

A world map with a dense network of green lines and red dots representing flight paths and communication nodes. The lines are concentrated in the Northern Hemisphere, particularly over North America, Europe, and Asia, indicating high traffic density. The red dots are scattered across the map, representing individual communication nodes or flight paths. The map is set against a dark blue background with a grid of white lines.

A PRIMER ON IN-FLIGHT COMMUNICATION (IFC)

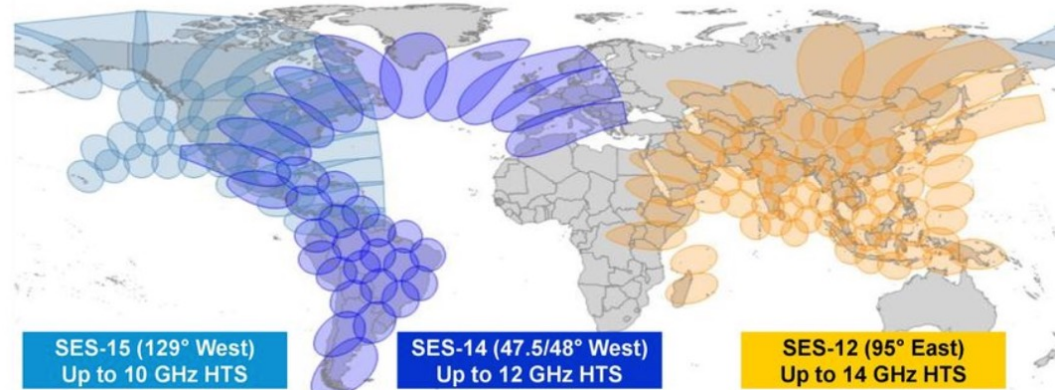
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Some Satellite Basics

GEO – Geostationary orbit, 36,000 km, sat has fixed location over the Equator

- Wide Beam Satellites are being replaced with High Throughput Satellites (HTS) and Very High Throughput Satellites (VHTS)
- Capacity is increasing from hundreds of MHz to tens, even hundreds, of GHz
- Increasing capacity through spectrum re-use
- Spot beams can place dedicated capacity where it's needed

SES-12, SES-14 and SES-15 HTS spot beam footprints



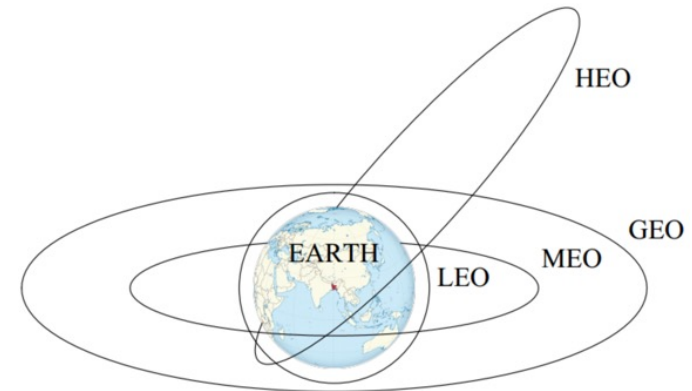
Note how spot beams are located where demand is needed

NGSO – Non-geostationary orbit, sat moves over Earth's surface

- MEO – Medium Earth Orbit ~8,000 km (SES)
- LEO – Low Earth Orbit <1,600 km (e.g., OneWeb and Starlink)
- HEO – Highly Elliptical (aka eccentric or inclined) Orbit (Space Norway)

Spectrum used for commercial aero satellite connectivity

- Ku-band 12-18 GHz – Panasonic, Intelsat (Gogo)
- Ka-band 26.5-40 GHz – Inmarsat, ViaSat, Thales
- L-band 1-2 GHz – Inmarsat (SwiftBroadband)



Connectivity to Commercial Aircraft

Wireless is different than connectivity –
a plane can have wireless without connectivity,
but a plane with connectivity always has wireless

