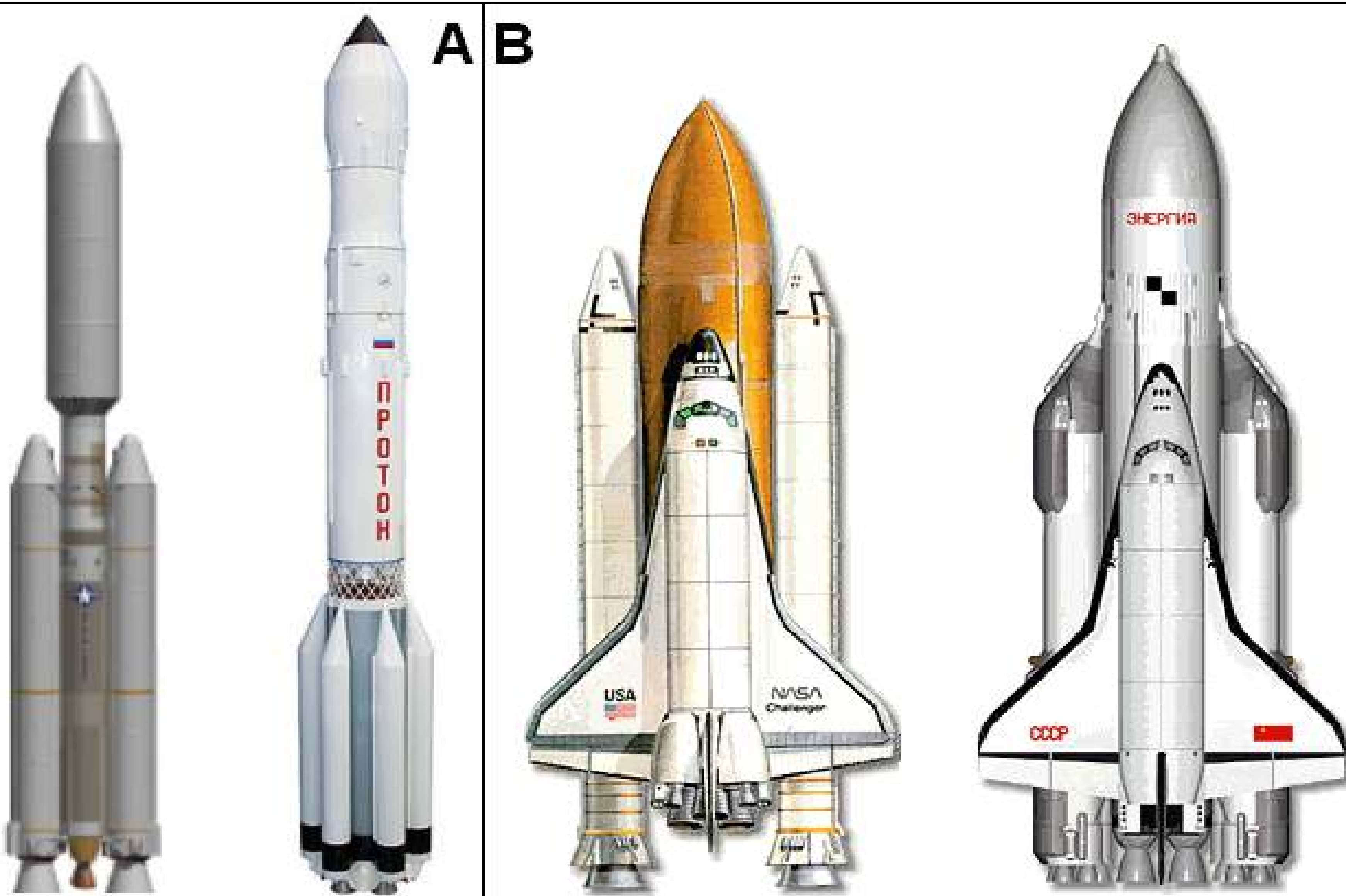
Kepler's Laws and theory were based on observational records and only described the planetary motion without attempting an additional theoretical or mathematical explanation of why the motion takes place in that manner. In 1687, Sir Isaac Newton published his breakthrough work
"Principia Mathematica" with own syntheses, known as the Three Laws of Motion:
1. Law I – Every body continues in its state of rest or uniform motion in a straight line, unless it is compelled to change that state by forces impressed on it.
2. Law II – The change of momentum per unit time of a body is proportional to the force impressed on it and is in the same direction as that force.
3. Law III – To every action there is always an equal and opposite reaction. Therefore, on the basis of Law II, Newton also formulated the Law of Universal Gravitation, which states that any two bodies attract one another with a force proportional to the products of their masses and inversely proportional to the square of distance between them.

Satellite Installation in Circular and Synchronous Orbit

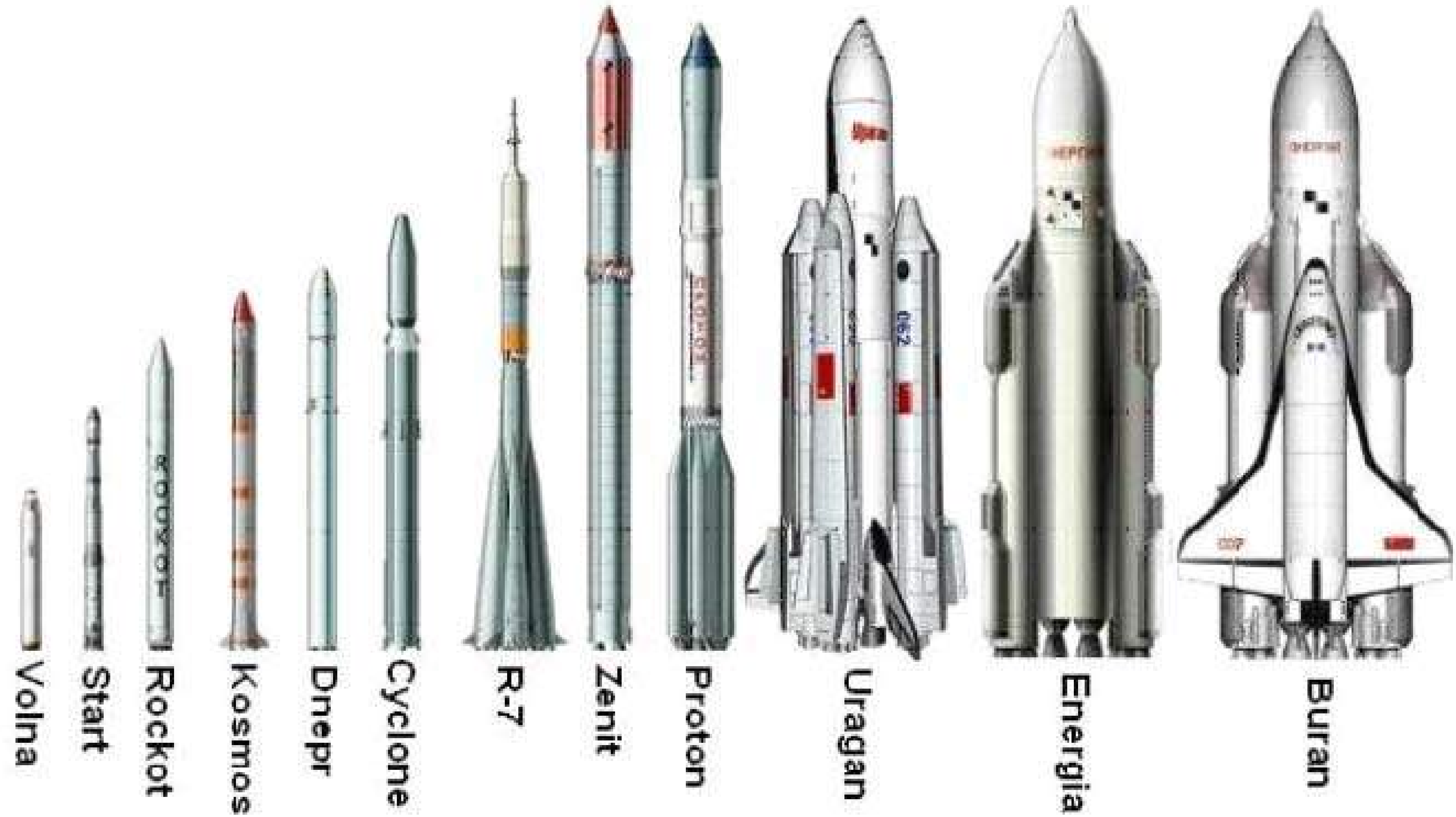
[Direct and Indirect Ascent Launching]



Expendable US Titan IV and Russian Proton (A) and Reusable US Space Shuttle and Russian Energia/Buran (B) Launch Vehicles (B not in use today)

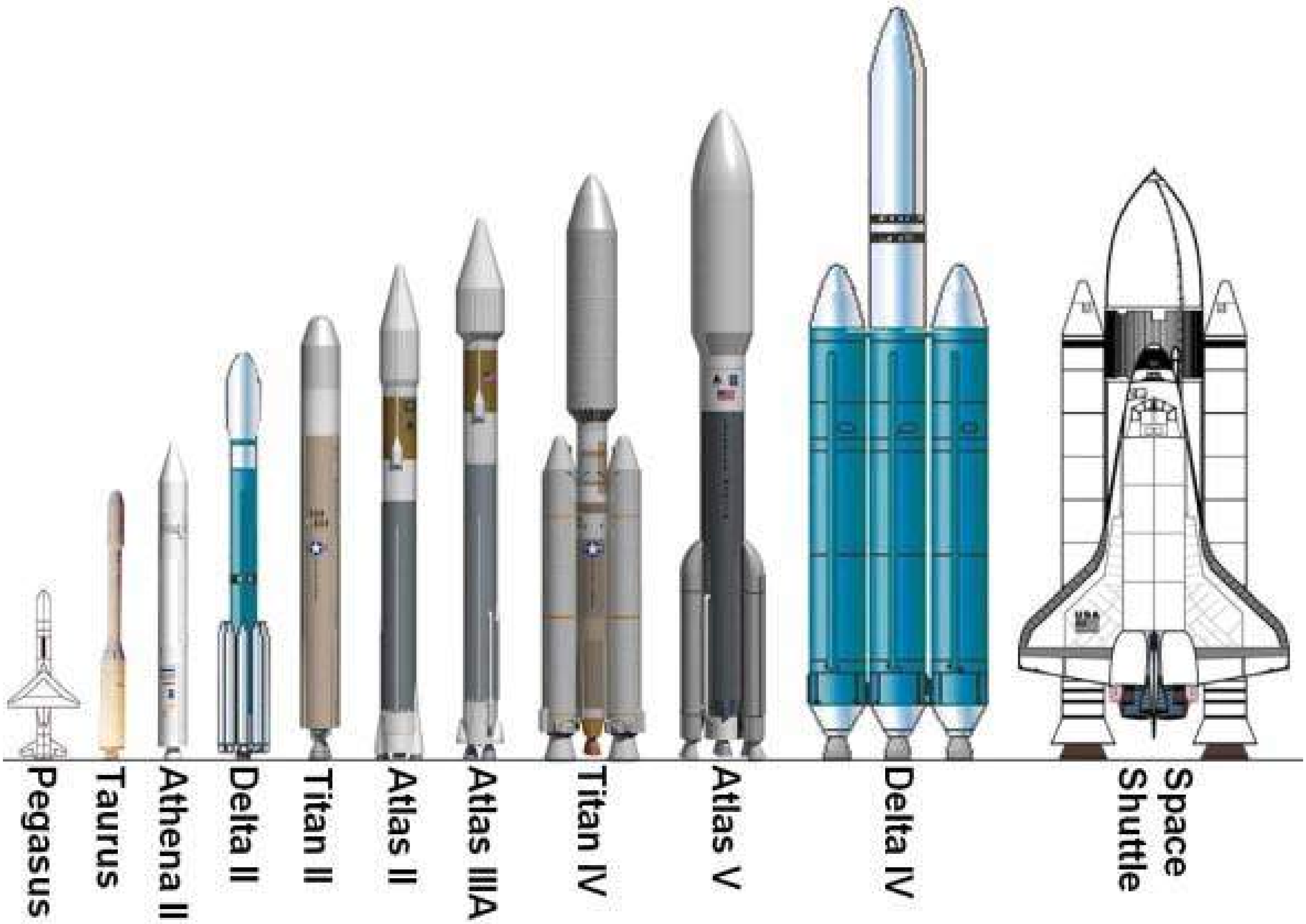


I. Evolution of Russian Launch Vehicles with Proton (4th from Right) as more Reliable Rocket today

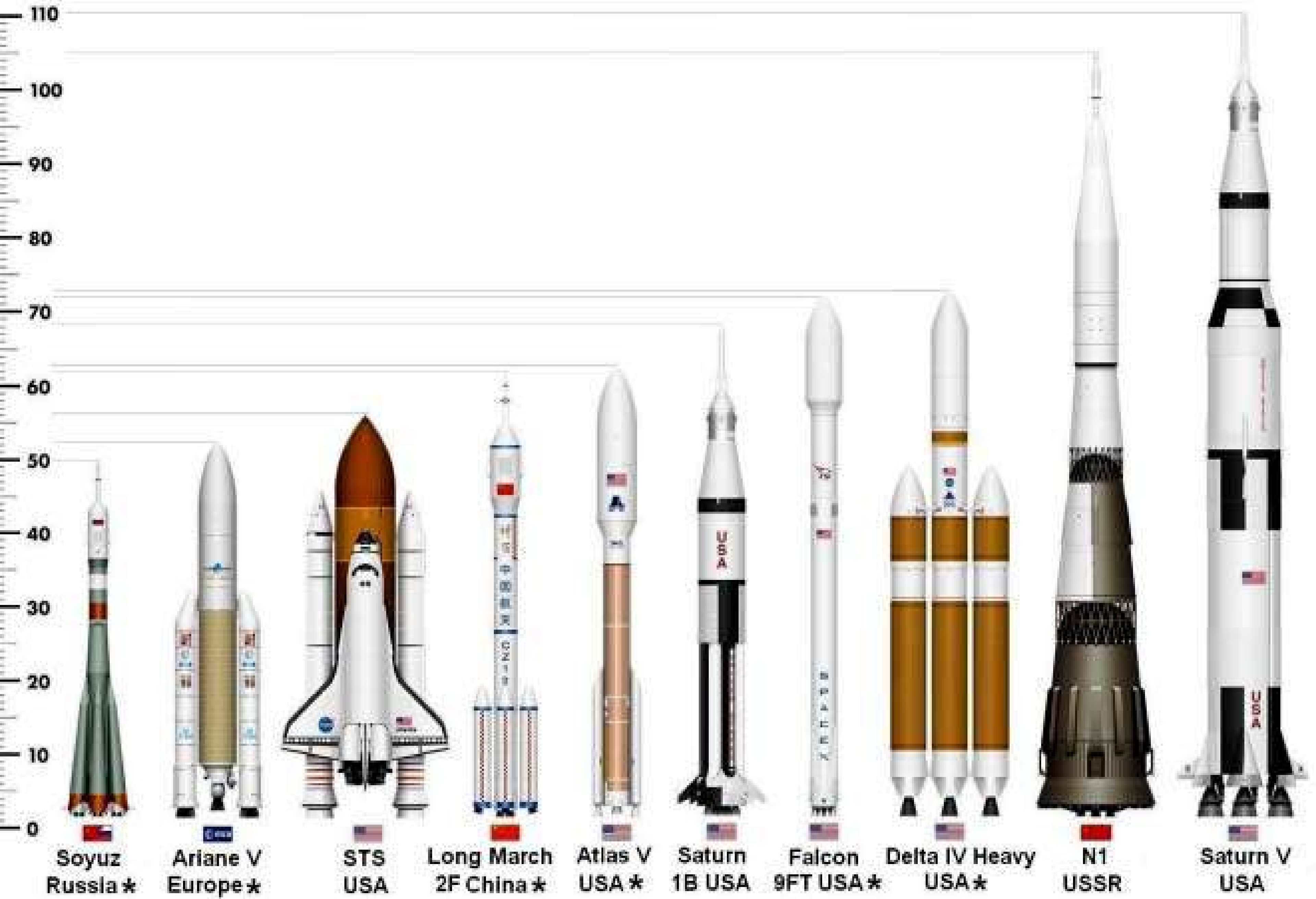


II. Evolution of Russian Launch Vehicles with Soyuz (3rd from Right) as a Present Successor

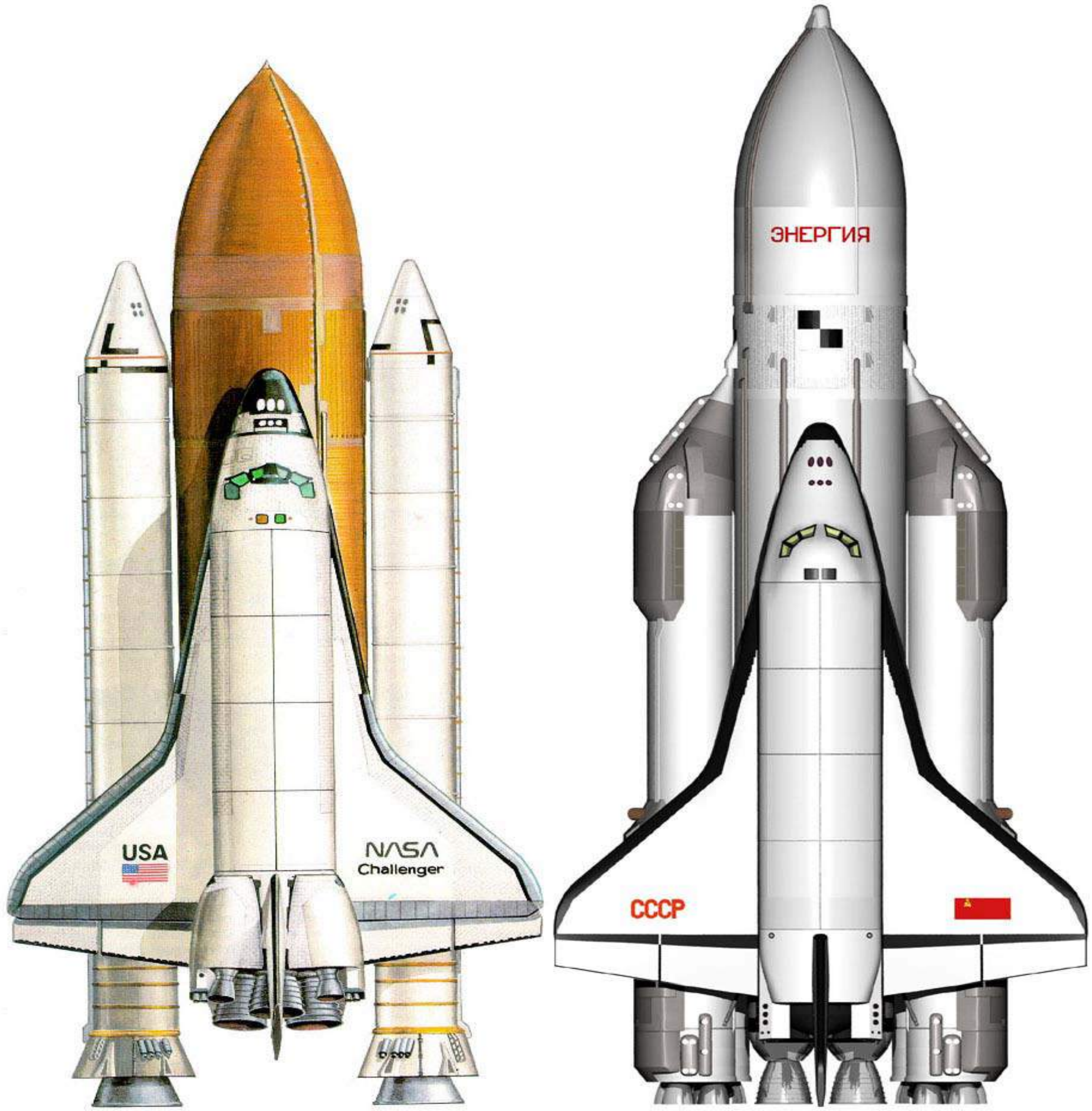
Evolution of US Rockets



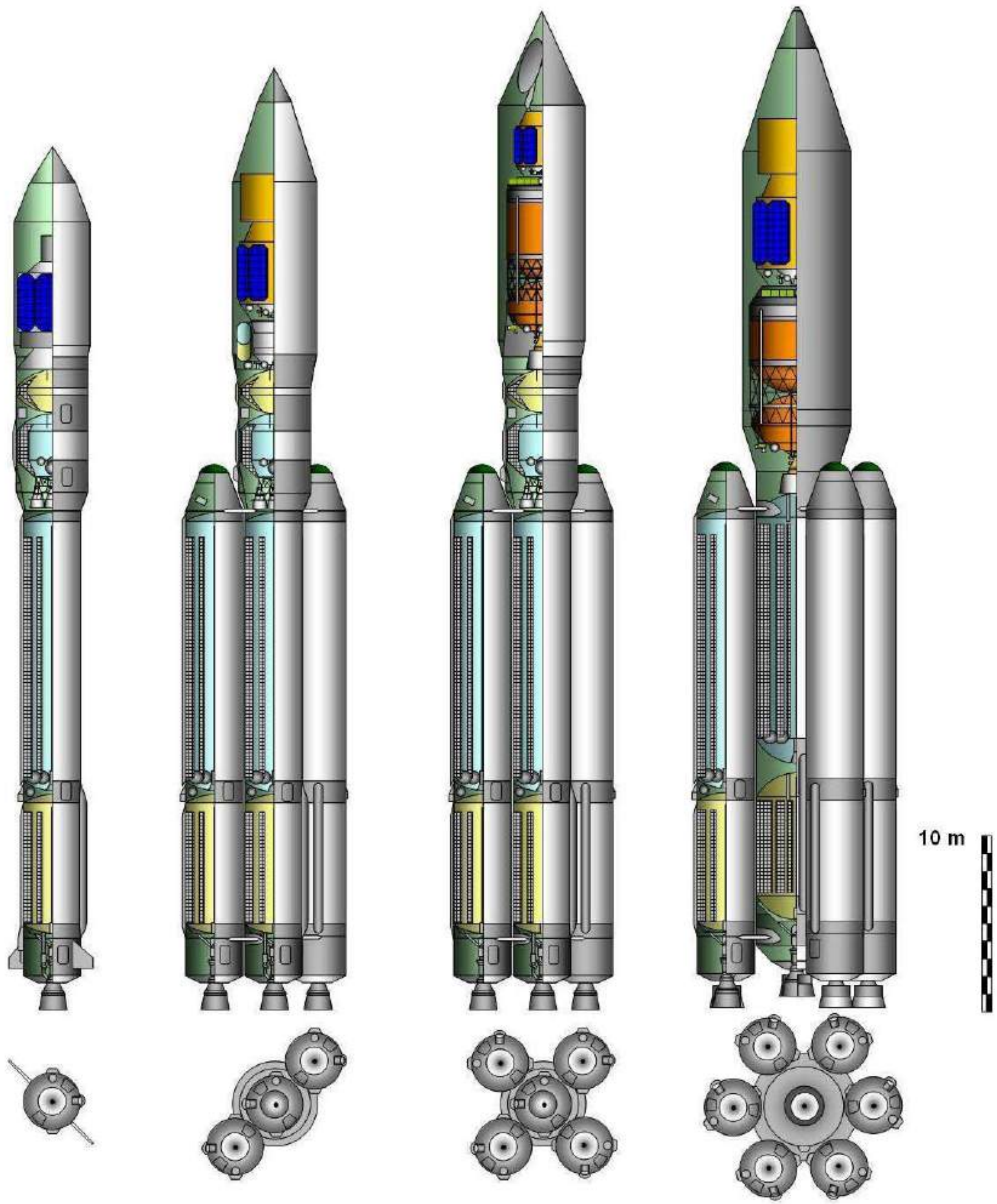
Comparison of Different Launcher (Present *)



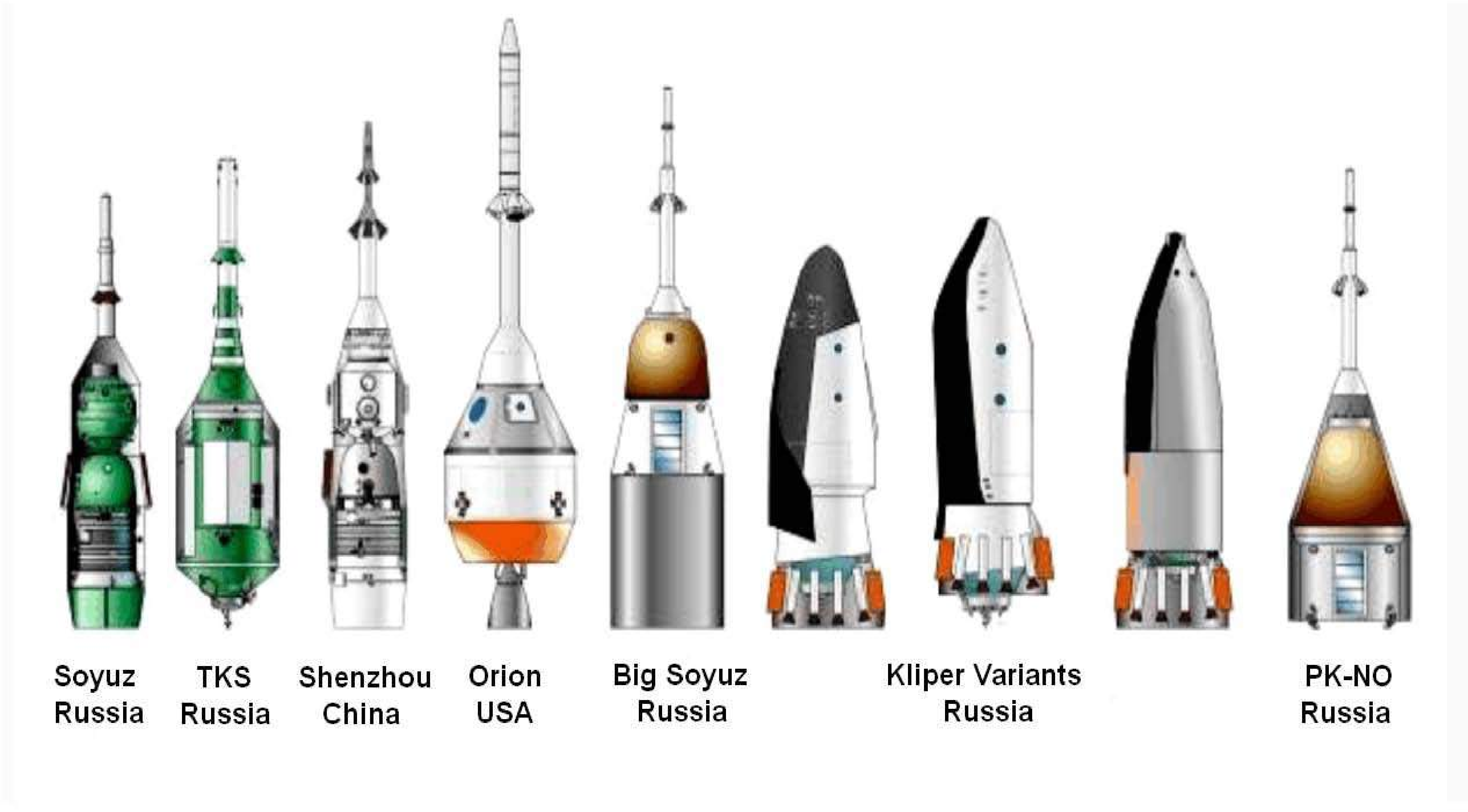
Ceased the US Space Shuttle and Russian Buran



Last Generation of Russian Launchers Angara 1.2; A3, A5 and A7



New Generation of Expendable and Reusable Spaceships

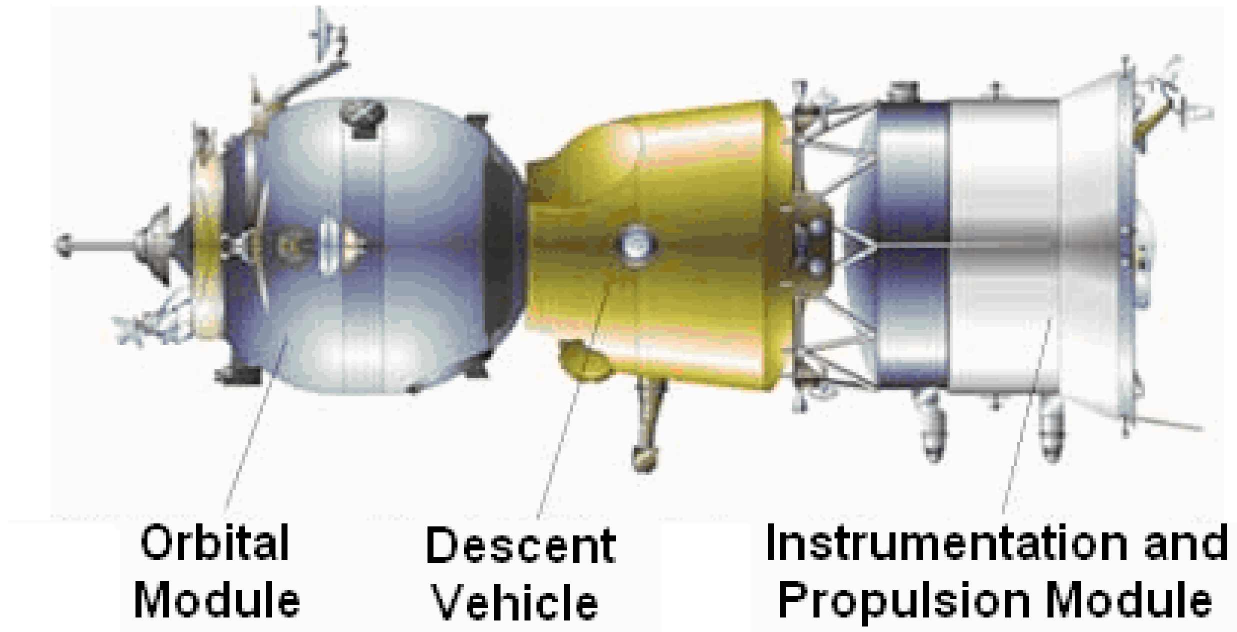


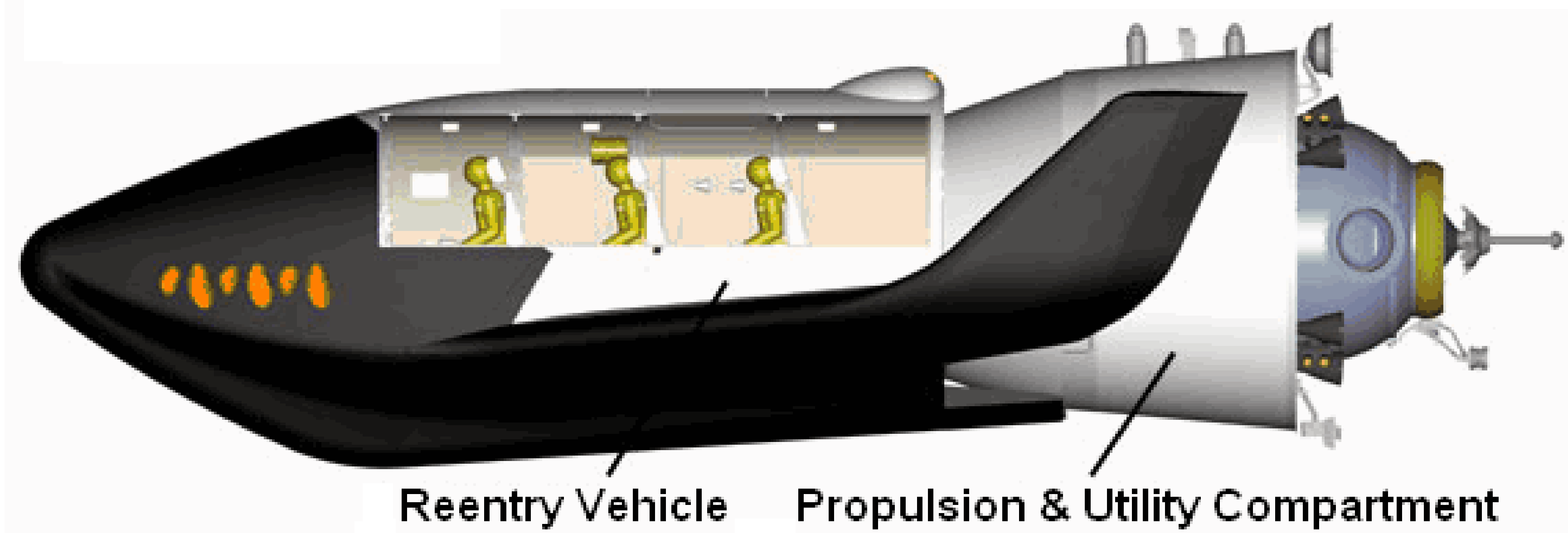
Russian New Heavy-lift Launcher Angara 100

Project of Russian Spaceplane Kliper

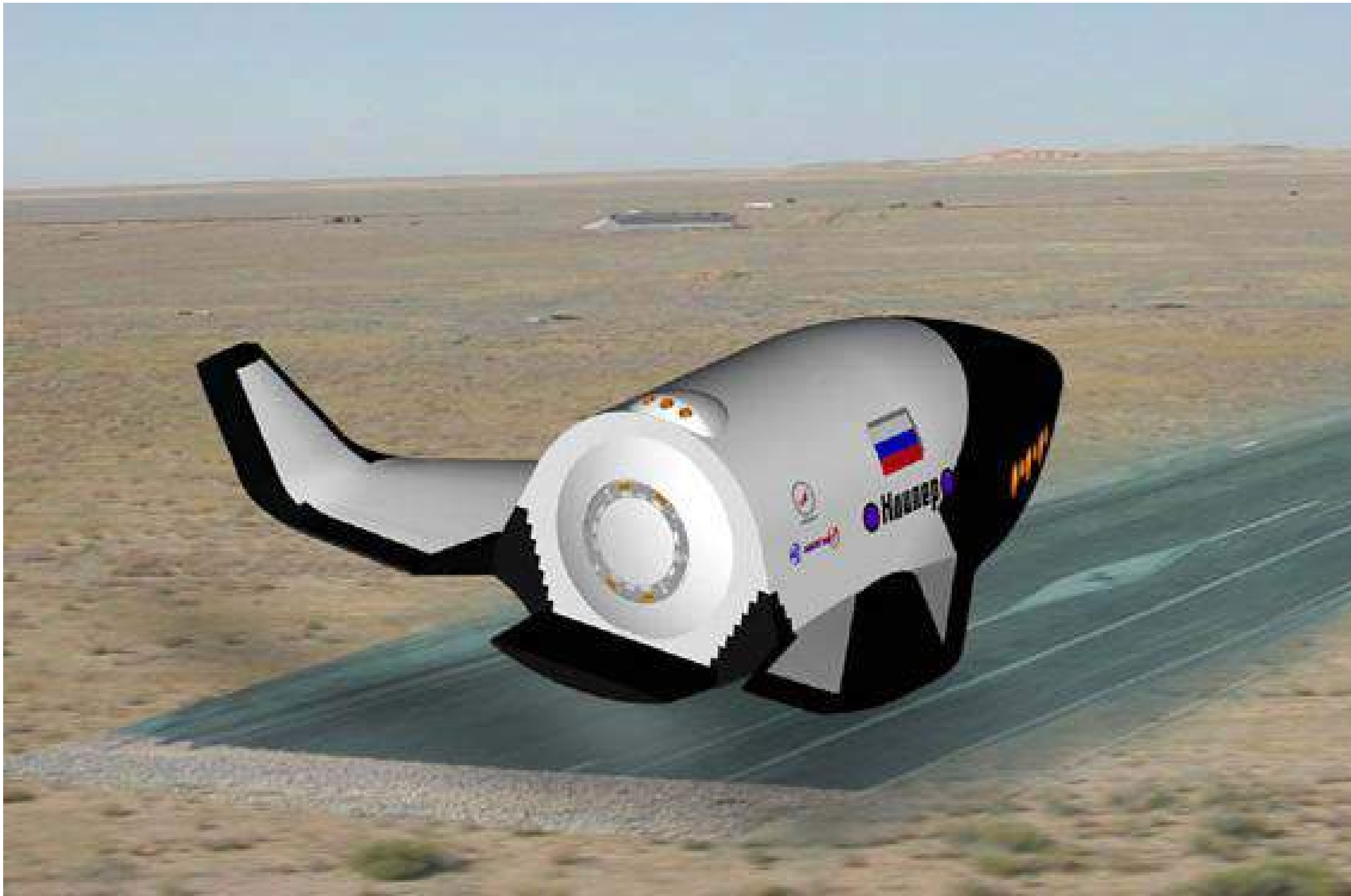
Spaceplane Kliper atop Launcher Soyuz

Comparison of Spaceships Soyuz and Kliper

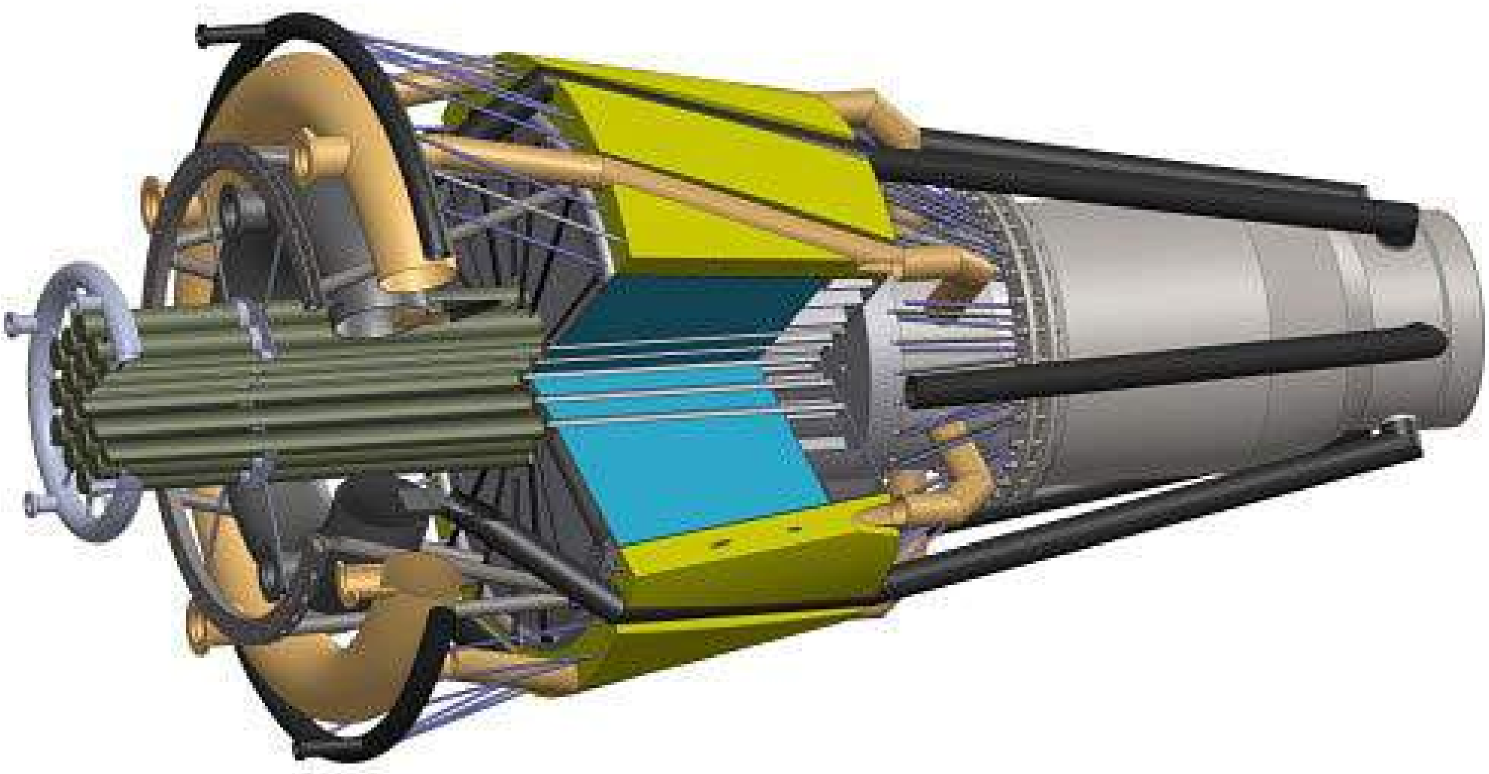




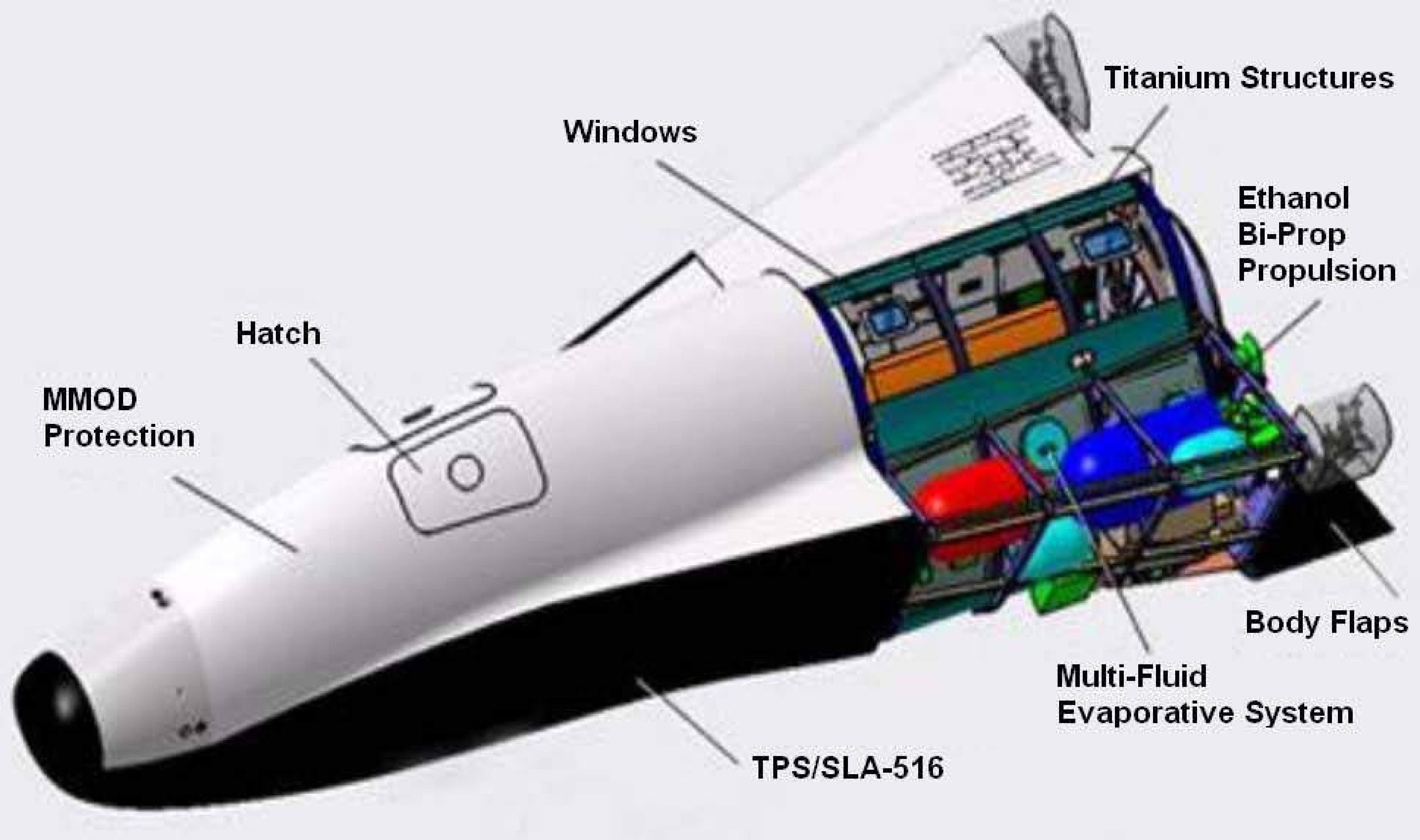
Landing of the Kliper Reentry Vehicle or may be Grounded by means of a Parachute



