Ingegneria delle Telecomunicazioni

Satellite Communications

14. SatCom Services and Constellations: Mobile

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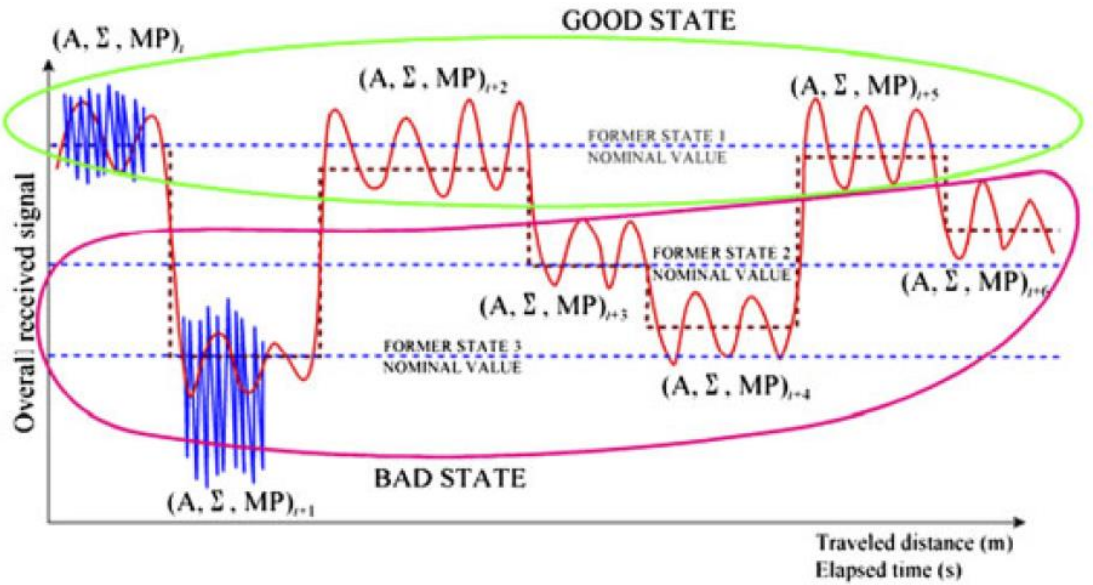
PART 1 - NON-GEOSTATIONARY MOBILE NETWORKS