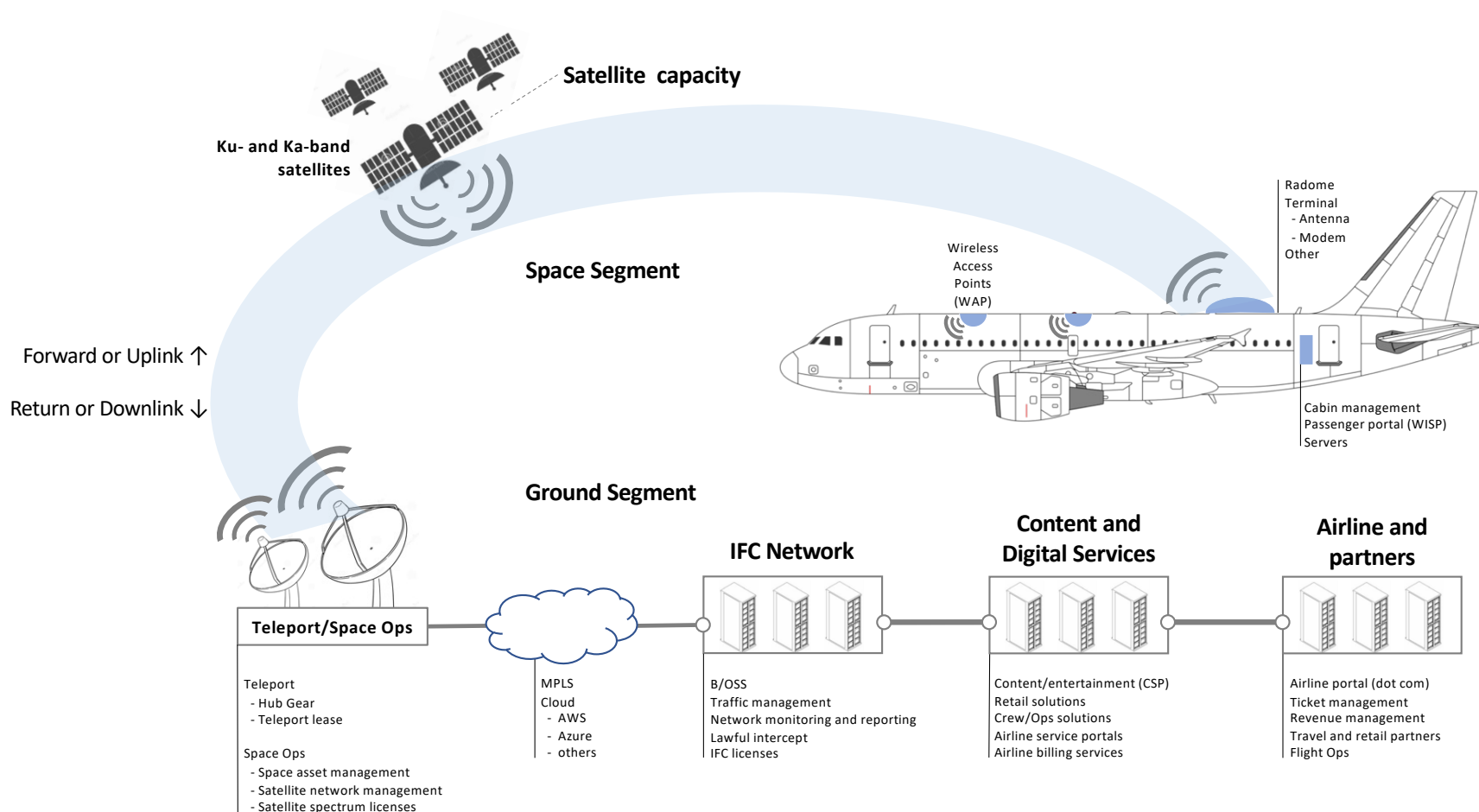
Air-to-ground (ATG)

- Gogo and Smartsky in the US, EAN in the EU
- Most use a modified cellular waveform
- May use licensed or unlicensed (ISM) spectrum
- Attractive solution for business aviation
- Limited in range and when over land

