Ingegneria delle Telecomunicazioni

Satellite Communications

1. Introduction to Satellite Communications

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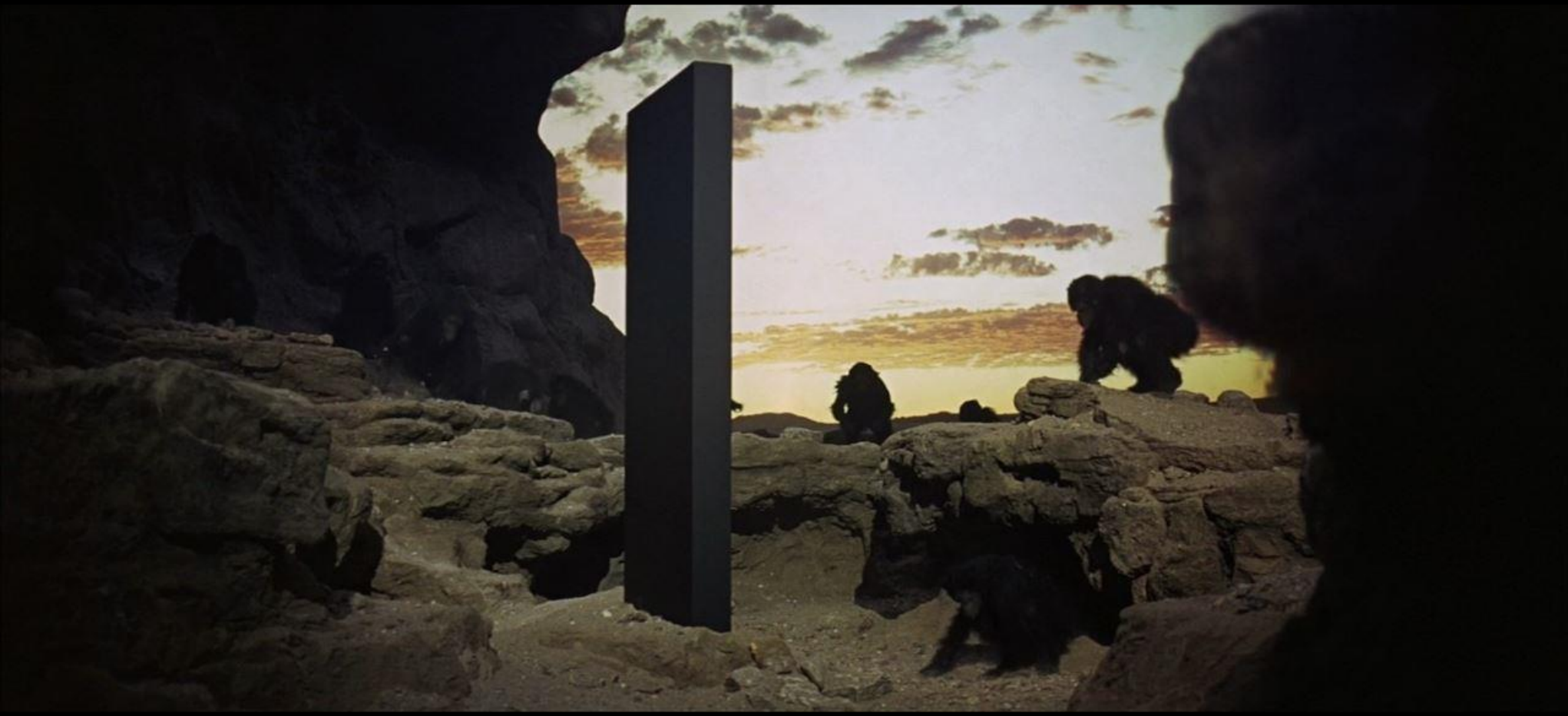


A dream (1945) ?

Extra-terrestrial Relays—
earth's equator, would revolve with the earth and would thus be stationary above the same spot on the planet. It would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set. A body in a smaller orbit would revolve more quickly than the earth and so would rise in the west, as indeed happens with the inner moon of Mars.

Using material ferried up by rockets, it would be possible to construct a "space-station" in such an orbit. The station could be provided with living quarters, laboratories and everything needed for the comfort of its crew, who would be relieved and provisioned by a regular rocket service. This project might be undertaken for purely scientific reasons as it would contribute enormously to our knowledge of astronomy, physics and meteorology. A good deal of literature has already been written on the subject.[2]

Although such an undertaking may seem fantastic, it requires for its fulfilment rockets only

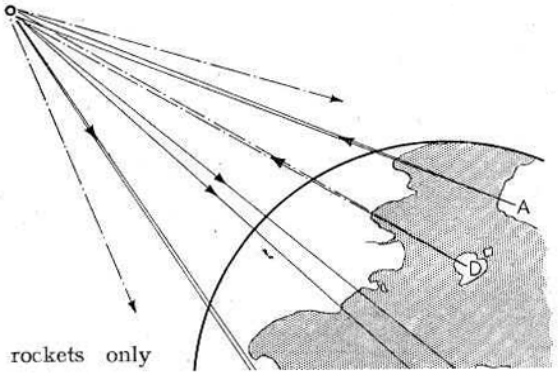


Fig. 2. Typical extra-terrestrial relay services. Transmission from A being relayed to point B and area C; transmission from D being relayed to whole hemisphere.

ments would be very small, as direct line of sight transmission would be used. There is the further important point that arrays on the earth, once set up, could remain fixed indefinitely.