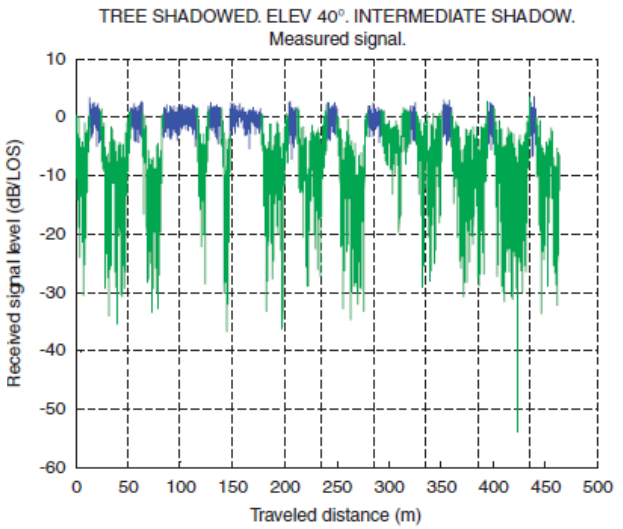
The Land Mobile Satellite Channel Model

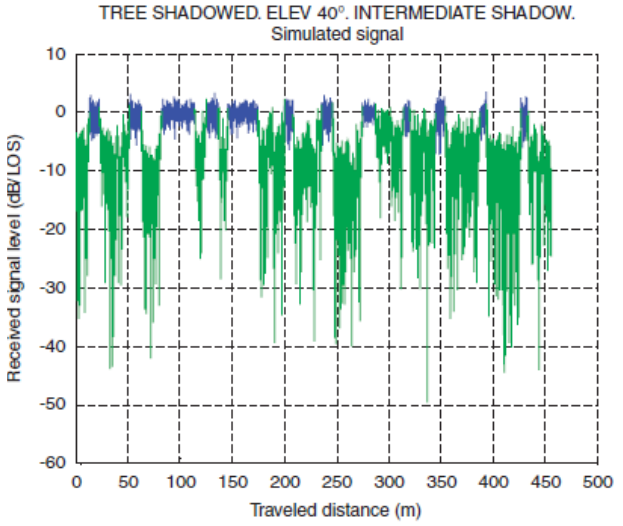
- **The L/S-band Land Mobile Satellite Channel (LMS) is different from the terrestrial one**
- **For satellite link budget line of sight (LoS) is key:**
  - Channel locally Ricean with fading bandwidth proportional to the user's speed
  - Shadowing is modelled as a lognormal process with lower dynamic
  - Blockage represents an extreme case of a shadowing event
- **Many channel models derived in the literature largely based on ESA/NASA experimental field trials**
- **State-of-the art LMS channel: two-state from Prieto Cerdeira, Fontan-Perez**
  - Two-state Markov model with lognormal and Ricean fading parameters
  - The parameters are dependent on the user environment and satellite elevation
  - State duration in meters so that can be easily scaled up to the mobile speed

The Land Mobile Satellite Channel Model

Two-state channel Markov Model



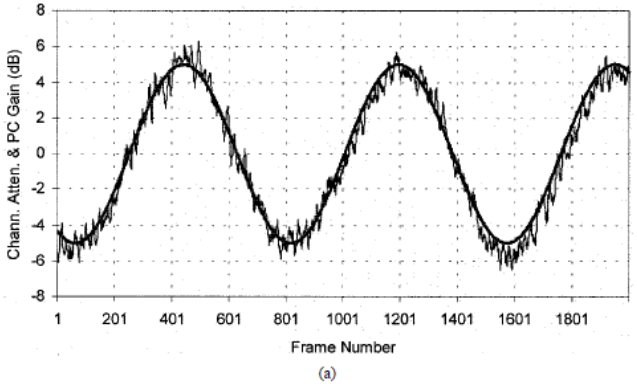




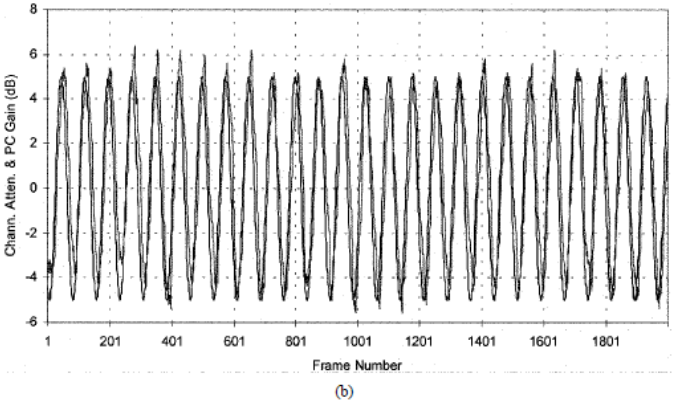
The Land Mobile Satellite Channel Challenges

- **Limited link margins make QoS challenging:**
  - Limited slow shadowing can be counteracted by closed loop power control (Target SNIR is environment dependent hence PER estimate is controlling it)
  - Fading can be counteracted with FEC block interleaving (latency impact)
  - Blockage can be counteracted by spatial diversity