Satellite

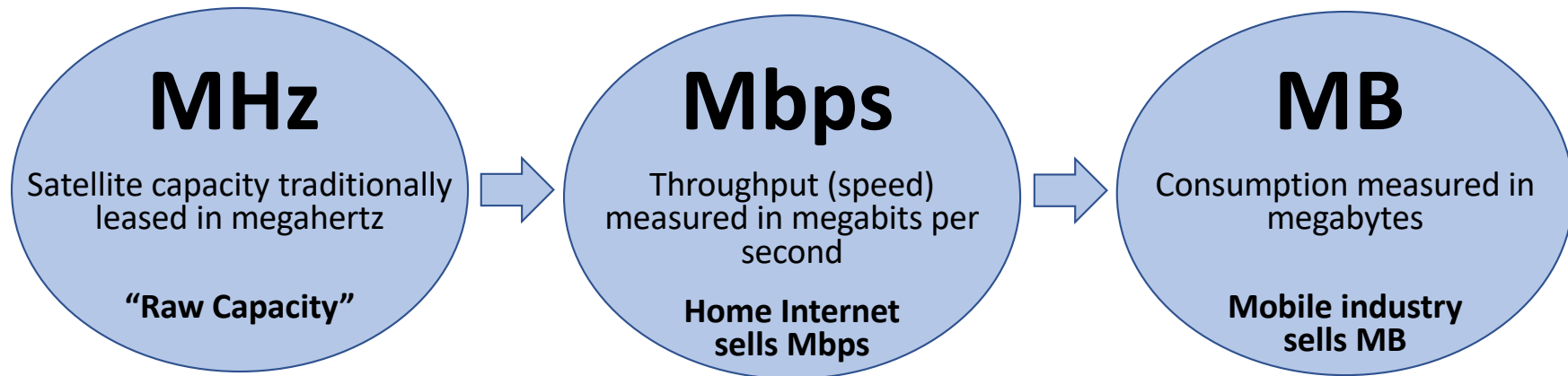
- With GEOs, when providers say coverage is “global,” it’s not fully global
- Radome size is standard but they are customized for band
- Limited antenna aperture constrains throughput
- Look angles are a challenge at high latitudes (above ~65 degrees)
- Antennas are mechanically steered (reliability and handoff issues)
- Aero terminals don’t interoperate among services – one needs to change the terminal if one changes service providers

Satellite-based In-Flight Communications (IFC)



Converting Capacity to Throughput

Service Providers begin with MHz and convert it to Mbps
Users (passengers, crew, and IoT) consume MB



The Commercial Aviation footprint is lumpy

Global Commercial Aero Traffic



More than 90% of commercial aero traffic flies over less than 5% of the globe's surface area

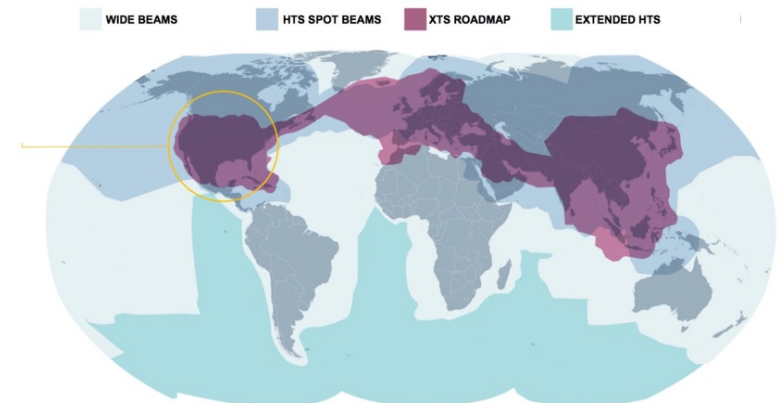
North Atlantic Operating Region (NAOR) Traffic and Beams