Moreover, a transmission received from any point on the hemisphere could be broadcast to the whole of the visible face of the globe, and thus the requirements of all possible services would be met (Fig. 2).

It may be argued that we have as yet no direct evidence of radio waves passing between the surface

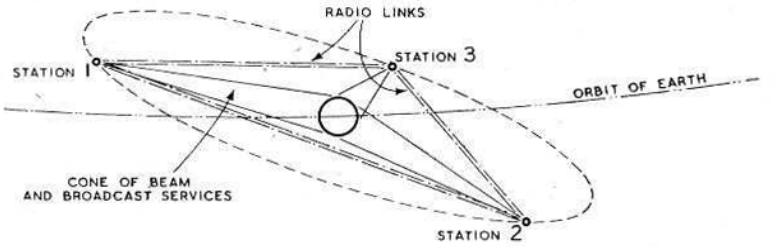


Fig. 3. Three satellite stations would ensure complete coverage of the globe.

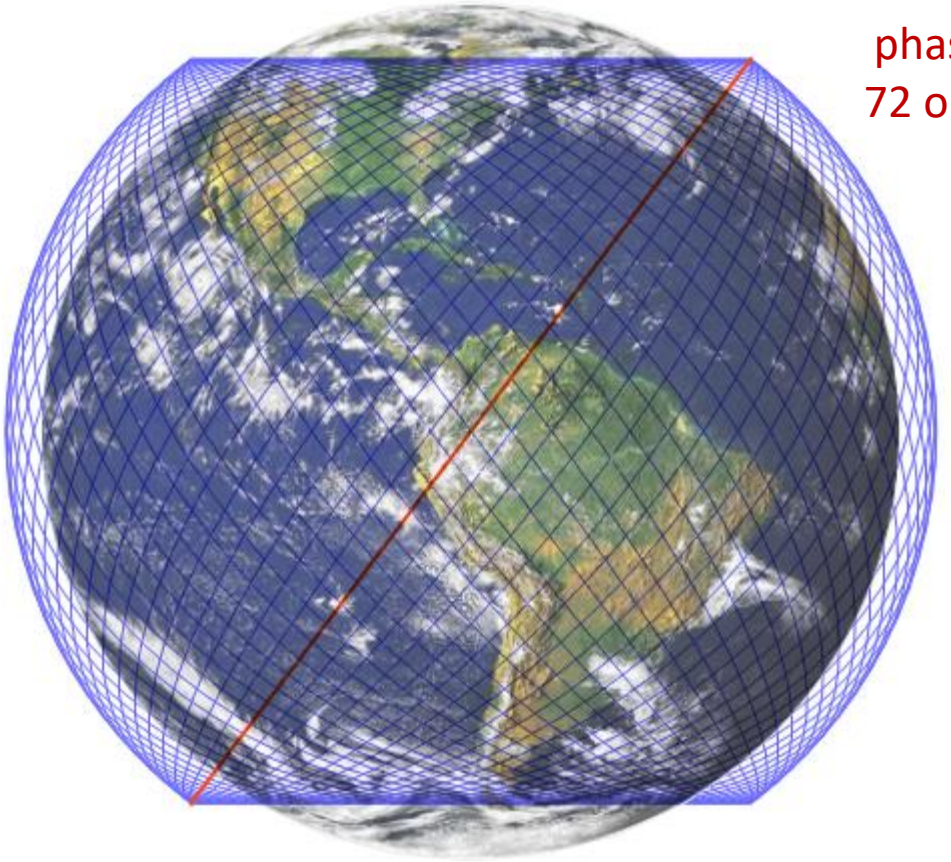
necessary evidence by exploring for echoes from the moon. In the meantime we have visual evidence that frequencies at the optical end of the spectrum pass through with little absorption except at certain frequencies at which resonance effects occur. Medium high frequencies go through the E layer twice to be reflected from the F layer and echoes have been received from meteors in or above the F layer. It seems fairly certain that frequencies from, say, 50 Mc/s to 100,000 Mc/s could be used without undue absorption in the atmosphere or the ionosphere.

A single station could only provide coverage to half the globe, and for a world service three would be required, though more could be readily utilised. Fig. 3 shows the simplest arrangement. The stations would be arranged approximately equidistantly around the earth, and the following longitudes appear to be suitable:—

30 E—Africa and Europe.
150 E—China and Oceana.
90 W—The Americas.

The stations in the chain would

The reality today (Sept. 2024)



Starlink constellation, phase 1, first orbital shell: 72 orbits with 22 satellites each, total of 1584 satellites at 550 km altitude

As of today, more that ***7000*** satellites on different LEO orbits !

Contents of the Course

- 1. What is Satellite Communications for ?
- 2. Spacecraft and Earth Station/Terminal Architecture
- 3. Basic Technologies, Design Objectives, and Performance Metrics of Satellite Links and Networks
- 4. Examples of Current GSO and NGSO SatCom Constellations and Related Services/Standards
  - *by Riccardo De Gaudenzi, Head of Electrical Systems Division, European Space Agency*
- 5. Fundamentals of Satellite Positioning and Navigation
- 6. GNSS Receiver Design and Performance Evauation

Why do we need satellites?