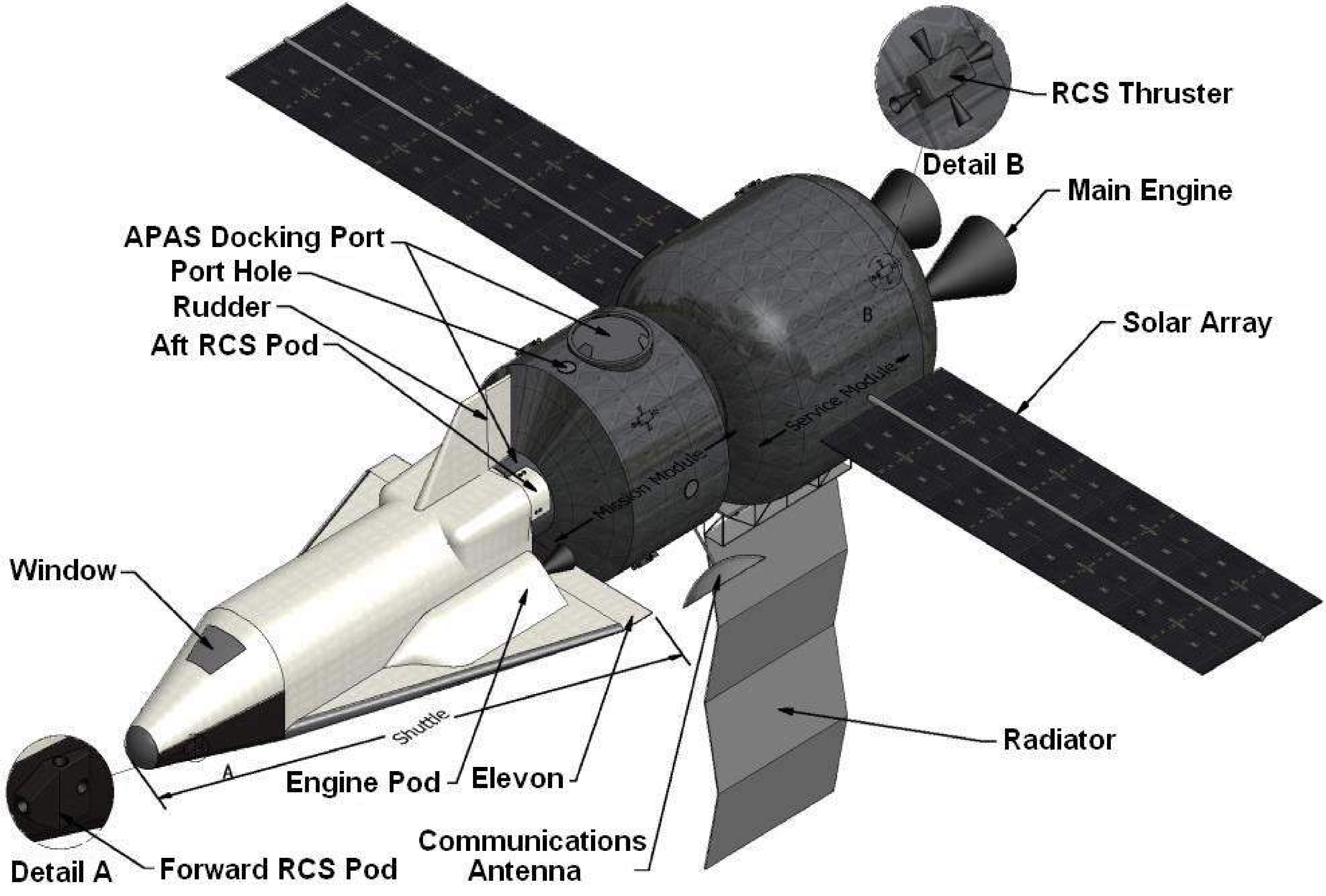
Russian Nuclear Propulsion Systems to be Used on New Angara Boosters made by Rosatom and Kurchatov Institute



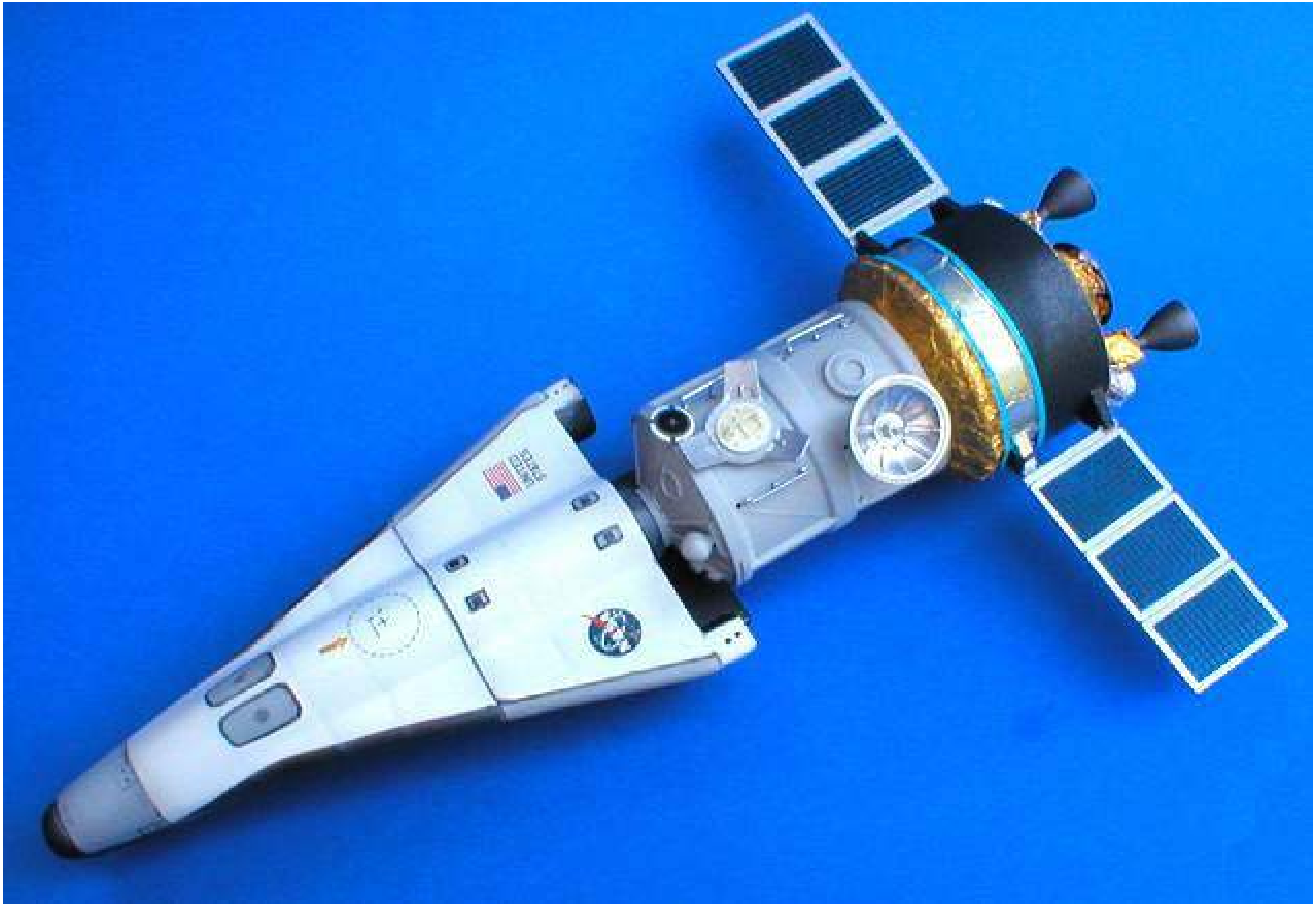
Crew Exploration Vehicle (CEV) of the USA Company Lockheed-Martin



Crew Exploration Vehicle (CEV) of USA

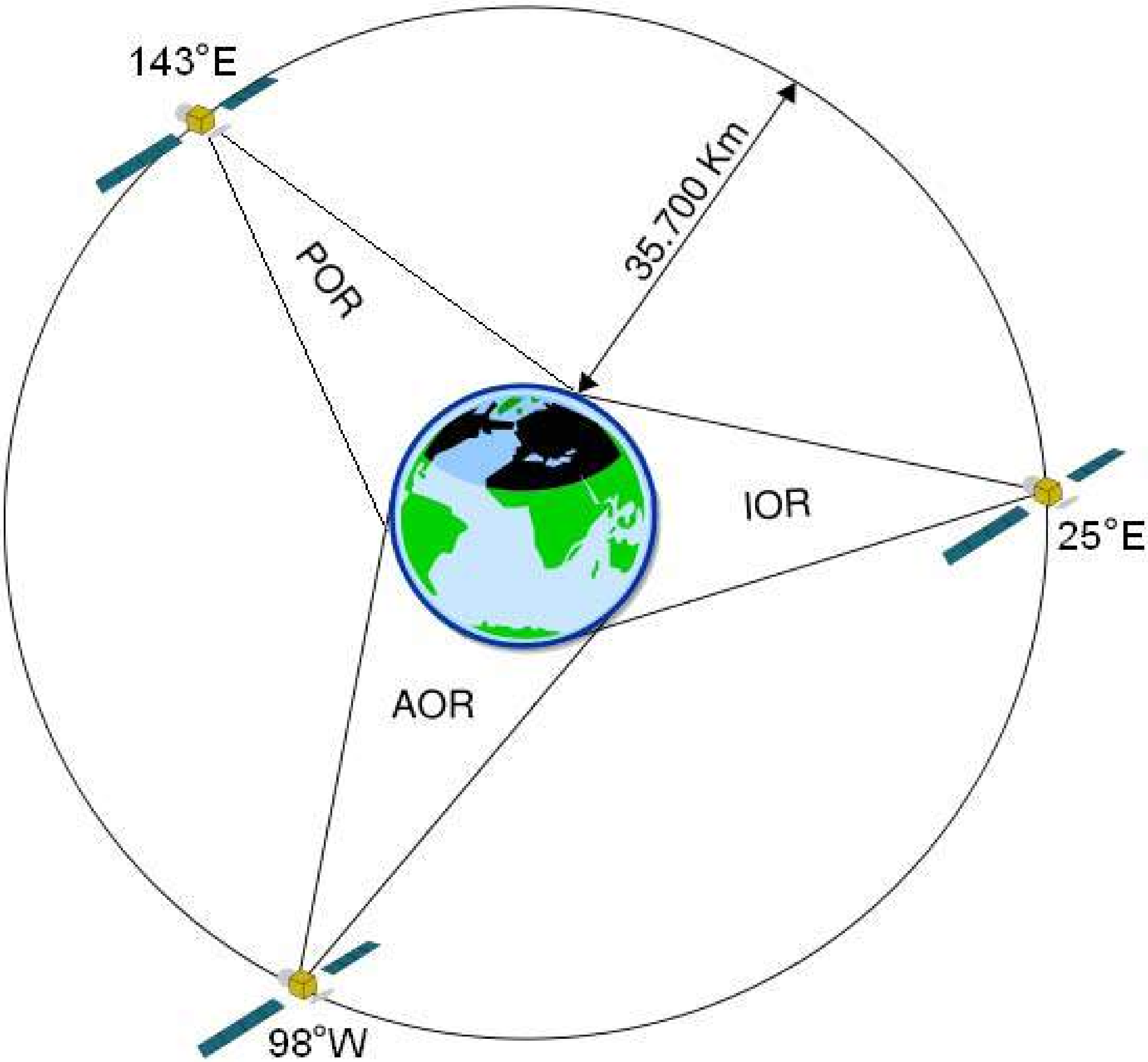


CEV with Service Module both may be Connected atop Launcher

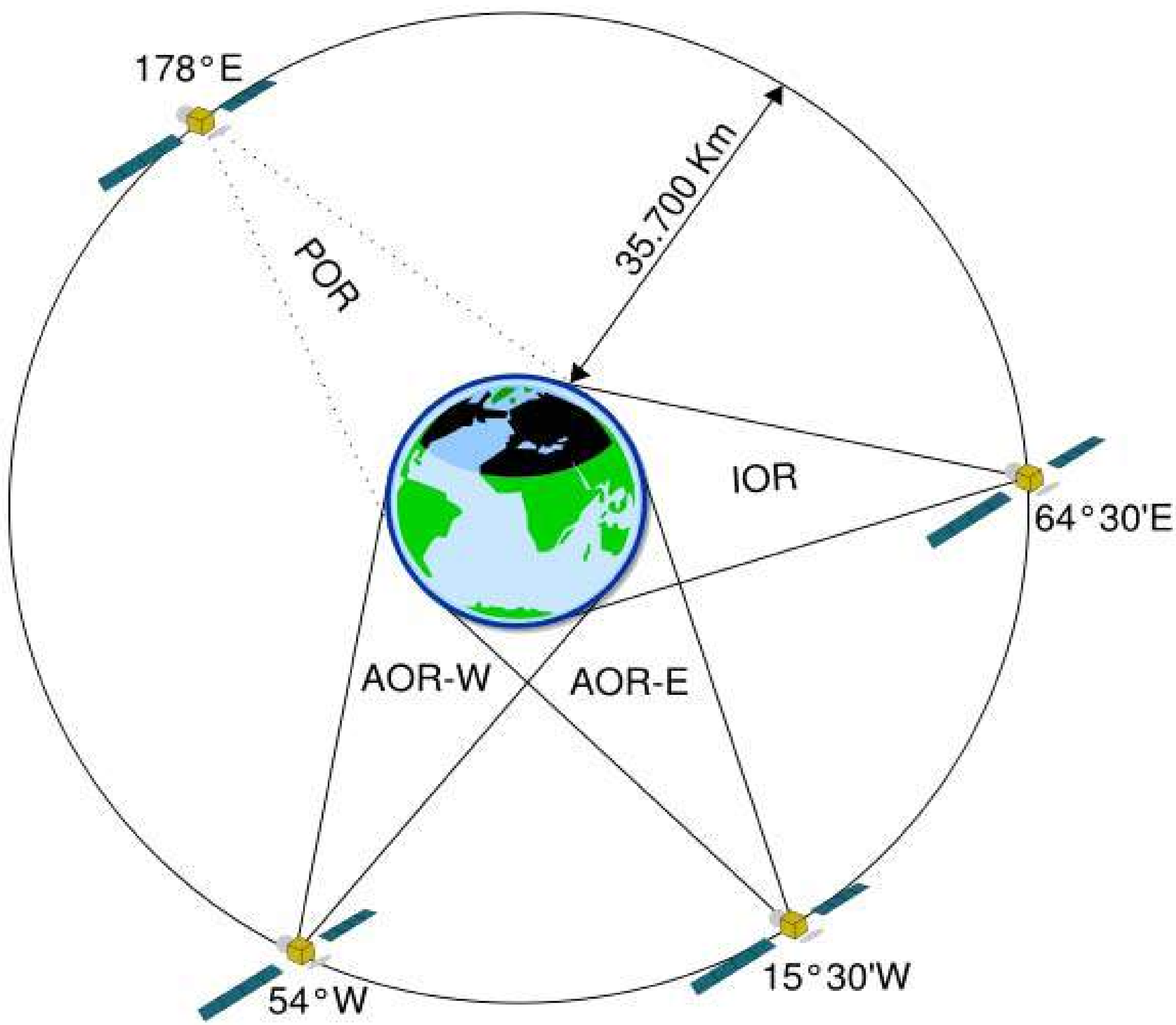


SeaLaunch System using Ukrainian (Ex-Soviet) Launcher Zenit

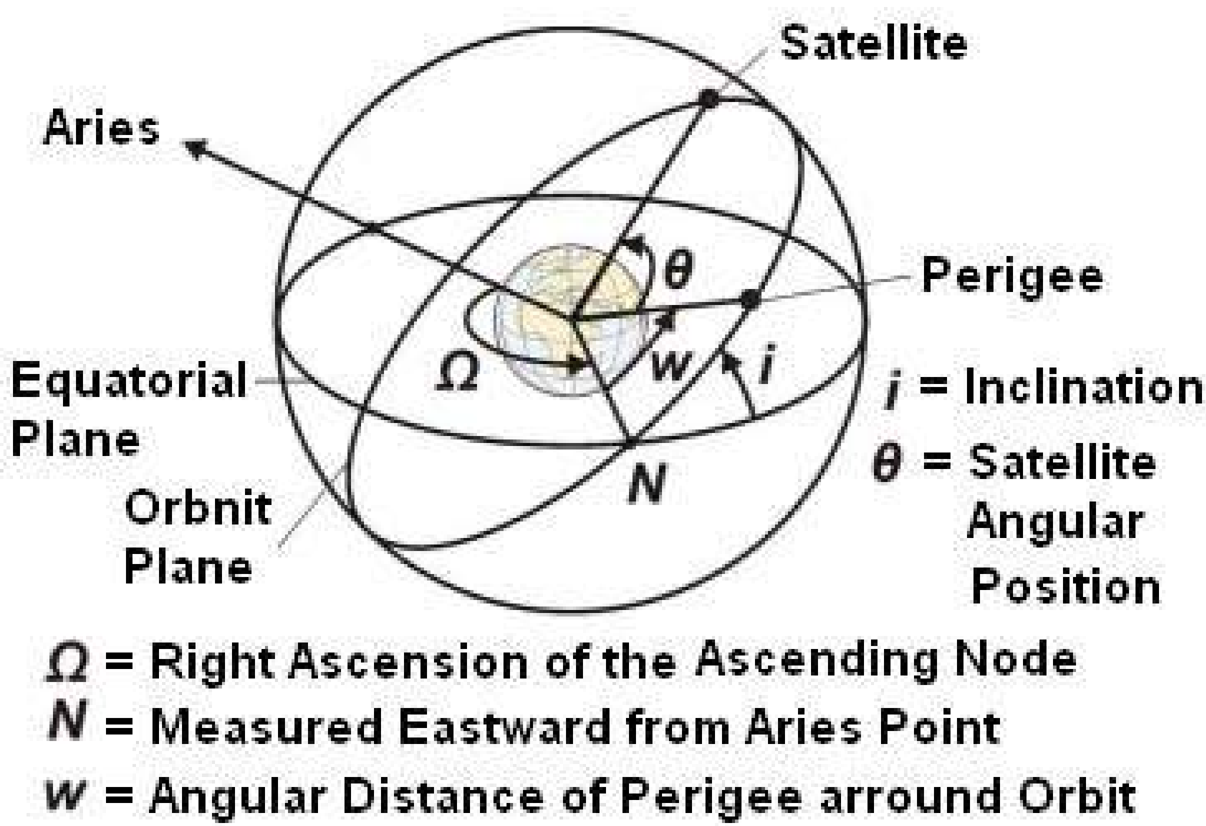
Global Coverage with 3 Inmarsat-4 Satellites similar to Sir Arthur Clarke

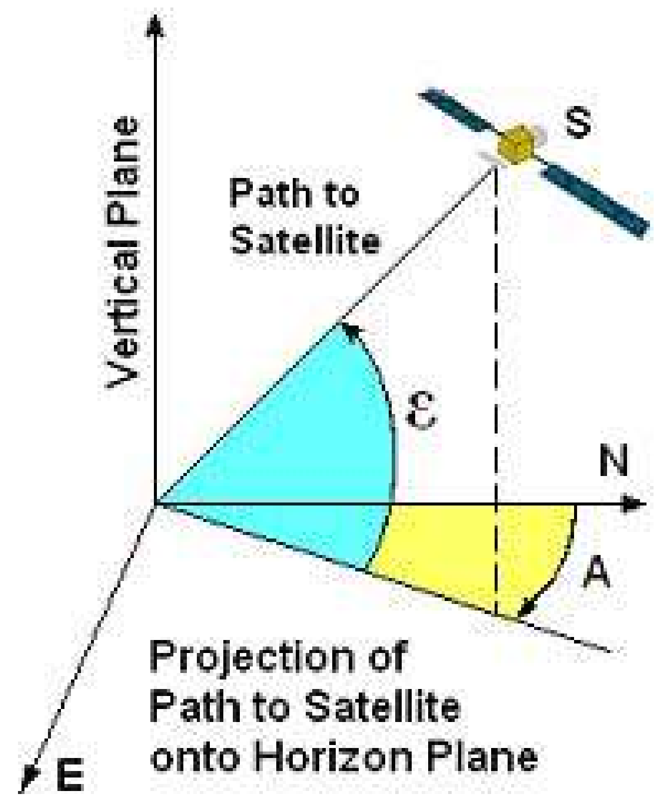


Global Coverage with 4 Inmarsat-3 Satellites



Satellite Orbital Elements on the Celestial Sphere (Left) and Satellite Determination Elevation (ε) and Azimuth (A) Angles





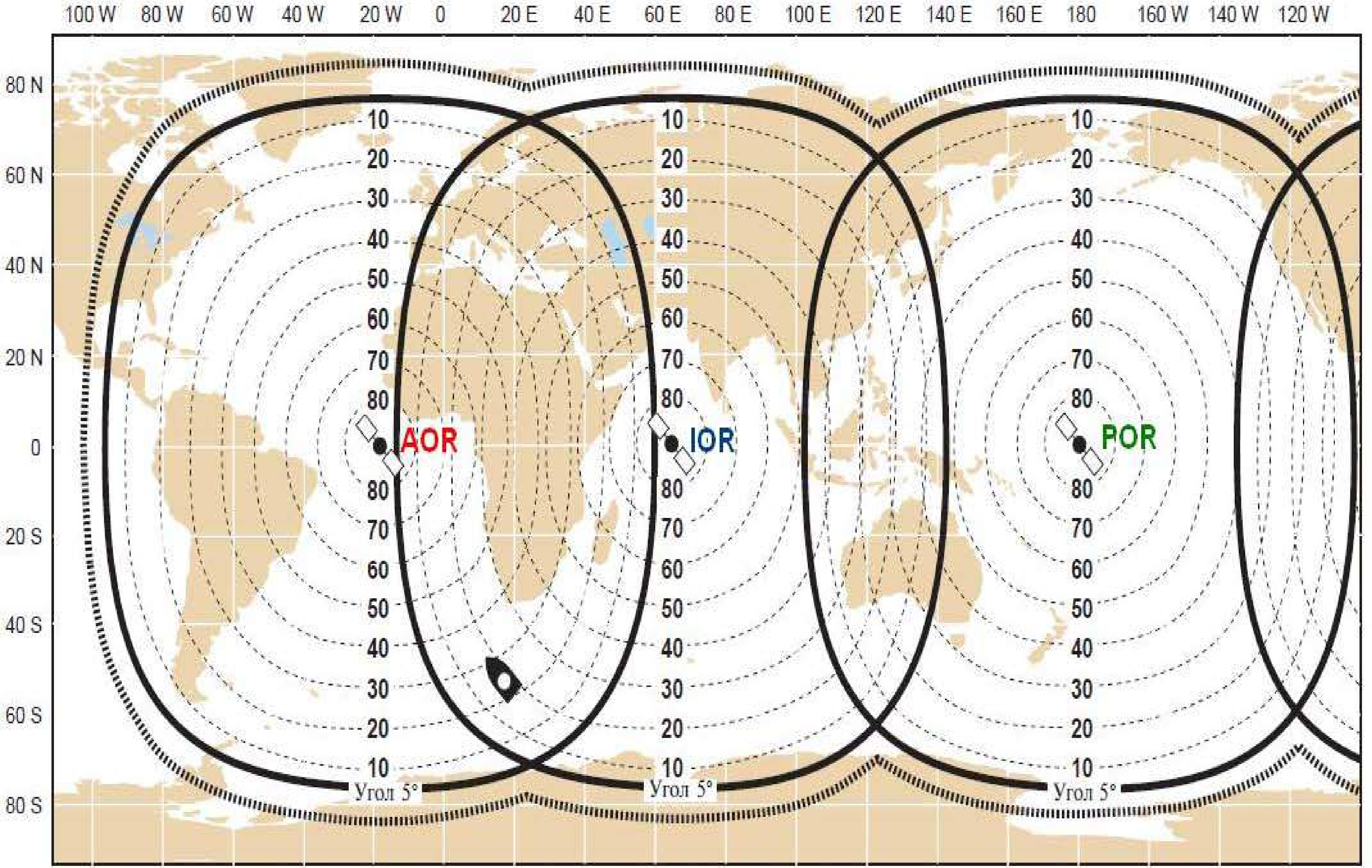
Satellite Look Angles

- **Satellite azimuth** is the angle measured eastward from the geographical North (N) line to the projection of the satellite path on the horizontal plane at the observer point.
- **Satellite elevation** is the angle composed upward from the horizon to the vertical satellite direction on the vertical plane at the observer point.

Calculation of Mobile Plotted Position (See next Slide)

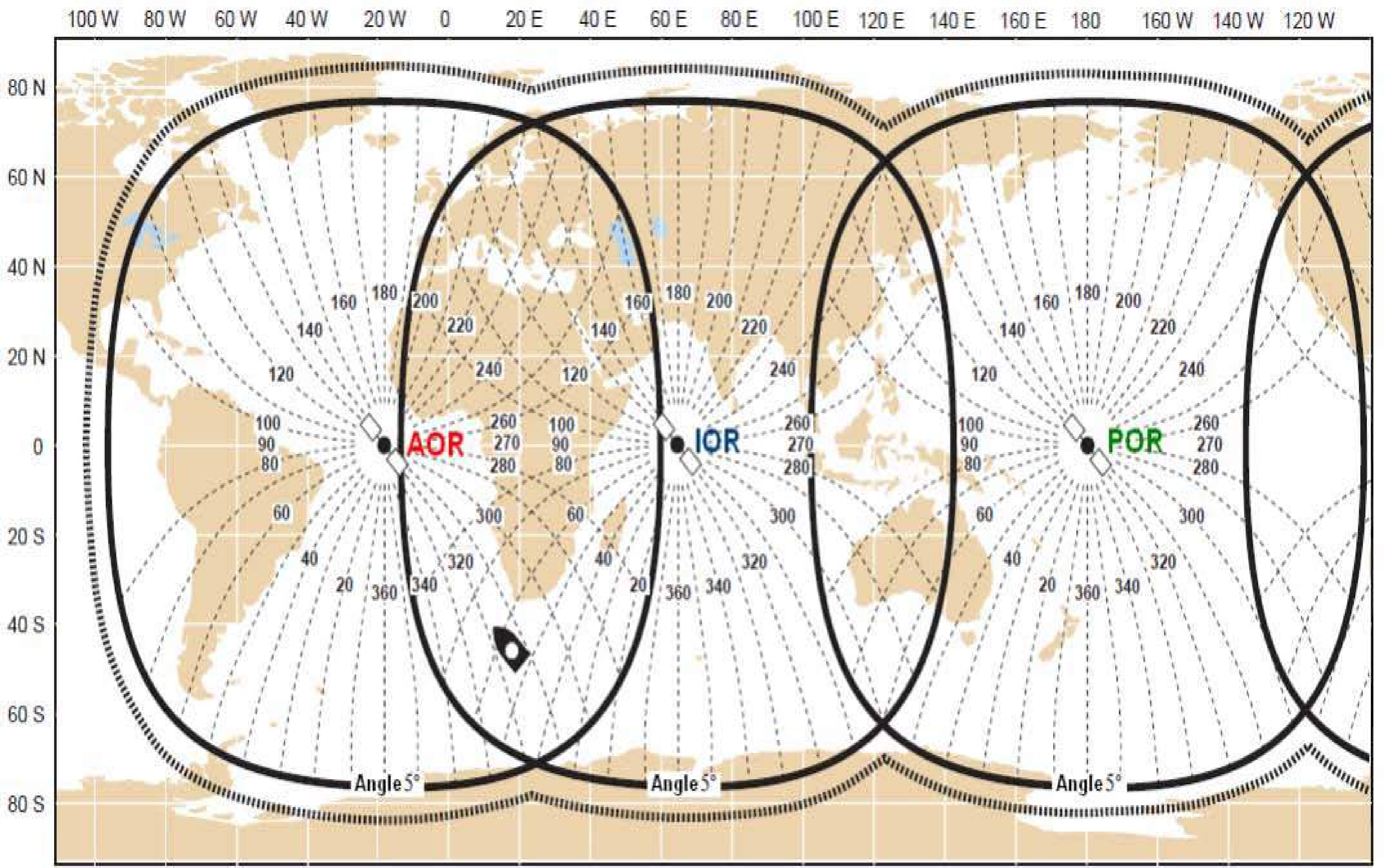
- **Elevation Angle Map (A)** with Plotted Position 17º for Indian Ocean Region (IOR) and 25º for Atlantic Ocean Region (AOR)
- **Azimuth Angle Map (B)** with Plotted Position 57º for Indian Ocean Region (IOR) and 313º for Atlantic Ocean Region (AOR)

Elevation Angle Map and Plotted Position



Example of Elevation Angle for the Plotted = 17^{0} for IOR & 25^{0} for AOR

Azimuth Angle Map and Plotted Position

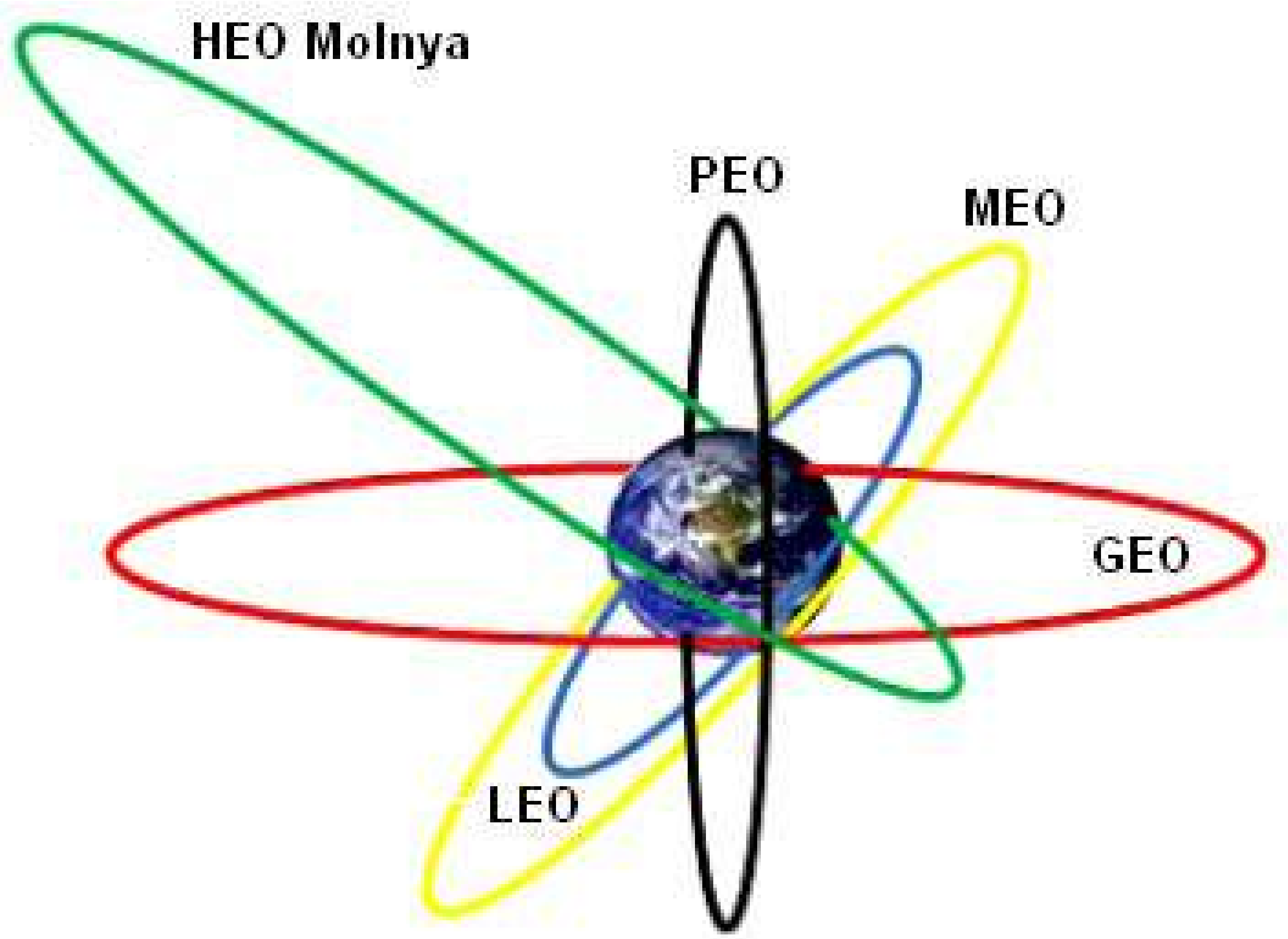


Example of Azimuth Angle for the Plotted = 57° for IOR & 313° for AOR

Type of Satellite Orbits

1. Low Earth Orbits (LEO): Little and Big LEO
2. Polar Earth Orbits (PEO)
3. Medium Earth Orbits (MEO)
4. Geosynchronous Inclined Orbits (GIO)
5. Geostationary Earth Orbits (GEO)
6. Highly Elliptical Orbits (HEO): Molnya, Tundra and Loopus.

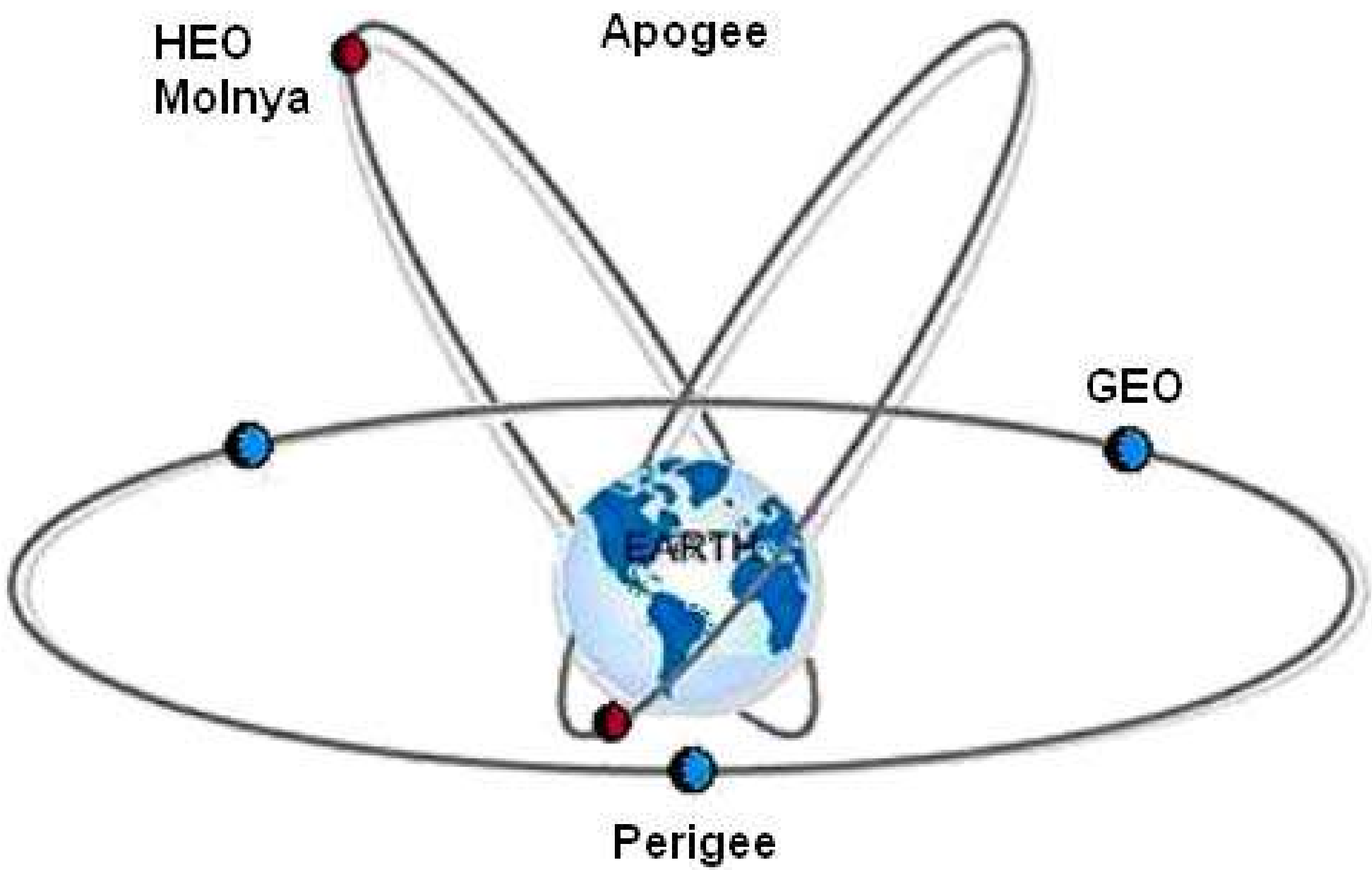
Type of Satellite Orbits: HEO= High Elliptical Orbit; GEO = Geostationary Earth Orbit; MEO= Medium Earth Orbit; LEO= Low Earth Orbit & PEO = Polar Earth Orbit



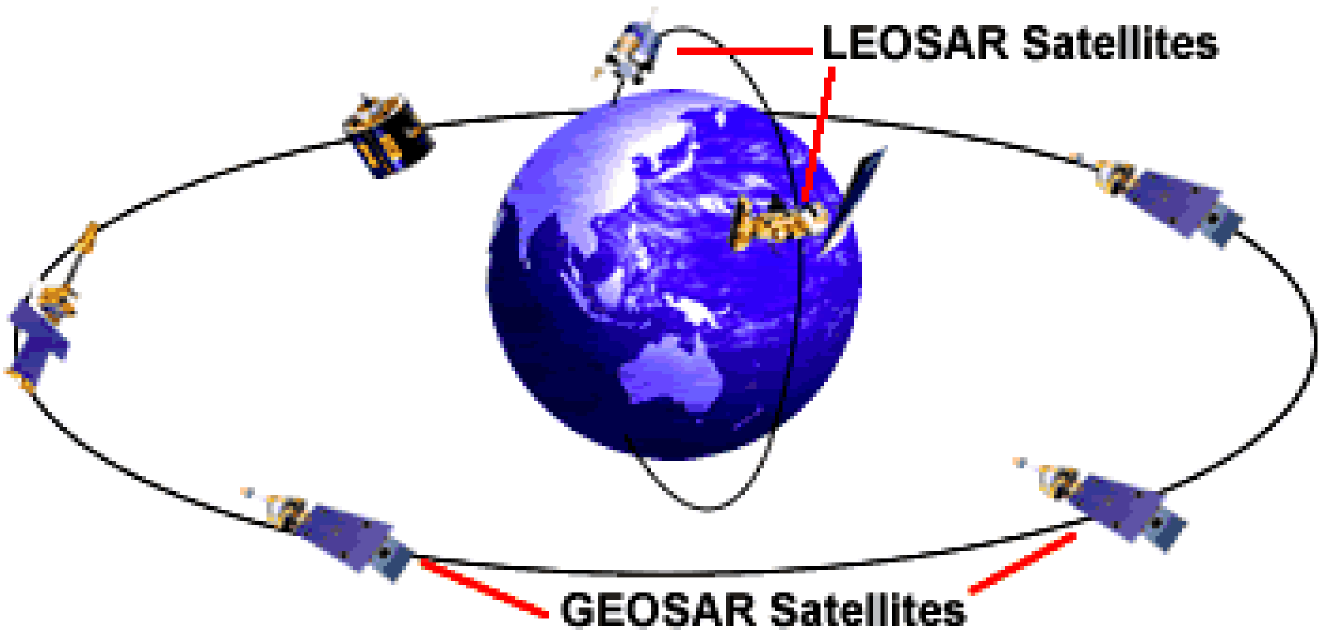
Properties of Four Major Orbits

Orbital Properties	LEO	MEO	HEO	GEO
Development Period	Long	Short	Medium	Long
Launch & Satellite Cost	Maximum	Maximum	Medium	Medium
Satellite Life (Years)	3–7	10–15	2–4	10–15
Congestion	Low	Low	Low	High
Radiation Damage	Zero	Small	Big	Small
Orbital Period	<100 min	8-12 hours	½ Sidereal Day	1 Sidereal Day
Inclination	90^o	45^o	63.4^o	Zero
Coverage	Global	Global	Near Global	Near Global
Altitude Range (km^{-3})	0.5–1.5	8–20	40/A – 1/P	40 (i=0)
Satellite Visibility	Short	Medium	Medium	Continuous
Handover	Very Much	Medium	No	No
Elevation Variations	Rapid	Slow	Zero	Zero
Eccentricity	0 to High	High	High	Zero
Handheld Terminal	Possible	Possible	Possible	Possible
Network Complexity	Complex	Medium	Simple	Simple
Tx Power/Antenna	Low	Low	Low/High	Low/High
Gain	Short	Medium	Large	Large
Propagation Delay	Low	Medium	High	High
Propagation Loss	High	Medium	Low	Zero

Proposal: Hybrid Constellation of GEO and HEO Molnya with High Apogee to provide Real Global Coverage