0.1 Hz sinusoidal shadowing



1 Hz sinusoidal shadowing



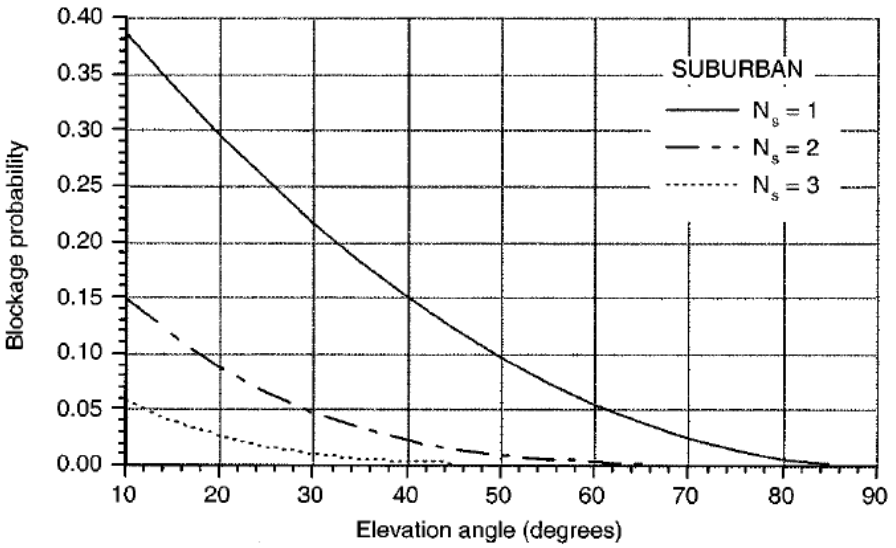
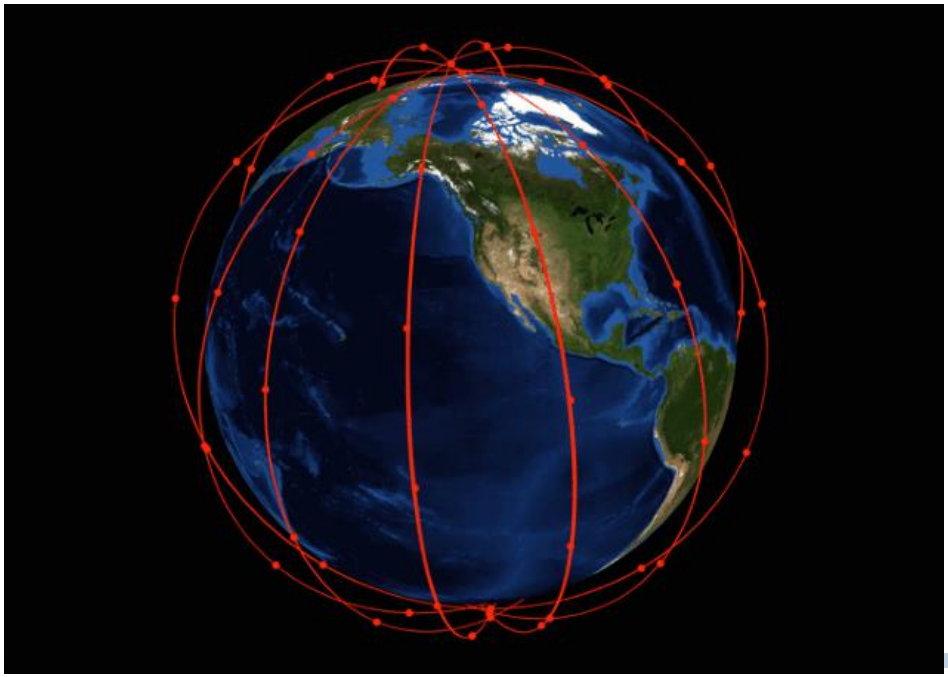


Fig. 1. Path blockage probability in a suburban area, with the number of satellites (N_s) above the minimum elevation angle as a parameter [6].