- **Communications (TV, Mobile, Trunk, Emergency) 67%**
  - satellites are used for television, radio, and internet broadcasting. This sector increased lately with more and more companies launching satellites to provide internet everywhere on the globe
- **Localization (GNSS, Global Navigation Satellites Systems) 3%**
  - via satellite navigation systems is widely used in almost all industries: transportation, emergency response, farming, banking, military, science. These satellites determine the location, velocity, and current time of small electronic devices (like the ones in our smart phones)
- **Earth Observation (METEOSAT, LandSat) 20%**
  - satellites provide information about earth resources, weather, climate, and environmental monitoring. Imaging satellites produce high-resolution data of almost the entire landmass on earth
- **Space Exploration (APOLLO…) 2 %**
  - satellite telescopes have been critical to understanding phenomena like pulsars and black holes as well as measuring the age of the universe

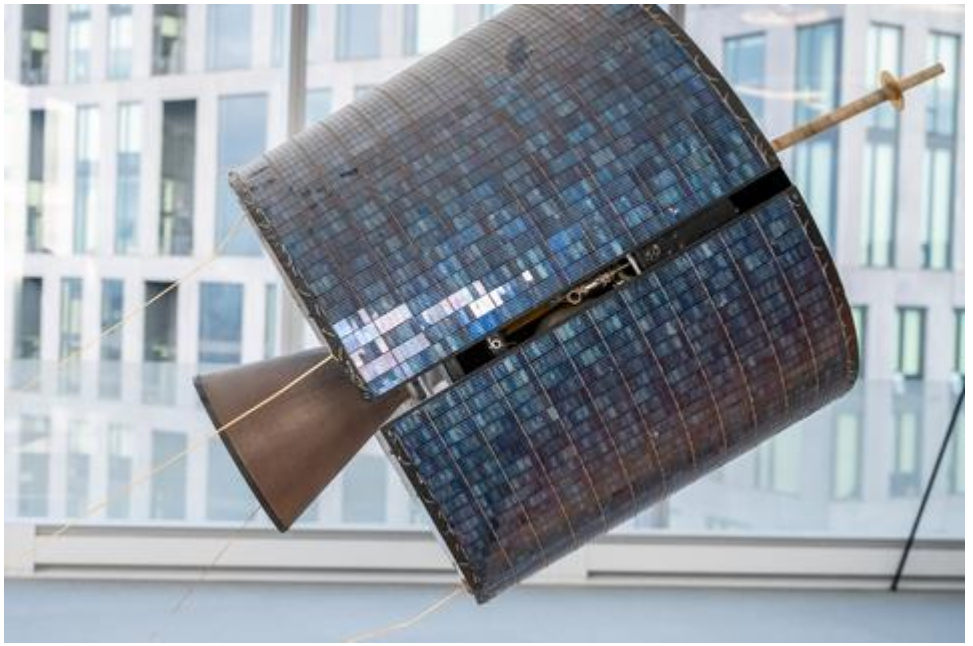
Communications Satellites: A bit of History

- **First experiment of uplink/downlink transmission:**
  - SCORE (1958, pre-recorded message in FM bands, 22 days of life)
- **First passive reflector:**
  - ECHO 1 (1960, 30-m metallized sphere bounching radio waves back, years of life)
- **First Wideband Active Satellite:**
  - TELSTAR 1 (1962, 50-MHz bandwdith at C-band, 6.4/4.2 GHz)
- **First GEOsynchronous satellite:**
  - SYNCOM (1963, range/range-rate tracking)
- **First commercial satellite:**
  - EARLY BIRD/INTELSAT I (1965, the actual date of birth of commercial satellite communications, , C-band 6.3/4.1 GHz, TWT amplifier, two 25-MHz transponders)
- **Direct TV Brodcasting:**
  - OTS (1982, by ESA with programs by SkyOne, UK)