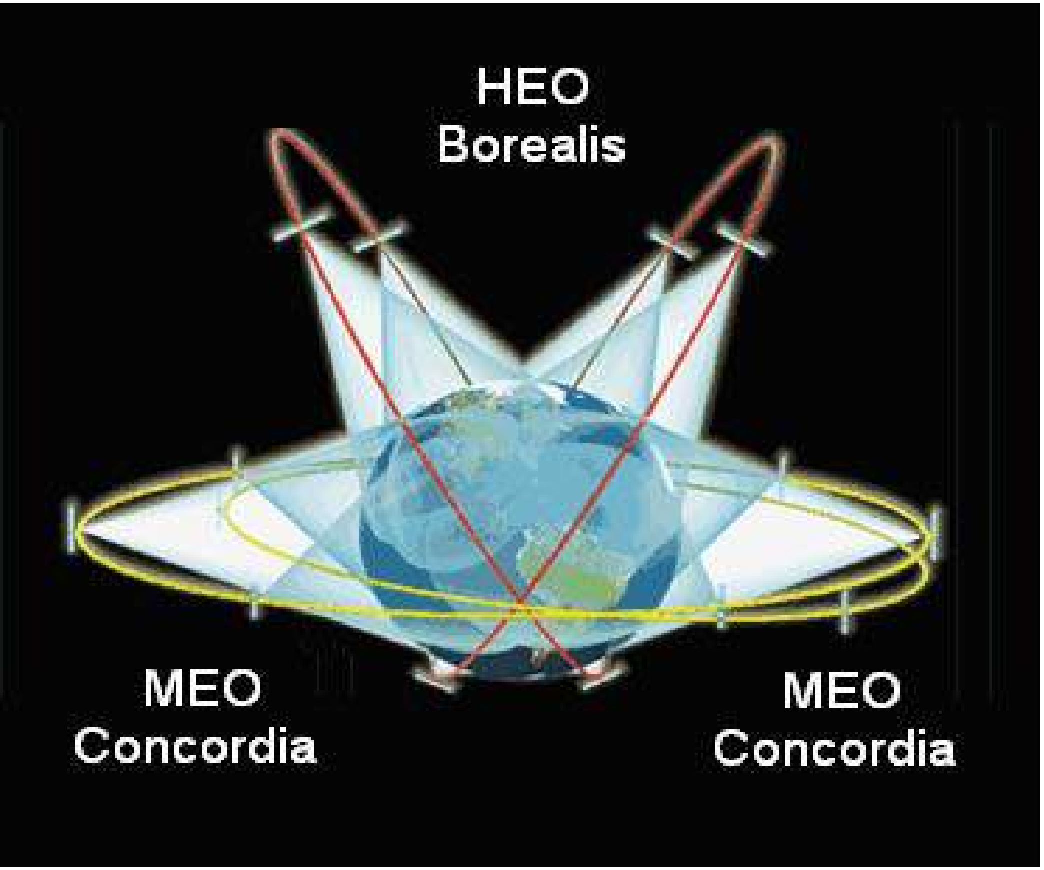


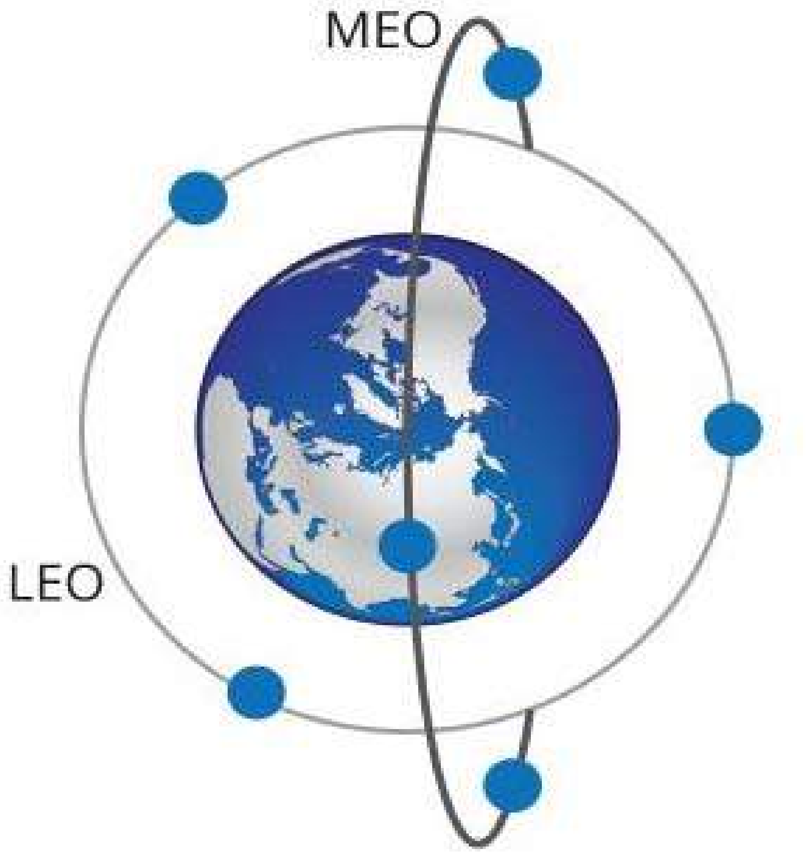
Proposal: Hybrid Constellation of GEO and PEO for Cospas-Sarsat GEOSAR and LEOSAR Global Coverage



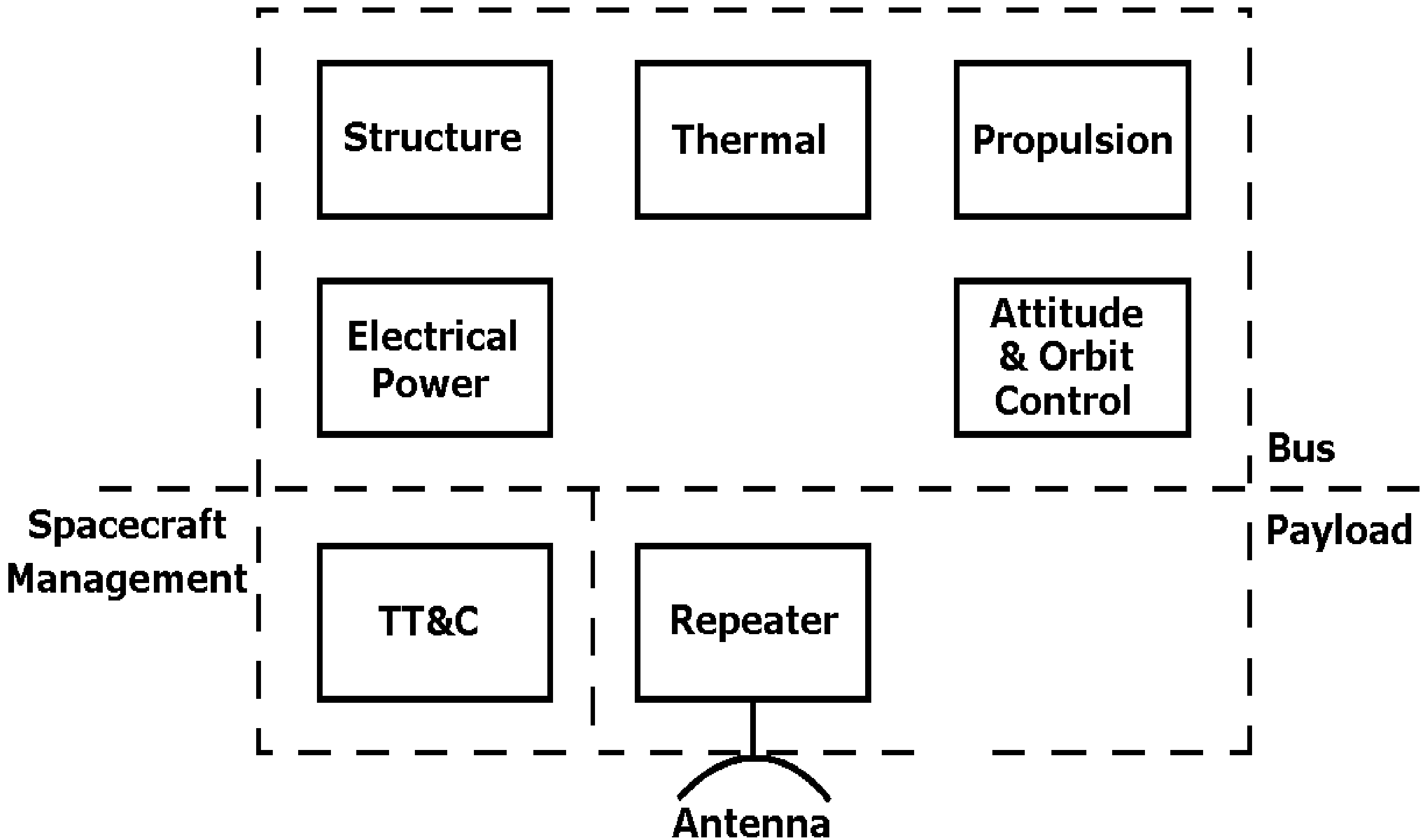
Proposal: Hybrid Constellation of GEO and LEO for Global Coverage

Proposal: Hybrid Constellations of HEO and MEO (Left) and MEO and LEO (Right) for Global Coverage





Spacecraft Sub-System



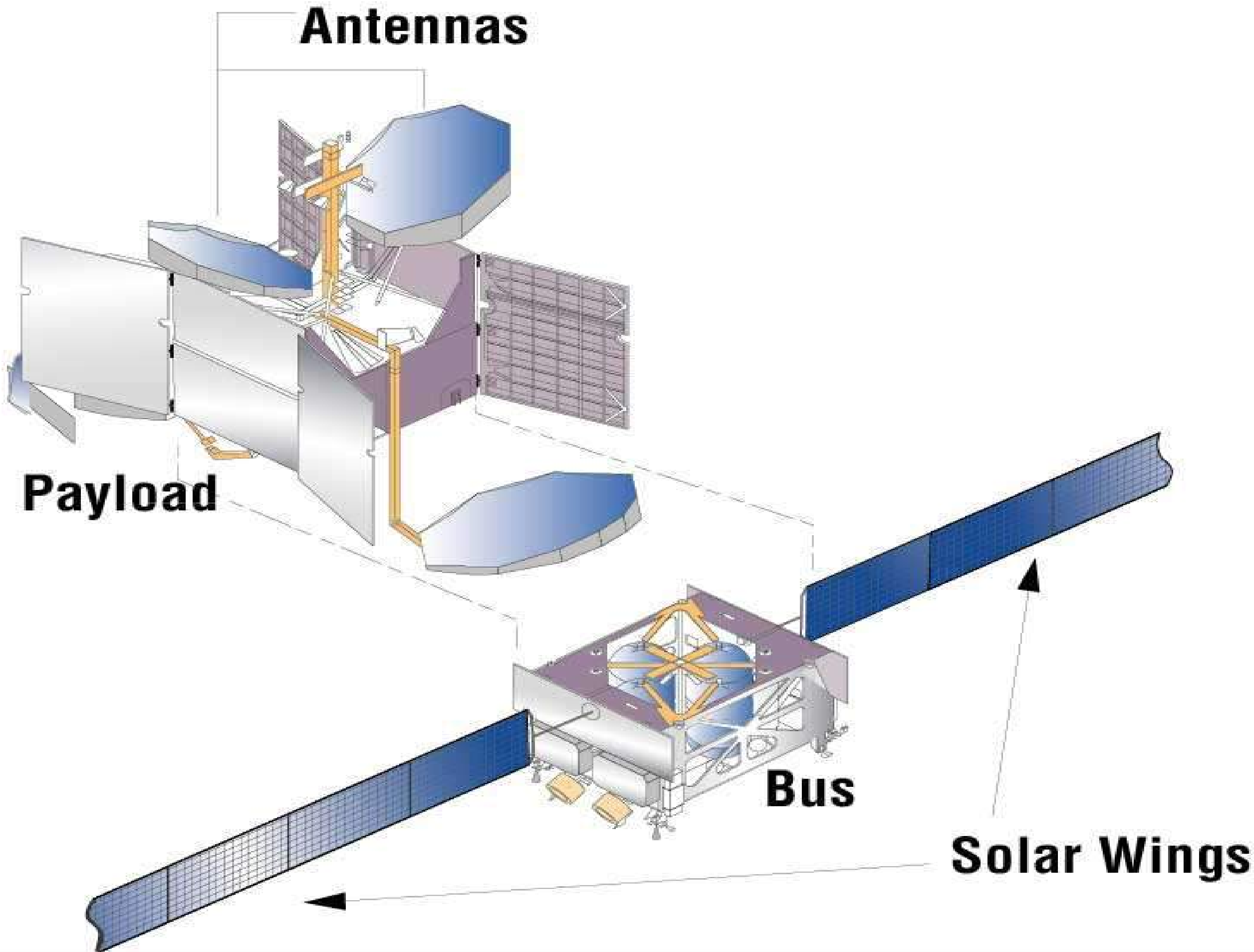
Three-axes Stabilized Spacecraft

- Momentum wheels in each axis: roll, pitch, yaw for stabilization
- No despun platform needed for antennas
- Large solar panels possible (power generation)
- Optimum orientation towards the Sun
- High efficiency
- More complex design
- More complicated thermal control

Spin-Stabilized Spacecraft

- Earliest version
- Whole body is momentum wheel
- For stability the momentum around desired axis must be greater than around any other axis
- Despun antenna platform for higher gain antennas
- Easy thermal balance
- Only ~ 1/3 of solar panel area useable

Components of GEO Spacecraft



Future Russian GEO Spacecraft Express-AM

[which Bus can be model to build new Multifunctional Spacecraft]

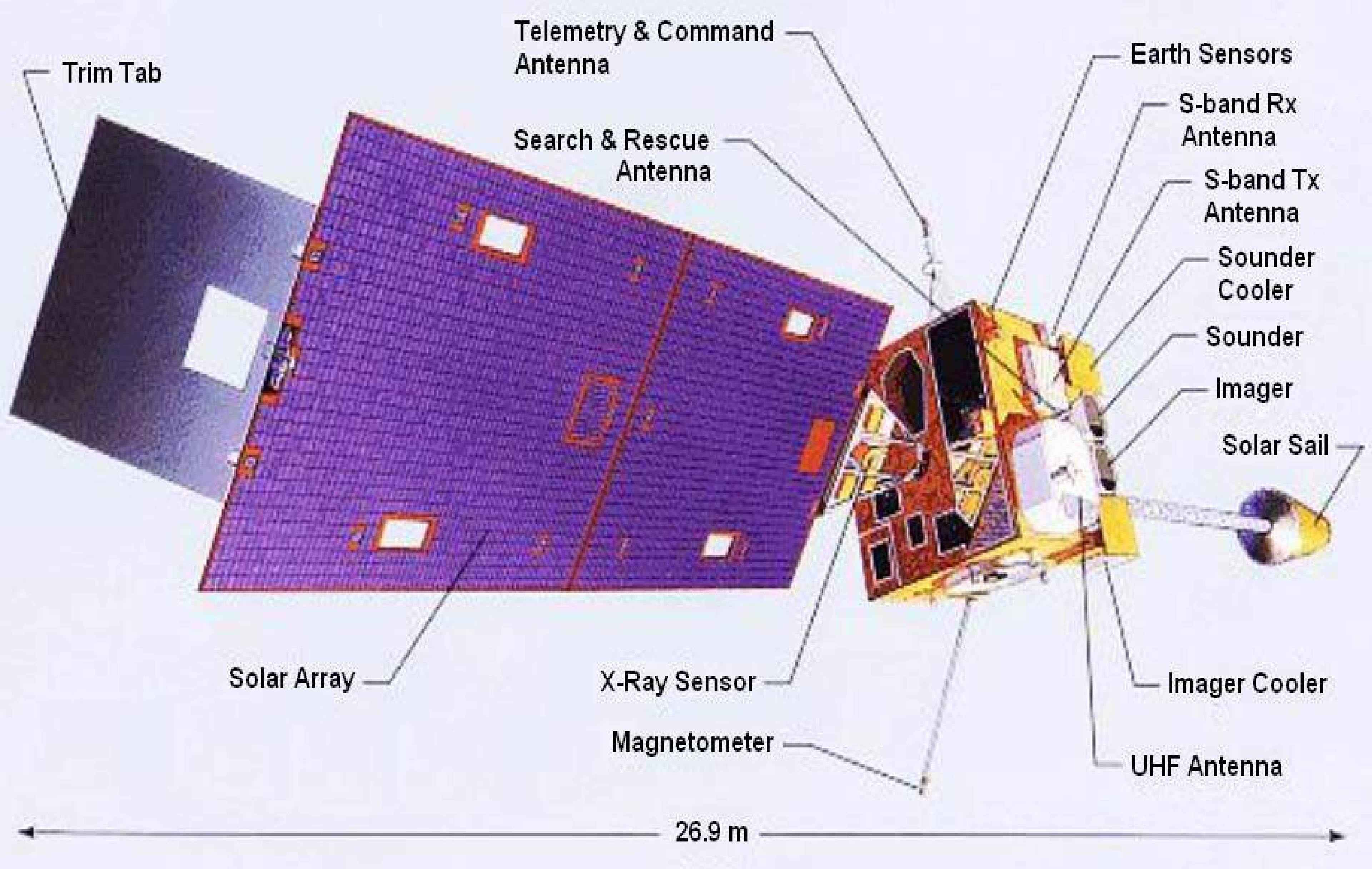
Specifications of GEO Spacecraft Express-AM built by Russian Company ISS Reshetnev

Spacecraft	Express-AM5	Express-AM6
Orbit	Geostationary	Geostationary
Designed lifetime	15 years	15 years
Orbital position	140°E	53°E
Station-keeping accuracy (longitude/inclination).	±0,05°	±0,05°
Launch mass	3270 kg	3270 kg
Number of transponders		
Ku-band	40	44
C-band	31	15
L-band	2	2
Ka-band	12	12
Transponder output power	110W	110W
Antenna type	1 deployable three-mirror antenna (each reflector is 1,2m in diameter)	1 deployable three-mirror antenna (each reflector is 1,2m in diameter)

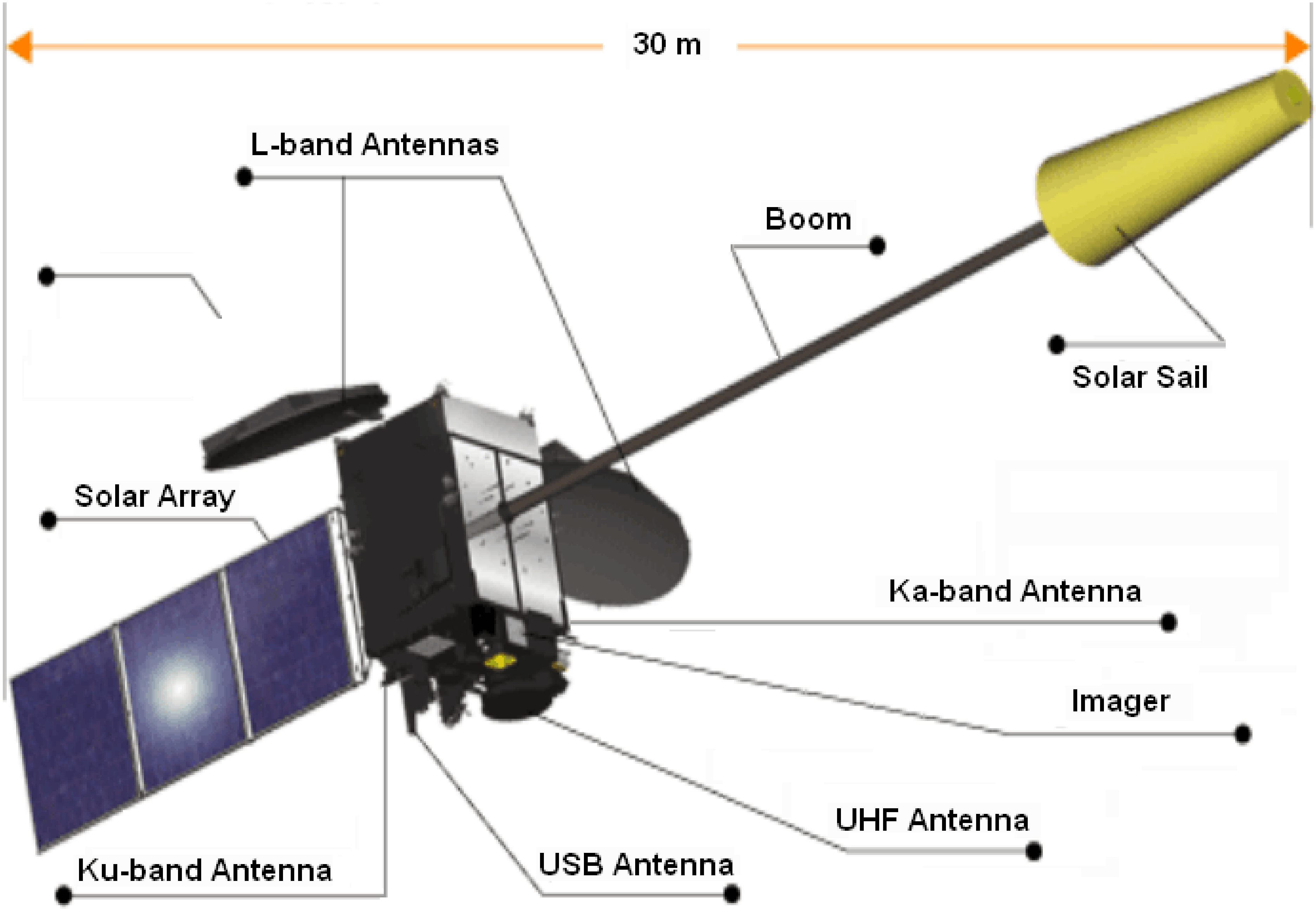
Reshetnev's GEO Spacecraft Loutch-5A

[which Bus can be model to build cheap Multifunctional Spacecraft]

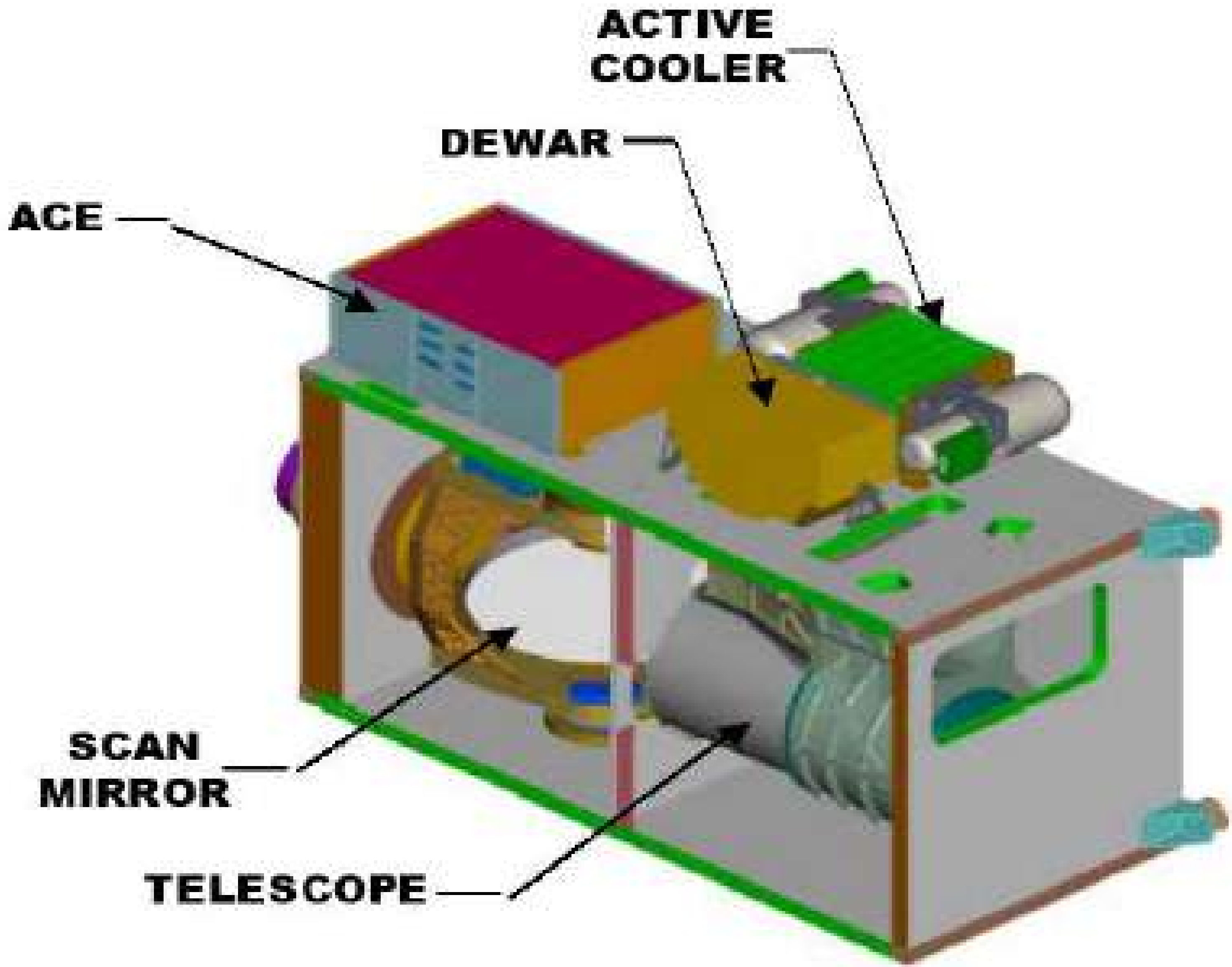
The US GEO Spacecraft GOES



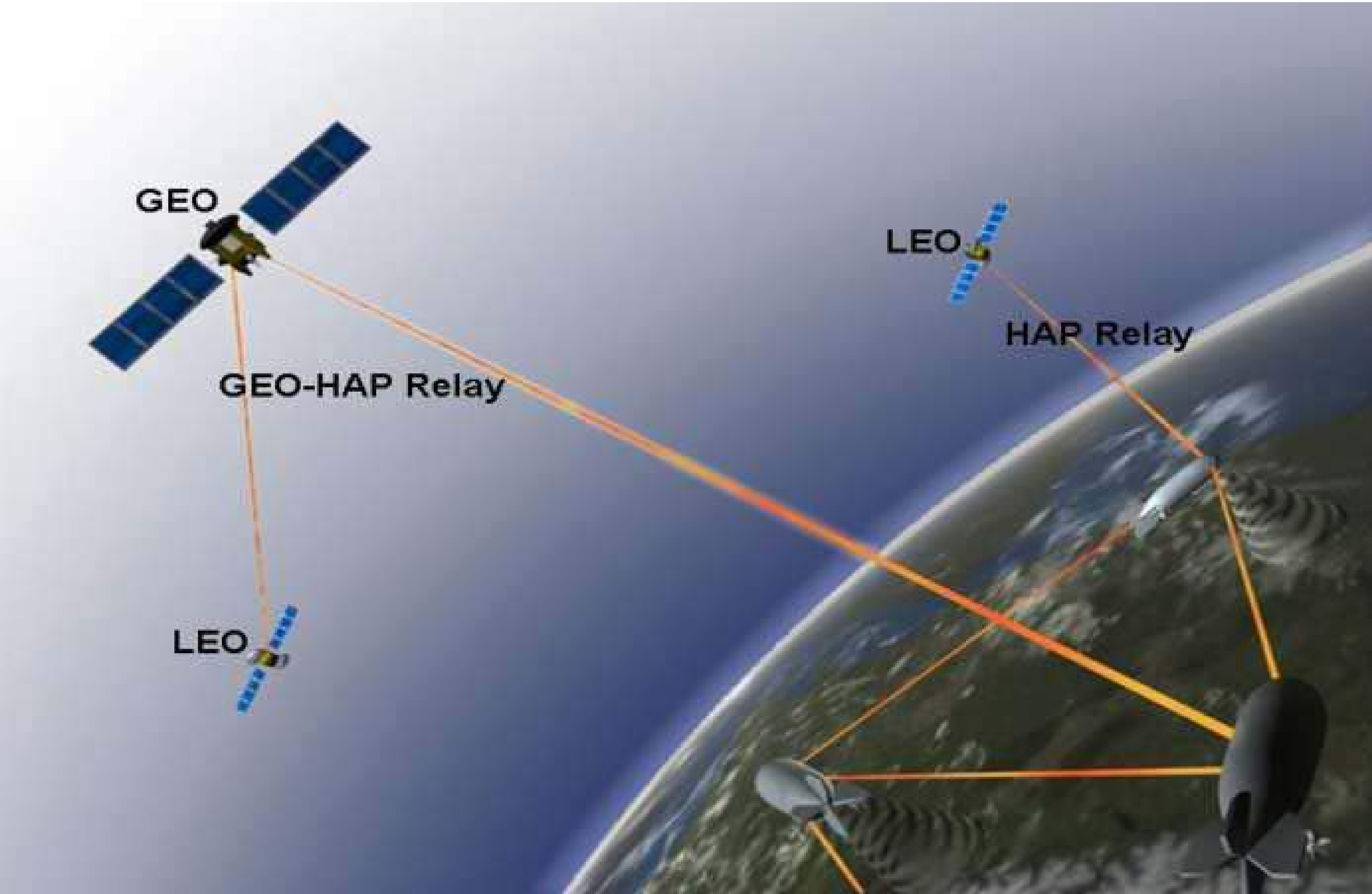
Multifunctional Japanese GEO Spacecraft MTSAT



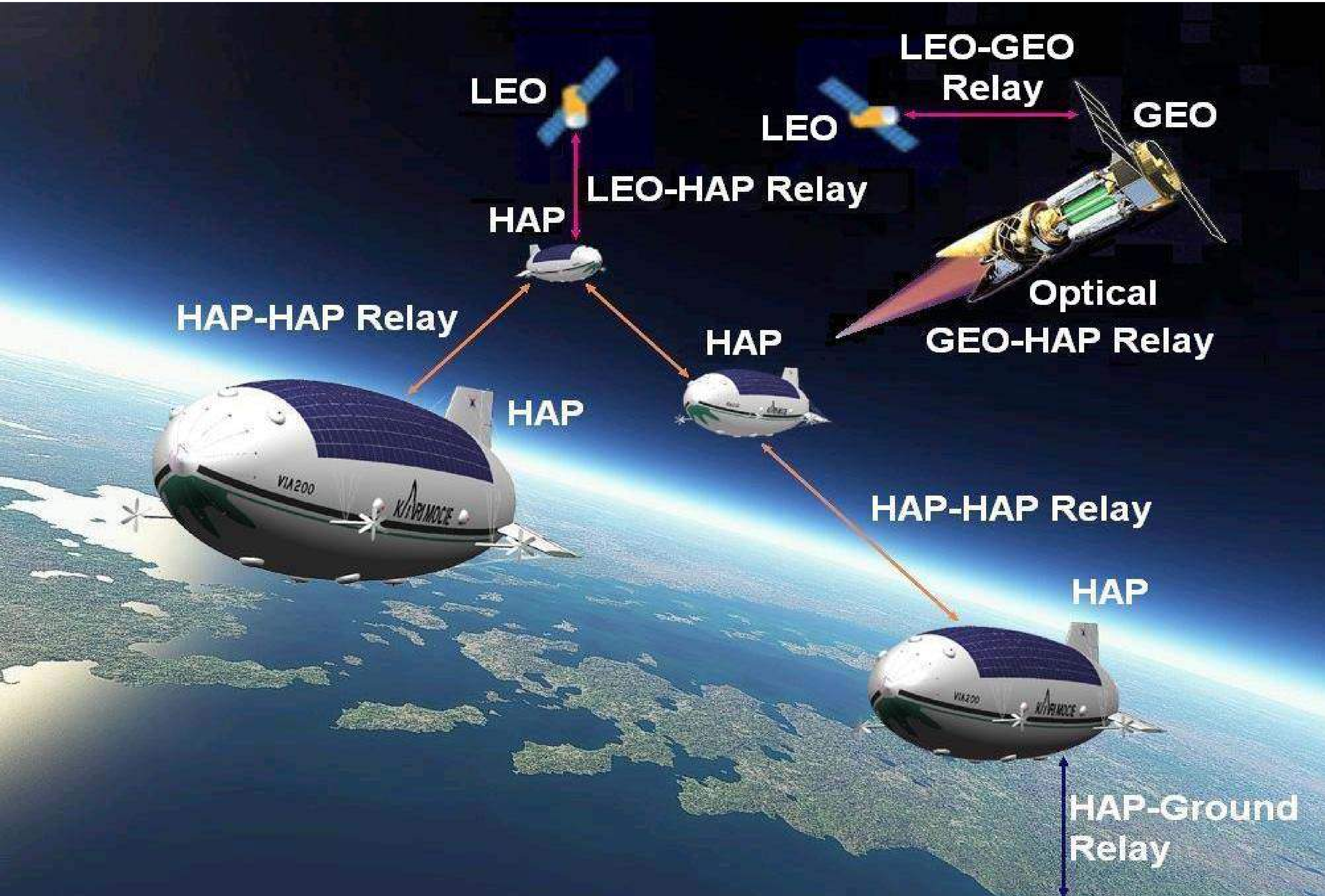
Advanced Imager of Multifunctional Japanese Spacecraft MTSAT-1R



Inter Satellite Link (ISL) Between GEO, LEO and High Altitude Platform (HAP)



Inter Platform and Satellite Links



Spacecraft Transparent or Bent-pipe (A) and Regenerative (B) or Onboard Processing Transponder (Repeater)

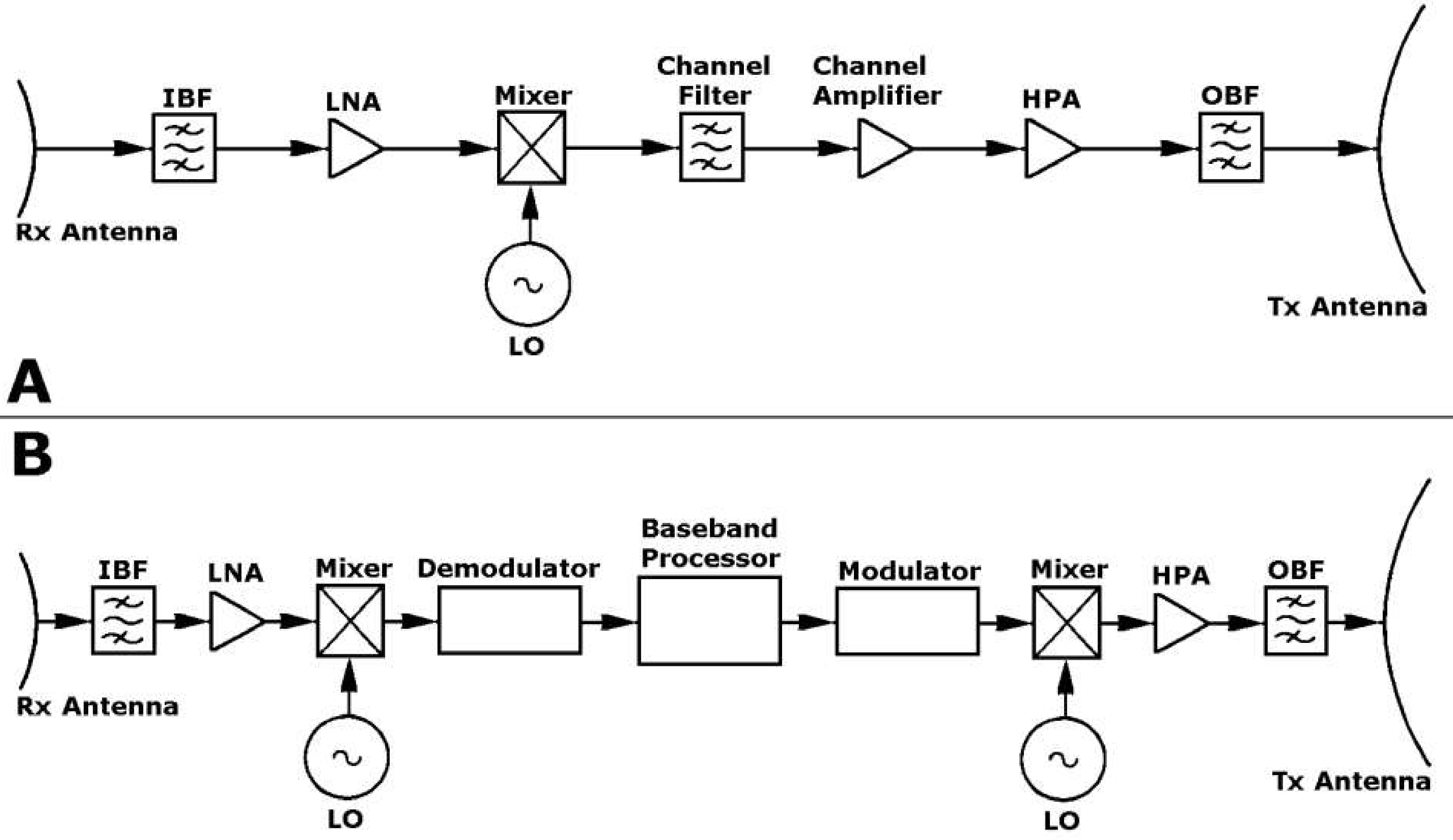
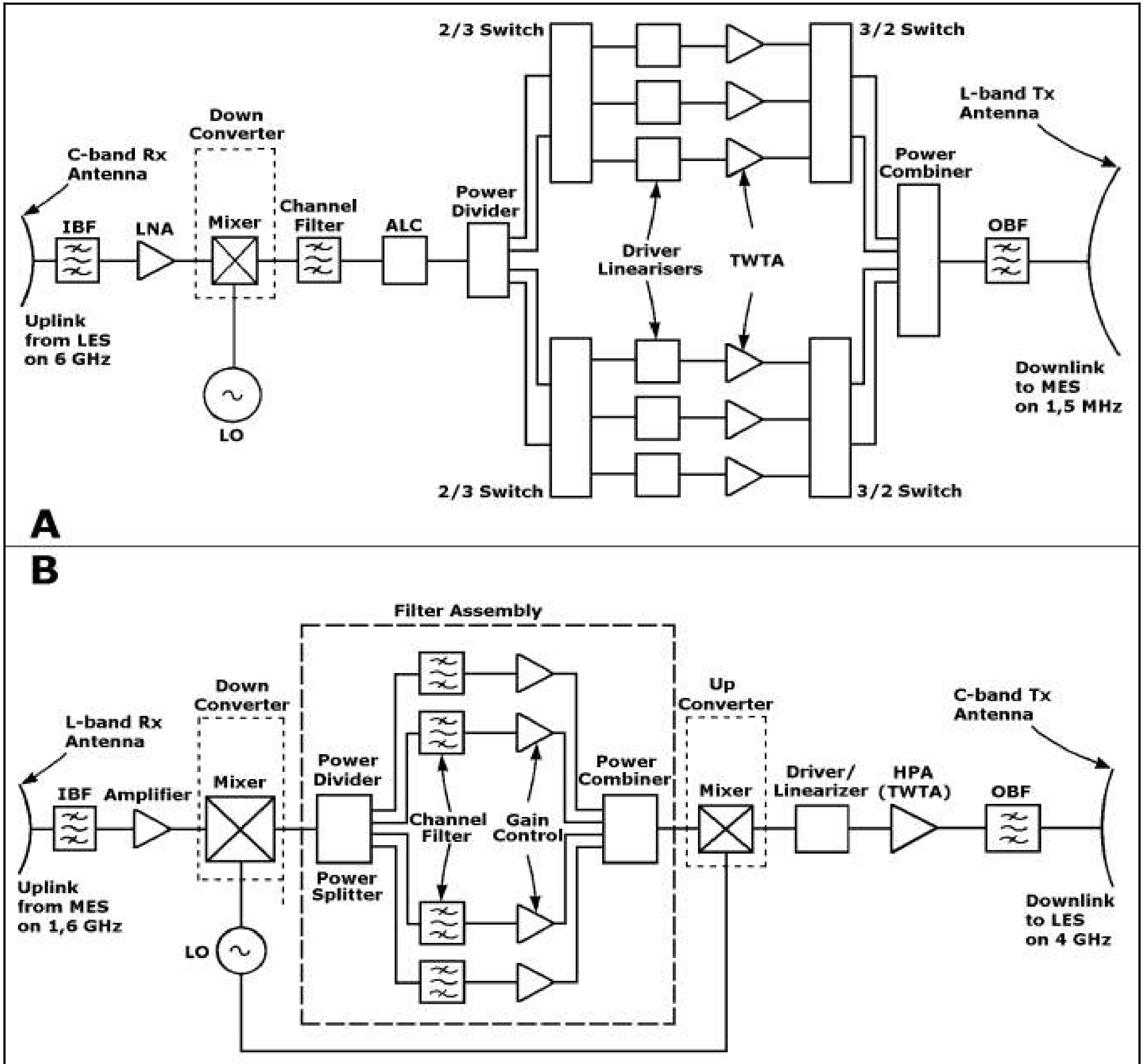
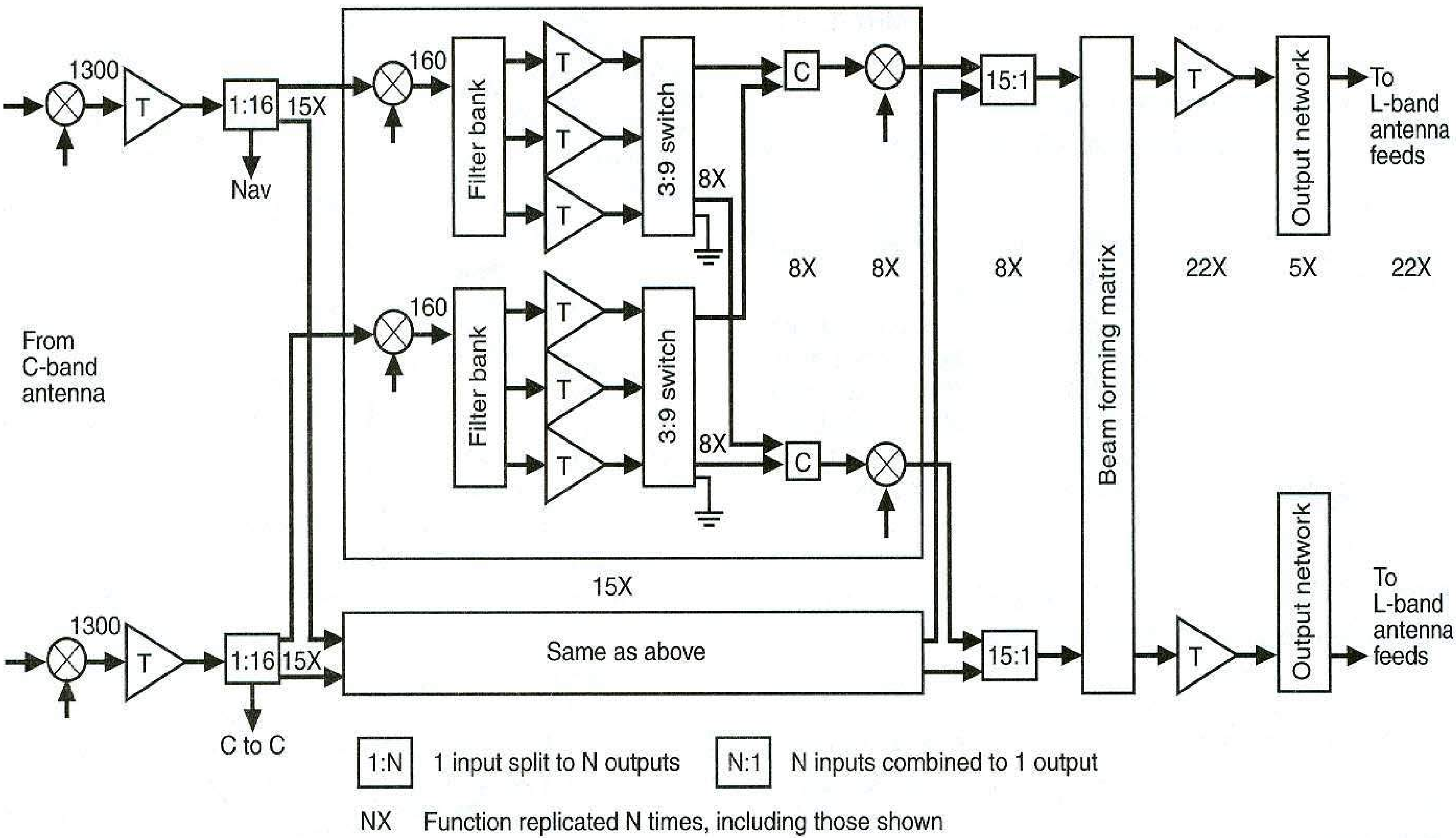