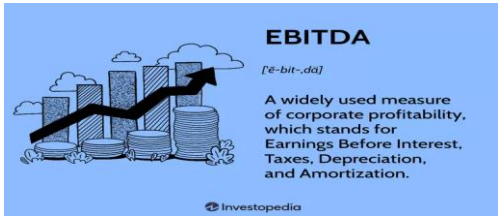
NGSO Mobile Iridium Constellation

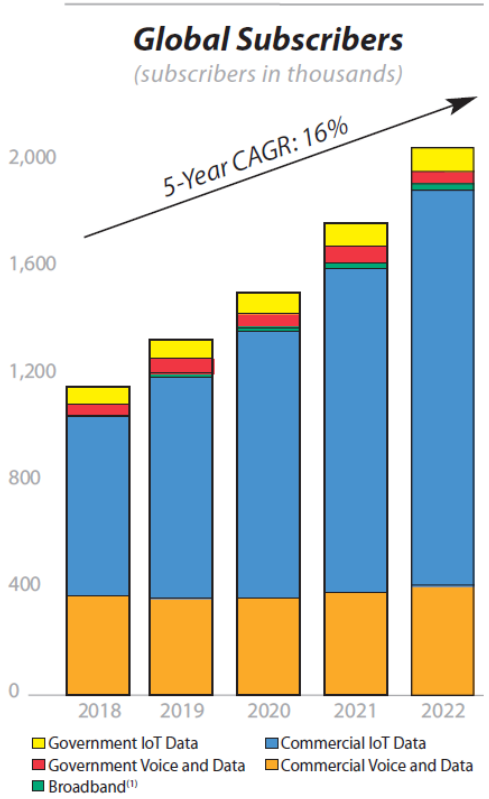
- LEO constellation at an altitude of 780 km for mobile telephony and low-rate data services – implemented by Motorola (US)
- 66 satellites in quasi polar orbits (86.4 degrees inclination) over 6 planes, 100 min orbit
- Inter-satellite links and on-board regeneration
- 1st generation started service in 1998 and became fully operational in 2002
- Iridium declared bankruptcy in 1999, the largest one at that time mainly due to GSM success