Early Samples…

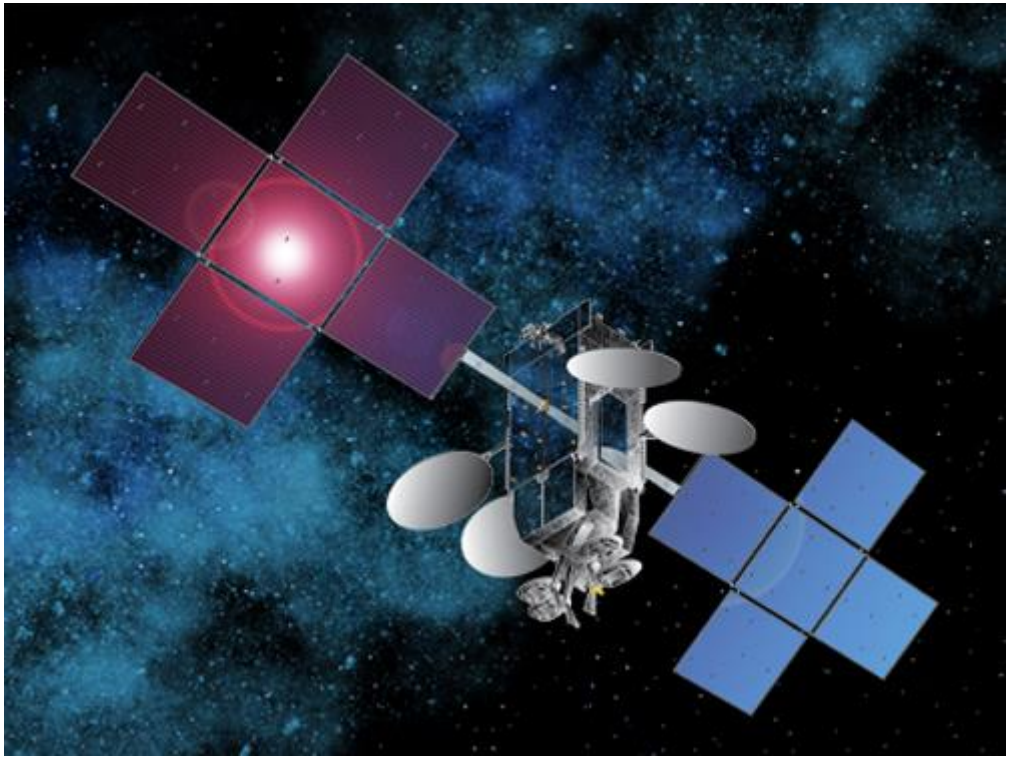
Telstar

INTELSAT I



INTELSAT 20

- **Example of modern High-Throughput Satellite**
  - Launched 2012
  - 6000 kg
  - 24 C-band transponders, 54 Ku-band transponders, 1 Ka-band transponder
  - 18 years expected lifetime



https://www.satbeams.com/satellites

Why a dedicated course on SatCom ?

- Satellite Communications traditionally require dedicated, expensive terminals and networks

- It is considered as a completely different technology than, say, cellular communications altogether
- Even service providers are not the same…