Diagram of Spacecraft C/L (A) and L/C-band (B) Transponders



Communication L/C-Band Transponder as a part of Multifunctional Payload



Block Diagram of Ka-band Communications Transponder

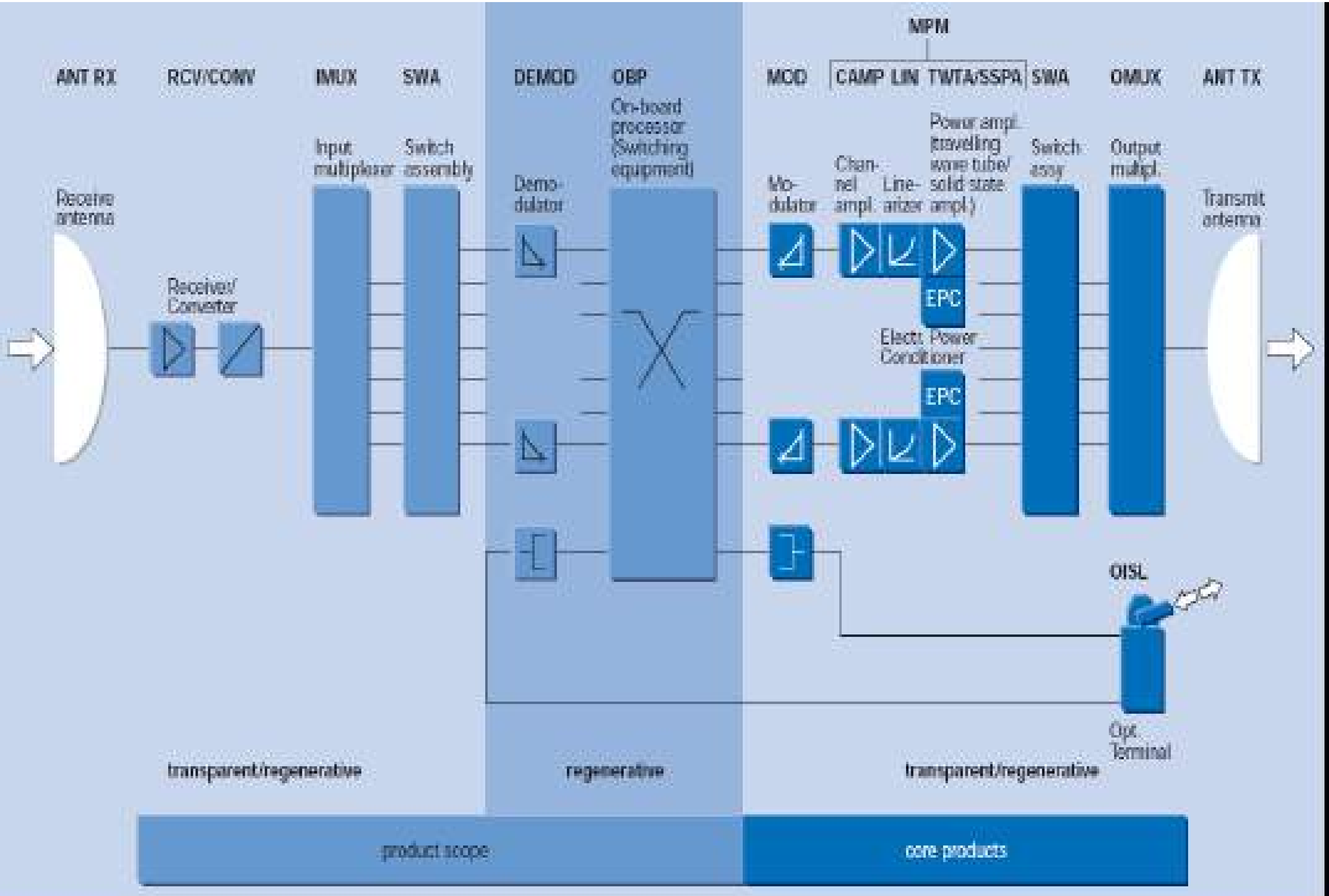
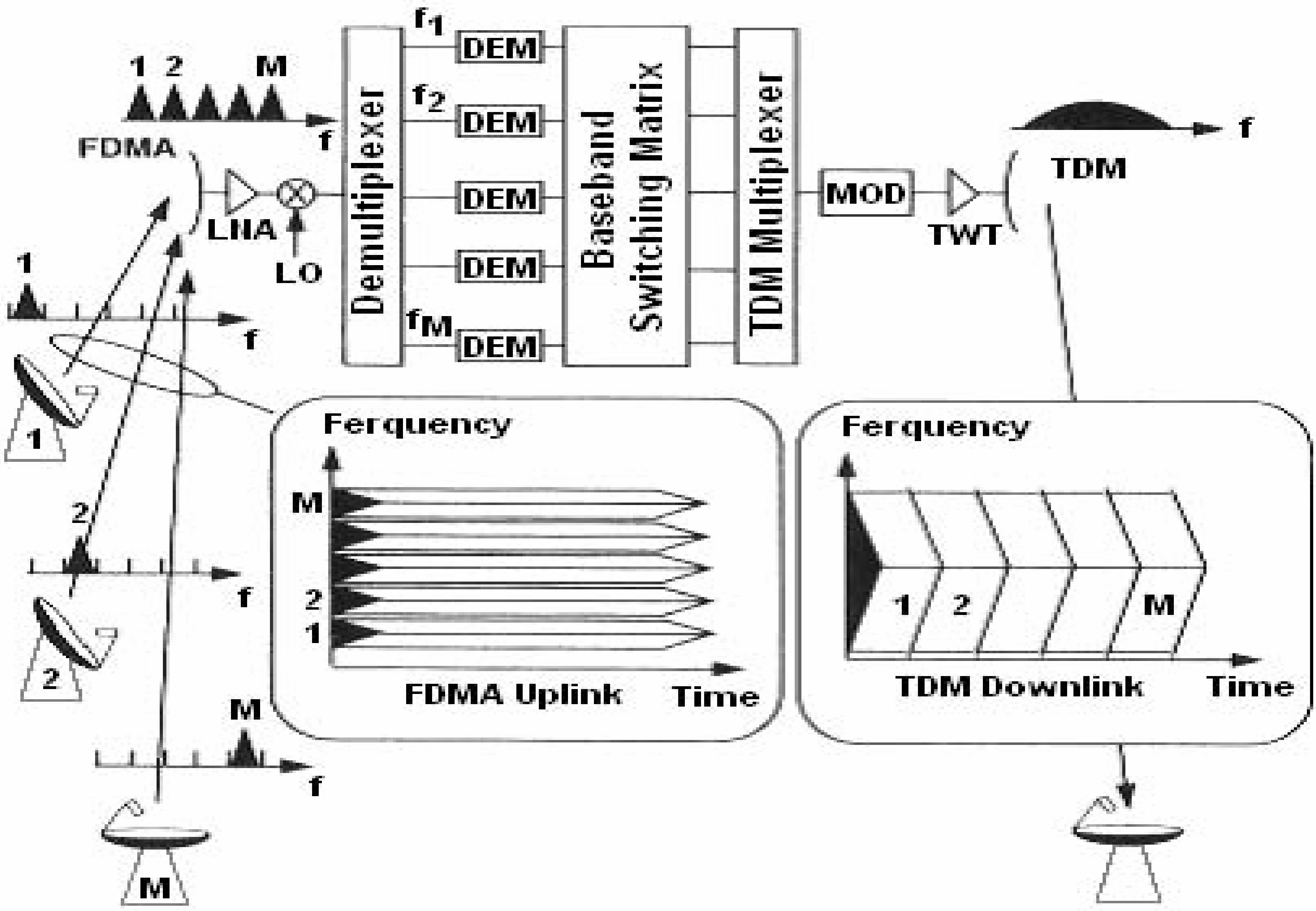
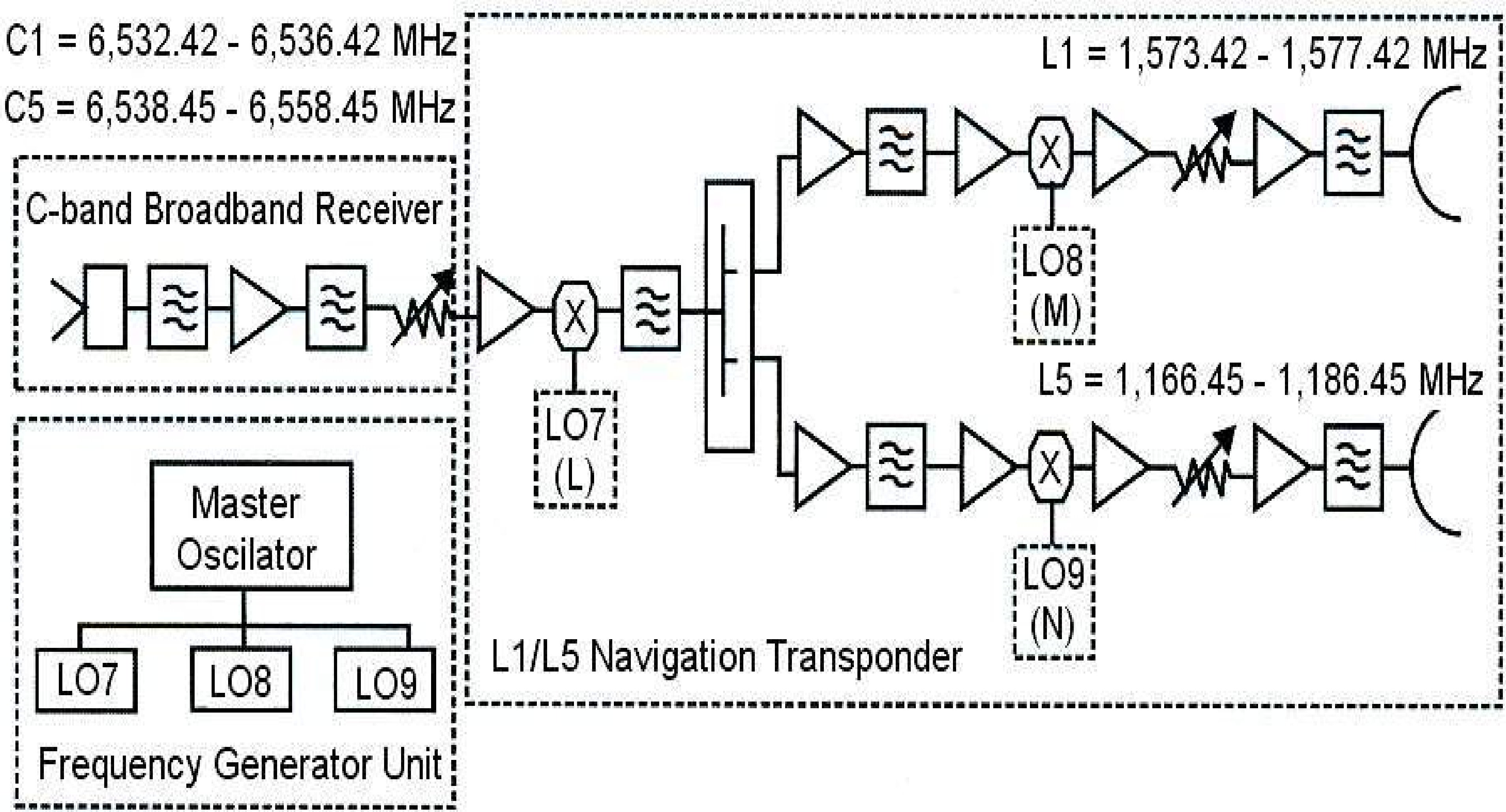


Diagram of VSAT Spacecraft Transponders



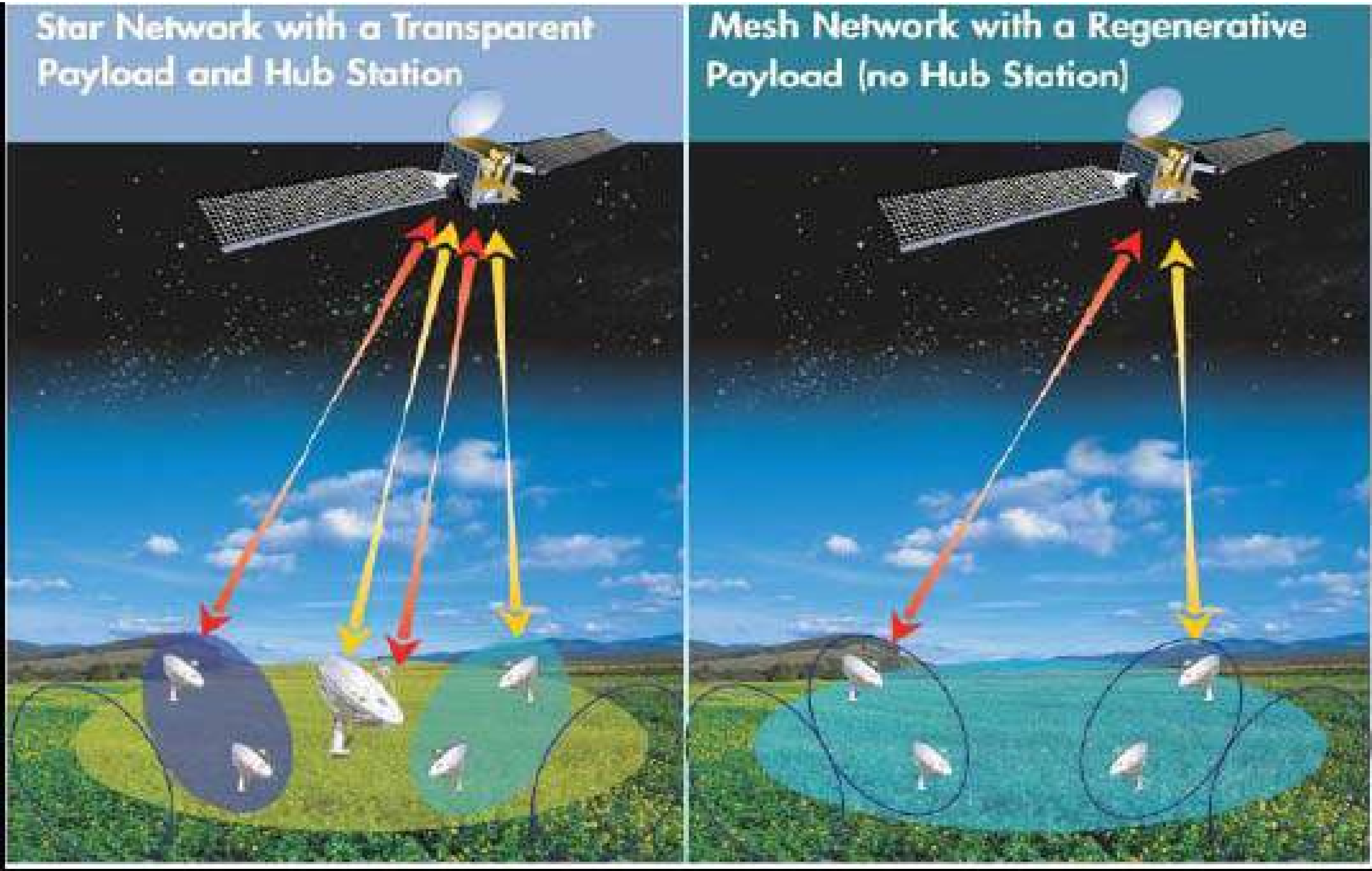
GNSS (Navigation) Transponder as a Part of Multifunctional Payload



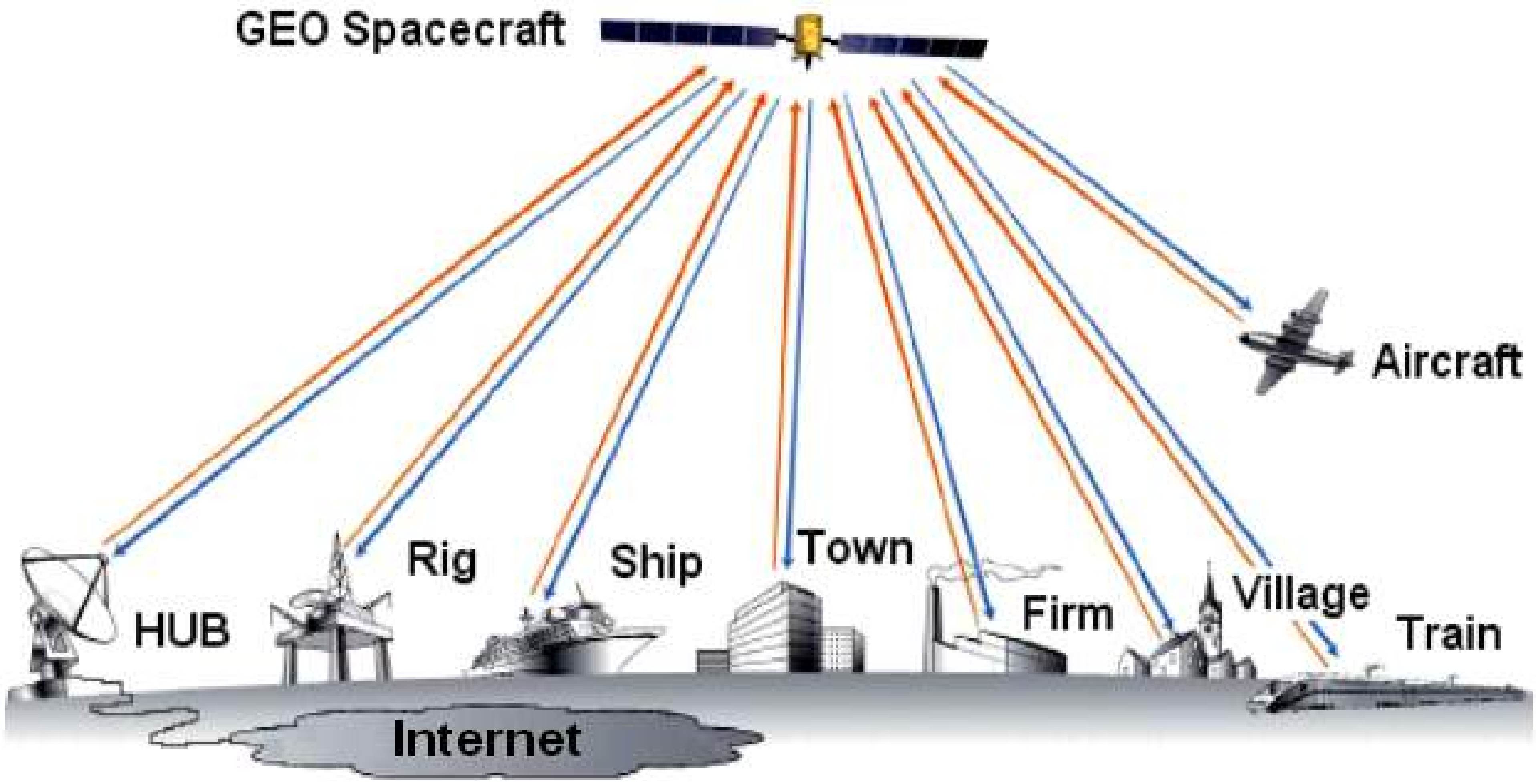
GEO Satellite Mission Services

– **Mobile Satellite Communications:**
• Maritime Mobile Satellite Communications
• Land (Road and Rail) Mobile Satellite Communications
• Aeronautical Mobile Satellite Communications
- Fixed Satellite Communications:
• DVB-RCS Communication via Star and Mesh Networks (Two-way VSAT)
• DVB-RCS Voice, Data and Video over IP (VDVoIP) and IPTV Services
• Communication links between Mobile and Ground Control Centers (GCC)
• Mobile Services (Traffic Services and Operational Communication)
• Passenger Services : VDVoIP, Telephony, Internet, SMS and so on
– **Satellite Navigation (GNSS) Augmentations:**
• Communication links between ground navigation system facilities (VSAT)
• Broadcast of GNSS Augmentation signals to mobiles via Navigation Payload
• Broadcast of GNSS signals from mobiles to GC
– **Service Coverage : Africa and Middle East**

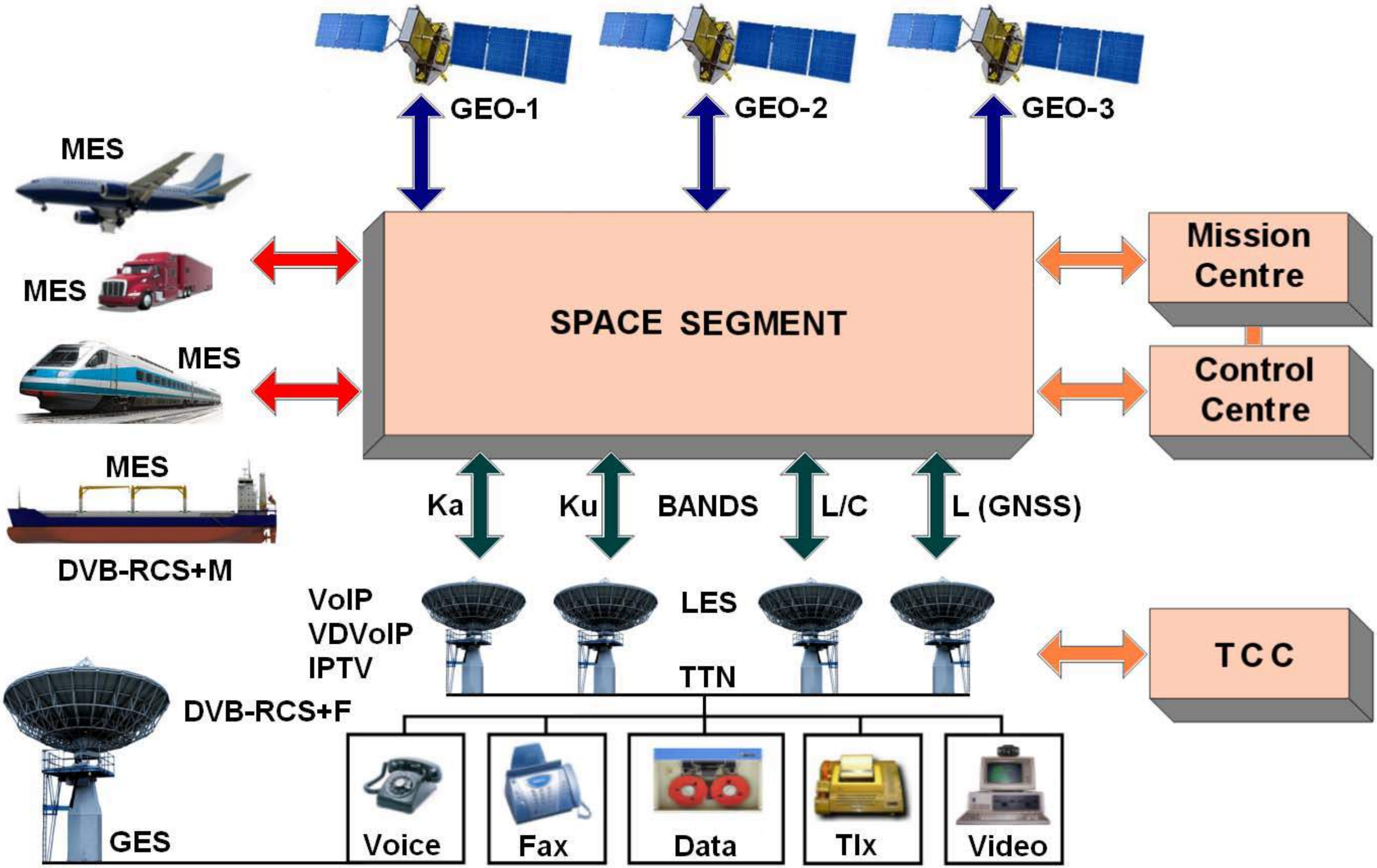
Satellite Networks via Transparent and Regenerative Transponders



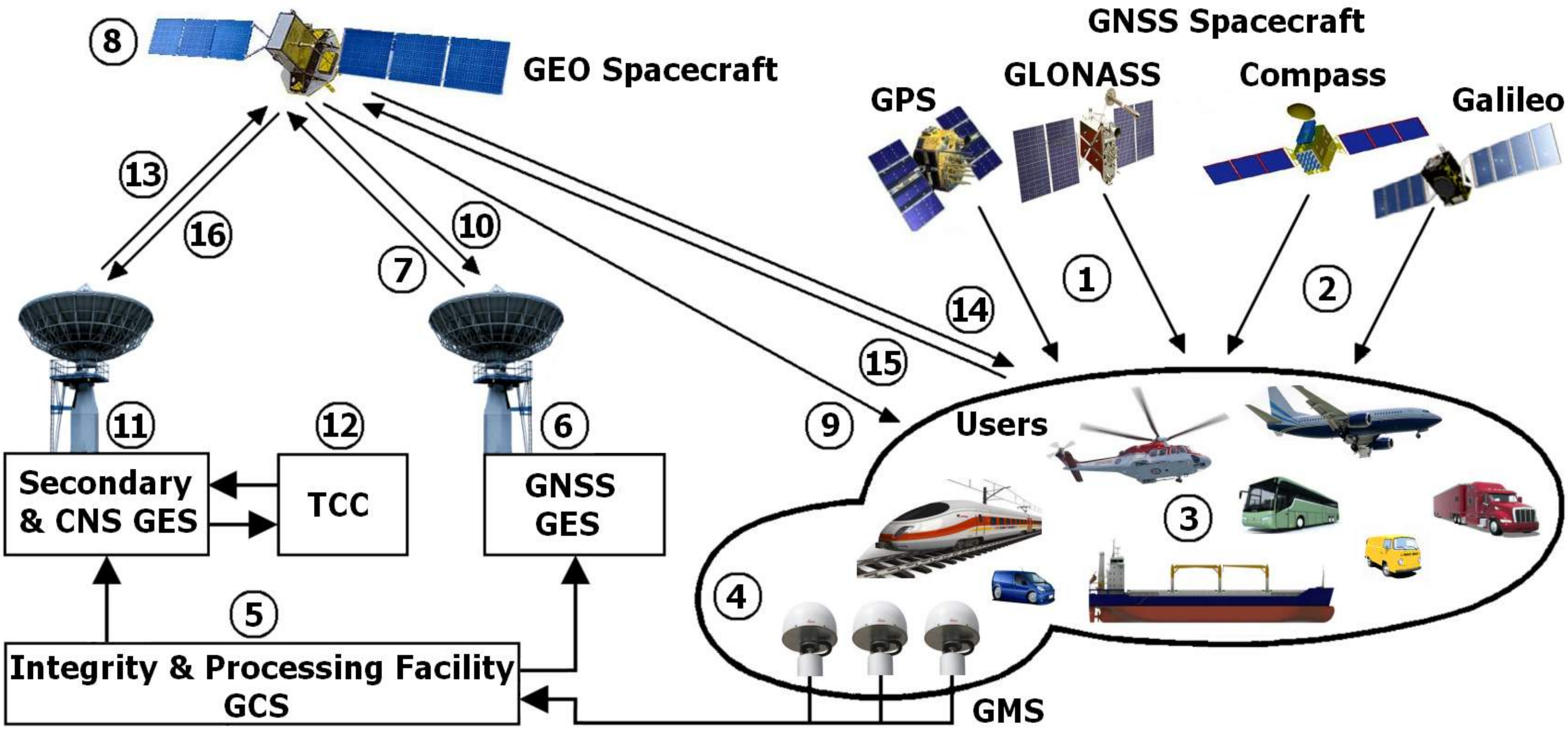
DVB-RCS Concept of Global Broadcasting Satellite System (GBSS)



Our Proposal: Future South African GEO Constellation of CNS/DVB-RCS Networks for Mobile (MES) and Fixed Earth Stations (FES)



Space Segment of Communication (GEO) and Global Navigation Satellite System (GNSS) for CNS



1. Highlights of ASAS Network

As observed previous figure, all mobile users (3) receive navigation signals (1) from GNSS-1 of GPS or GLONASS satellites. In the near future can be used GNSS-2 signals of EU Galileo and Chinese Compass satellites (2). These GNSS signals are also received by all Reference Stations (RS) or Ground Monitoring Stations (GMS) of integrity monitoring networks (4) operated by governmental agencies within Africa and Middle East. The monitored data are sent to a regional Integrity and Processing Facility of Master Station or Ground Control Station (GCS) (5), where the data is processed to form the integrity and WADGNSS correction messages, which are then forwarded to the Primary GNSS GES (6).

2. Highlights of ASAS Network

At the Ground Earth Station (GES), the navigation signals are precisely synchronized to a reference time and modulated with the GIC message data and WADGNSS corrections. The signals are sent to a satellite on the C-band uplink (7) via communication payload located in Inmarsat and Artemis satellite (8), the augmented signals are frequency-translated and after sent to the mobile user on GNSS L1 and new L5-band like GPS (9) and also to the C-band (10) used for maintaining the navigation signal timing loop. The timing of the signal is done in a very precise manner in order that the signal will appear as though it was generated on board the satellite as a GPS or GLONASS ranging signal.

3. Highlights of ASAS Network

The Secondary GNSS GES can be separate or installed in Communication CNS GES (11), as a hot standby in the event of failure at the Primary GNSS GES. The Traffic Control Centres (TCC) terminals (12) could send request for CNS information by Voice, Data and Video (VDV) on C-band uplink (13) via Communication payload located in GEO spacecraft and on C-band downlink (14) to mobile users (3). The mobile users are able to send augmented CNS data on L-band uplink (15) via GEO communication payload and downlink (16). The TCC sites are processing CNS data received from mobile users and displaying on the like radar screen their current positions very accurate and in the real time for traffic control and management purpose.

4. Highlights of ASAS Network

The most important and unique sequence in this stage is that traffic controller can use the position data for managing certain traffic in more safe way than surveillance radar for collision avoidance, during any weather or visibility conditions.
In addition, on mobile request TCC operator may send position data of each mobile in vicinity for enhanced collision avoidance (13 and 14). Each mobiles, such as ships and aircraft will be also able to provide polling of position data memorized in TCC for any adjacent mobile (ship or aircraft) and use it for enhanced collision avoidance.

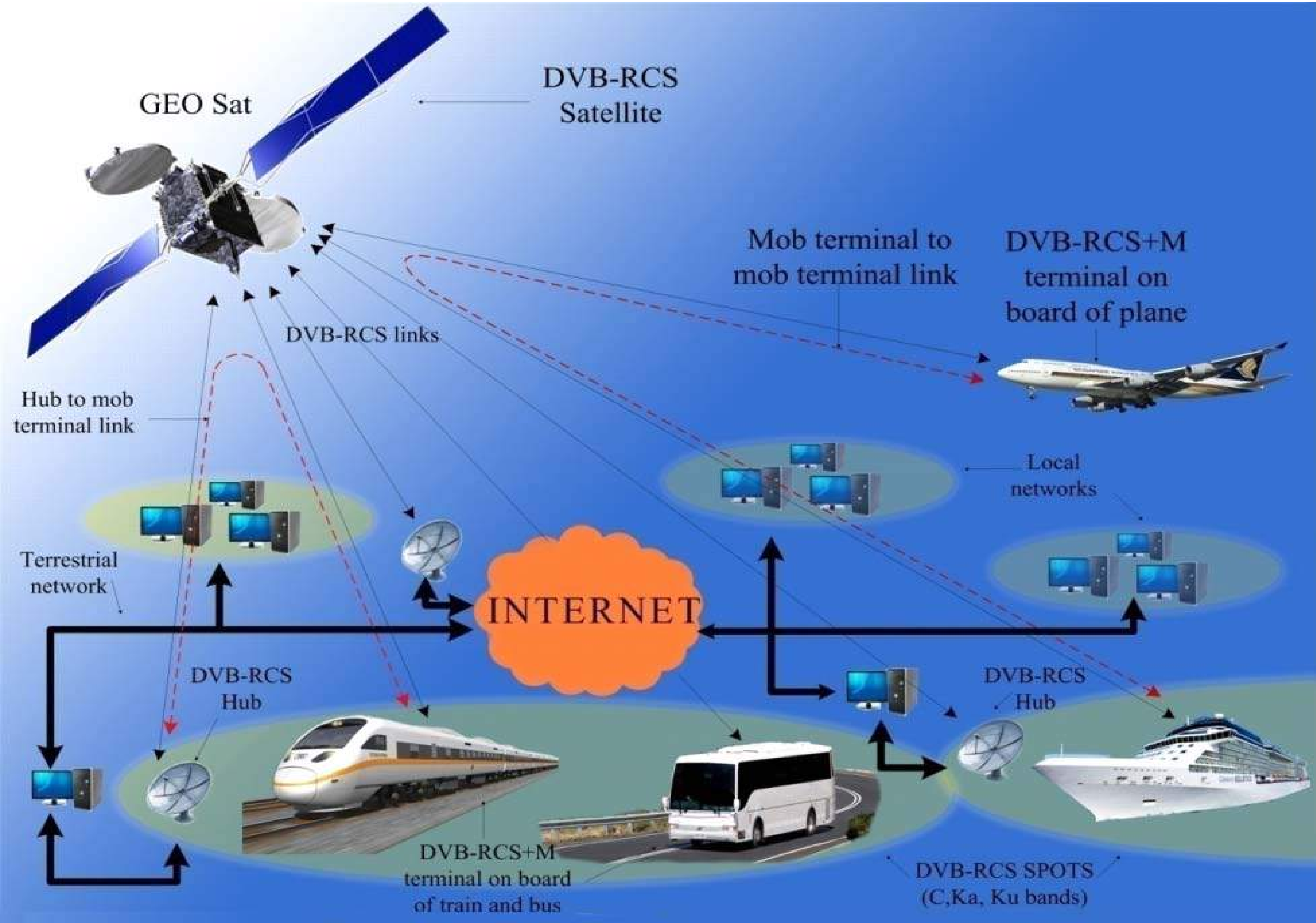
Future African Multipurpose GEO Spacecraft Coverage

DVB-RCS Bands and Backhaul

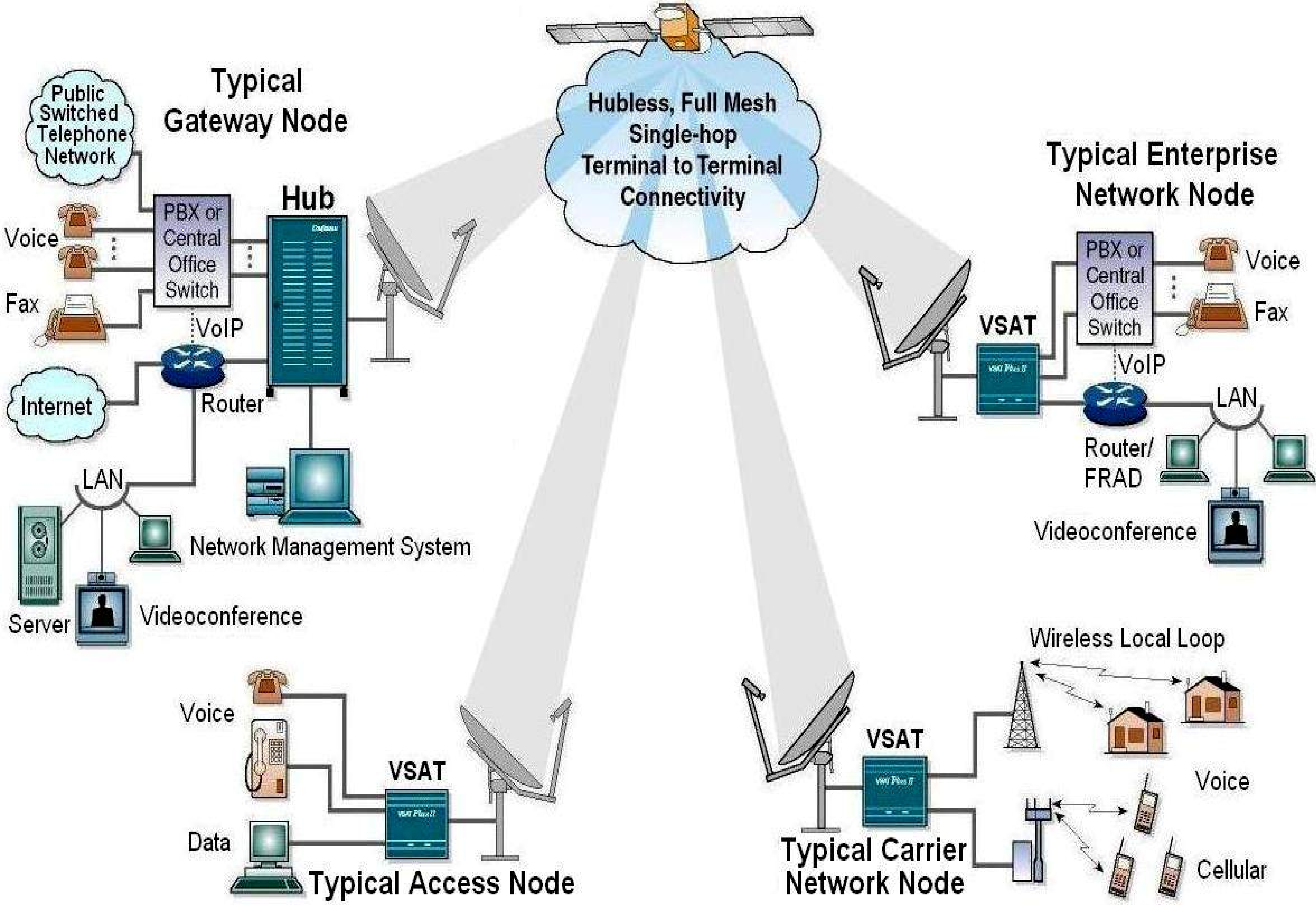
- Hub provides Voice, Data and Video over IP
- (VDVoIP) & IPTV on C (4-8 GHz), Ku (12-18 GHz)
- or Ka-band (27- 40 GHz) antenna interfaces and
- extends the Terrestrial Broadband, ISP, Video
- Broadcasting, UMTS/GPRS (Universal Mobile
- Telecommunications System/General Packet
- Radio Service), Asynchronous Transfer Mode
- (ATM), ISDN/ADSL, Fiber Optic Lines, Terrestrial
- Telecommunication Network (TTN), Cellular
- Networks, Virtual Private Networks (VPN), etc.

Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) Solutions

Interactive Internet via DVB-RCS+M Backbone for Mobile Applications



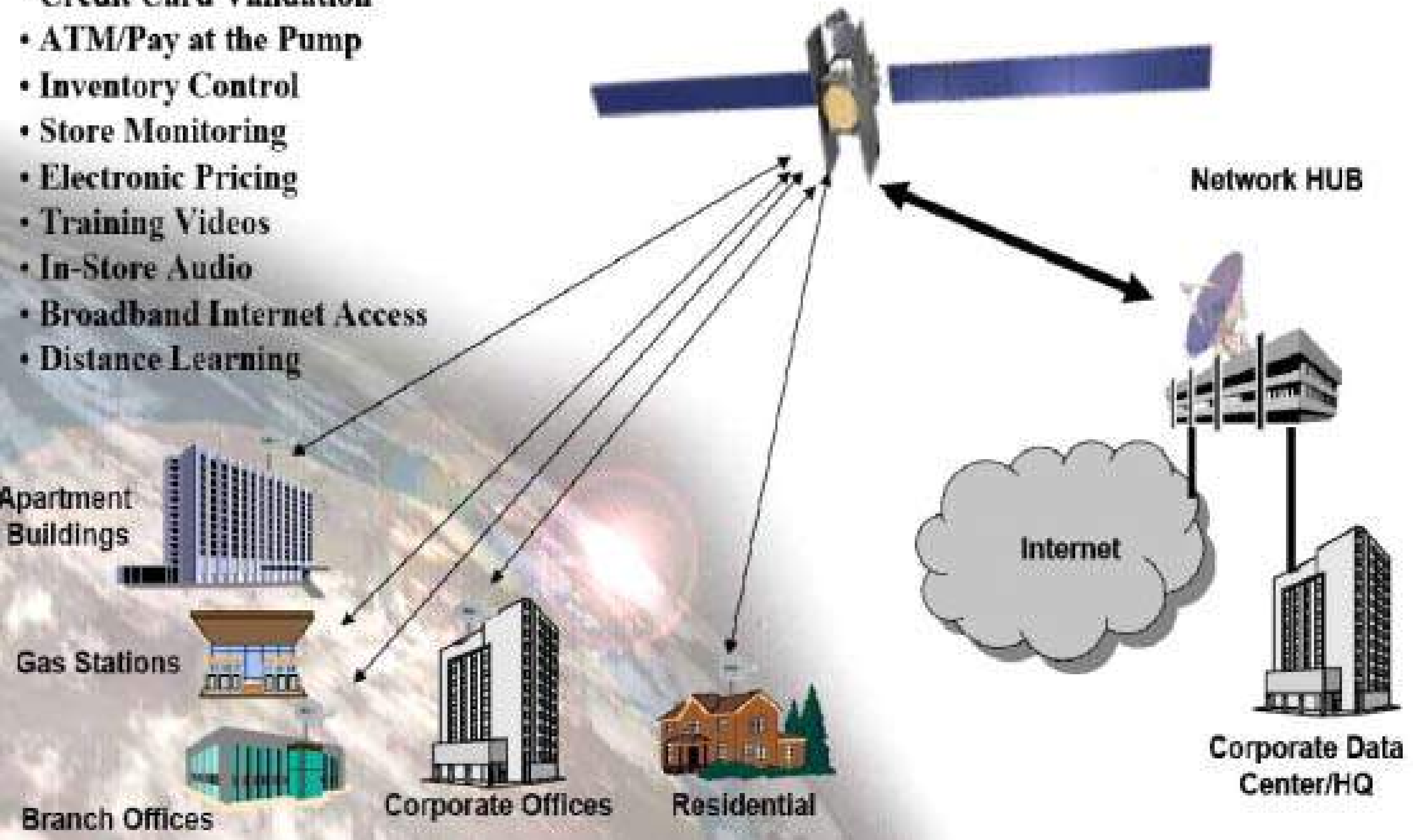
DVB-RCS/S2 VSAT Network Configuration



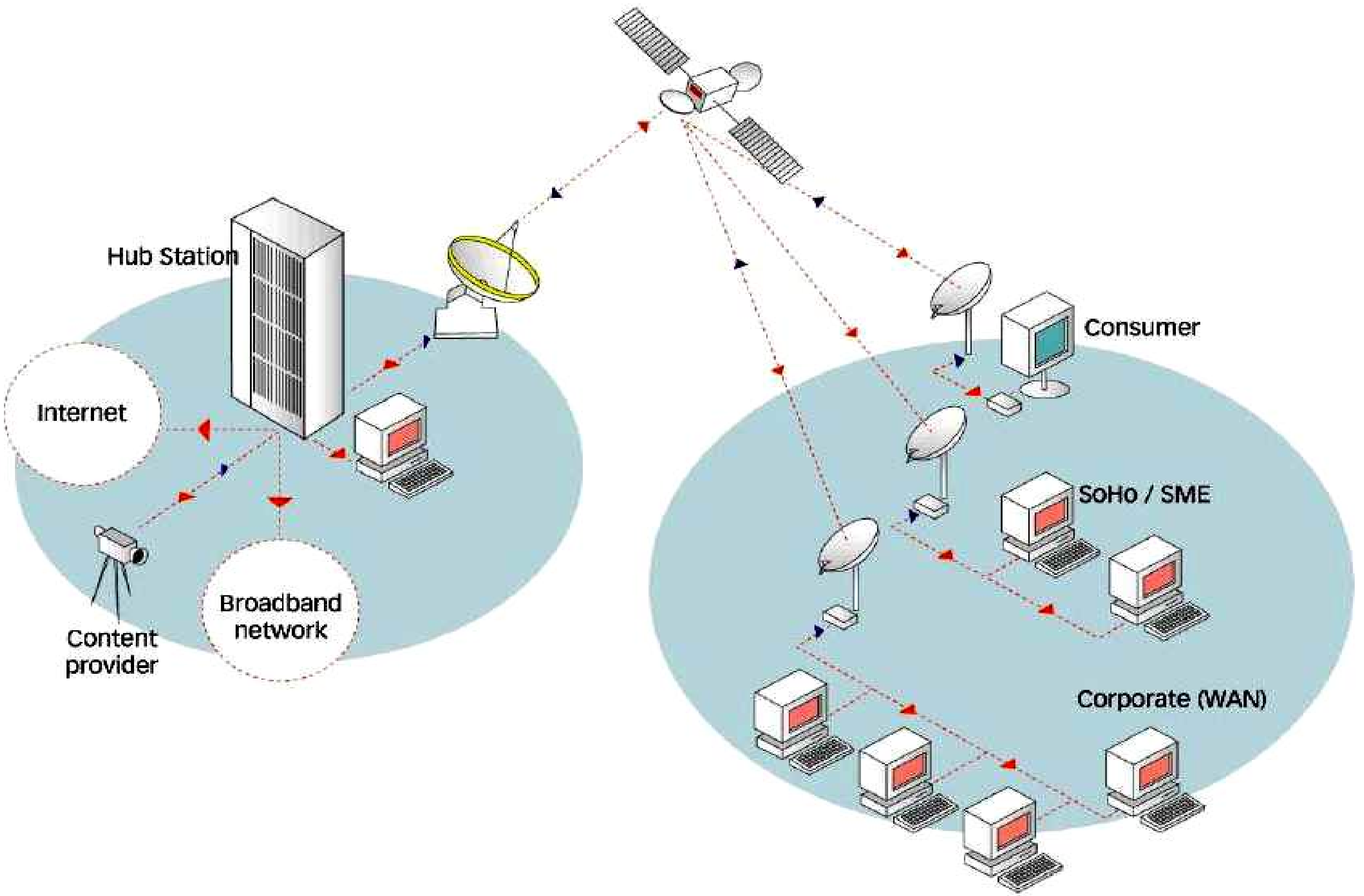
Typical Fixed VSAT Satellite Network

Applications

- Credit Card Validation
- ATM/Pay at the Pump
- Inventory Control
- Store Monitoring
- Electronic Pricing
- Training Videos
- In-Store Audio
- Broadband Internet Access
- Distance Learning



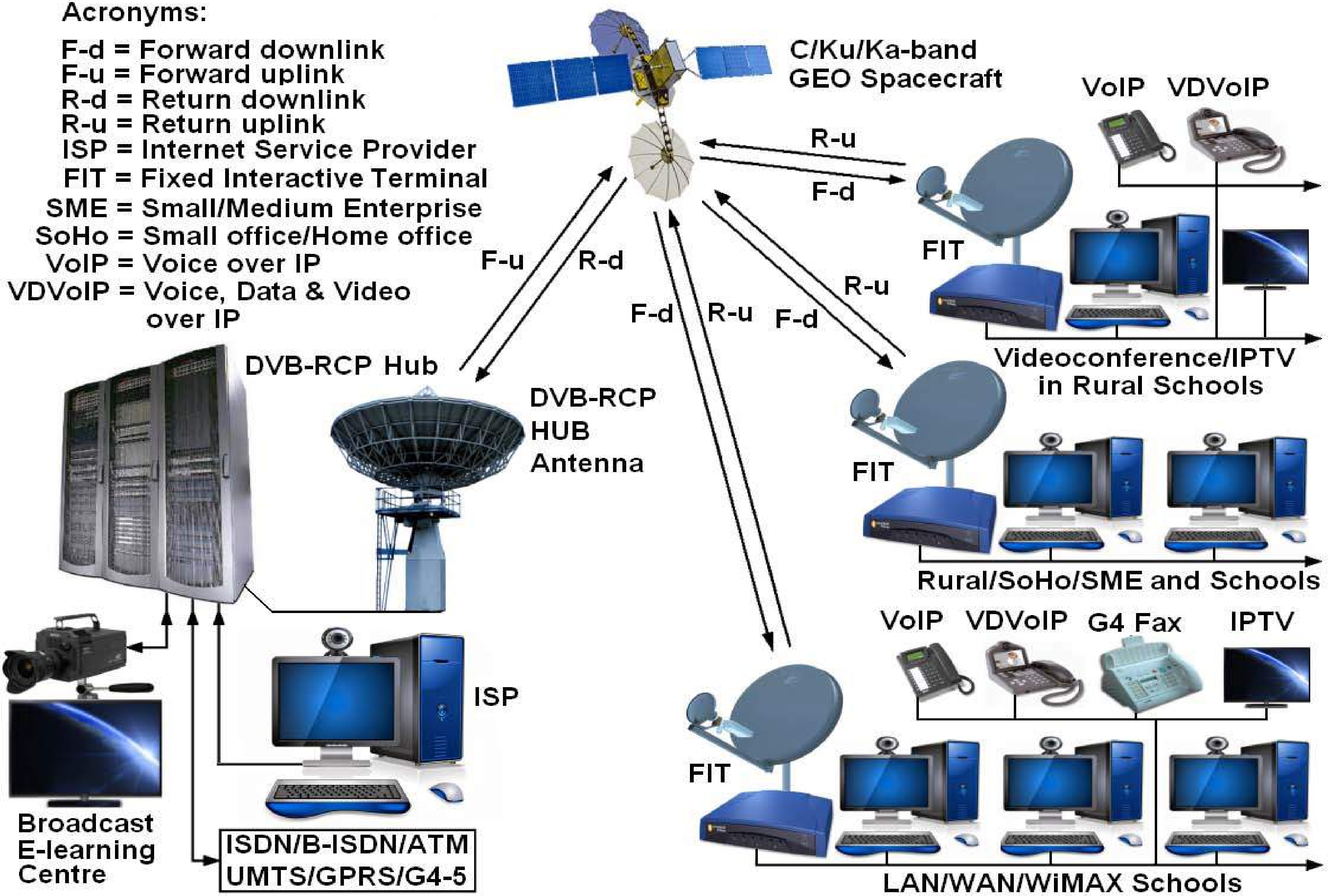
DVB-RCS Backbone to Rural Areas



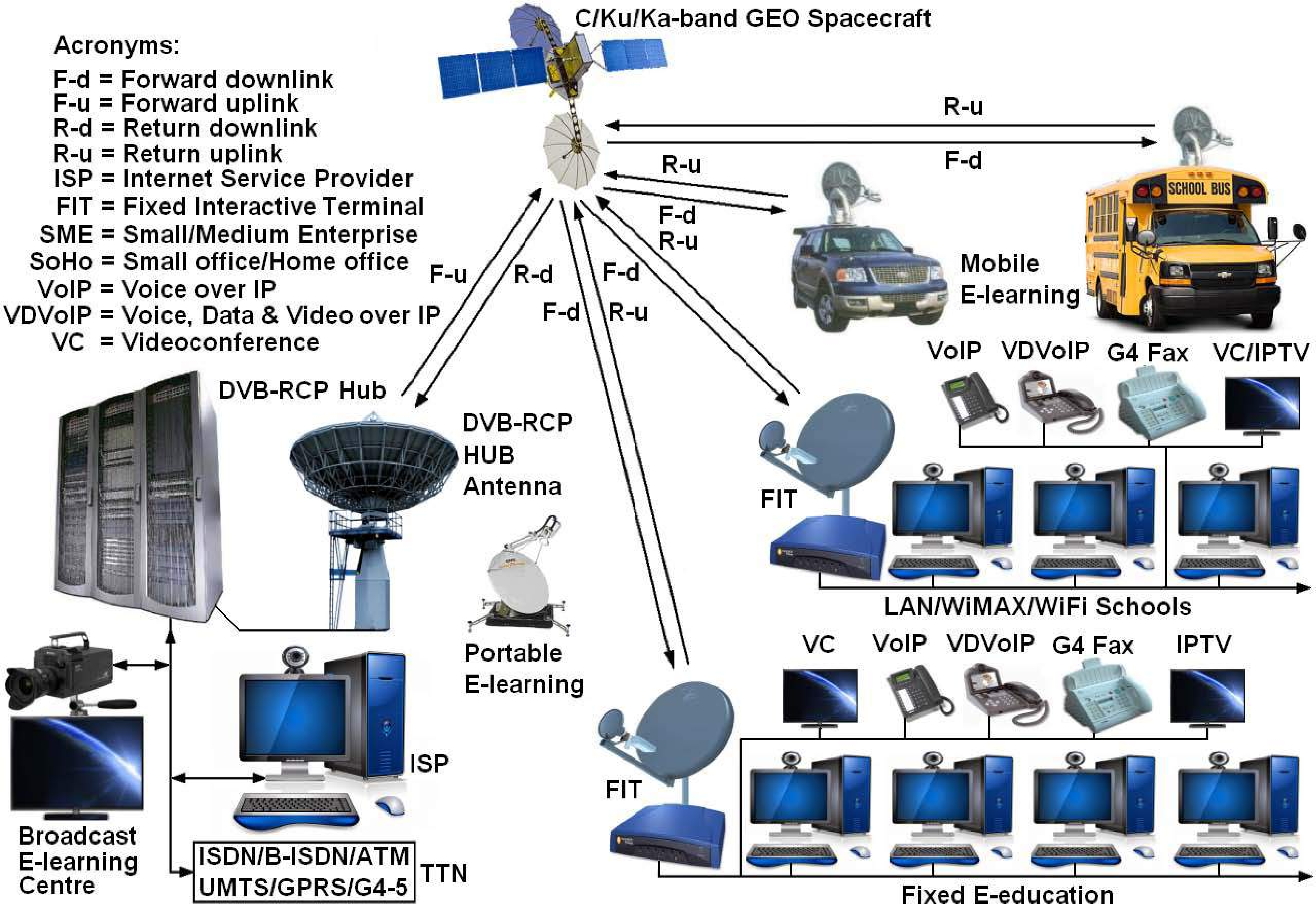
Fixed DVB-RCS Network Designed in 2000

Acronyms:

F-d = Forward downlink
F-u = Forward uplink
R-d = Return downlink
R-u = Return uplink
ISP = Internet Service Provider
FIT = Fixed Interactive Terminal
SME = Small/Medium Enterprise
SoHo = Small office/Home office
VoIP = Voice over IP
VDVoIP = Voice, Data & Video over IP



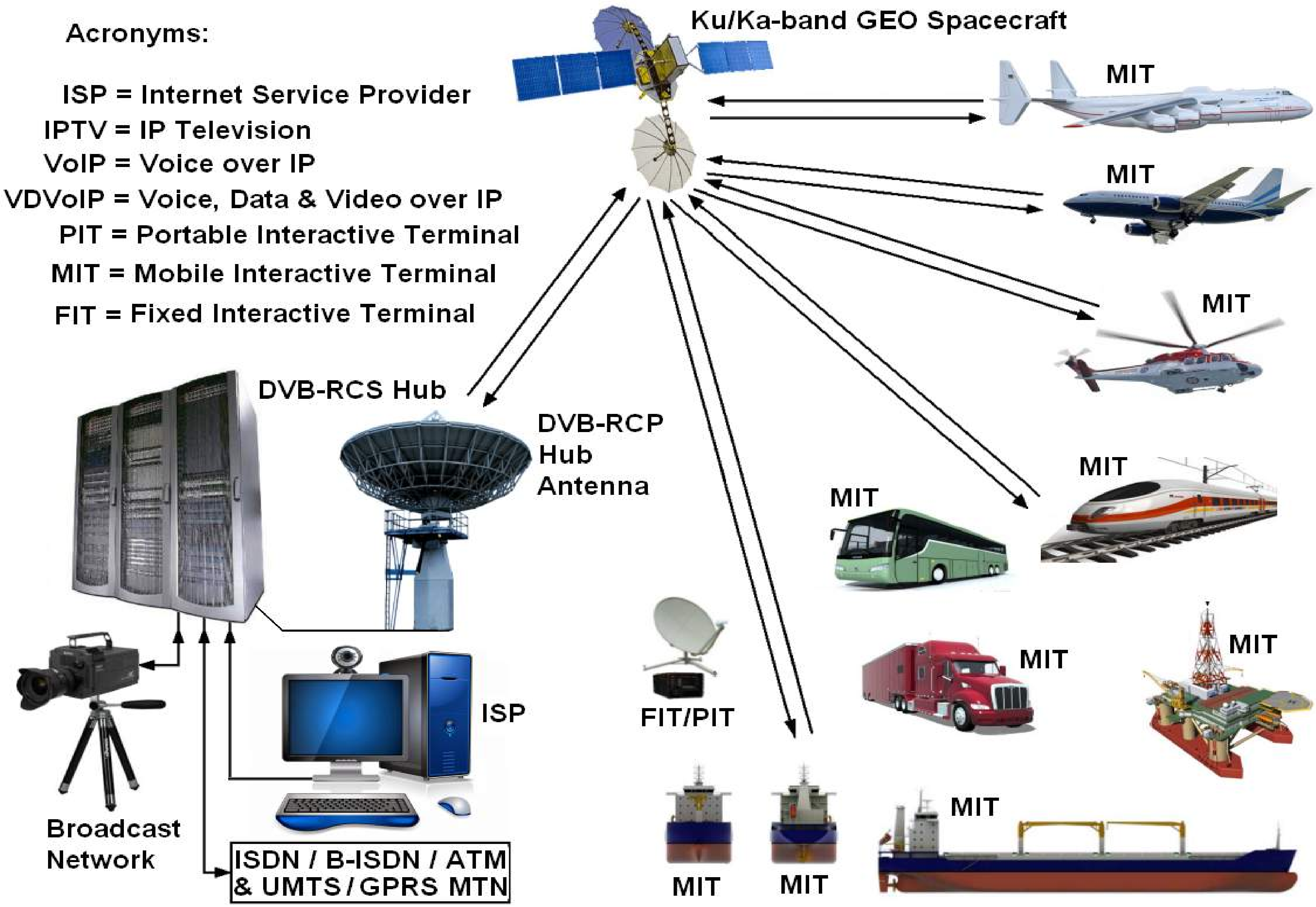
E-education via DVB-RCS Network Designed in 2000



Mobile DVB-RCS Network Designed in 2000

Acronyms:

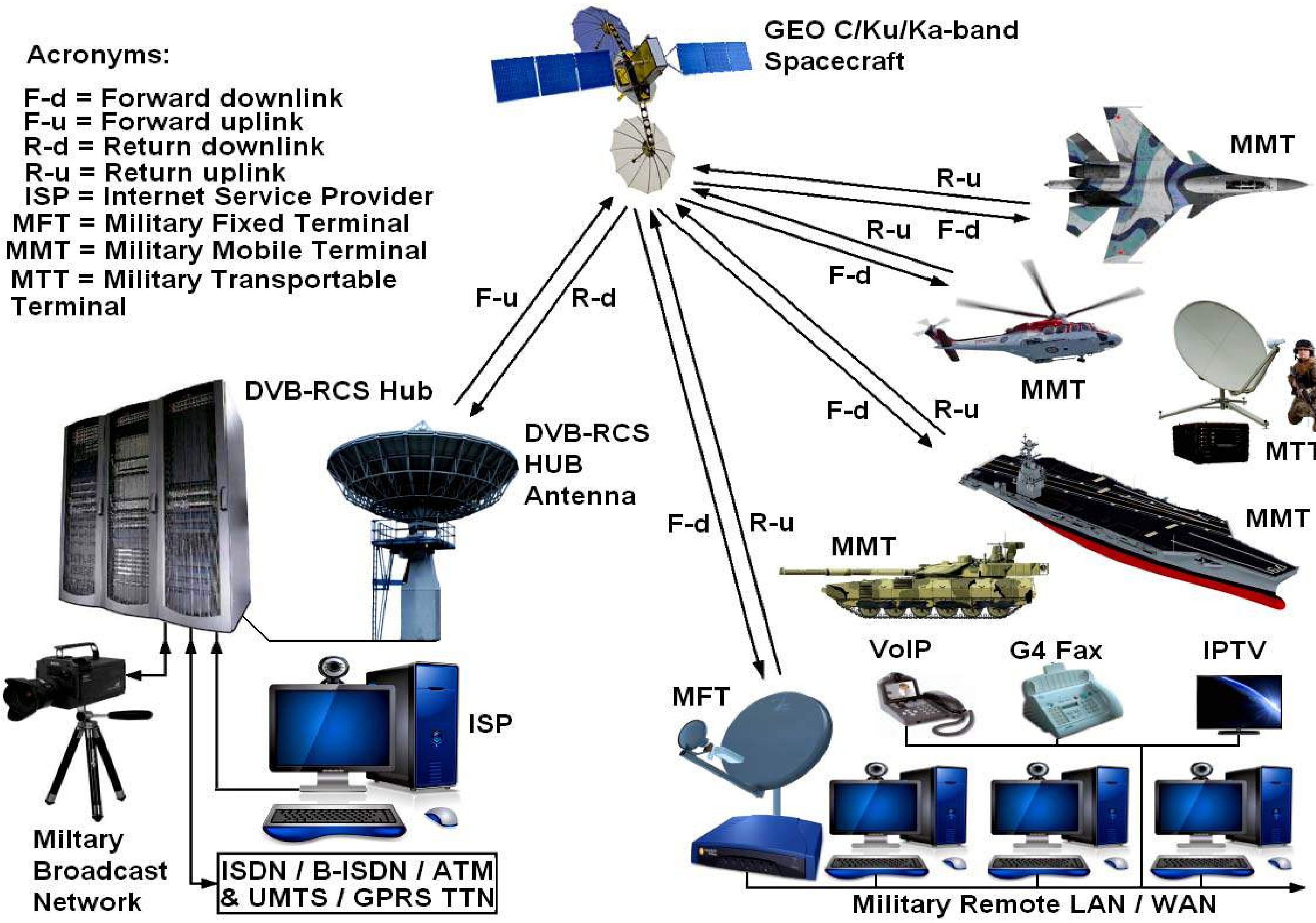
ISP = Internet Service Provider
IPTV = IP Television
VoIP = Voice over IP
VDVoIP = Voice, Data & Video over IP
PIT = Portable Interactive Terminal
MIT = Mobile Interactive Terminal
FIT = Fixed Interactive Terminal



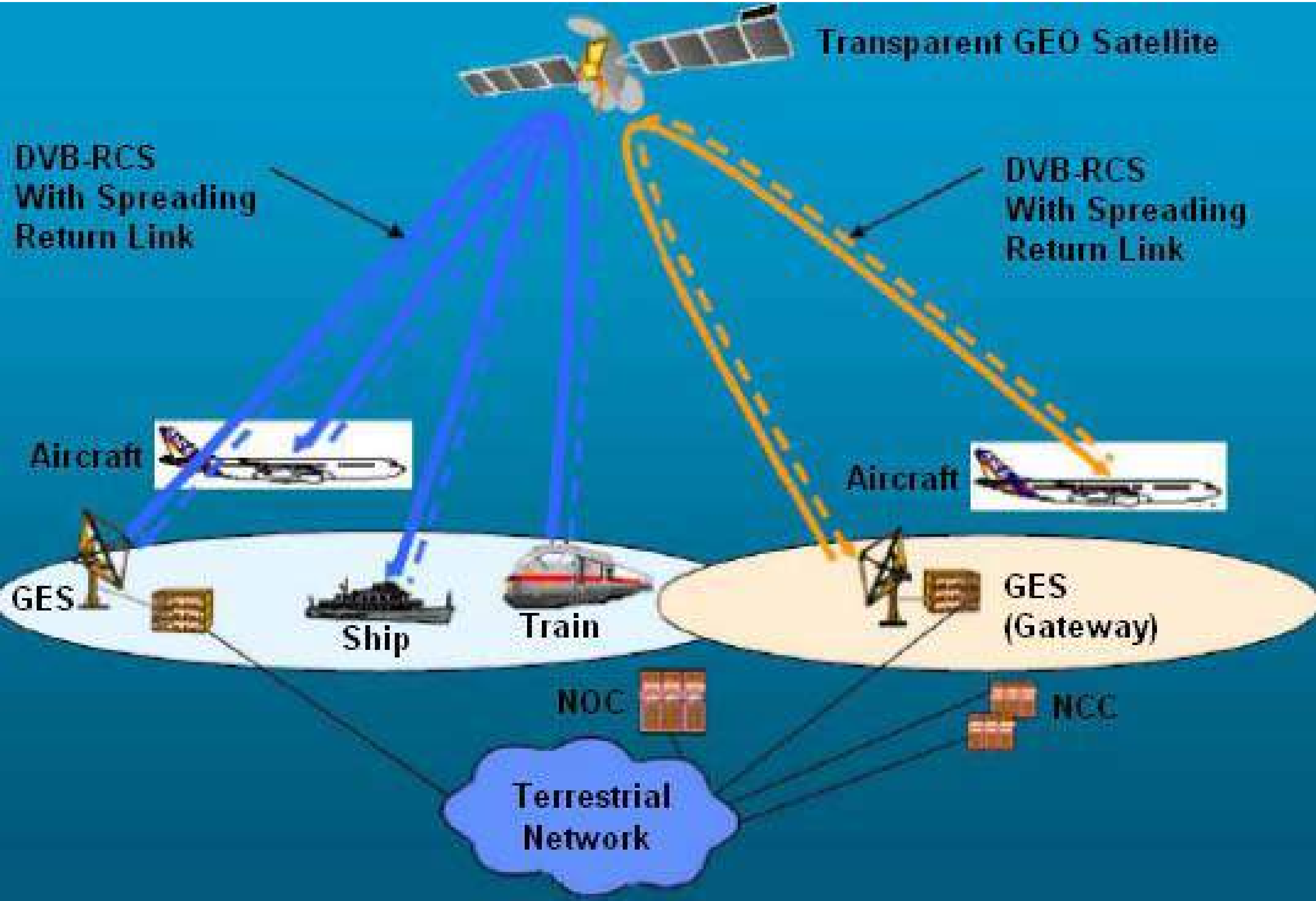
Military DVB-RCS Network Designed in 2000

Acronyms:

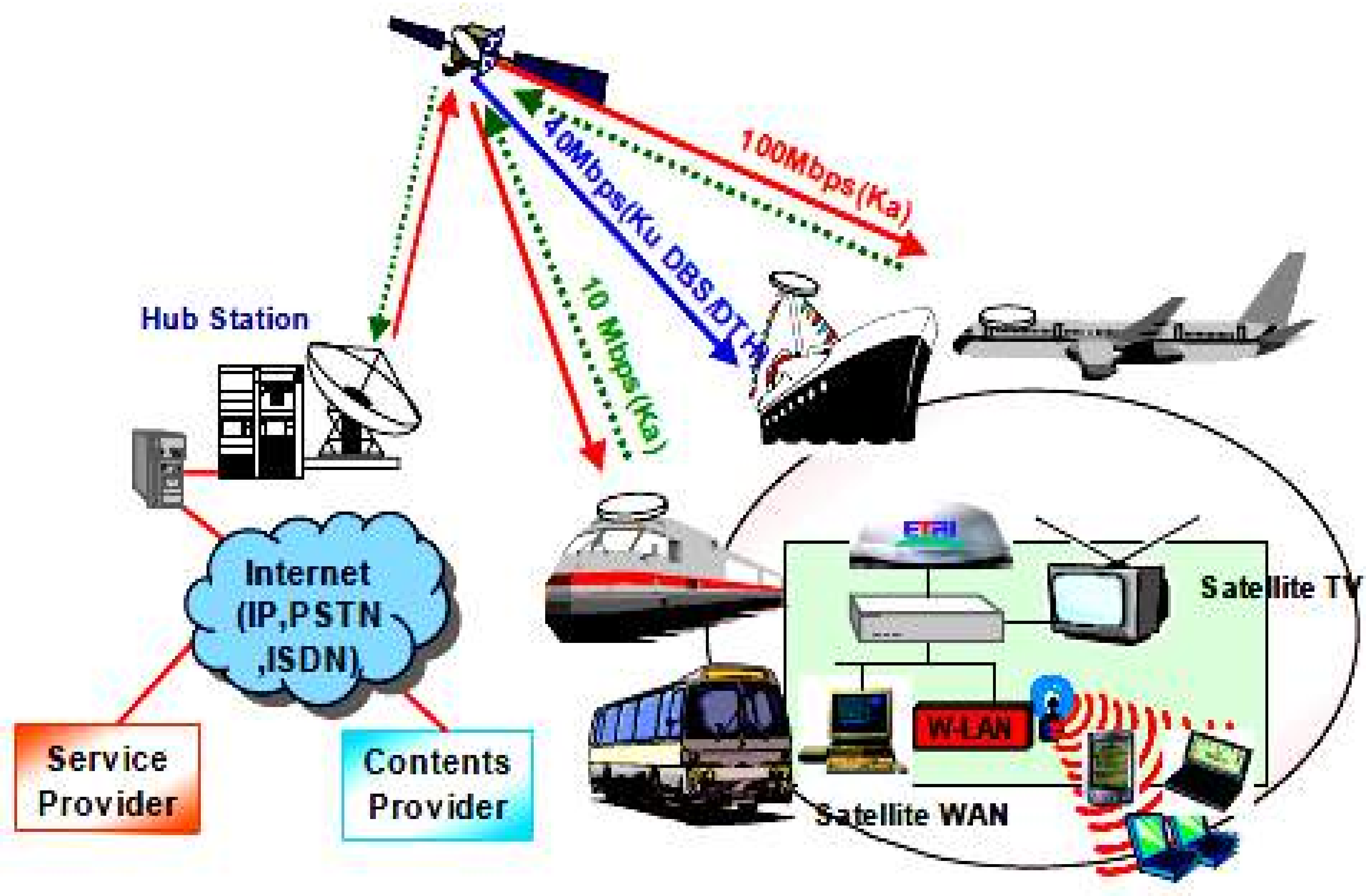
F-d = Forward downlink
F-u = Forward uplink
R-d = Return downlink
R-u = Return uplink
ISP = Internet Service Provider
MFT = Military Fixed Terminal
MMT = Military Mobile Terminal
MTT = Military Transportable Terminal



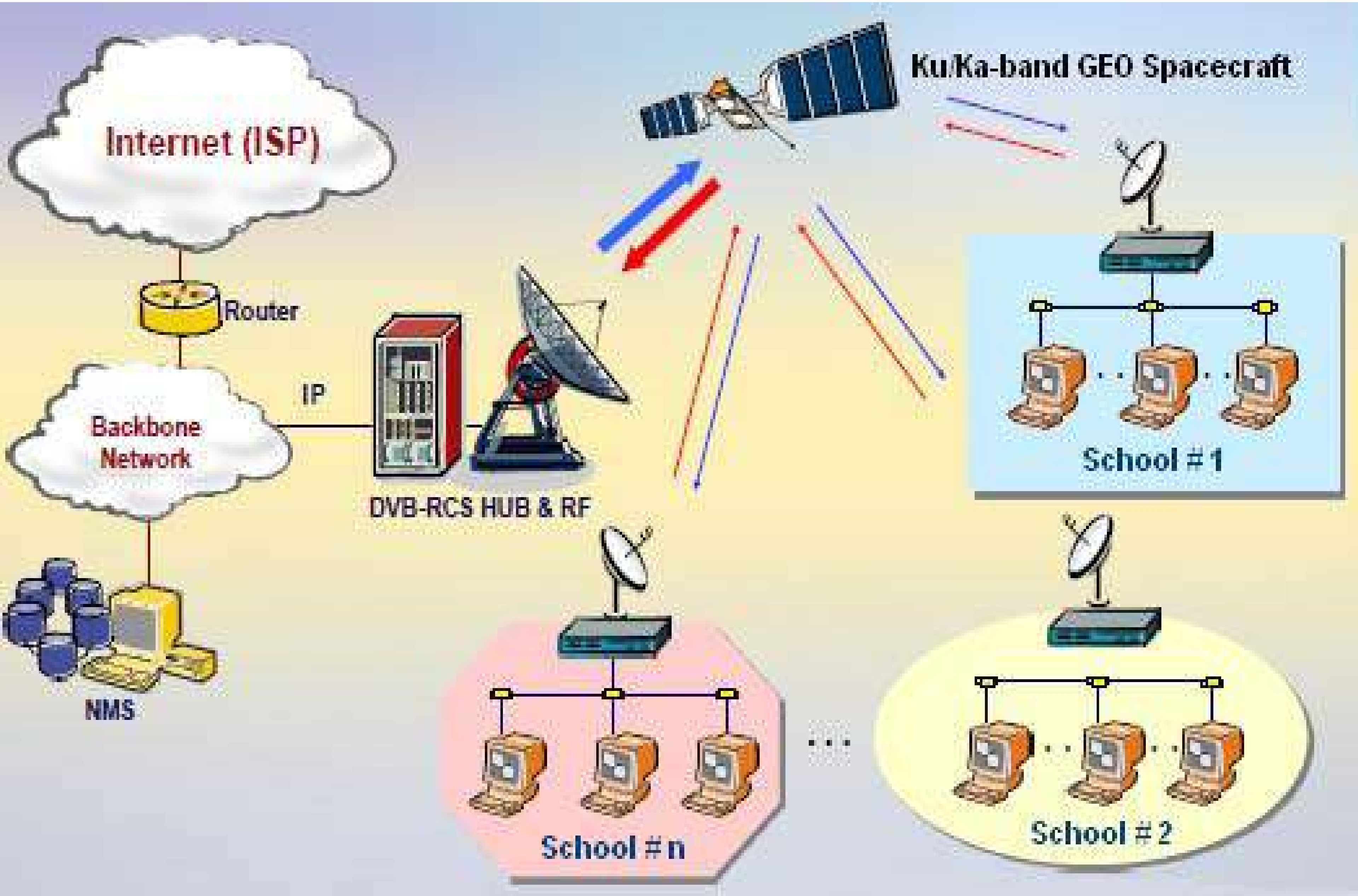
ESA Design of Mobile DVB-RCS Applications in 2006



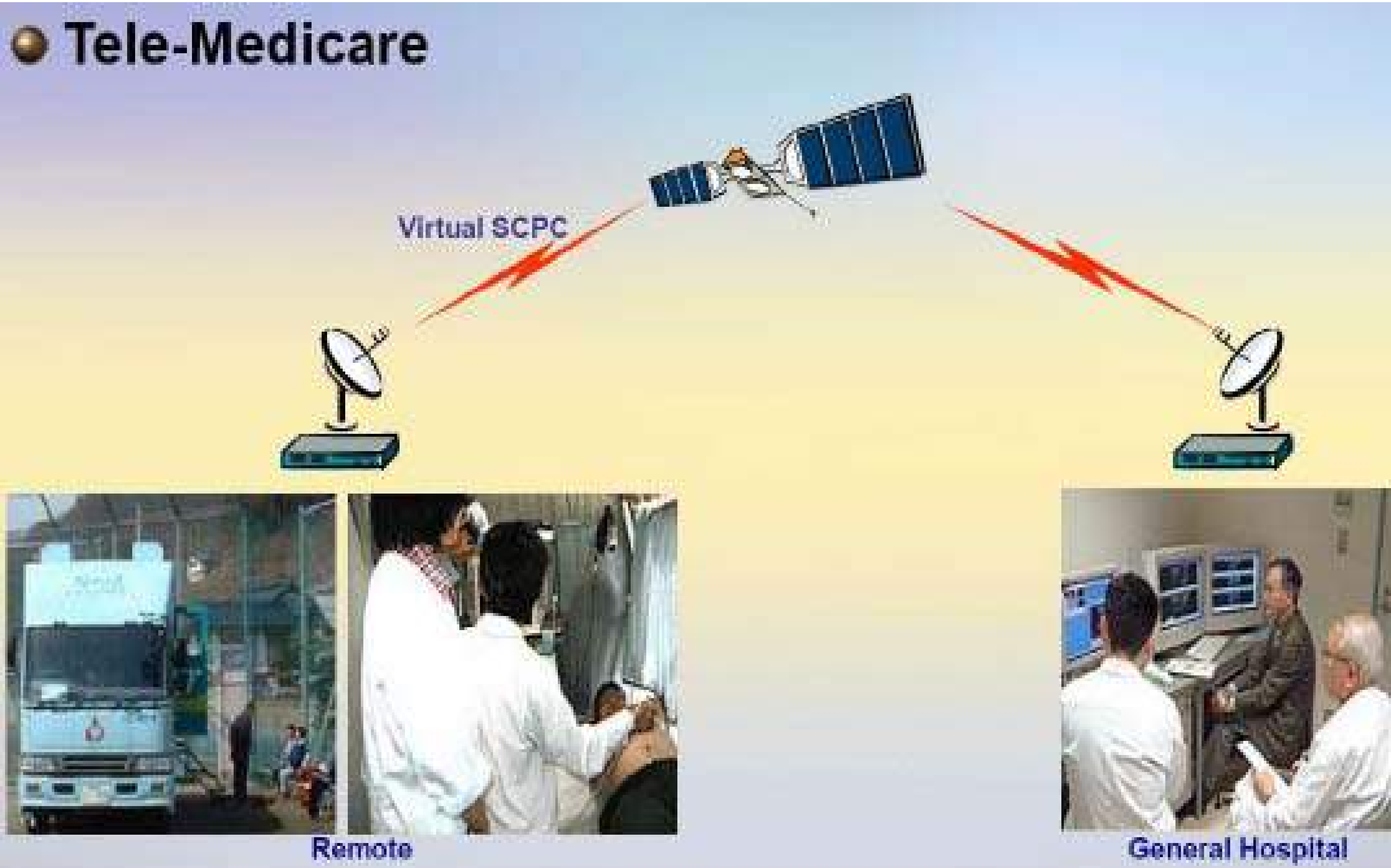
DVB-RCS Architecture for Mobile Broadband



E-education via DVB-RCS



E-medicine via DVB-RCS

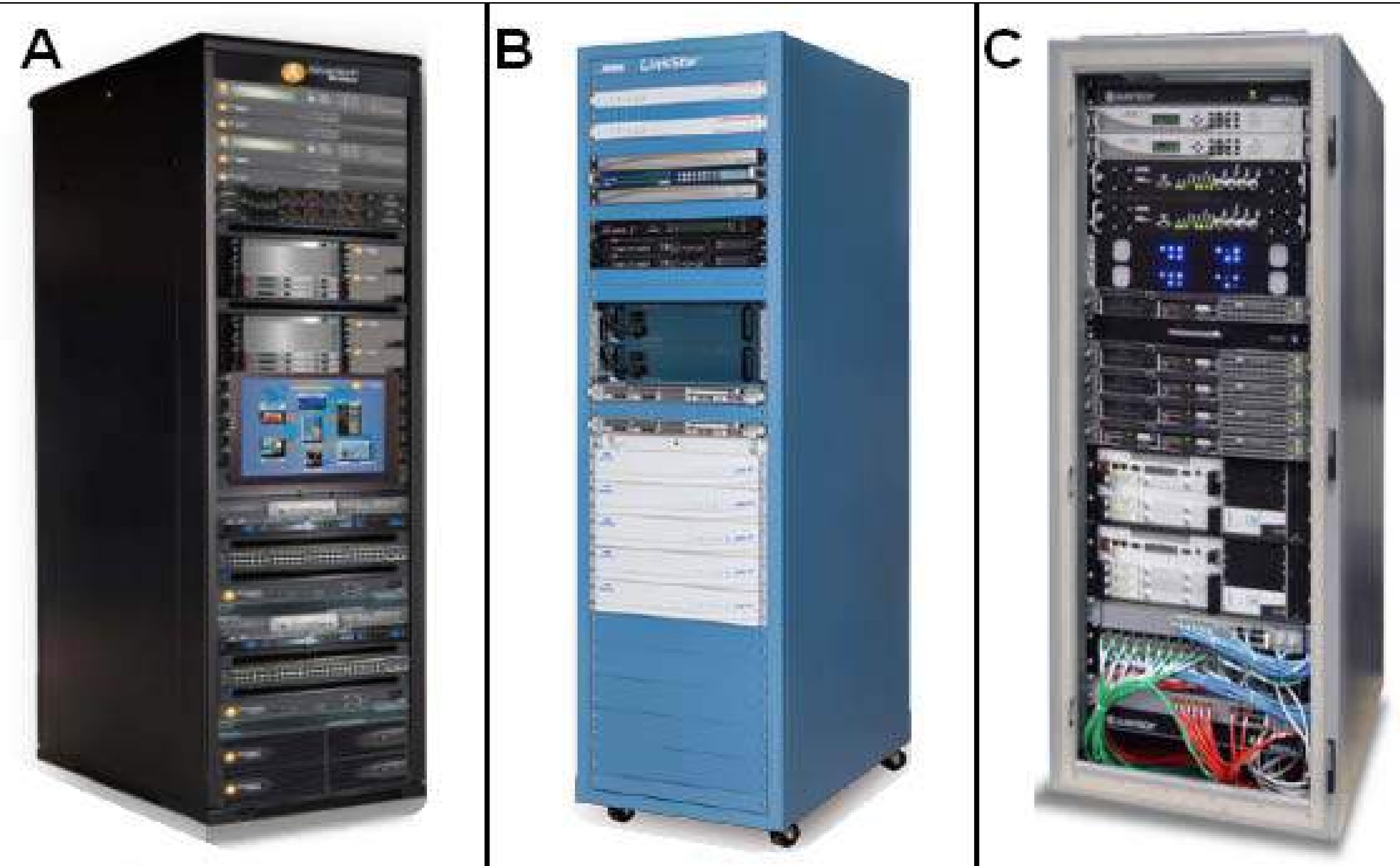


Wi-Fi Solutions via DVB-RCS

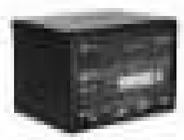
Emergency Response via DVB-RCS

- **Monitoring & Control**

DVB-RCS HUB Terminals of A) Advantech; B) ViaSat and C) Hughes



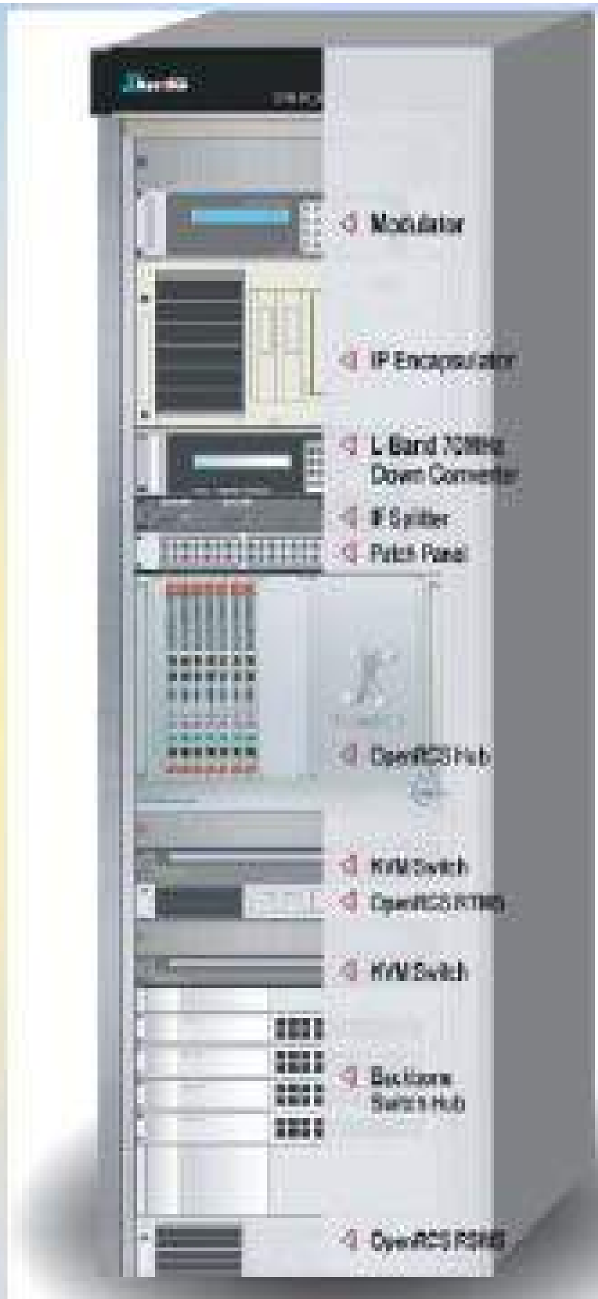
Advantech Family of DVB-RCS HUB Terminals

Type of Terminal	Discovery	Challenger	Millennium	Raptor
Advantech Hub Configuration **Type of Service**				
		Standard Rates Supported		
Throughput Mb/s*	155	n x 155	n x 155	155
Forward Link Mb/s*	135	n x 135	n x 135	135
Return Link Mb/s*	24	48 (2x24)	120 (5x24)	24
# of Terminals Supported	10 – 500	100 – 1,500	1,000 +	10 – 500
*Maximum. Other rates are available on special order. n = number of outbound links				

DVB-RCS Hub of S. Korean NanoTronix

Open-RCSTM HUB

- Ka / Ku or C band
- Forward link
  - Max. 80Mbps
  - TDM, IP over MPEG2-TS, DVB-S/S2
- Return link
  - Up to 2Mbps
  - MF-TDMA, IP over ATM(AAL5), DVB-RCS
- System capacity
  - VSAT : Max. 250 client PCs
  - Hub : Max. 10,000 VSAT