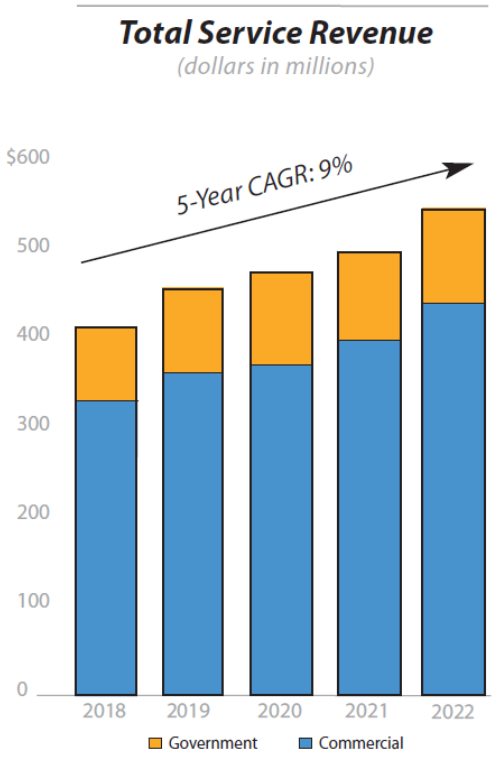


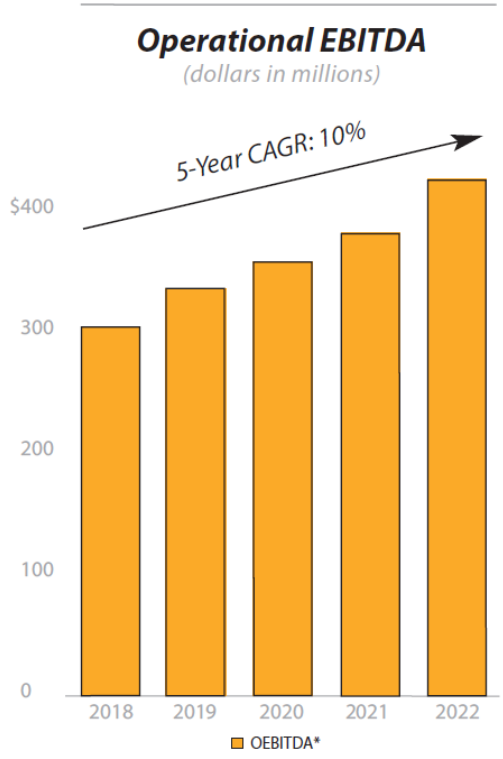
NGSO Mobile Iridium Constellation

- 2nd generation (Iridium Next) put in operation in 2017-2019 – 2022 2.0 Million users
- Debt of 1.5 BEURO despite positive income in 2022









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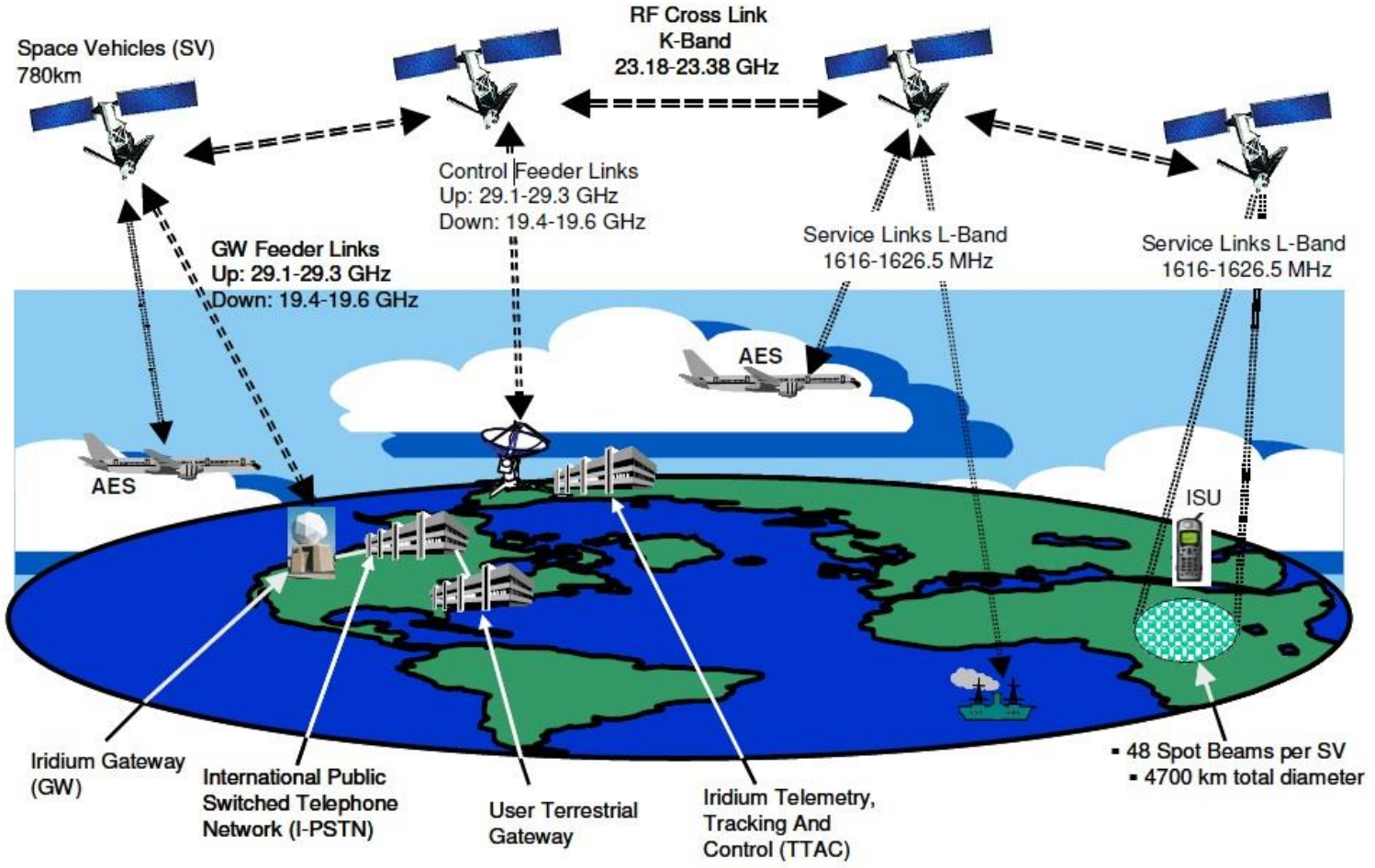
NGSO Mobile Iridium Constellation