Satellite Handheld User Terminals

- **Different from Cellular Networks'**

Overall | Durability | Coverage | Features | Cost

Iridium 9575 Extreme
Rating: 7.5/10

MORE INFO

Inmarsat IsatPhone 2
Rating: 7.3/10

MORE INFO

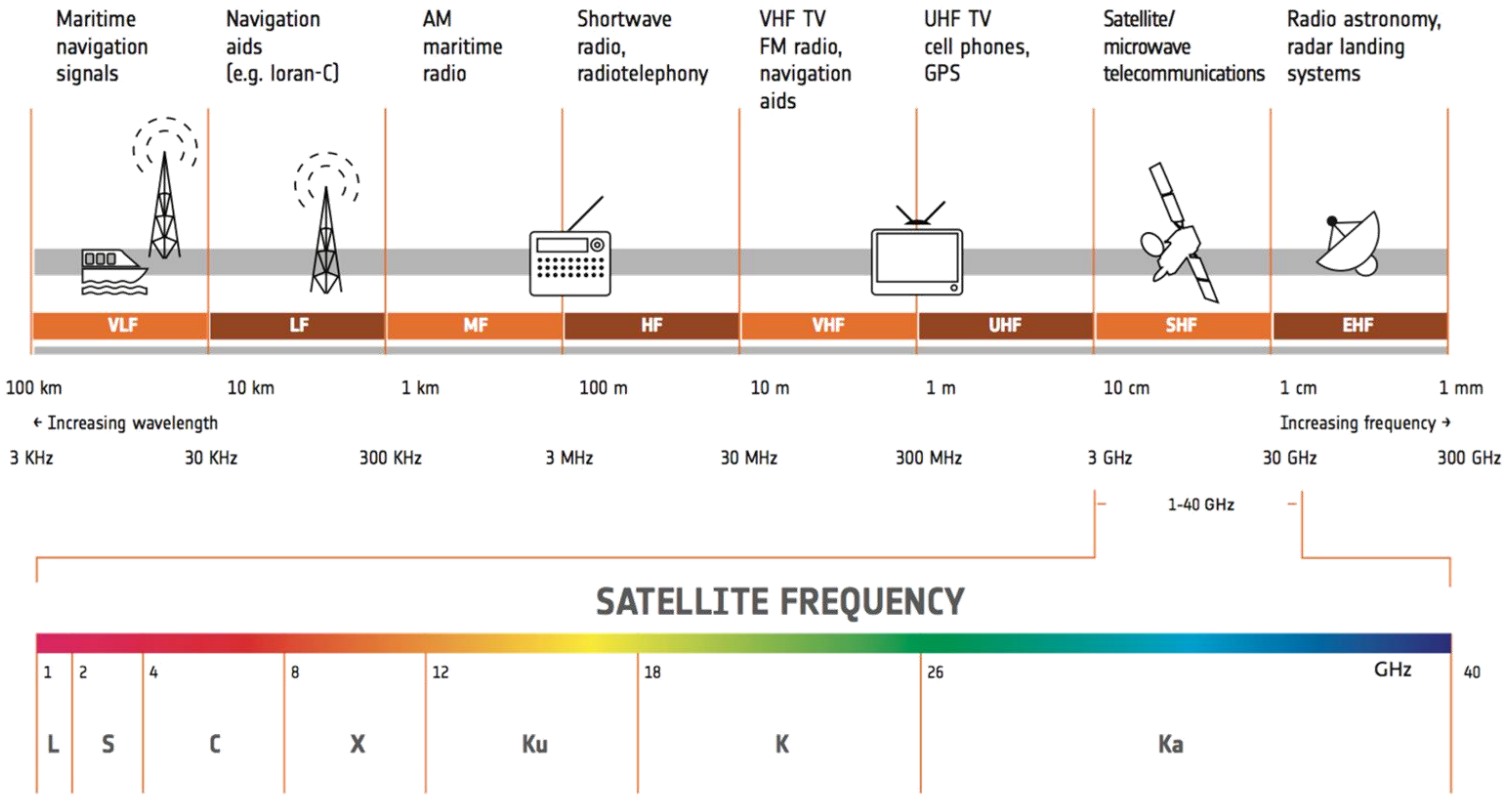
Iridium 9555 Extreme