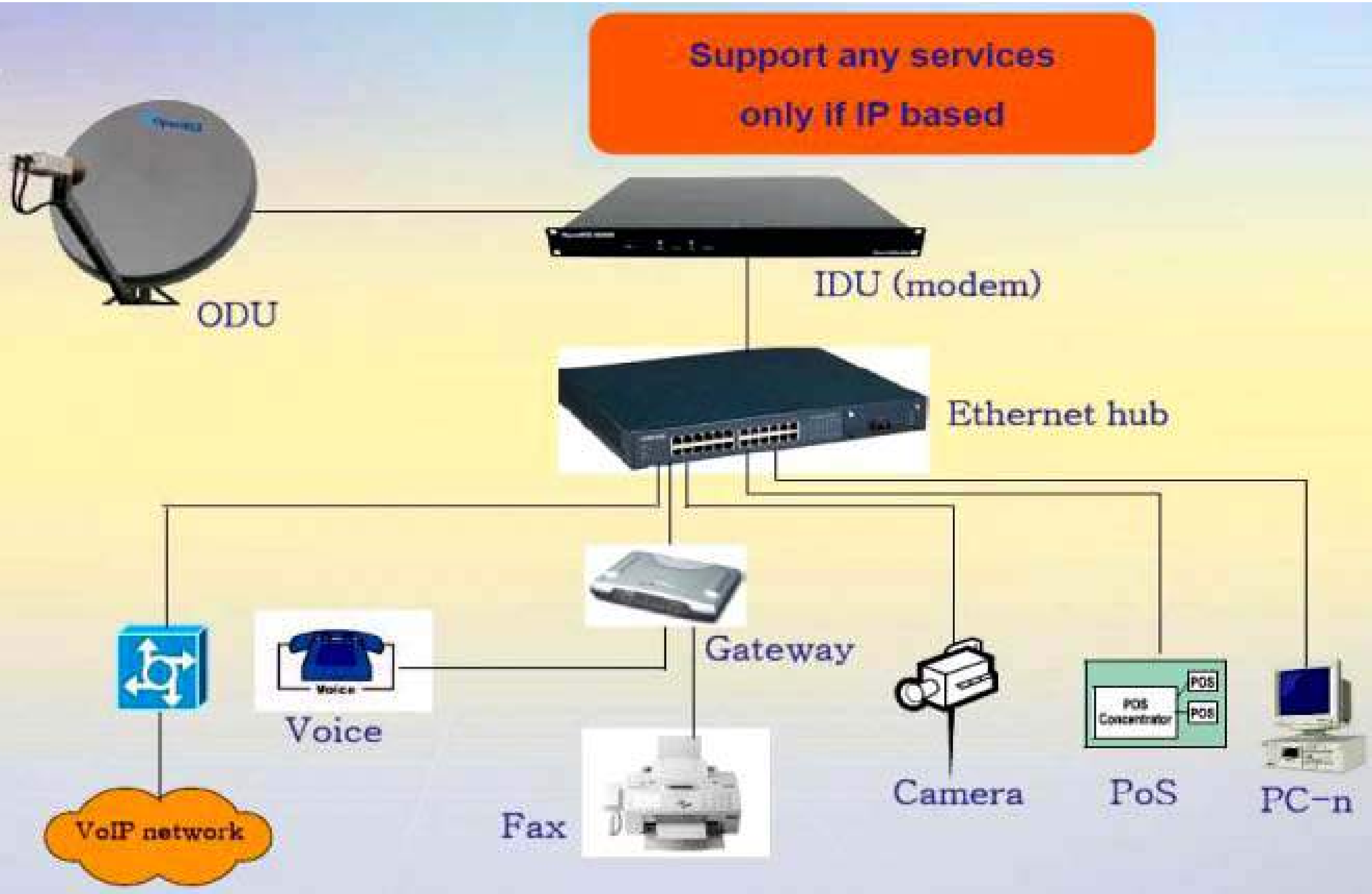
DVB-RCS Terminals or VSAT

- Two-Way PC Card
  - OpenRCS-4000 Series

- Two-Way Standalone for SOHO
  - OpenRCS-4200 Series

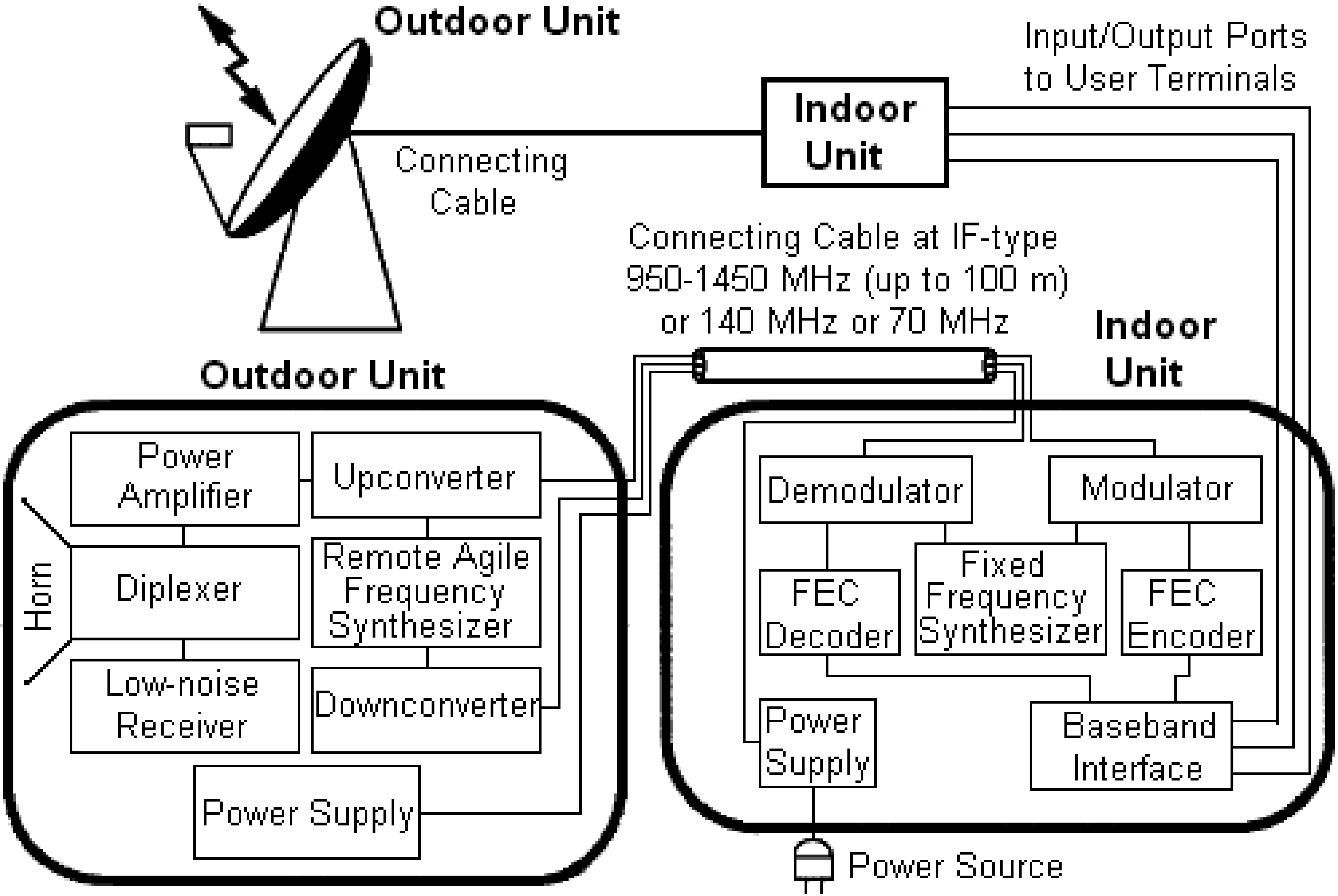
- Two-Way Standalone for enterprise
  - OpenRCS-4500 Series

DVB-RCS VSAT Configuration



Remote In-Door Units (IDU) Terminals with Antenna or Out-Door Unit (ODU)

DVB-RCS Indoor and Outdoor Units



Satellite Operators

The current GEO Satellite Constellation Suitable for Satellite Communication, Navigation and Surveillance (CNS) Space Segment over Africa and Middle East is as follows:

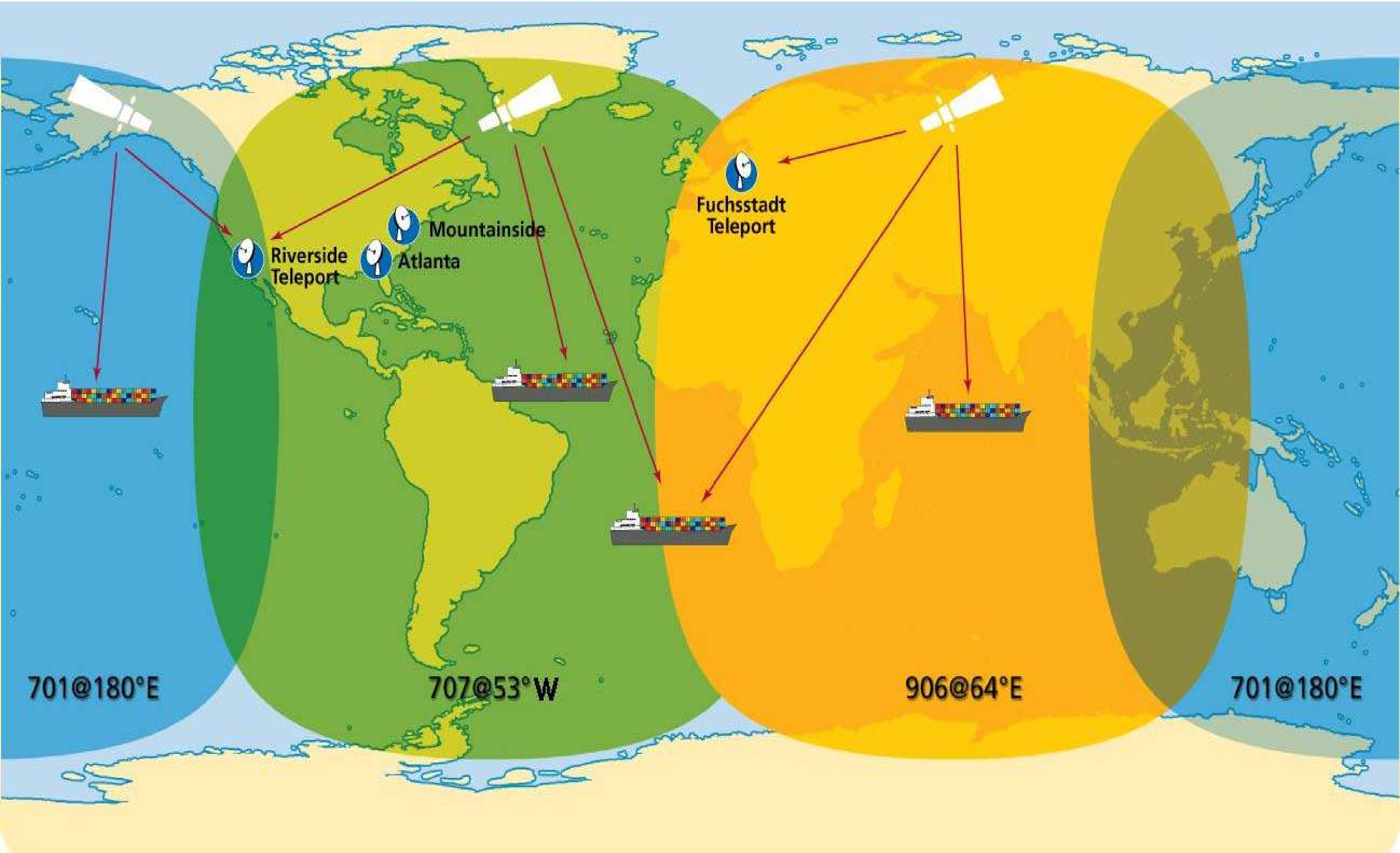
1. Inmarsat Indian Ocean region (IOR)
2. Inmarsat Atlantic Ocean Region East (AORE)
3. Artemis

The Current GEO Satellites suitable for Space Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) system over Africa and Middle East are as follows:

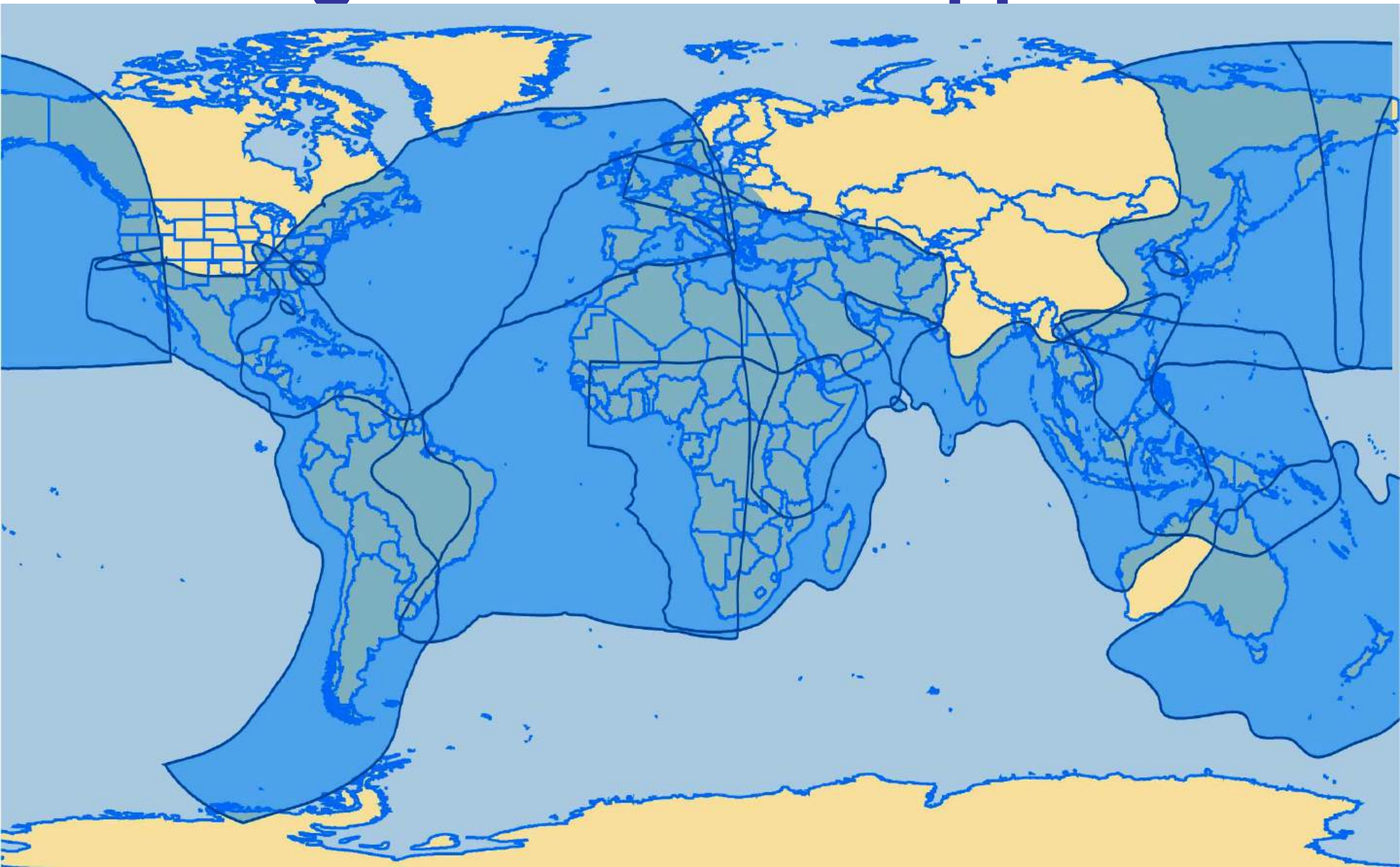
1. Intelsat IS802 Spot Beam and PanAmSat PAS10 Ku band
3. SES – NewSkies NSS71 Ku & C band
4. Eutelsat Ku & Ka band W3A

Research Group in Space Science at DUT already proposed a Multipurpose Space Segment of three GEO satellites for CNS over Africa and Middle East offering L/C, Ku and Ka-band with regional and spot coverages.

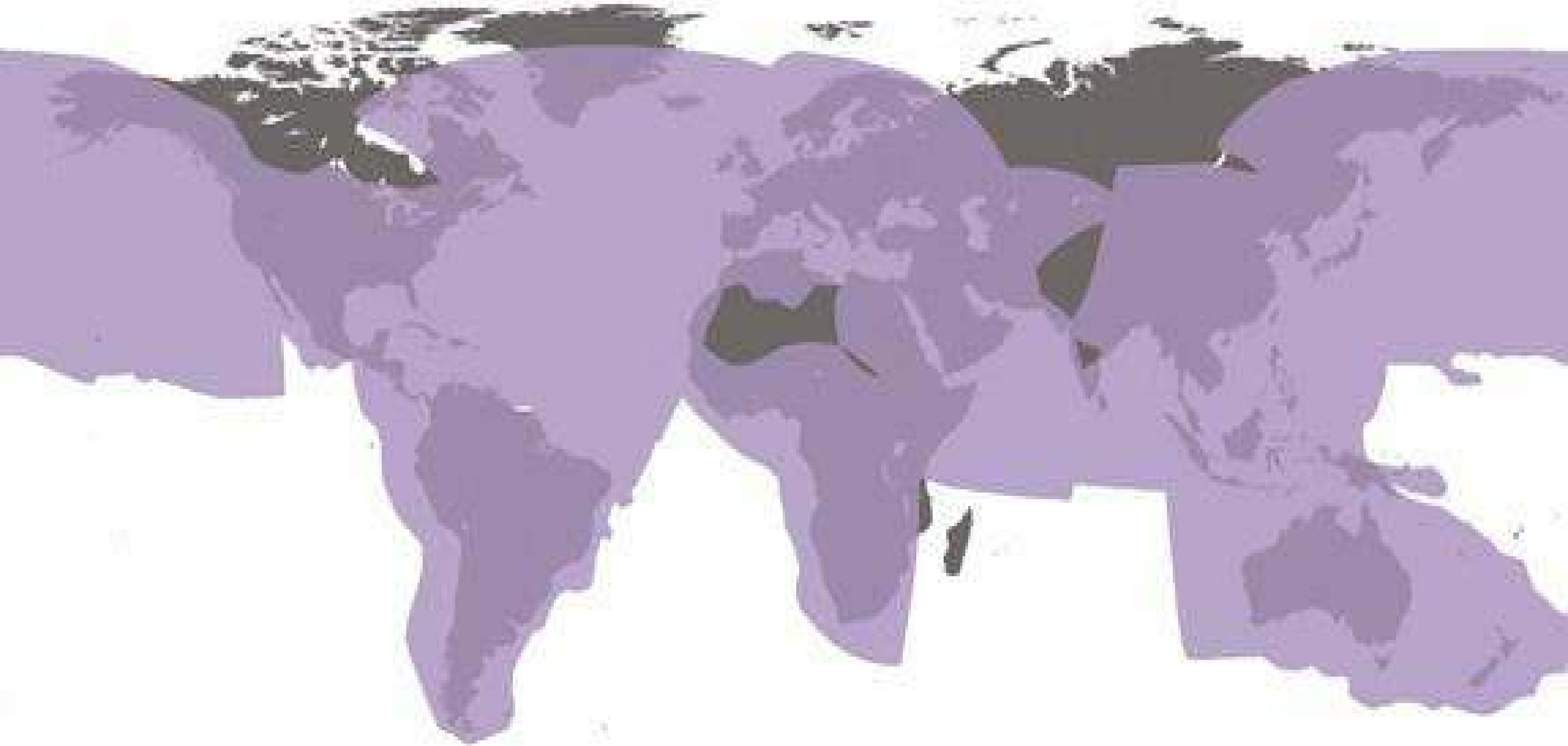
Global Intelsat DVB-RCS C-band Coverage for Maritime Applications



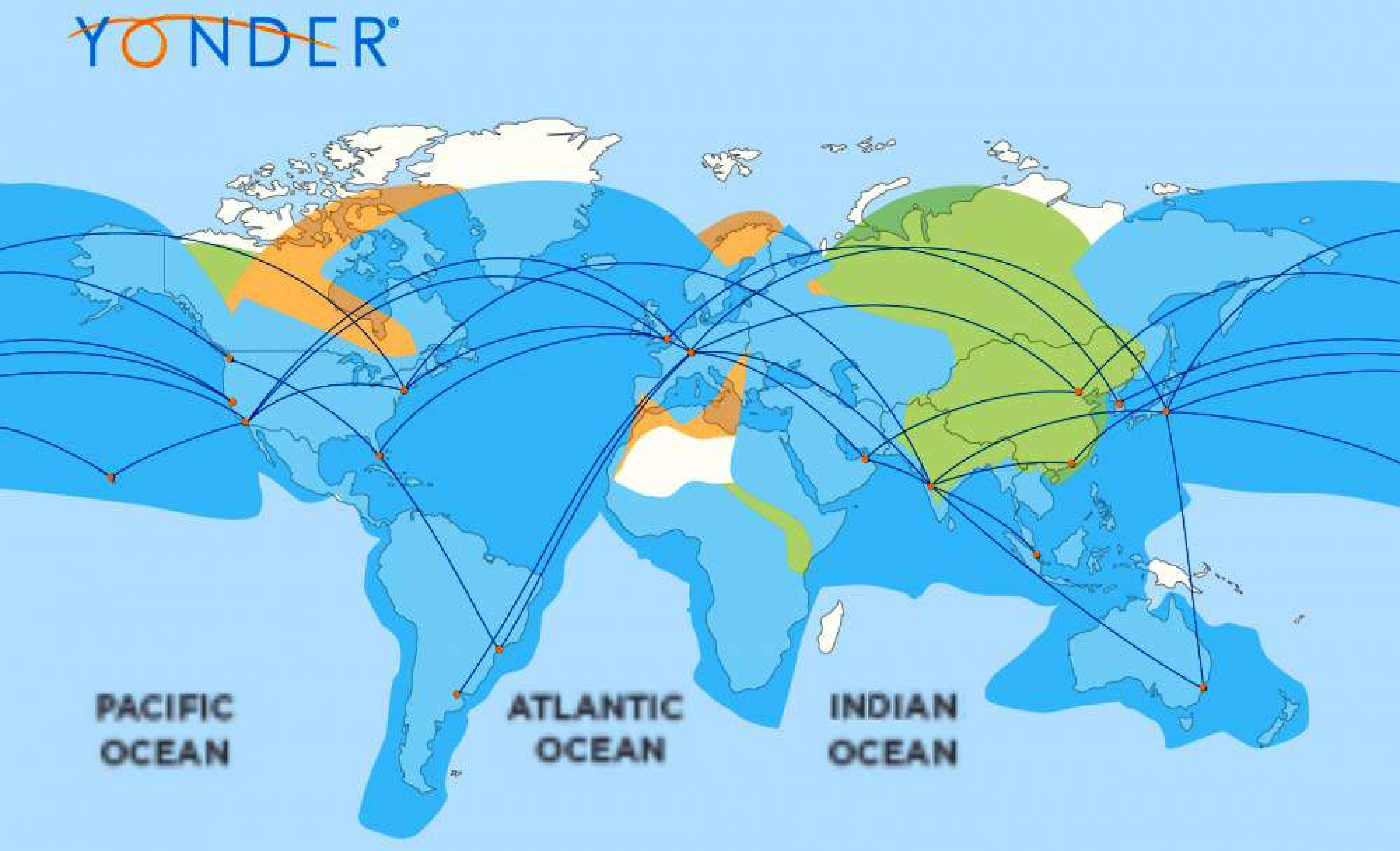
Global Intelsat DVB-RCS Ku-band Coverage for Maritime Applications



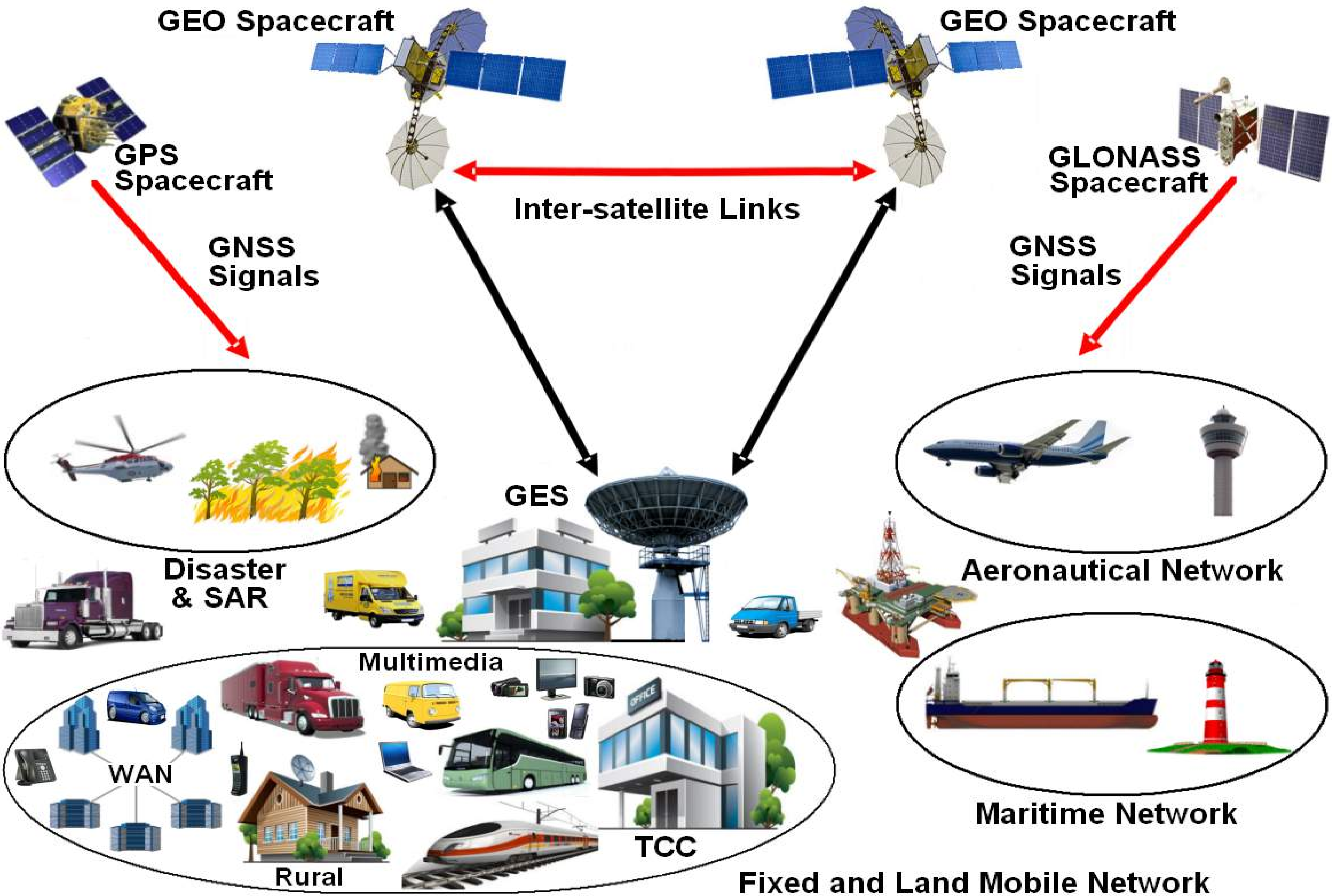
Global KVH DVB-RCS Ku-band VSAT Coverage for Maritime Applications



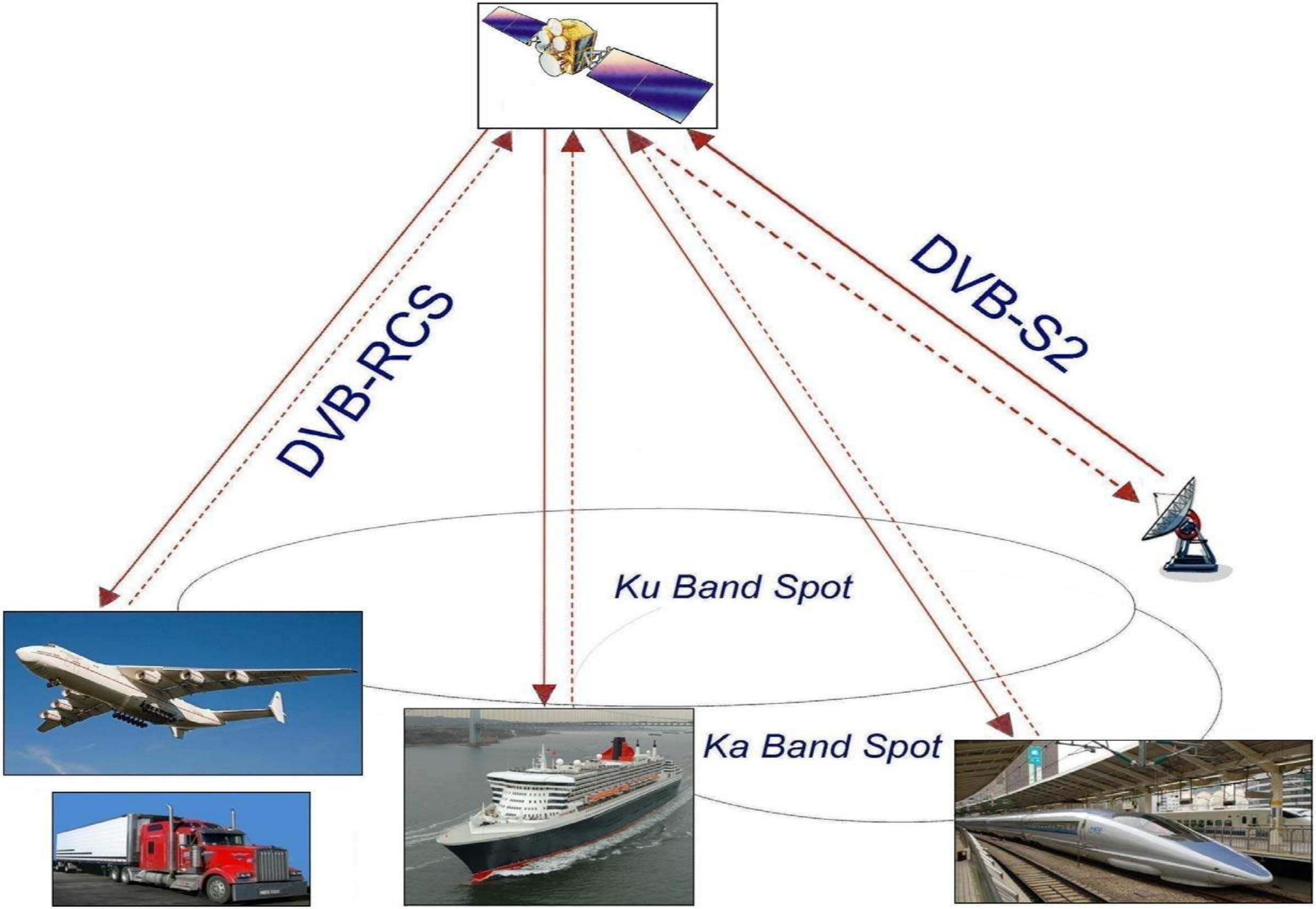
Yonder/ViaSat DVB-RCS Ku-band Coverage for Aeronautical Applications



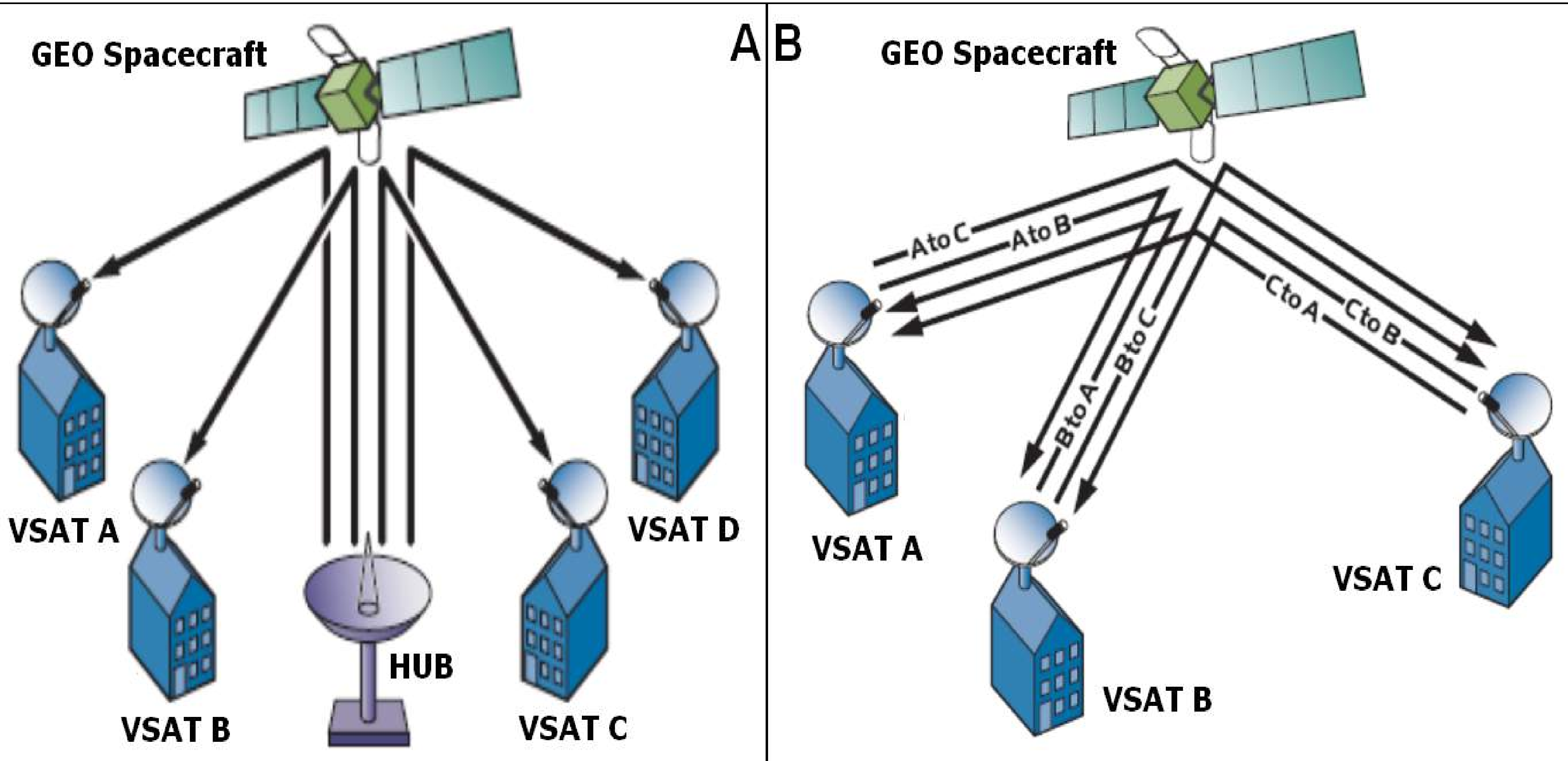
Satellite Space and Ground Segment



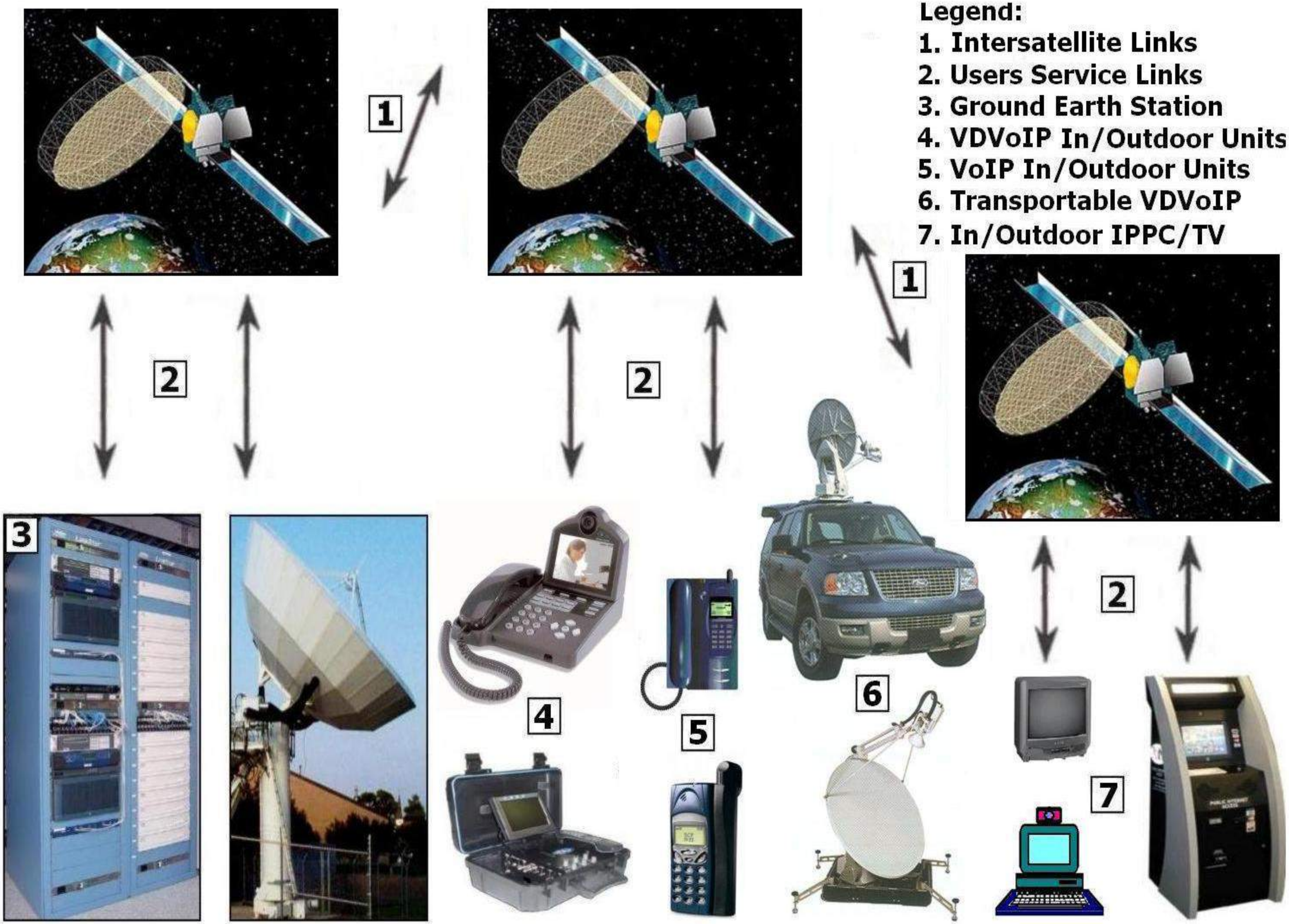
DVB-RCS for Mobile Users



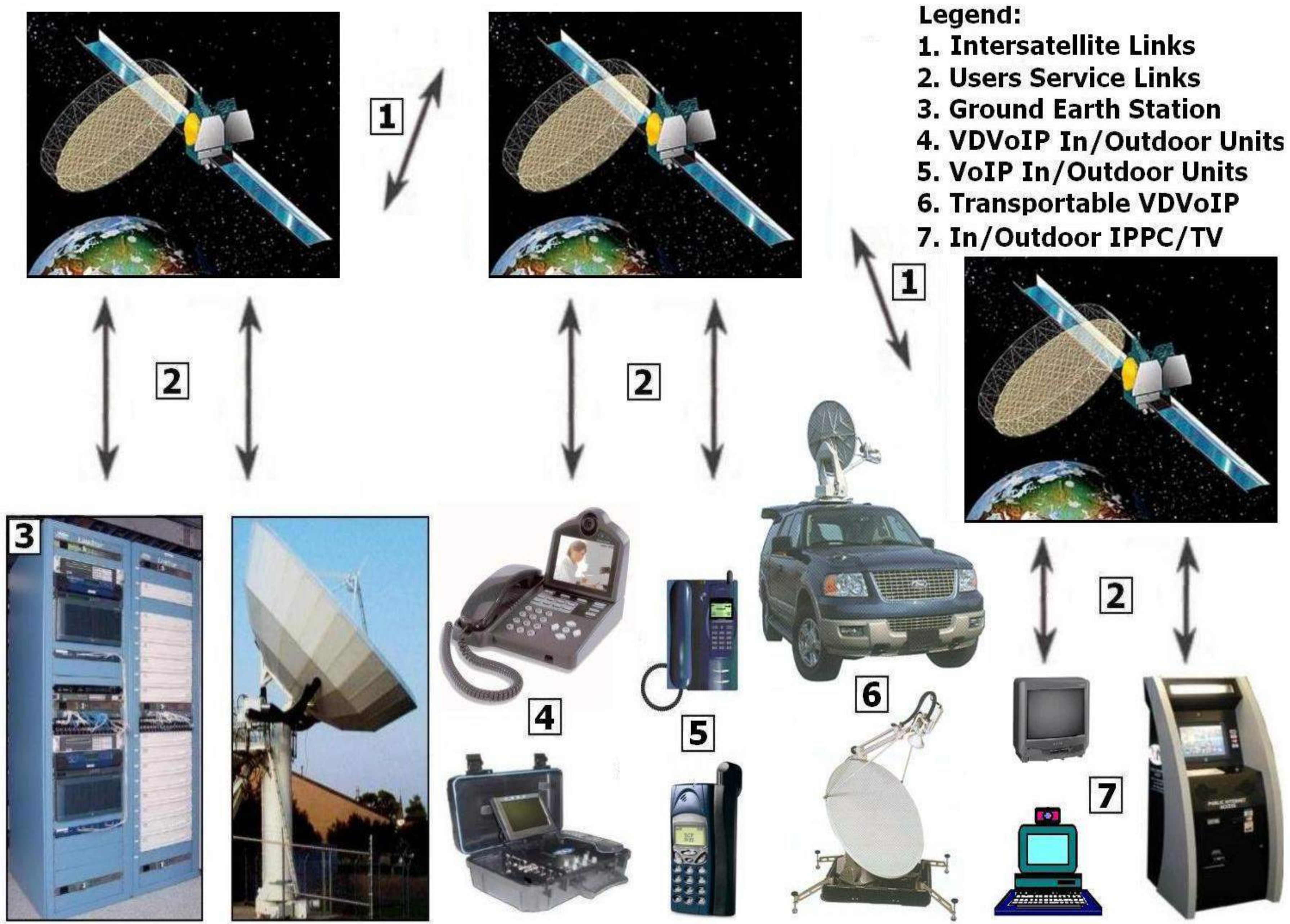
DVB-RCS VSAT (A) Star and (B) Mesh Connectivity with GEO Spacecraft