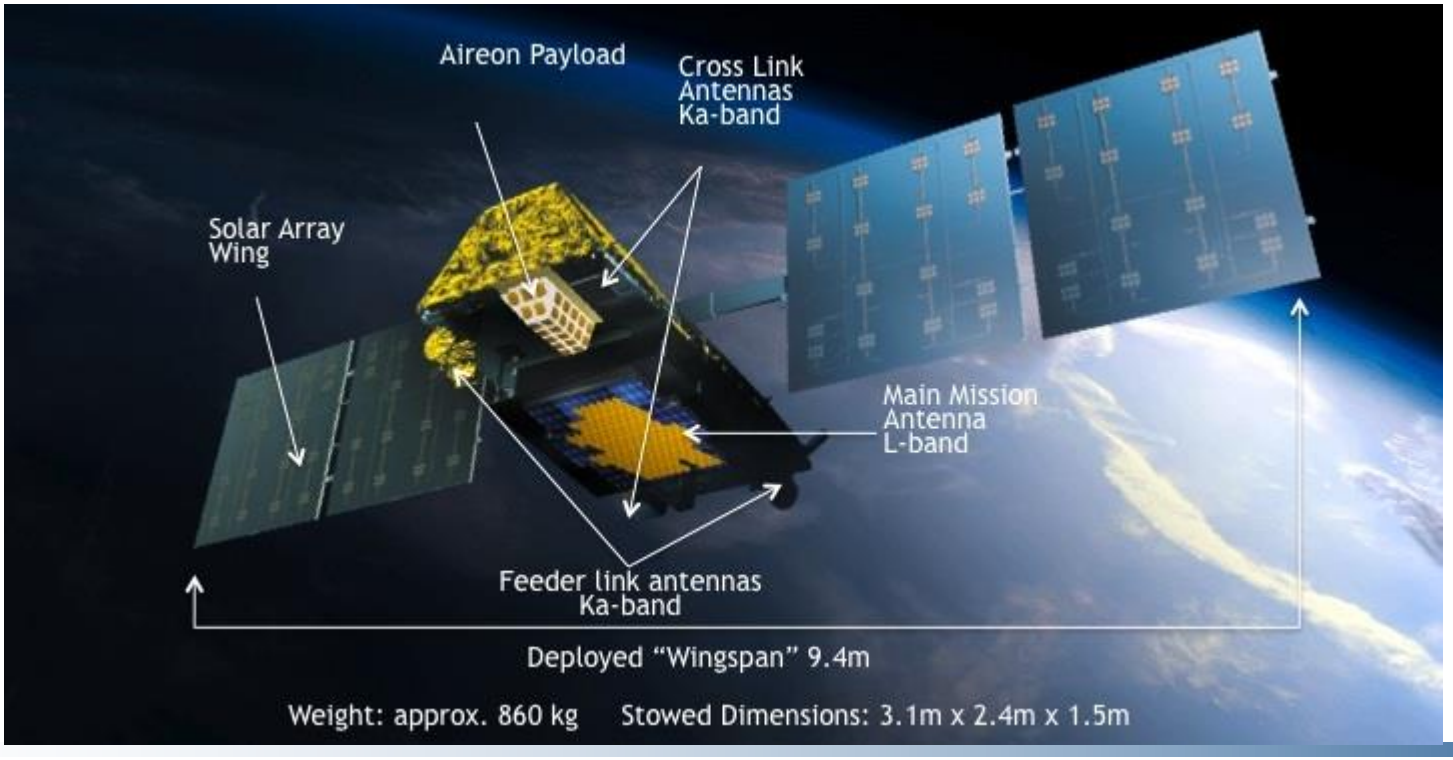
The Iridium system architecture



NGSO Mobile Iridium Constellation

The Iridium Next spacecraft:

- L-band direct-radiating array with digital regenerative fully reprogrammable payload
- 2 feeder link antennas with mechanical steering (Ka-band)
- 4 crosslink antennas (K-band forward/back/left/right, 2 with mechanical steering)
- Aireon hosted payload for air traffic management (airplanes ADS-B messages reception)

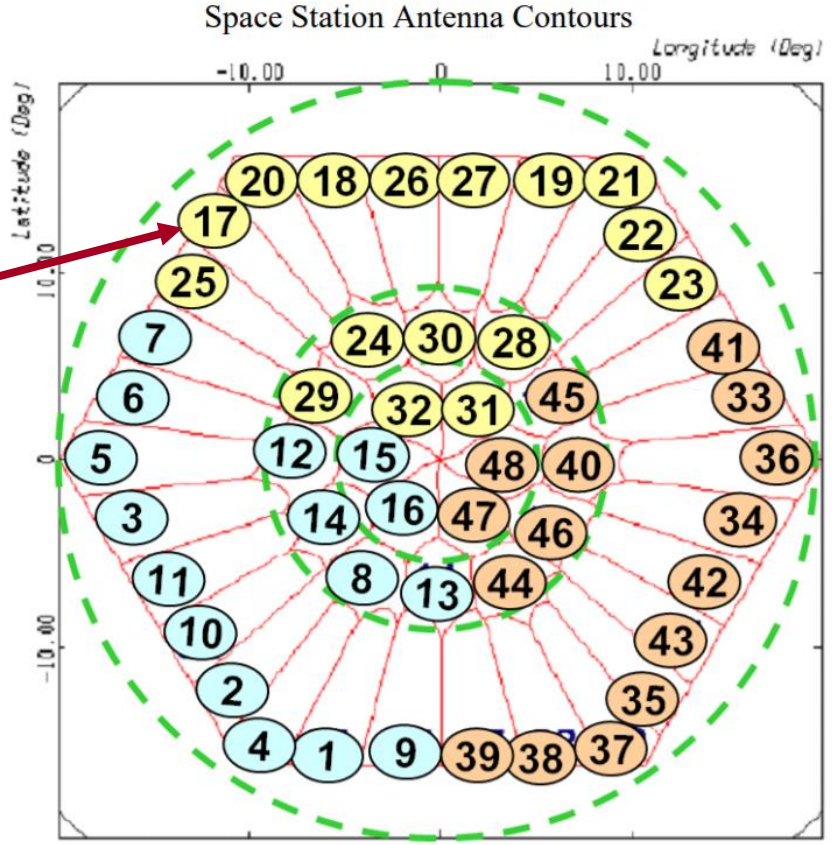


NGSO Mobile Iridium Constellation

The Iridium Next L-band antenna pattern:

- 48 non steerable beams
- Satellite handoff every 7 minutes
- Beam hand-off every 50 sec

Beam shape in the outer ring heavily distorted when projected on ground



NGSO Mobile Iridium Constellation

The Iridium ground segment (user terminal and gateways)

- Thanks to ISL only few gateways required to provide global coverage
- From hand-held to compact maritime terminals
- Powerful paging capability for providing some indoor penetration