Aircraft tend to fly in "herds"/strong diurnal pattern

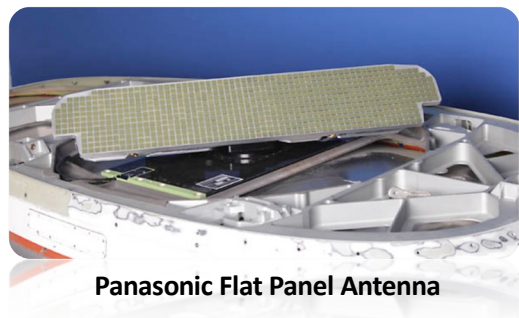


Panasonic Aero Network

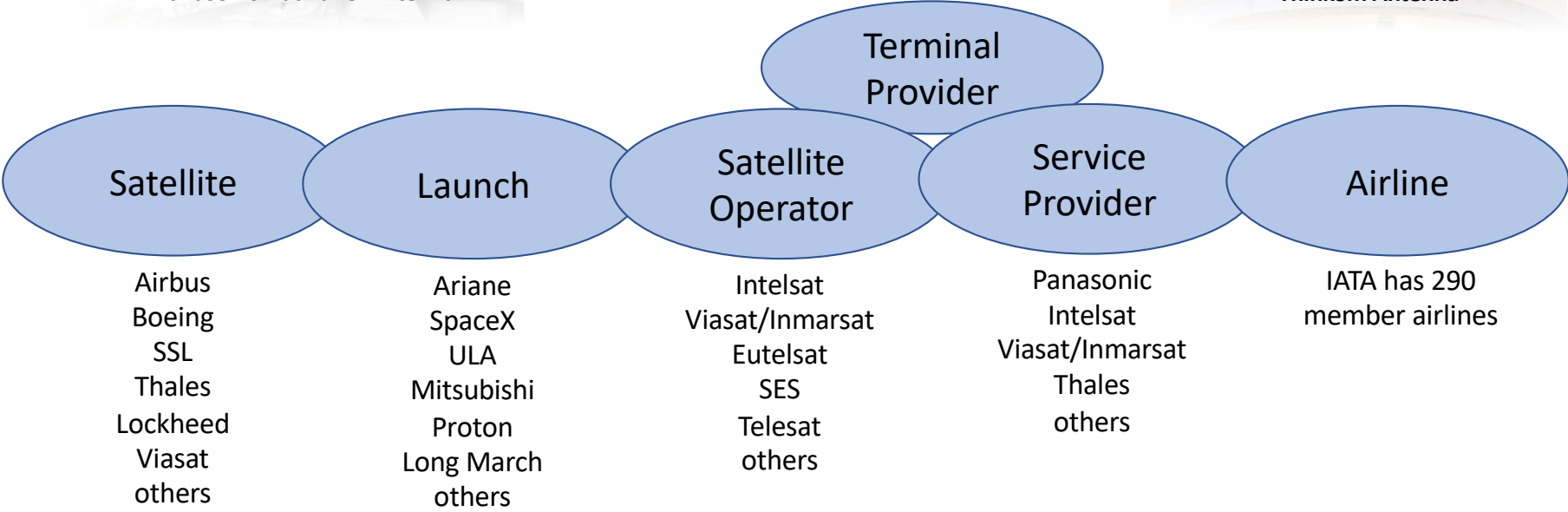
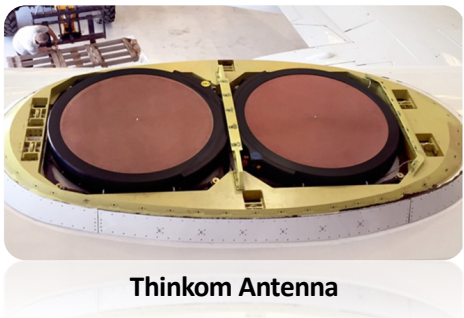
Designed expressly for commercial aviation



Satellite IFC Value Web



iDirect
Hughes
Gilat
Rockwell
Honeywell
Viasat
others



GEO Satellite Operator Economics

Most satellite cost is upfront

- Satellite build, launch and insurance costs are large
- Ongoing satellite operation cost is relatively low
- Satellite life is ~15 years for GEOs
- Capacity lease terms reflect long service life
- Focus on mobility as broadcast revenue stagnates/declines

Available spectrum limits capacity, especially in dense traffic areas

- “Create” more bandwidth with spectrum re-use (spot beams)
- Return link issues (more capacity requires multiple gateways)
- Limited orbital slots, coordination issues
- Looking at Q and V bands, also optical

Long lead times and lack of redundancy create risk

- Failures create issues that can't be quickly resolved (Viasat 2 and 3.1, IS-29e, Chinasat-18, Eutelsat 5 West B)

Opportunities through Innovation

- Launch market competition
- GaN SSPAs replacing tubes
- Part standardization and volume production
- Large unfurlable antennas
- Electronically steered antennas (ESAs)
- LEOs - Starlink and OneWeb are building constellations but do not yet have solutions for commercial IFC and LEOs present other issues for IFC

Service Provider Economics

The Terminal enables the Service

- But airlines don't want terminals, they want connectivity
- Terminals weigh too much, cost too much, are too large, and not interoperable
- Terminal cost is usually subsidized, recouped in cost of Service
- OEMs would prefer fewer linefit options
- Once installed, expensive to replace (also means Service is "sticky")

COGS dominated by capacity leases and ground segment

- Location, location, location – beam costs can vary widely
- Capacity not always available where needed
- Efficient use of capacity requires efficient and reliable terminal, plus robust B/OSS and traffic shaping
- Ground segment becoming greater percentage of COGS
- Can be long lead-time (>36 months) for bulk or "custom" capacity
- Managing oversubscription
- **Pressure building for "managed services" ←**

Airlines on different parts of the learning curve but getting more knowledgeable every day

- Linefit IFC is bid on a program-by-program basis, retrofit can be fleetwide
- SLAs (how to set, measure and ensure)
- New awards applying to existing contracts
- Price-adjustment mechanisms
- Technology outs
- Capacity guarantees
- Dealing with route deviation/evolution
- Move to charge by consumption with throughput as an SLA rather than MHz CIR (committed information rate)