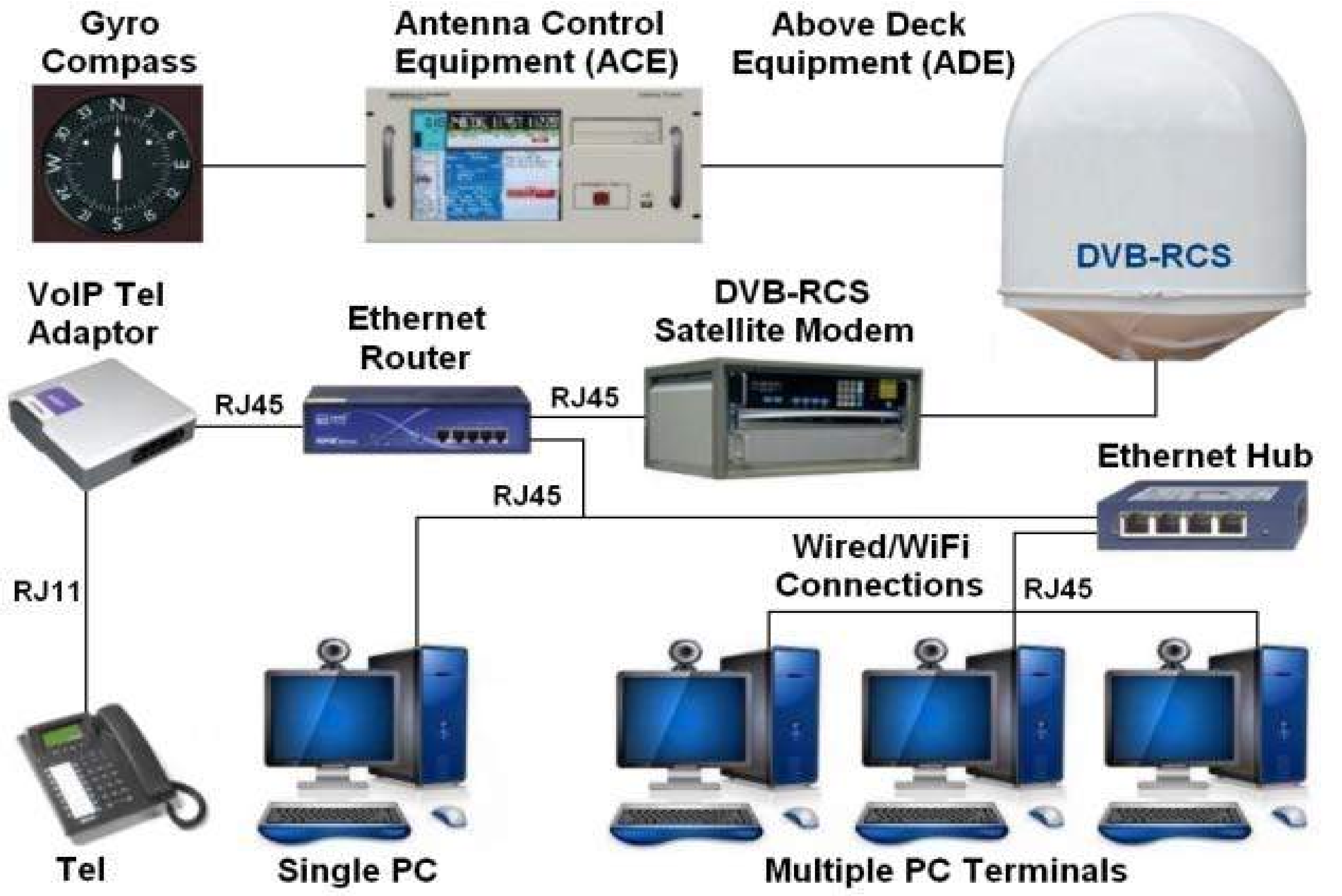
DVB-RCS for Fixed and Portable Users



DVB-RCS for Fixed and Portable Users

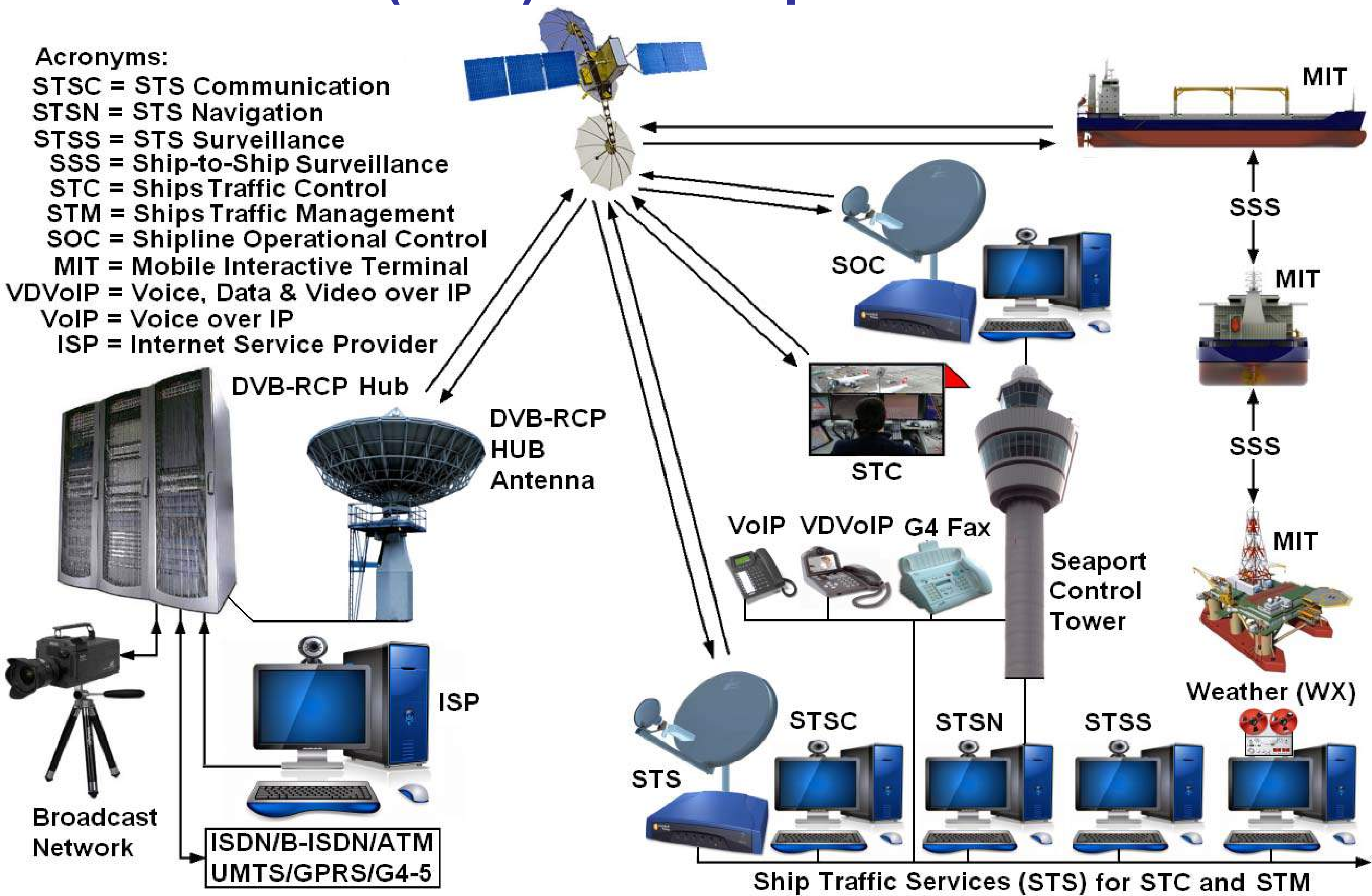


Our Proposal: Shipborne DVB-RCS

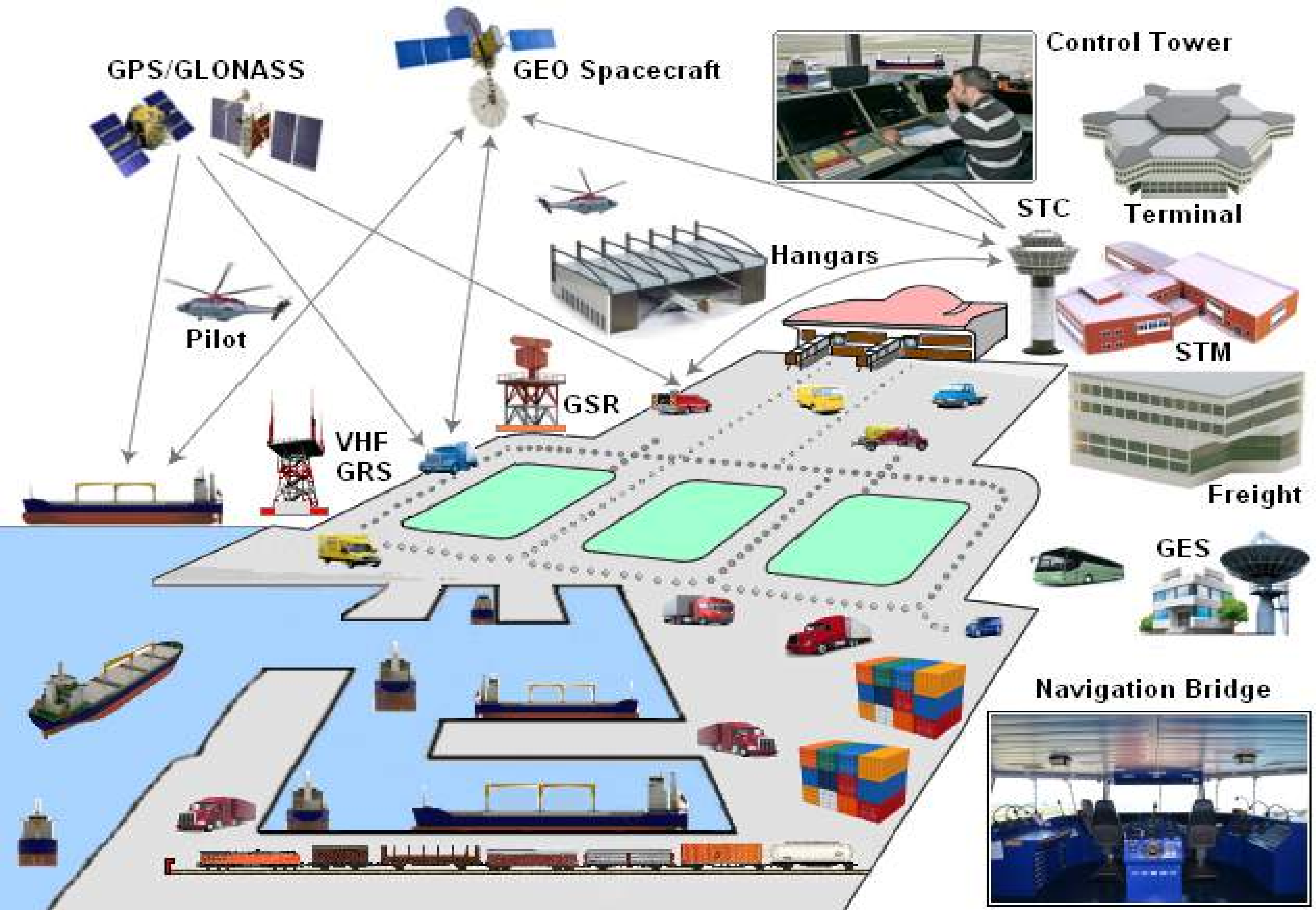


NERA DVB-RCS Ku-band Unit for Maritime Applications

Our Proposal: CNS for Enhanced Ship Traffic Control (STC) and Seaports DVB-RCS

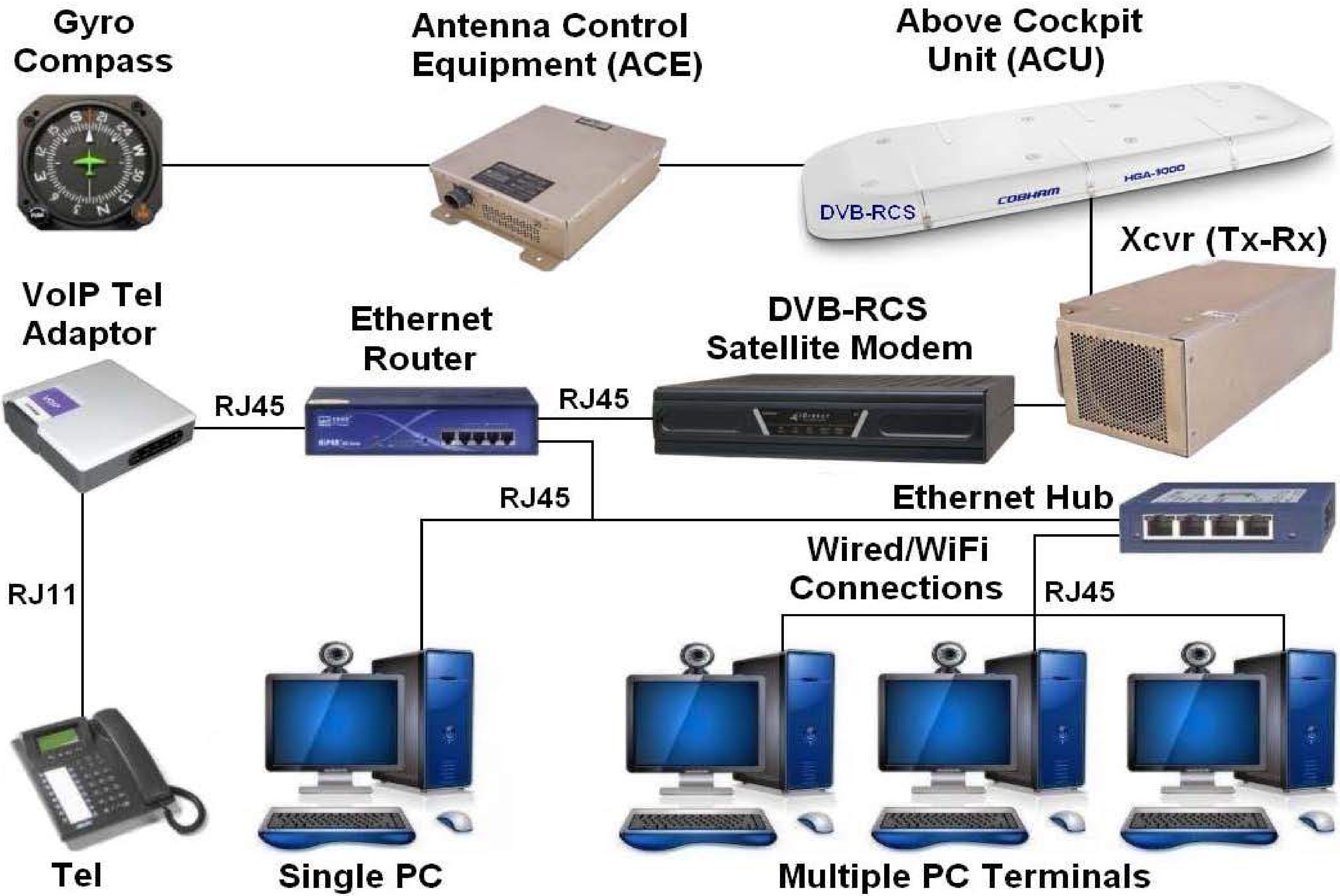


Coastal Movement Guidance and Control (CMGC)

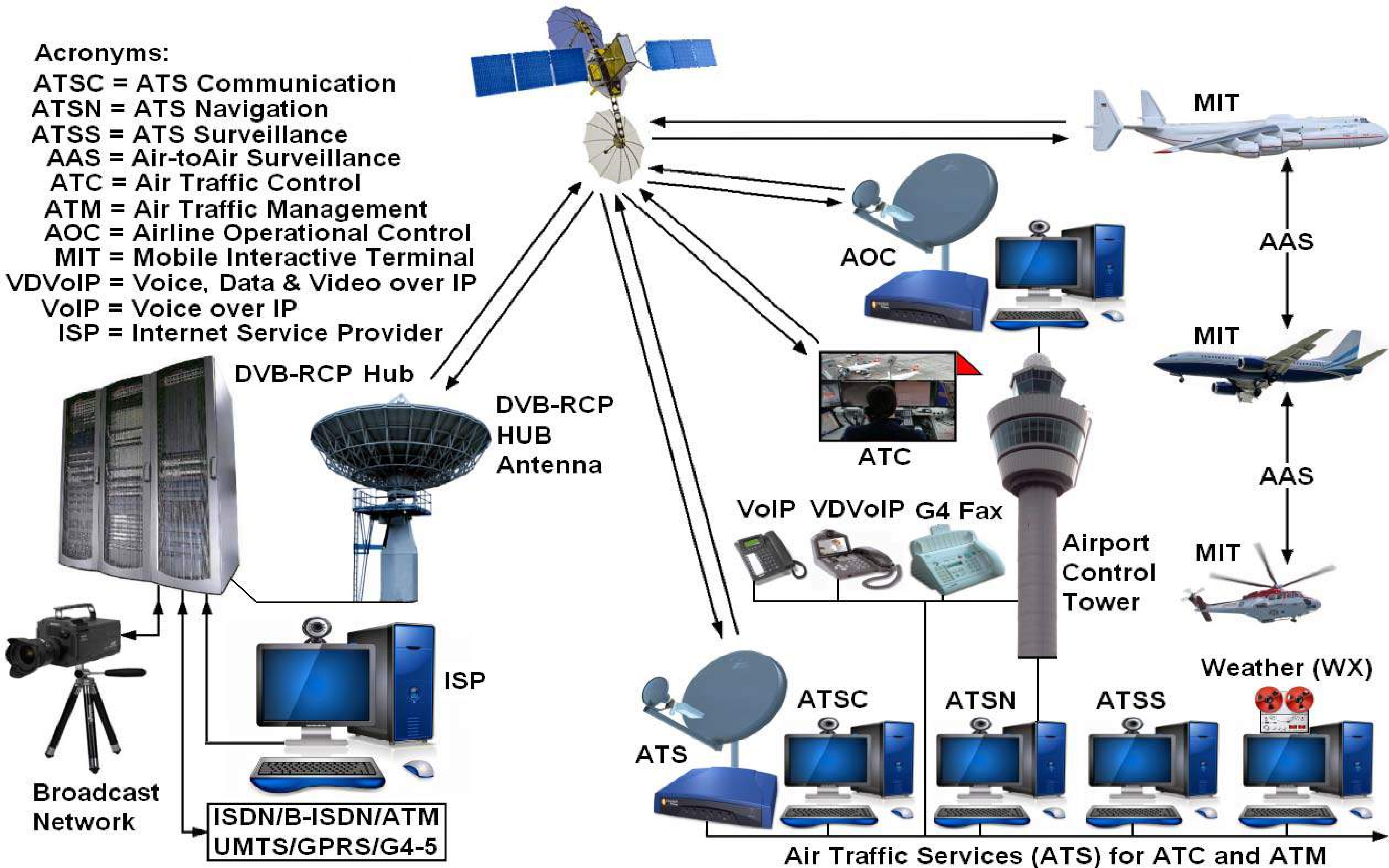


ARINK DVB-RCS Ku-band Unit for Yonder Aeronautical Applications

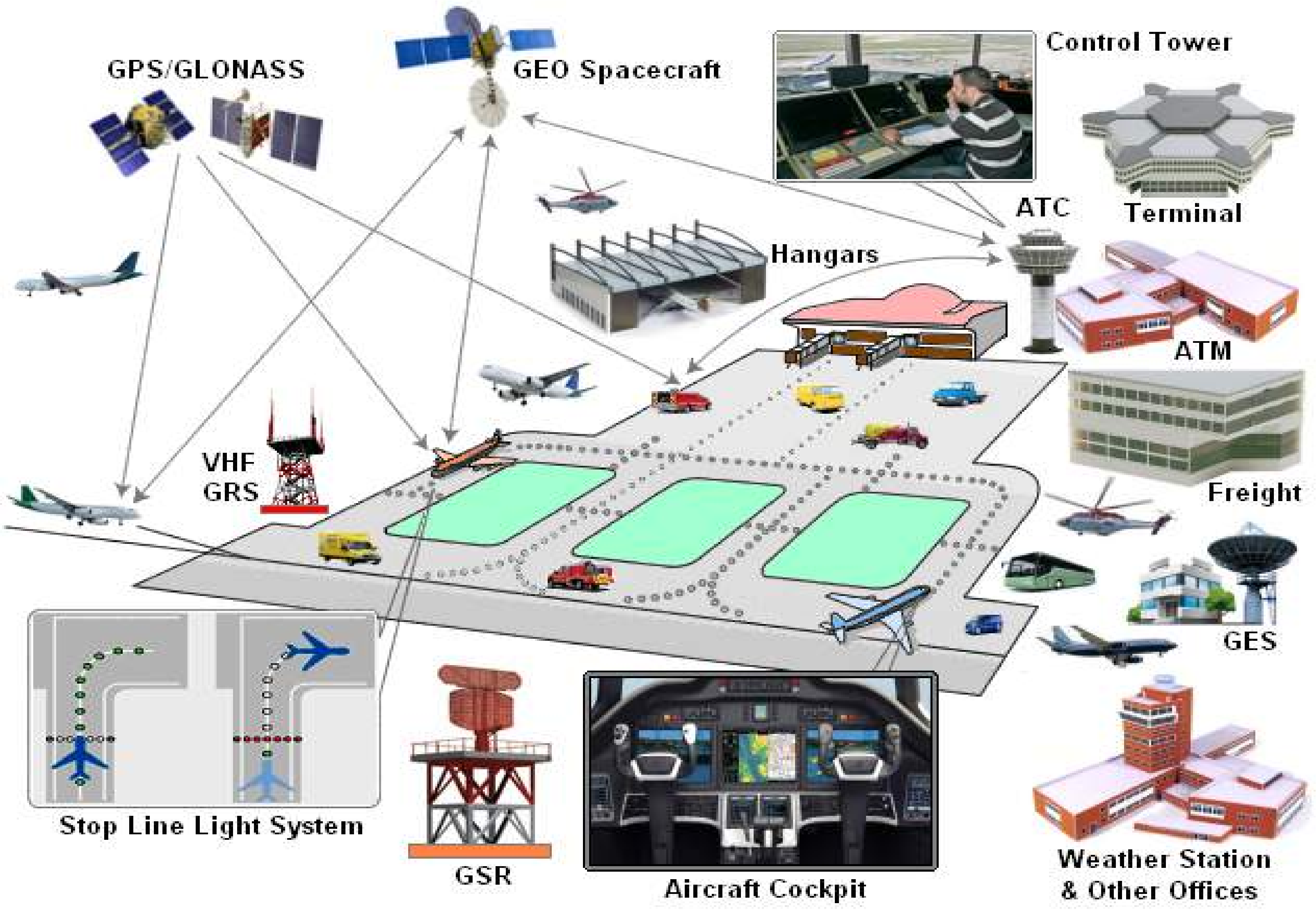
Our Proposal: Airborne DVB-RCS



Our Proposal: CNS for Enhanced Air Traffic Control (ATC) and Airport DVB-RCS

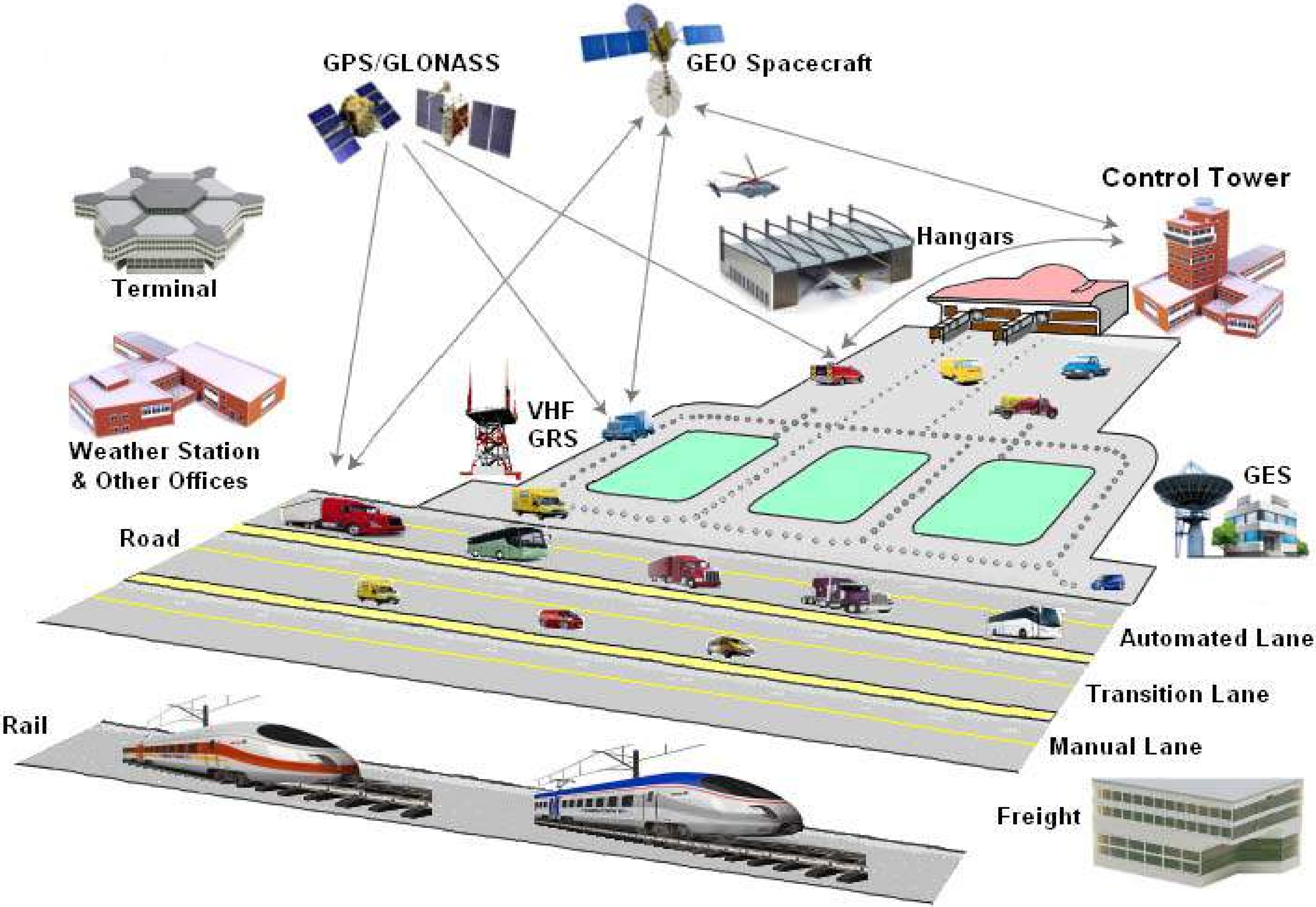


Surface Movement Guidance and Control (SMGC)



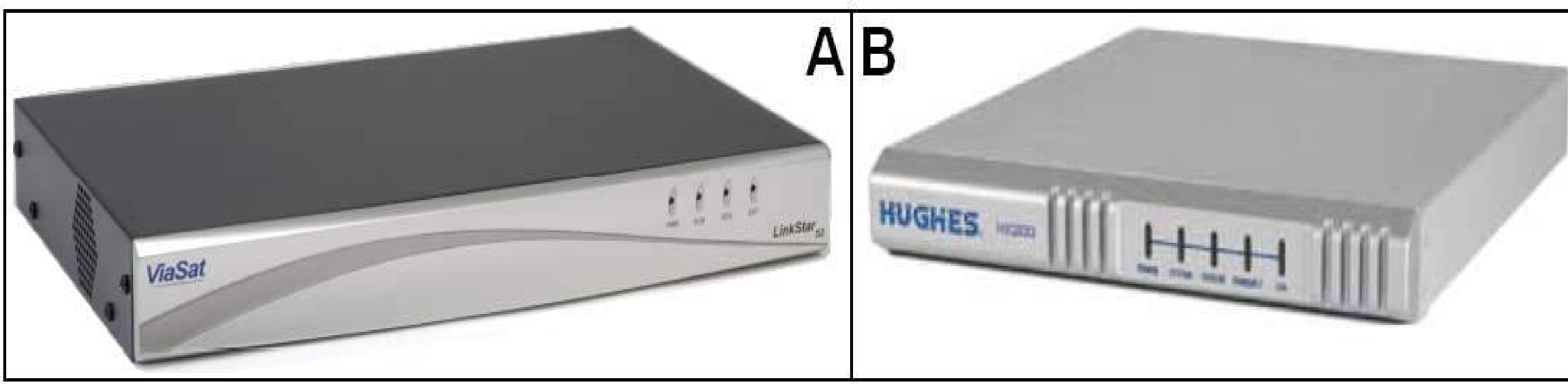
Mobile (MSS) and Fixed Satellite System (FSS) onboard Equipment

Land Movement Guidance and Control (LMGC)

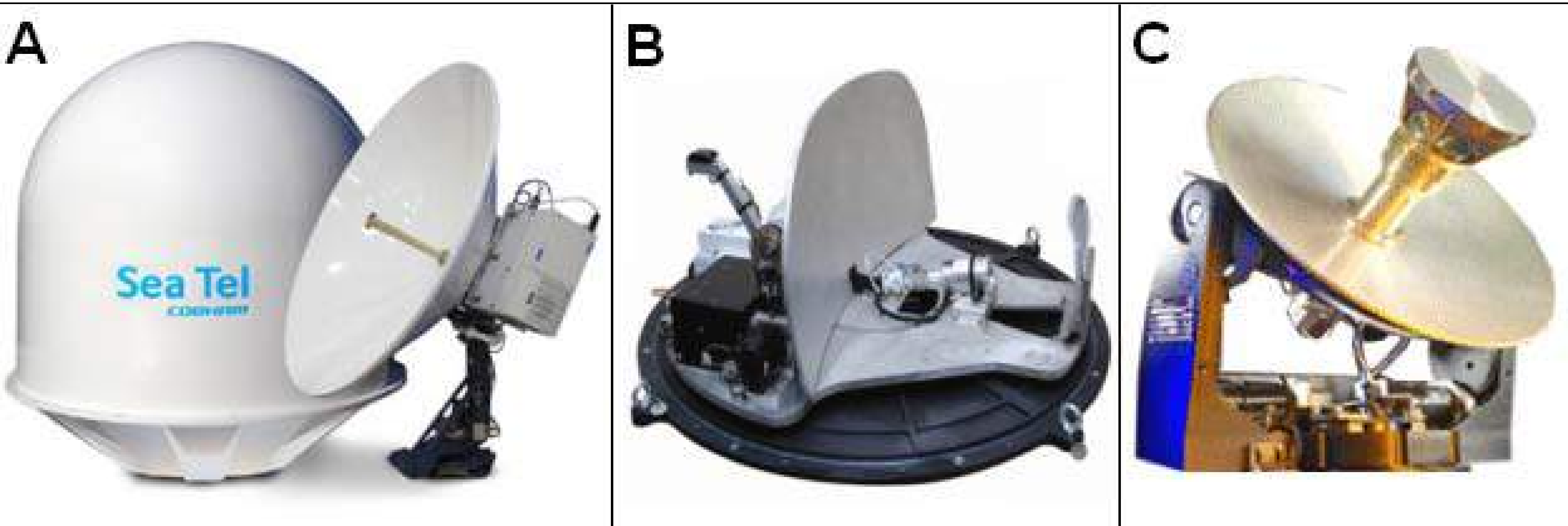


Local Fixed or Mobile DVB-RCS Solutions

DVB-RCS C, Ku and Ka-band (A) ViaSat and (B) Hughes Transceivers for Mobile Applications



Broadband Antenna Systems for Ships (A), Trains or Busses (B) & Aircraft (C)



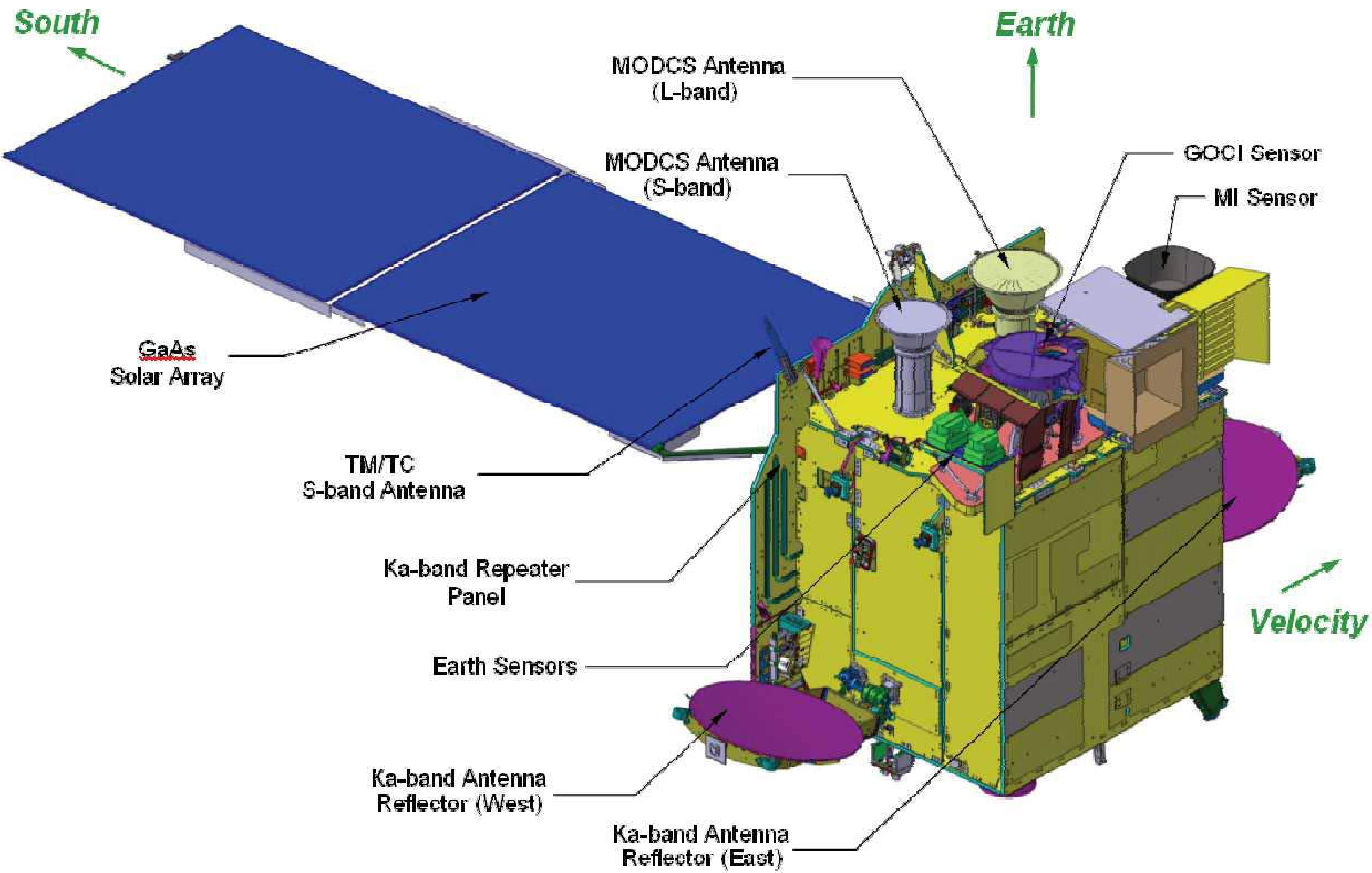
DVB-RCS Transportable & Portable Antennas for Satellite News Gathering (SNG)

DVB-RCS Mobile and Portable Antennas for Military Applications

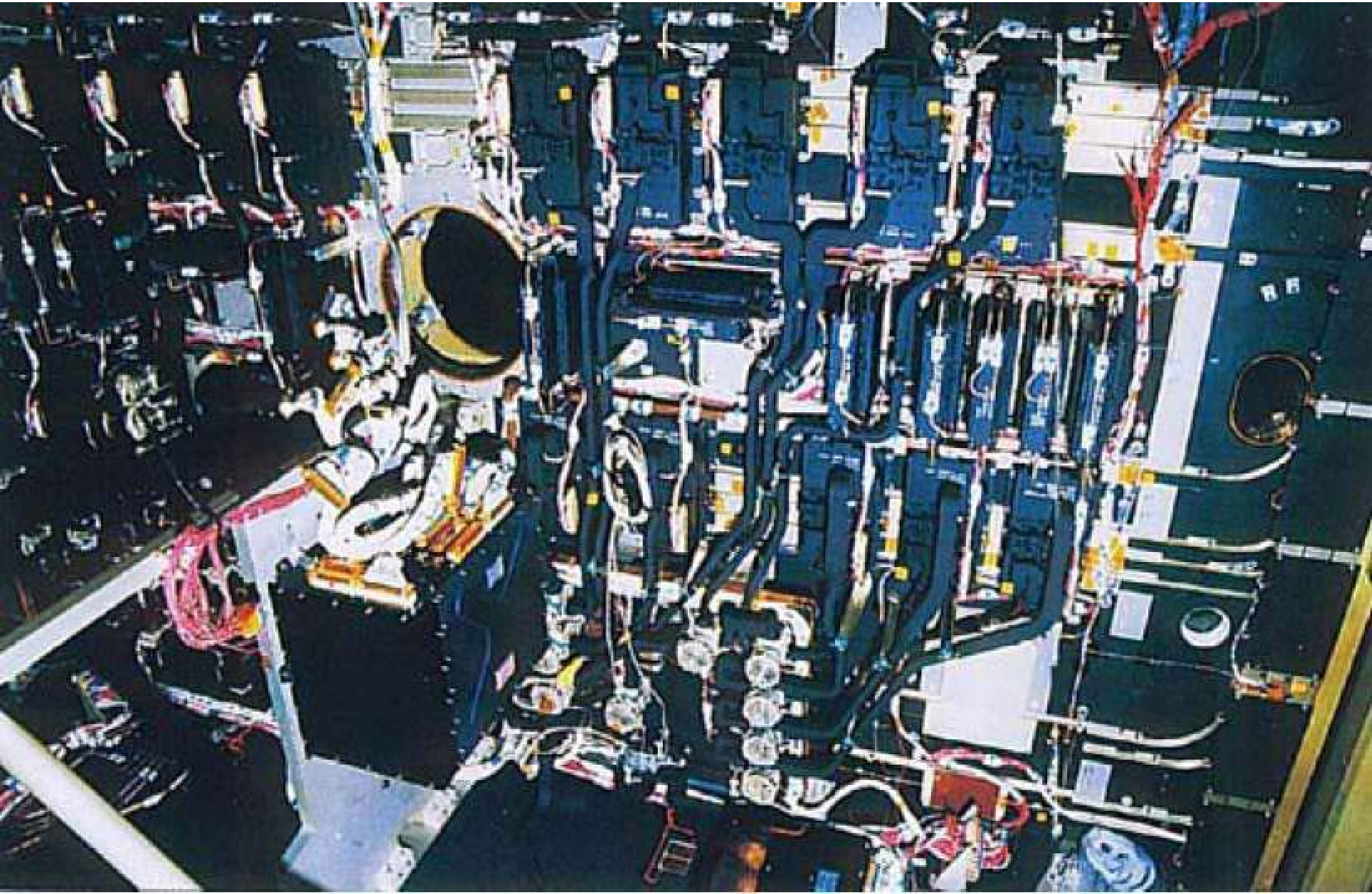
Functions of Satellite Payload/Bus

1. Spacecraft Solar Arrays
2. Spacecraft Power Supply
3. Thermal and Electrical Control
4. Attitude and Orbital Control
5. Spacecraft Telemetry, Tracking and Command (TT&C)
6. Propulsion Engine
7. Intersatellite Link System (ILS)

Modern Ka-band Payload Overview



Ku-band Solid State Transponder



Controls of the Antenna Pointing Mechanism (APM) and the Solar Array (SADE)

Applications

- Telecommunications Satellites.
- Scientific and Earth Observation missions.

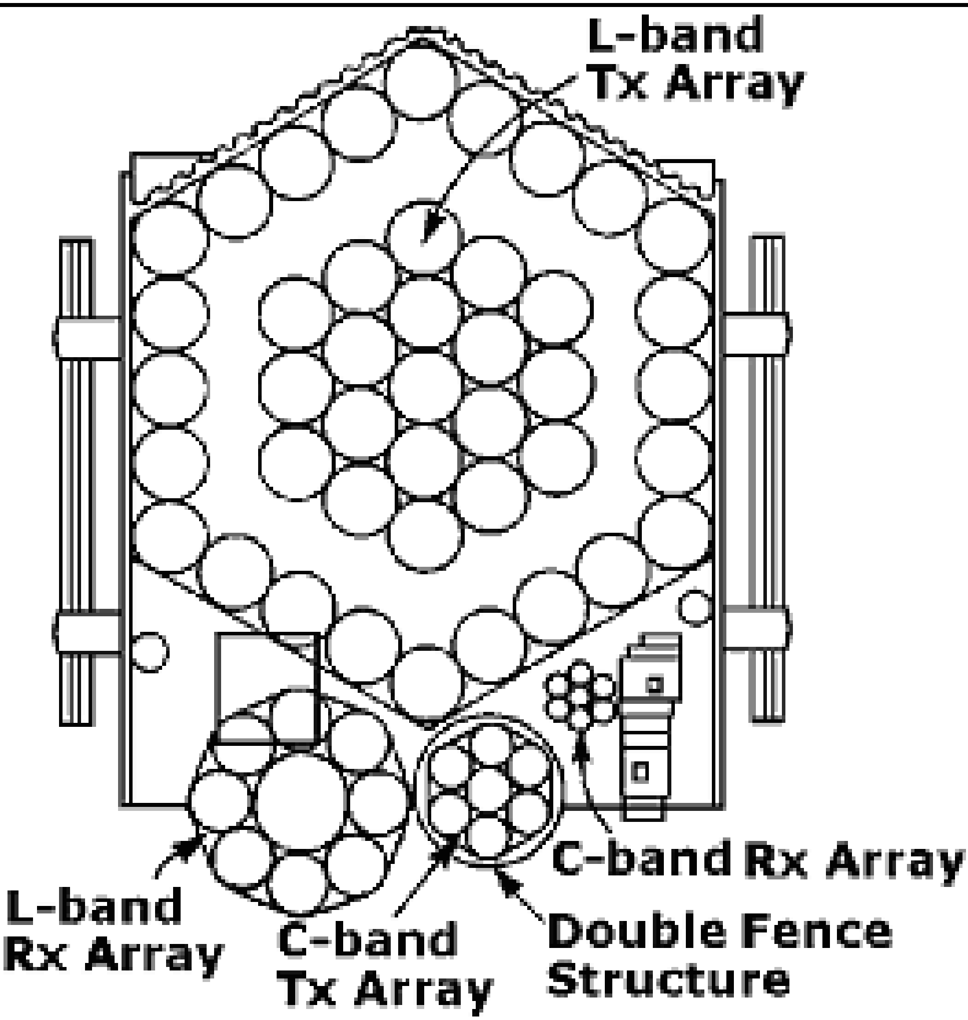
Main Features

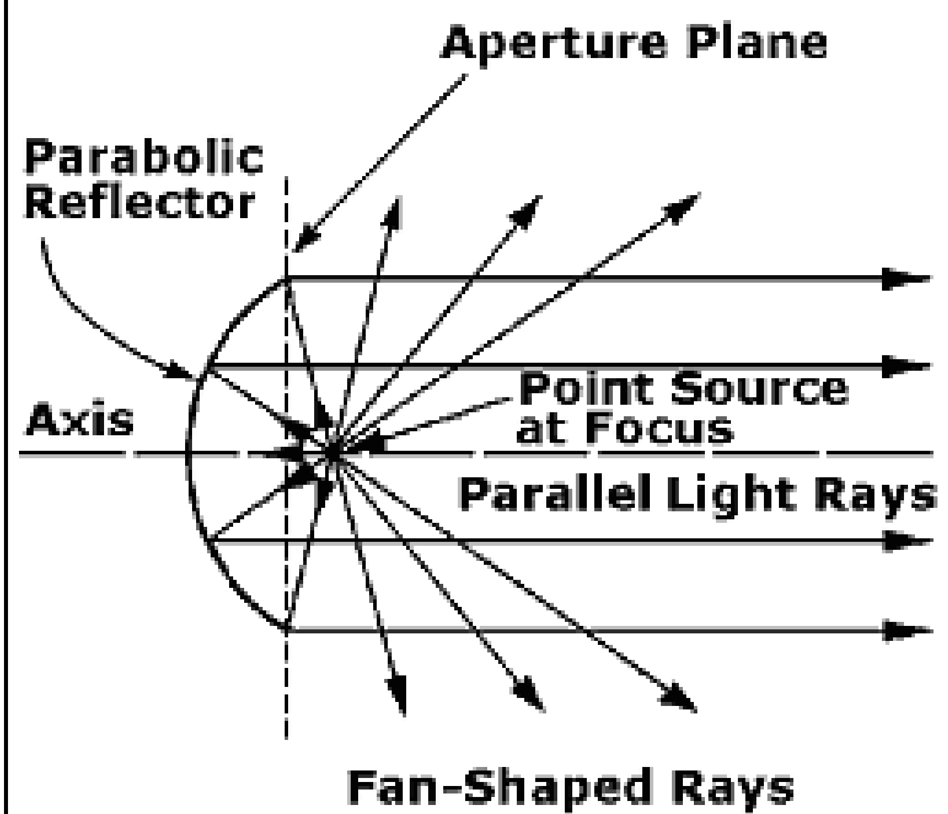
- Redundant Flight Units and Compact lightweight design.
- Low Power CMOS technology.
- Simultaneous control for two or more axis motors.
- Step by step motors controlled by Micro-Stepping technique.
- Angular acquisition by Optical or Magneto-resistive Encoders.