Rating: 6.5/10

MORE INFO

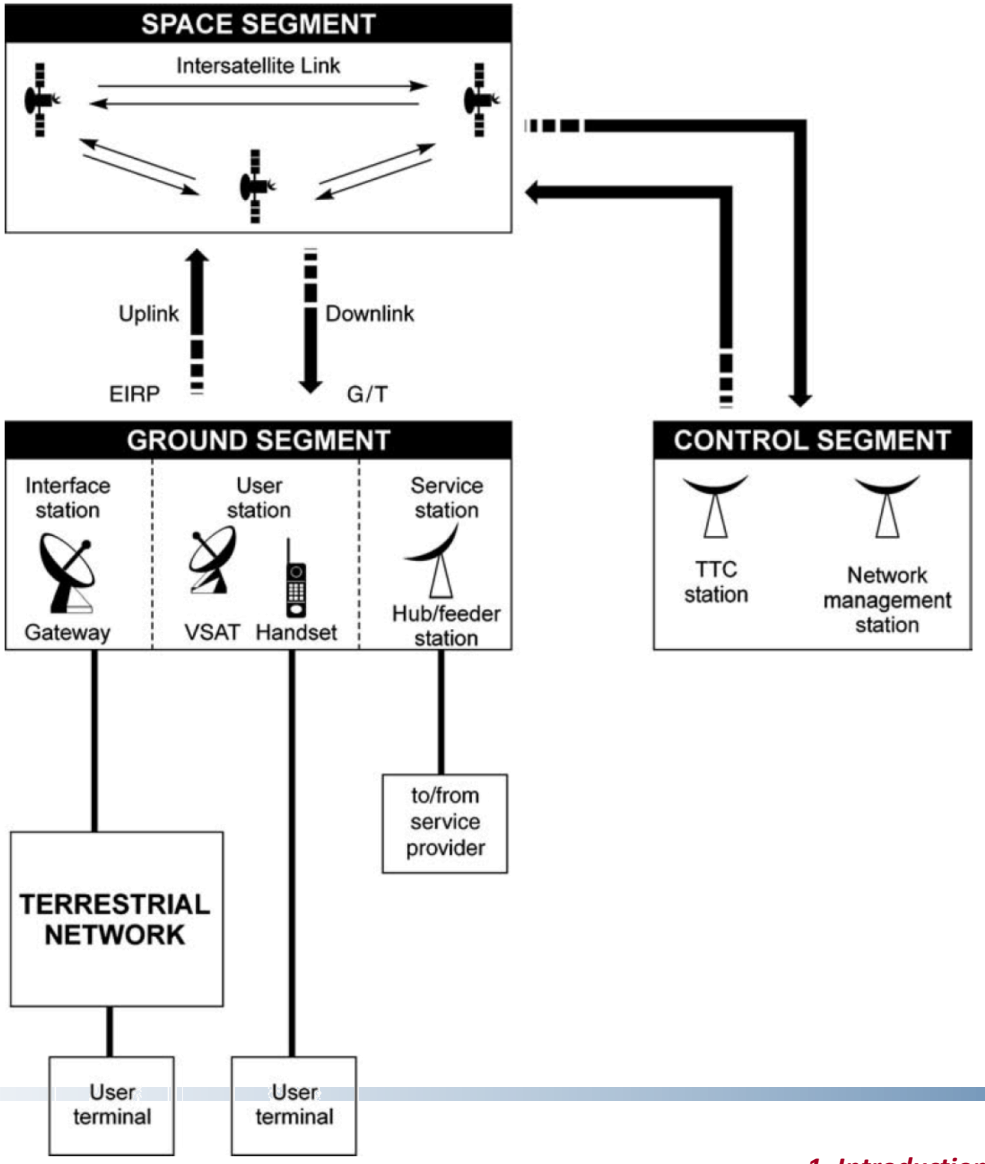
Thuraya X5 TOUCH
Rating: 5.3/10

MORE INFO

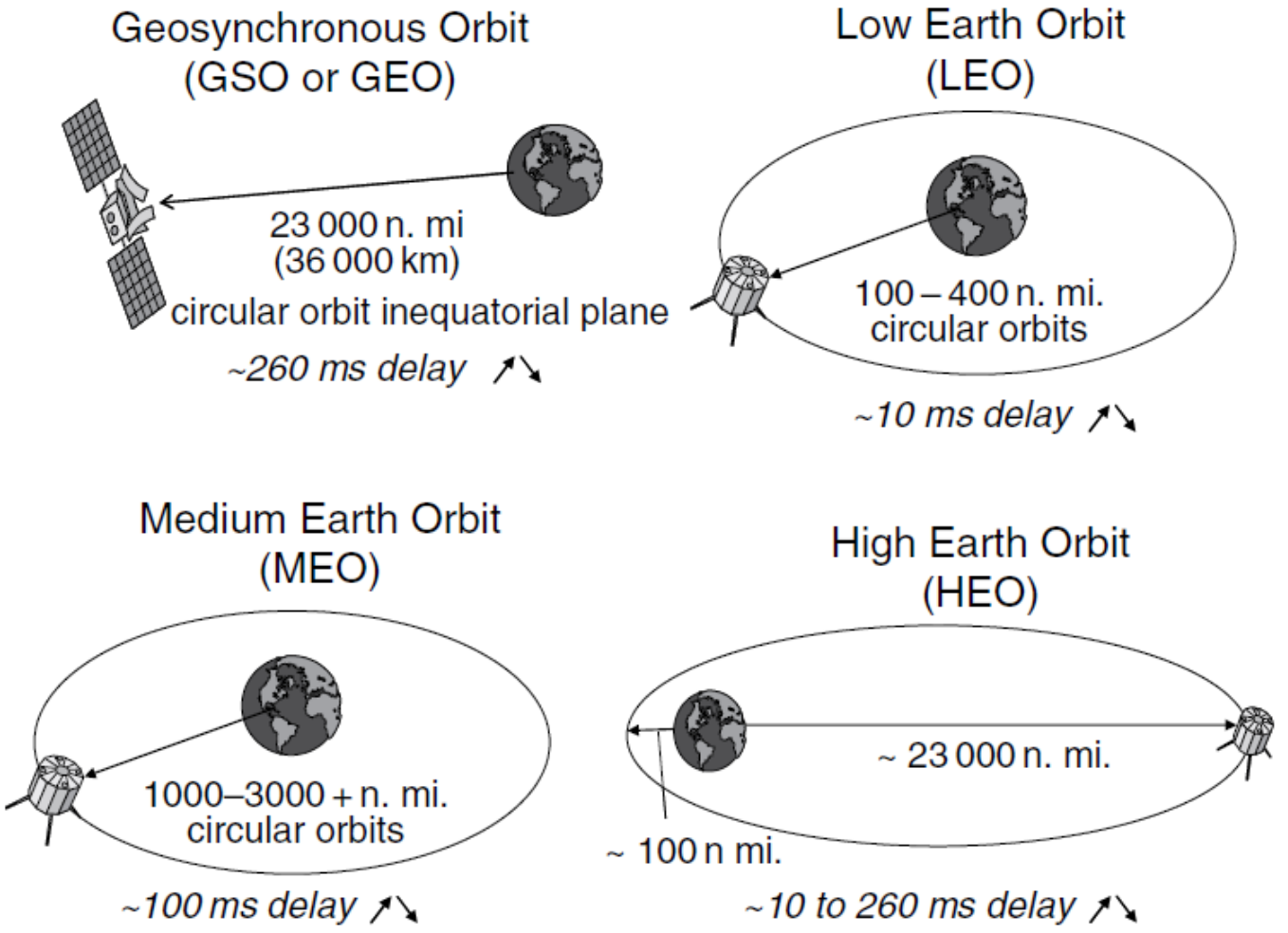
Satellite Bands



How does it work ?



GEO,LEO, MEO HEO Satellites

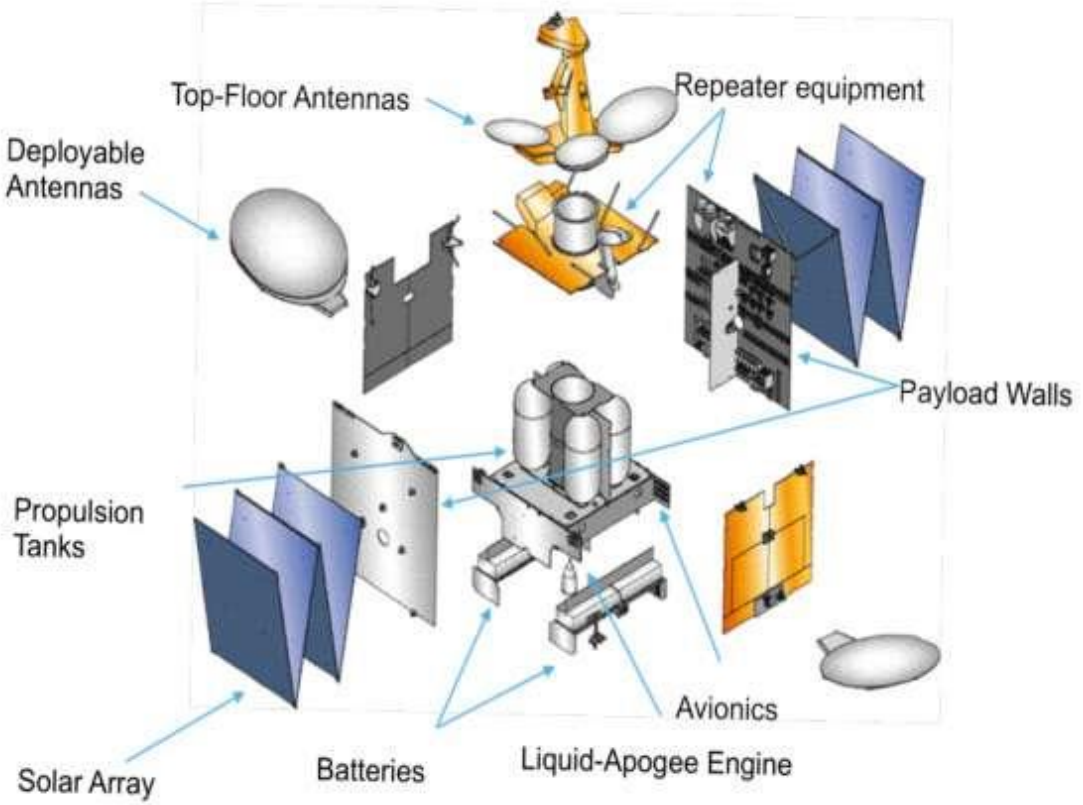


How do they launch it?

Soyuz IOV-1 launch, 2011

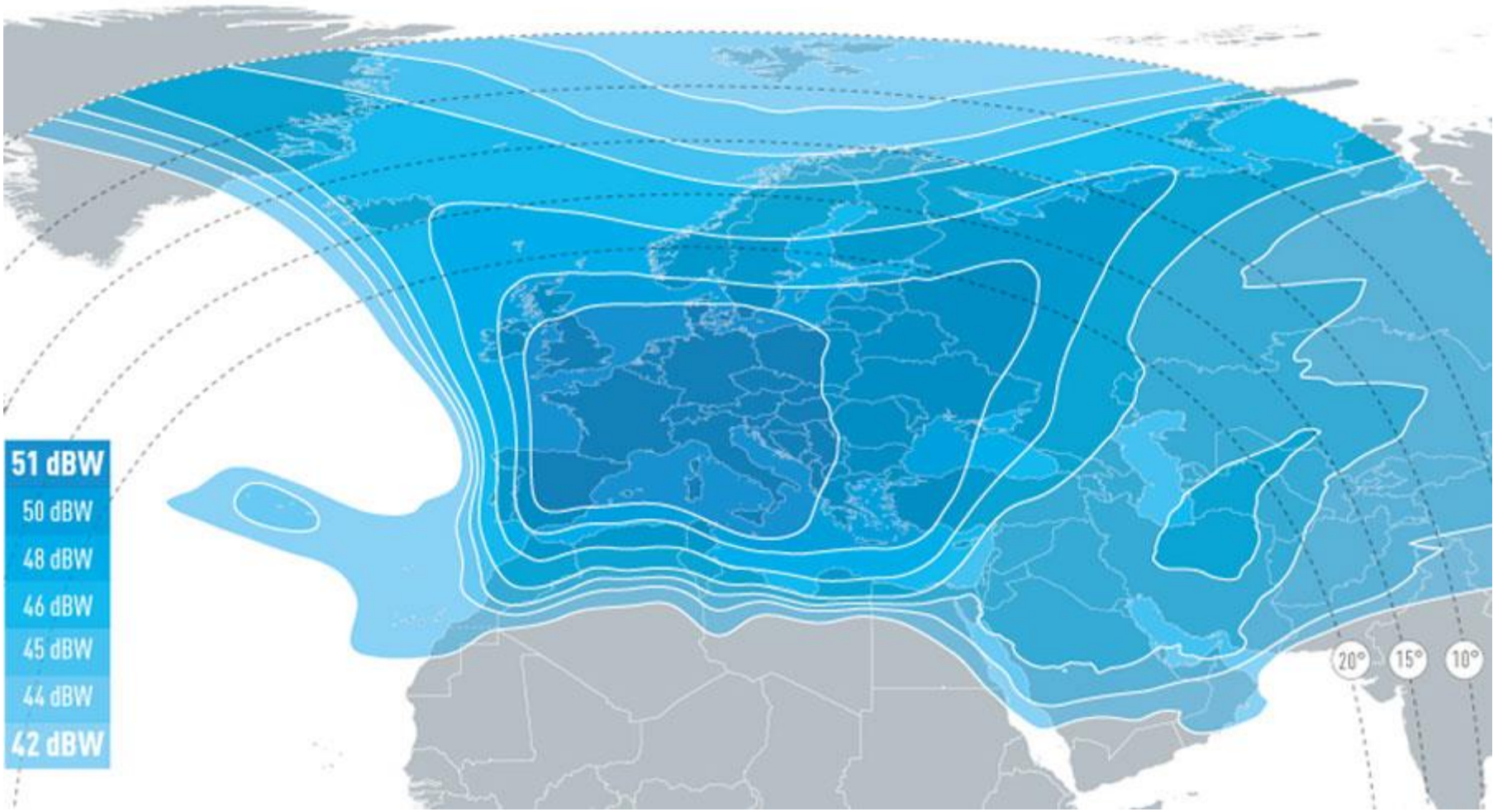
Sentinel 1-B satellite inside Soyuz fairing