Key Benefits

- Flight heritage.
- Multi-platform Compatibility

Inmarsat Spacecraft Antenna System (Left) and Principal Property of a Parabolic Reflector (Right)



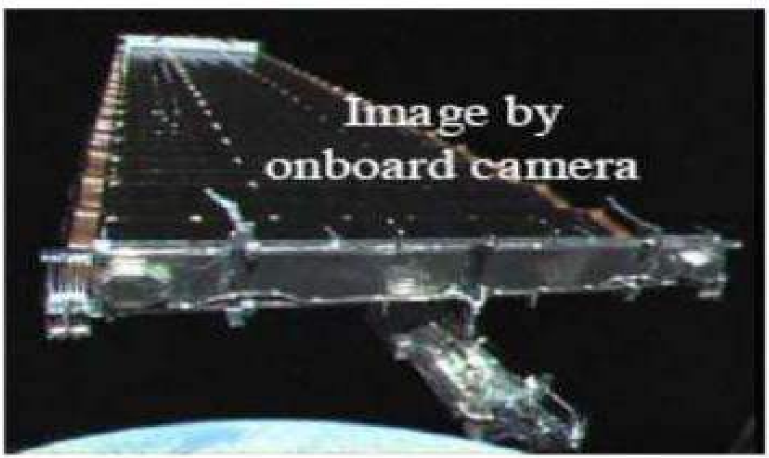


Mechanical Parts of APM and SADE

Spacecraft Solar Array

ETS-VIII (2006) Two Wings /Rigid Wing 3.23m x 2.46m

ALOS (2006) One Wing /Rigid Wing 2.3m x 3.04m



COMETS (1997) GaAs Flexible Solar Array 3m x 15m

WINDS (2007) Two Wings /Rigid Wing 2.0m x 2.34m

Electronic Parts of Satellite APM and SADE

Spacecraft Command Receivers (Specifications)

Main Characteristics

- Uplink Frequency: C/X/Ku/K-band
- Dual Frequency Operation (Option)
- Modulation : PSK/FM or PSK/PM
- Demodulation of command signal and output of the base-band bit stream data
- Demodulation of ranging signal and output of the video ranging signal to TLMTX
- Common housing design for all frequency bands

Specification Table

No.	Parameter	Performance
1	Input Frequency	C-band : 5.9-6.4GHz X-band : 7.0-7.2GHz Ku-band : 12.75-14.5GHz K-band : 17.3-18.1GHz
2	Carrier Modulation	FM option : +/-400kHz deviation PM option : 0.6-1.5rad
3	Input Signal Dynamic Range	-112 to -60dBm
4	No-damage Input Level	up to -35Bm
5	Selectivity	>47dBc @2MHz
6	Bit Error Rate	1e-6 max. @ Pin=-112dBm
7	Ranging Delay Variation	100nsecp-p max.
8	Power Consumption	11W nom.
9	Mass	1.65kg
10	Operating Temperature	QT : -20 to +70degC
11	Non-operating Temperature	-30 to +75degC

Spacecraft Command Receivers (Equipment)

C-band CMDRX

K-band CMDRX

Spacecraft C-Band Beacon Transmitter

Specification Table

Parameter	Unit	Typical Performance
Output Frequency	GHz	C-Band
Output Frequency Stability	ppm	+/-5 max.
Output Power	dBm	+30dBm min.
Spurious Output	dBc dBc	Harmonics: -20 max. Other : -70 max.
DC Power Consumption	W	12 max.
Mass	kg	0.9 nom.
Temperature Range	degC	-25 to +65

Spacecraft Ku-band Beacon Transmitter

Specification Table

Parameter	Unit	Typical Performance
Output Frequency	GHz	Ku-Band
Output Frequency Stability	ppm	+/-5 max.
Output Power	dBm	+28dBm min.
Spurious Output	dBc dBc	Harmonics: -30 max. Other : -70 max.
DC Power Consumption	W	12.5 max.
Mass	kg	1.0 nom.
Temperature Range	degC	-10 to +60

Spacecraft Telemetry Transmitter

Ku-band TLMTX

Ku-band TLMTX with 10W SSPA

Specification Table

No.	Parameter	Performance
1	Output Frequency	C-band : 3.7-4.2GHz Ku-band : 10.7-12.75GHz
2	Output Frequency Stability	Overlife : ±5ppm max.
3	Output Power	Hi Power Output : +26dBm min Lo Power Output : +8dBm nom
4	Phase Noise	3deg rms
5 6	Spurious Output	Harmonics : -40dBc max. Others : -60dBc max.
7	Modulation	PM (Up to 3 sources)
8	Modulation Index	1.0rad o-p (Automatic MI control)

Spacecraft Microwave Devices

Applications

- Communications Satellite payloads.
- Scientific payloads.
- Telecommand, Telemetry and Ranging subsystems.

Main Features

- Waveguide, coaxial and dielectric resonator based filters.
- Bandpass, lowpass and stopband responses. Wide and narrow band filters.
- High Power handling capabilities.
- Light weight silver plated aluminium and thermally stable thin wall INVAR
- From C to Ka Band.

Microwave Filters, Diplexers and RF Assemblies from S to Ka Band for Space Applications

Spacecraft Receiver of Regenerative Transponder

The components of Spacecraft Receivers (Rx) are as follows:

1. Rx Antenna and Input Bandpass Filter (IBF)
2. Low Noise Amplifier (LNA) and Downconverter
3. Mixer/Local Oscillator (LO)
4. Input Multiplexer (IMUX)
5. Switch Assembly (SWA)
6. Demodulator and Automatic Level Control (ALC)
7. Power Divider and Onboard Processor (OBP)

Spacecraft Low Noise Amplifier (LNA)

FSS LNA

BSS LNA

Main Characteristics

- o Low noise figure and high gain performance
  - Ku-band FSS:
    Noise figure: 1.5 dB max. at +58degC
    (f=12.75GHz to 13.2GHz, 13.75GHz to 14.50GHz)
    Gain: 40 dB nom.
    (f=12.75GHz to 13.2GHz, 13.75GHz to 14.50GHz)
  - Ku-band BSS:
    Noise figure: 1.80 dB max. at +58degC
    (f=17.3GHz to 18.1GHz)
    Gain: 40 dB nom. (f=17.3GHz to 18.1GHz)
- o Self gain compensation over temp. using PIN diode attenuator

Spacecraft L-band Low Noise Amplifier (LNA)

L-band LNA

Specification Table

Parameter	Unit	Specification	Typical Performance
Frequency Range	MHz	1626.5 to 1660.5	1626.5 to 1660.5
Usable Bandwidth	MHz	34	34
Gain	dB	43+/-0.5	43
Gain Flatness	dBp-p	0.7 max	0.6
Noise Figure (LNA Portion)	dB	0.85 max	0.81 (0.65 at AMB)
C/3IM	dBc	-70 max at Pout -31dBm	-82
Power Consumption	W	0.5 (7V)	0.44
Mass	kg	0.42	0.41
Size (L x W x H)	mm	97 x 50 x 105	97 x 50 x 105
Temperature Range	℃	-15 to 65	-15 to 65

Main Characteristics

- Low noise figure and high gain performance
  - Noise figure: 0.65 dB max. at +23degC
  - Gain: 43 dB nom.
- Light weight and small size
  - Mass: 0.41 kg nom. (each LNA)
  - Size: 97 x 50 x105 mm (each LNA)
- L-band LNA Assembly are 2 for 1 redundant configuration which consists of 2 RF Amp and Input/Output switch.
- We can provide the Central Power Supply (CPSU) for each LNA.

Spacecraft Low Noise Amplifier (LNA)

C-band LNA

Specification Table

Parameter	Unit	Spec.	Typical Performnace
Frequency Range	GHz	5.845 to 6.725	5.845 to 6.425 6.145 to 6.725
Usable Bandwidth	MHz	580	Same as left
Gain	dB	40.0±0.5	40.0±0.3
Gain Flatness over usable bandwidth	dBp-p	0.75 max.	0.5 max.
Noise Figure	dB	1.45 max.	1.45 max., 1.20 @Amb.
ICP(C/3IM)	dBm	+19 min.(OIP3)	+21.0 dBm
Power Consumption Voltage DC Power	 V W	Per LNA/Power Supply 51.55 min., 53.15 max. 1.2 max.	 Same as left 0.8W
Mass(4LNAs with 4 Power supplies)	kg	1.30 max.	0.941 kg
Size(L×W×H)	mm	129×119×91	Same as left
Temperature Range	℃	+5 min., +58 max.	Same as left

Main Characteristics

- Low noise figure and high gain performance
  - Noise figure: 1.2 dB max. at +23degC
  - Gain: 40 dB nom.
- Self gain compensation over temperature using the PIN diode attenuator
- Two band width
  - Low band type: 5.845GHz to 6.425GHz, Bandwidth = 580MHz
  - High band type: 6.145GHz to 6.725GHz, Bandwidth = 580MHz
- Quad type configuration:
  - 4 LNAs (RF portion) and 4 power supply boards

Spacecraft Ka-band Low Noise Amplifier (LNA)

Main Characteristics

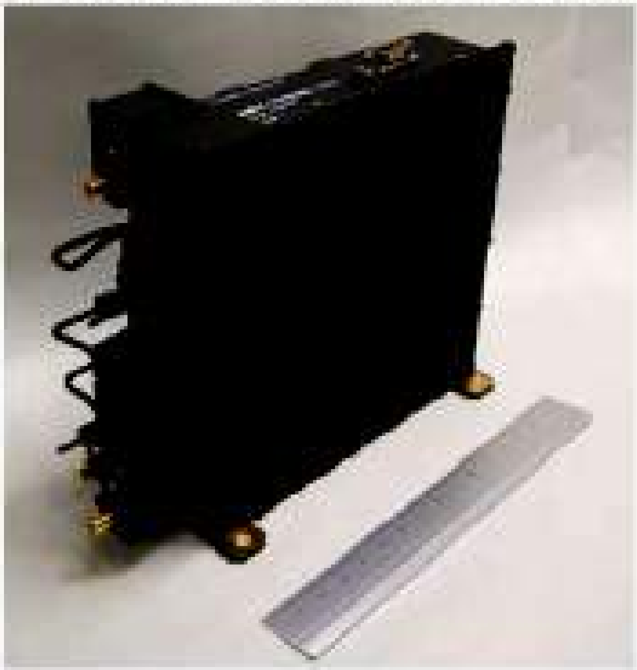
- Frequency range: 28.0GHz to 30GHz, Operational Bandwidth 1,500MHz
- Low noise figure and high gain performance
  Noise figure: 2.34 dB max. at +60degC and life
  Gain: 45.0 dB nom.
- Quad configuration which consists of 4 RF portions and 4 power supplies
- The LNA module for Ka-band LNA is using super low noise PHEMTs for front 2 stages and GaAs MMIC's for output stage
- Self gain compensation over temperature using the MMIC's attenuator

Specification Table

Parameter	Unit	Major Performance
Operating Frequency Range	GHz	28.0 to 30.0
Usable Bandwidth	MHz	1500
Gain	dB	45 +/-0.5
Gain Flatness over usable bandwidth	dBp-p	0.9 max
Noise Figure	dB	2.0 typ at +23degC 2.4 max. at +60degC
ICP(C/3IM)	dBm	+18 min.
Power Consumption	W	1.5W max. (1RF portion and 1PS)
RF Interface		
RF Input		WR28 or WR34
RF Output		WR28 or WR34
BUS/CMD/TLM Interface		D-sub 15pins
Mass(Quad configuration)	kg	1.3
Dimension(Quad configuration)	mm	135*165*91
Temperature Range	degC	-10 min.+60max.

Spacecraft C-Band Receiver/Downconverter

C-band Downconverter



Specification Table

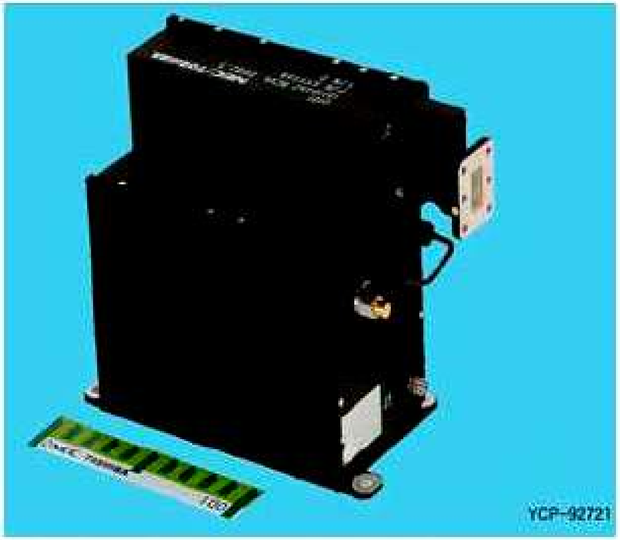
Parameter	Unit	Typical Performance
RF Frequency	GHz	5.925 to 6.425 (Type1), 6.425 to 6.725 (Type2)
IF Frequency	GHz	3.7 to 4.2 (Type1), 3.4 to 3.7 (Type2)
LO Frequency	GHz	2.225 (Type1), 3.025 (Type2)
Usable Bandwidth	MHz	500 (Type1), 300 (Type2)
Gain	dB	24.5 nom.
Gain Flatness	dBp-p	0.8 max. (over operational bandwidth)
Noise Figure	dB	20 max. (Over AT and EOL)
C/3IM	dBc	-47 max (Pin = -16dBm each)
In-Band Spurious	dBc	-65 max.
Frequency Stability	ppm	+/-1 max. (Initial setting) +/-2 max. (Over Diurnal) +/-3.5 max. (Over AT & Life w/o initial setting)
Phase Noise @10Hz @100Hz @1kHz @10kHz @100kHz @1MHz @10MHz	dBc/Hz	 -50 max. -70 max. -100 max. -110 max. -110 max. -120 max. -120 max.
DC Power Consumption	W	7.5 max.
Mass	kg	1.01 max.
Temperature Range	degC	+5 to +66 (AT), -5 to +76 (QT)

Main Characteristics

- C-band DNC consists of an RF Section, a Local Oscillator and a DC/DC Converter.
- RF Section converts the 6GHz input signals to the 4GHz signals using Local signal of 2.225GHz(Type 1) and 3.025GHz(Type 2).
- Local Oscillator provides the Local signal to the Mixer of the RF Section.
  TCXO is used for Local signal reference source.
- DC/DC Converter supplies the secondary voltage to the RF Section and the Local Oscillator.
  And it receives the Turn ON and OFF commands and provide the ON/OFF Status telemetry.
- Typical performance of C-band DNC is as follows;
  Gain: 24.5dB nom. / NF: 20dB max. / IP3: +32.5dBm min. / Pdc: 7.5W max.

Spacecraft Ku-band Receiver/Downconverter for Broadband Satellite Service (BSS)

Ku-band (BSS) RCVR



Main Characteristics

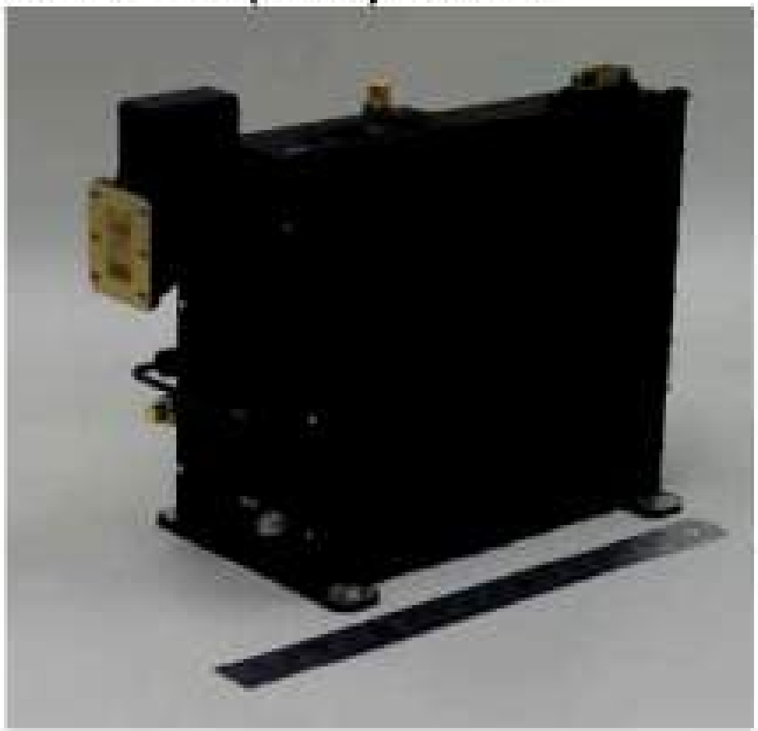
- Low Noise Figure, High Gain & Linearity
  NF= 1.8dB nom. @+60degC
  Gain= 53dB min.
  C/3IM= -51dBc max. (Pin= -52 dBm each)
- High Frequency Stability:
  Over Temperature Stability : less than ±0.8ppm
- Self gain compensation by using the Variable Gain Amp over temperature.
- This Ku-band RCVR was developed for BSAT-2c Satellite, and has already qualified (PFM/FM : 2units)

Specification Table

PARAMETER	TYPICAL PERFORMANCE	Remark
Frequency Range		
Input	17.31 to 17.77 GHz	
Output	11.71 to 12.17 GHz	
Local	5.6 GHz	
Bandwidth	460 MHz	
Noise Figure	1.8 dB 1.6 dB	@+60deg.C,BOL @+23deg.C,BOL
Gain	53.5 dB	
Gain Flatness	0.3 dBp-p	any 34.5MHz
Gain Stability	0.3 dBp-p	any 10deg.C
Third oder IM	51.0 dBc	Pin=-52dBm each
Local Frequency Stability	+/-0.8 ppm	over QT Temp.
Phase Noise		
10Hz offset	-52 dBc/Hz	
100Hz offset	-78 dBc/Hz	
1kHz offset	-88 dBc/Hz	
10kHz offset	-99 dBc/Hz	
100kHz offset	-115 dBc/Hz	
1MHz offset	-140 dBc/Hz	
Power Consumption	6.9 W	
Temperature Range		
QT	-10 to +60 deg.C	
Start Up	-35 deg.C	
Mass	0.79 kg	
Dimension	173x79x137	

Spacecraft Ku-band Receiver/Downconverter for Fixed Satellite Service (FSS)

Ku-band (FSS) RCVR



Specification Table

Parameter	UNIT	Typical Performance	
RF FREQ	GHz	14.0 to 14.5	
IF FREQ	GHz	11.7 to 12.2	
LO FREQ	GHz	2.3	
Usable Bandwidth	MHz	500	
Gain	dB	58 min	
Gain Flatness	dBp-p	0.75/500MHz	
Noise Figure	dB	1.8 max	
C/3IM	dBc	-50 at Pin=-54dBm	
In-Band Spurious	dBc	-65	
Out of Band Spurious			
2RF-7LO	dBc	-60	
5*LO	dBm	-20	
6*LO	dBm	-40	
Frequency Stability	ppm	Setting	+/-1.0
		Over 15°C	1.0
		Over Life	+/-8.0
Phase Noise	dBc/Hz		
10Hz		-50 max	
100Hz		-80 max	
1KHz		-100 max	
10KHz		-111 max	
100KHz		-115 max	
1MHz		-120 max	
14GHz CPL OUT			
Frequency	GHz	13.994 to 14.001	
Gain	dB	23 min.	
Noise Figure	dB	1.8 max.	
Power Consumption	W	8.5 max. (Using TCXO)	
Dimension	mm	170x64x147	
Mass	g	820 max	
Temperqture Range	°C	-15 to +60	

Main Characteristics

- Ku-band (FSS) RCVR consists of an RF Section and a DC/DC Converter
- RF Section converts the 14GHz input signals to the 12GHz output signals using external Local signal
- DC/DC Converter supplies the secondary voltage to the RF Sectior
- Self gain compensation by using the Variable Gain Amp over temperature

Spacecraft Ka/Ku-band Receiver/Downconverter

Ka/Ku-band RCVR

Main Characteristics

- Ka/Ku-band RCVR consists of an RF Section, a Local Oscillator and a DC/DC Converter
- RF Section converts the 27GHz input signals to the downlink frequency of 12GHz using Local Oscillator frequency of 15GHz
  27.5 to 27.75→12.5 to 12.75GHz
- Light Weight: 0.93kg nom
- Self gain compensation by using the Variable Gain Amp over temperature

Specification Table

PARAMETER		UNIT	SPECIFICATION	TYPICAL PERFORMANCE
Input Frequency		GHz	27.5 to 27.75	Same as left
Output Frequency		GHz	12.5 to 12.75	Same as left
Conversion Frequency		GHz	15	Same as left
Frequency Stability	any 15degC	ppm	+/- 0.1	< 0.04
	Over 15years	ppm	+/- 2	< 0.13
Gain		dB	61.5 min	62.5 nom
Gain Flatness	Any39MHz	dBp-p	0.4	0.07 nom
	250MHz	dBp-p	N/A	0.22 nom
Gain Slope		dB/MHz	0.01 max	0.003 nom
Gain Stability	@any15degC	dBp-p	0.5	< 0.03
NF	@QT Range	dB	2.6	1.99 @amb
C/3IM	@-65dBm 2 carriers input	dBc	-57.1	-62 nom
Inband Spurious		dBm	-75	< -78 (Noise Level)
AM/PM Conversion		deg/dB	0.2 max	< 0.09
Phase Shift	@ ~-60dBm input	deg	0.5 max	< 0.13
Group Delay	@Any36MHz	nsec	0.5 max	< 0.22
Power Consumption	Steady State	W	11.5 max	8.9 nom
	Transient	W	12.5 max	10.4 nom
Mass		g	1200	930
Temperature	Acceptance Temp	degC	-15 to +60	Same as left
	Qualification Temp	degC	-20 to +65	Same as left

Spacecraft Ka-band Receiver/Downconverter

Ka-band RCVR

Specification Table

Parameter	Unit	Typical Performance
RF Frequency	GHz	29.4 to 29.9
IF Frequency	GHz	19.7 to 20.2
LO Frequency	GHz	9.7
Usable Bandwidth	MHz	500
Gain	dB	63 nom.
Gain Flatness	dBp-p	0.8 max. (over operational bandwidth)
Noise Figure	dB	2.6 max. (Over AT and EOL)
C/3IM	dBc	-40 max (Pin = -64dBm each)
In-Band Spurious	dBc	-60 max.
Frequency Stability	ppm	+/-1 max. (any 15degC) +/-5 max. (Over AT & Life)
Phase Noise @10Hz @100Hz @1kHz @10kHz @100kHz @1MHz @10MHz	dBc/Hz	 -40 max. -70 max. -90 max. -100 max. -105 max. -115 max. -130 max.
DC Power Consumption	W	8 max.
Mass	kg	0.9 max.
Temperature Range	degC	-15 to +60 (AT), -20 to +65 (QT)

Main Characteristics

- Ka-band RCVR consists of an RF Section and a DC/DC Converter
- RF Section converts the 30GHz input signals to the 20GHz output signals using external Local signal
- Self gain compensation by using the Variable Gain Amp over temperature

New Generation of Spacecraft Ka-band Downconverter

Mass Reduction and Compact Size Achieved by Application of Multi Chip Module Technology

Previous Design

New Downconverter

Features

- Low mass of 630g (max)
- High performance and reliability backed up
- Outstanding Noise Figure performance of 7dB (max)

Spacecraft C/X/Ku/Ka-band Input Multiplexers (IMUX)

Applications

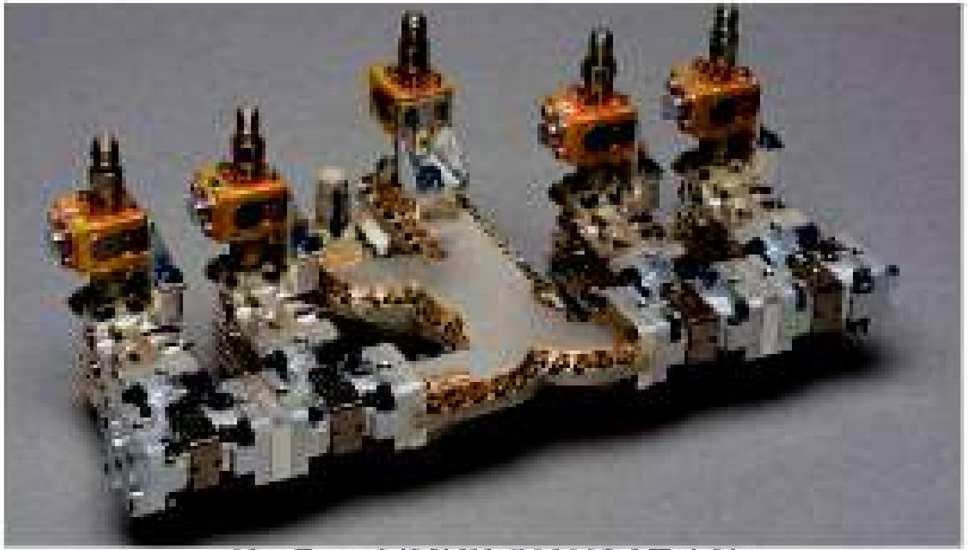
- Telecommunications Payloads.
- Broadband Multimedia Satellites

Main Features

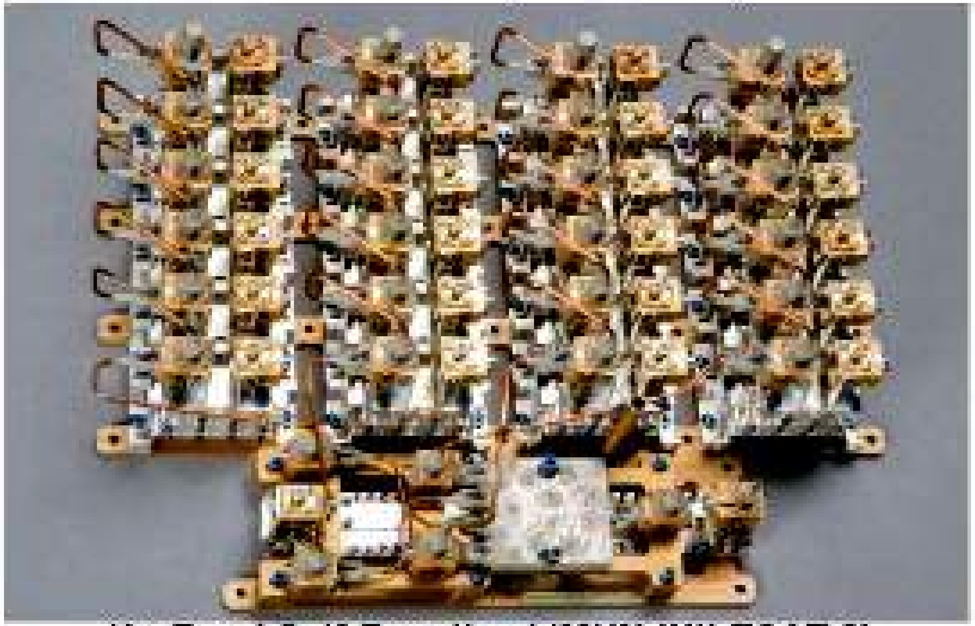
- Miniaturized lightweight technology based on Dielectric Resonators
- Narrowband (<16 MHz) and wideband designs (>500MHz BW achievable in Ku band)
- Ultra low frequency drift with temperature
- Modular design allowing customized mechanical arrangements
- Dual-channel assemblies with integrated switches

Technical Description

- Filter technology based on the use of Dielectric Resonators
- Folded monomode cavities arrangement in a single mechanical block
- Self-equalised channel filter implementation
- Input/Output sections in coaxial or waveguide technology
- Compact mechanical assembly with flat or stacked configuration



Ka-Band IMUX (YAHSAT 1A)



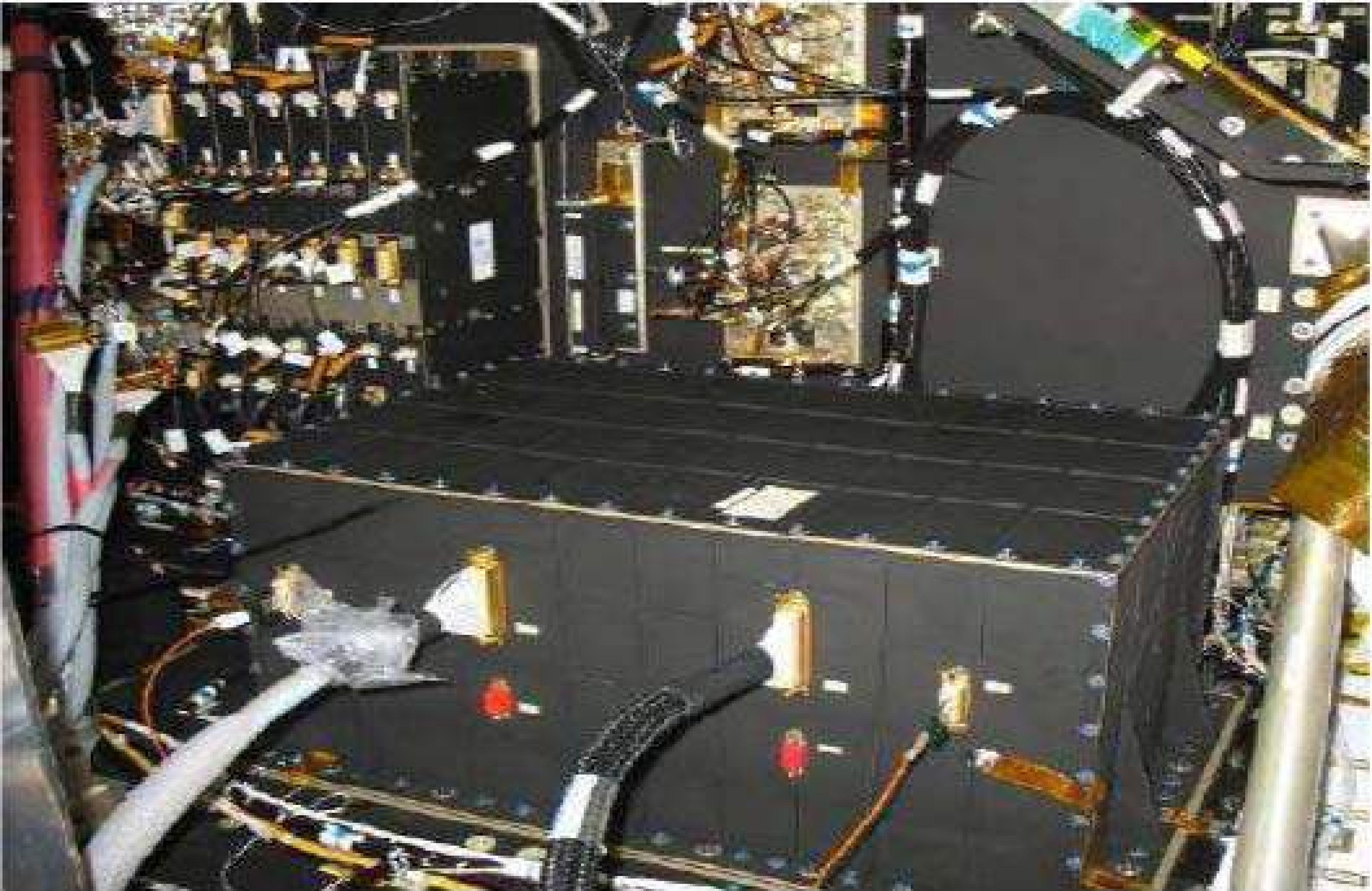
Ku-Band Self-Equalised IMUX (NILESAT 2)

Spacecraft Transmitter of Regenerative Transponder

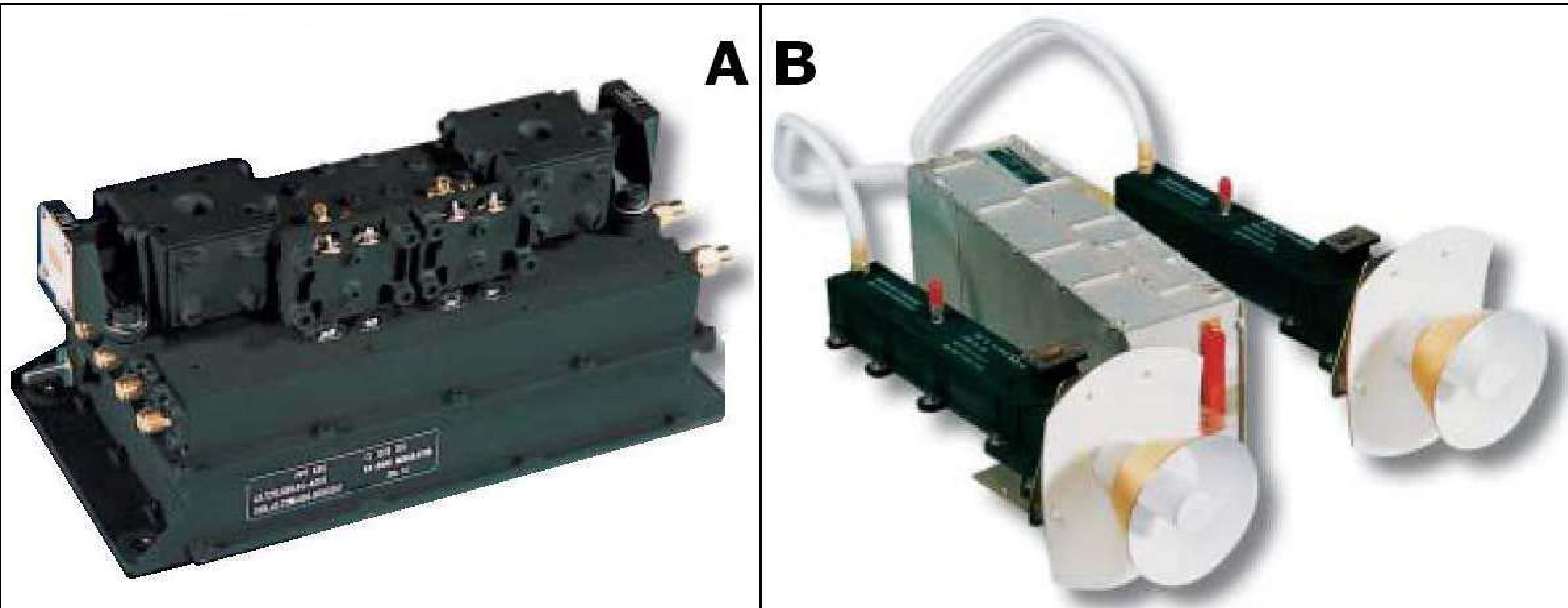
The components of Spacecraft Transmitter (Tx) are as follows:

1. Onboard Processor (OBP)
2. Modulator (MOD) and Channel Amplifier (CAMP)
3. Linearizer (LIN)
4. Upconverter/Mixer and Drivers
5. Power Amplifier: Travelling Wave Tube Amplifier
(TWTA) and Solid State Power Amplifier (SSPA)
6. Switch Assembly (SWA)
7. Tx Antenna

Spacecraft Onboard Processor (OBP)

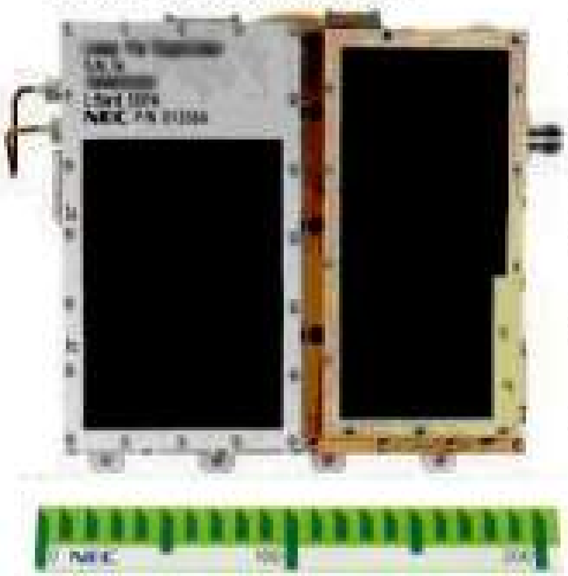


Ka-band Modulator (A) and Dual TWTA (B)



Spacecraft High Linearity SSPA

L-band 40W SSPA



Main Characteristics

- Operational Frequency Range: 1525 – 1559MHz
- High power and High gain
- Output Power : 24W min. at NPR 16dB
- Gain : 91.5dB min
- L-band SSPA consists of the Low Power Section (LPS), High Power Section (HPS) and dedicated power supply (EPC)
- L-band SSPA has the gain control function over 15.5dB 0.5dB step
- L-band SSPA output Output power monitor telemetry, Bus input current telemetry, Temperature telemetry, ON/OFF status telemetry and Gain status telemetry

L-band 55W SSPA

Main Characteristics

- Operational Frequency Range: 1540 – 1580MHz
- High power and High gain
- Output Power : 55W min
- Gain : 61dB min
- L-band SSPA consists of the LPS, HPS and EPC
- L-band SSPA has low phase shift and high linearity using linearizer.
- Phase shift: 10deg at saturation point (2dB compression)
- C/3IM: -18dB at saturation point.
- L-band SSPA output Output power monitor telemetry, Bus input current telemetry and Temperature telemetry

Satellite C-band Solid State Power Amplifiers (SSPA)

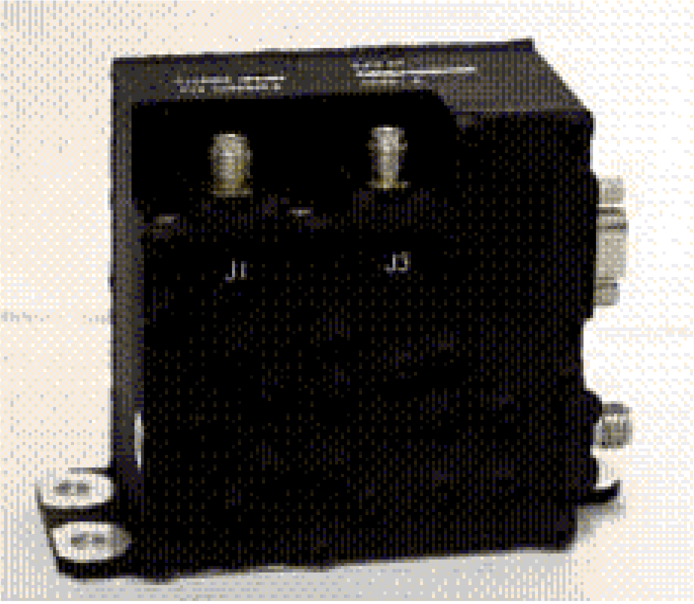
C-Band SSPA

Main Characteristics

- High power and High gain
- Output Power : 20W min ,42W min at saturation.
- Gain : 86dB nominal.
- Operational Frequency Range.
- 3400MHz to 4200MHz   Operational Bandwidth 250MHz
- C-band SSPA consists of the Low Power Section (LPS), High Power Section (HPS) and dedicated power supply (EPC).
- C-band SSPA has gain control function over 31dB 1dB step and over drive protection function.
- C-band SSPA output Bus input current telemetry, ON/OFF telemetry and Gain status telemetry.

Spacecraft C/Ka-band Upconverter

C/Ka-band Upconverter



Specification Table

Parameter	Unit	Typical performance	
		Type1	Type2
Input Frequency Range	GHz	3.583 to 3.728	3.583 to 3.728
Output Frequency Range	GHz	19.69 to 20.21	18.628 to 19.96
LO Input Frequency	GHz	8.0535 8.1160 8.1785 8.2410	7.5225 8.0535 8.1160
Gain	dB	-7.5 to -9.5	
Gain Flatness	dBp-p	0.5 / 125MHz	
Noise Figure	dB	14 max.	
Power Consumption	W	2.6 max.	
Mass	kg	0.18	
Dimension	mm	87.6 X 35.5 X 60.6	

Main Characteristics

- C/Ka-band UPCN consists of an RF Section and a STB circuit.
- RF Section converts the 4GHz input signals to the 20GHz output signal using external Local signal.
- Key parameter of C/Ka-band UPCN is as follows;

  Noise Figure: 15dB max. @ +74degC, EOL

  Gain: -835dB nom.

  C/3IM: 47dB min. (Pin = -24dBm each)

  DC Power: 2.6W max.

  Mass: 180g max.
- Self gain compensation by using the Variable Gain Amp over temperature

Spacecraft Ku/Ka-band Upconverter

Ku/Ka-band Upconverter

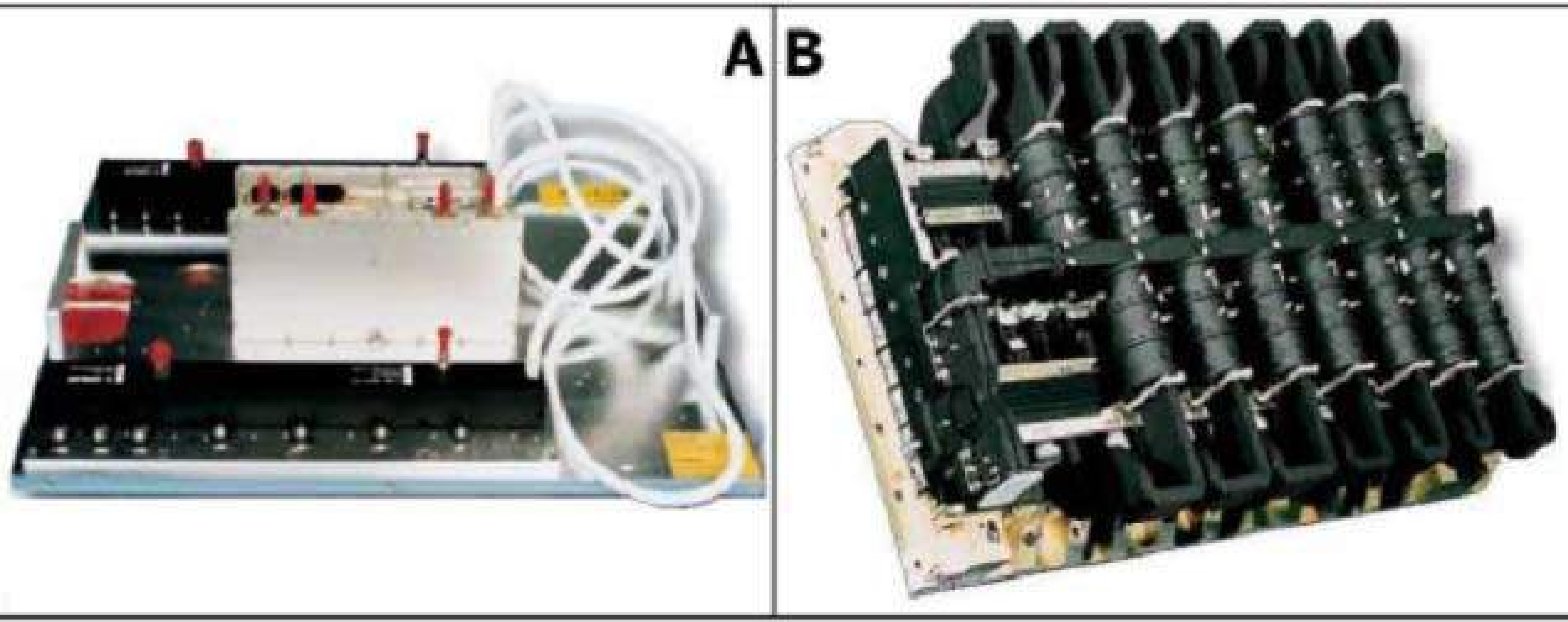
Main Characteristics

- o Low Noise Figure, High Linearity
  - NF= 8.5dB max. @+60degC
  - Gain= 30 dB min.
  - C/3IM= -50dBc max. (Pin= -38 dBm each)
- o Self gain compensation by using the Variable Gain Amp over temperature.
- o Positive Slope : Ghot-Gcold= 0.5 to 1.5dB

Specification Table

PARAMETER	UNIT	Performance		
		Min.	Nom.	Max.
Input FREQ	GHz			
Type1	GHz	14		14.375
Type2	GHz	14		14.5
External LO FREQ				
Type1	GHz		4.3	
Type2	GHz		5.7	
Output FREQ				
	GHz	18.3		18.675
	GHz	19.7		20.2
BW				
Type1	MHz		375	
Type2	MHz		500	
Gain	dB	30	31	
NF	dB			8.5
ICP (OUT)	dBm	+20		
Spurious Output				
Inband Spurious	dBc			-60
LO Harmonics	dBm			-90
In/Out Return Loss	dB	21		
RF Input I/F		SMA Female		
IF Output I/F		Extended SMA Female		
Pdc	W			5.5
Mass	Kg			0.8
Temp				
Qualification	degC	-15		65
Acceptance	degC	-10		60

Dual Microwave Power Module – MPM (A) and C-band OMUX (B)



Thanks for your attention!!!

Please, any questions?!

The End

Thank you for your attention!

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DUT

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