Satellite Anatomy



Satellite Anatomy

Satellite Footprint



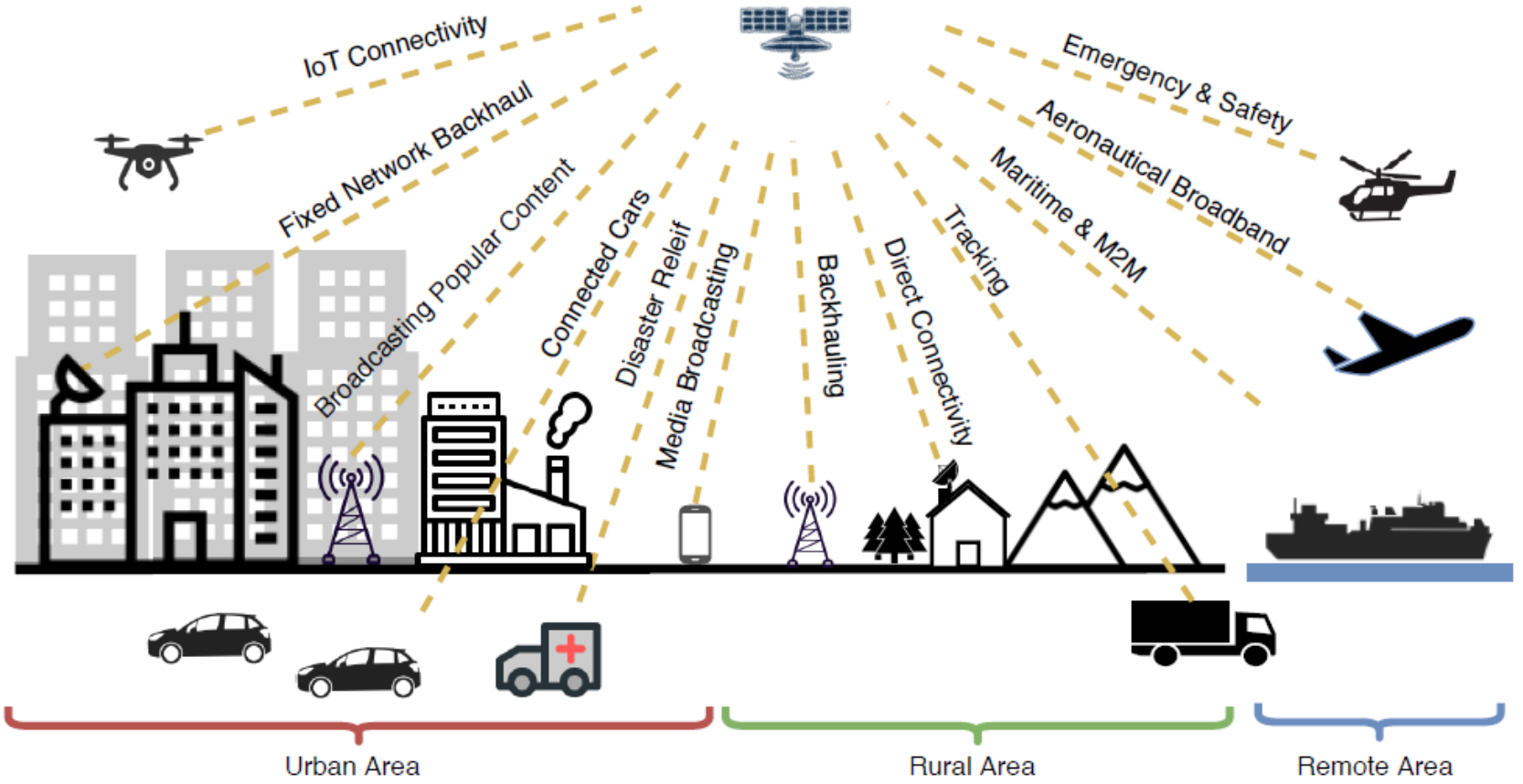
SatCom Services 1/2

- **Broadcasting**
  - By far, the most money-making. Being supplanted by streaming.
- **Backbone (Trunk)**
  - Was, togethere with broadcasting, the killer application until the ’90s. Being supplantyed by fiber cables.
- **Internet Connection to fixed points**
  - Intended to break the Digital Divide into remote areas. Revived by StarLink.
- **Mass-Market Mobile Communications/IoT**
  - Was the future of SatCom in the 90’s (IRIDIUM, GLOBALSTAR), before the advent of digital cellular. Now relegated to governmental usage.

SatCom Services 2/2

- **Remote-Areas Mobile Communications**
  - At sea, in the desert, a niche but safe market (INMARSAT, THURAYA).
- **Emergency**
  - When the terrestrial network is disrupted (flooding, earthquake, terrorism) satellite is the only means
- **Military**
  - A resilient (see above), private and secure network under the control of Defense Departments
- **Interplanetary**
  - Imagine Man really goes to Mars…

To sum-up…


IoT Connectivity
Fixed Network Backhaul
Broadcasting Popular Content
Connected Cars
Disaster Relief
Media Broadcasting
Backhauling
Direct Connectivity
Tracking
Maritime & M2M
Aeronautical Broadband
Emergency & Safety
Urban Area
Rural Area
Remote Area

Space Agencies/Entities

- **NASA National Aeronautics and Space Administration (USA)**
- **ESA European Space Agency**
- **EUSPA European Union Agency for the Space Program**
- **ASI Agenzia Spaziale Italiana**
- **CNES Centre National d'Etudes Spatiales (FR)**
- **DLR Deutsches Zentrum für Luft- und Raumfahrt (D)**
- **CNSA China National Space Administration**
- **ROSCOSMOS** федеральное космическое агентство (Russia)
- **JAXA** Japan Aerospace Exploration Agency

- **SPACEX** Space Exploration Technologies Corporation, Elon Musk, 2002

SatCom Companies

Company	Revenue (USD millions)	Country
Singtel Satellite	12,041	Singapore
SES	2,328	Luxembourg
Intelsat	2,061	Luxembourg
Eutelsat	1,499	France
Arqiva	1,290	UK
Telesat	684	Canada
Hispasat	239	Spain
Globecast	188	France
Thaicom	150	Thailand
EchoStar Satellite Services	1.886	USA

Internet Resources

- **Map of Satellites**
  - https://in-the-sky.org/satmap_worldmap.php
- **List of Satellites**
  - https://www.satbeams.com/satellites
- **Statistics**
  - https://geoxc-apps.bd.esri.com/space/satellite-explorer/
- **Naïve Orbit Calculator**
  - https://www.omnicalculator.com/physics/earth-orbit