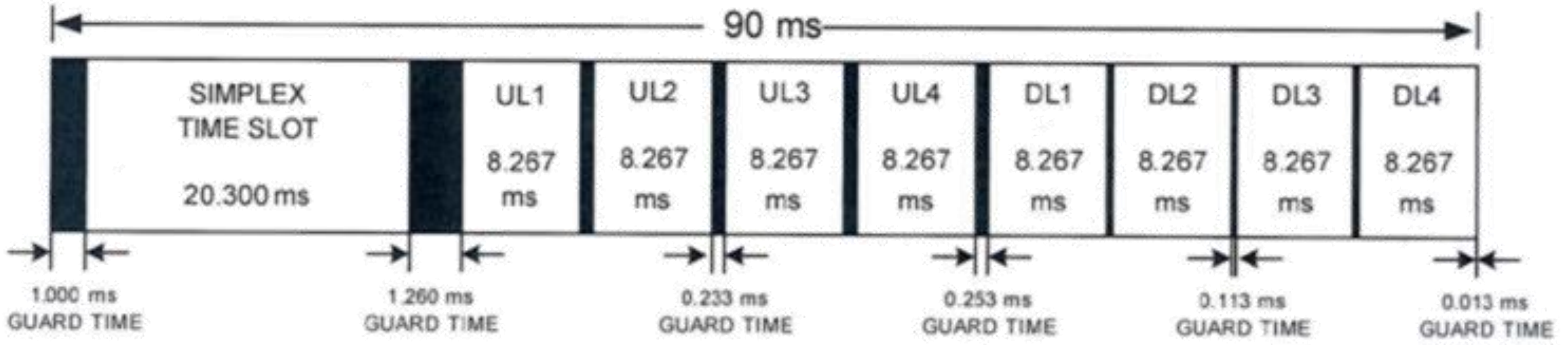
User terminals

Gateway

NGSO Mobile Iridium Constellation

The Iridium air interface

- Up/downlink in time division duplexing (TDD) to simplify user terminal RF front-end (unique case in MSS!)
- TDM(A) multiplexing
- 252 x 35 kHz carriers in 1610.0-1625.5 MHz band, up to 8 carriers can be aggregated for data services
- Differentially encoded QPSK for traffic channel, D-BPSK for uplink acquisition
- FEC with code rates 4/5 and 2/3
- Powerful paging for some indoor penetration

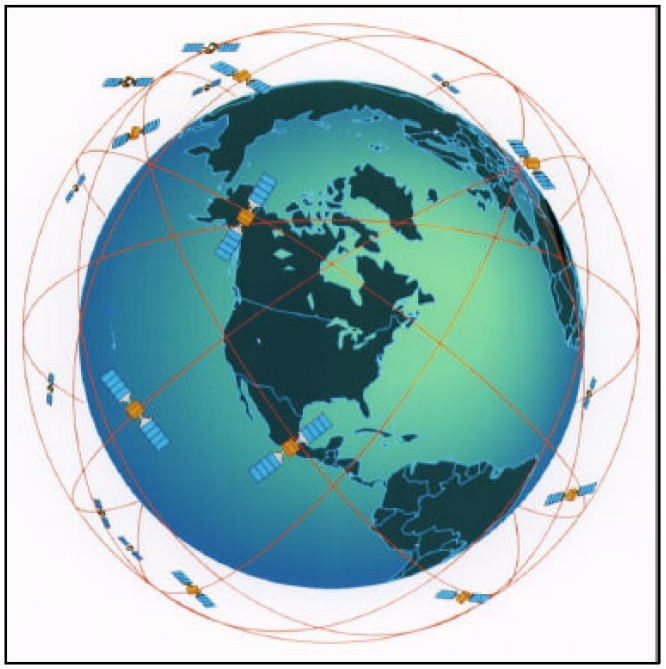


TDMA/TDD frame

Uplink/downlink slots are time multiplexed in the frame => simpler user terminal (no diplexer)

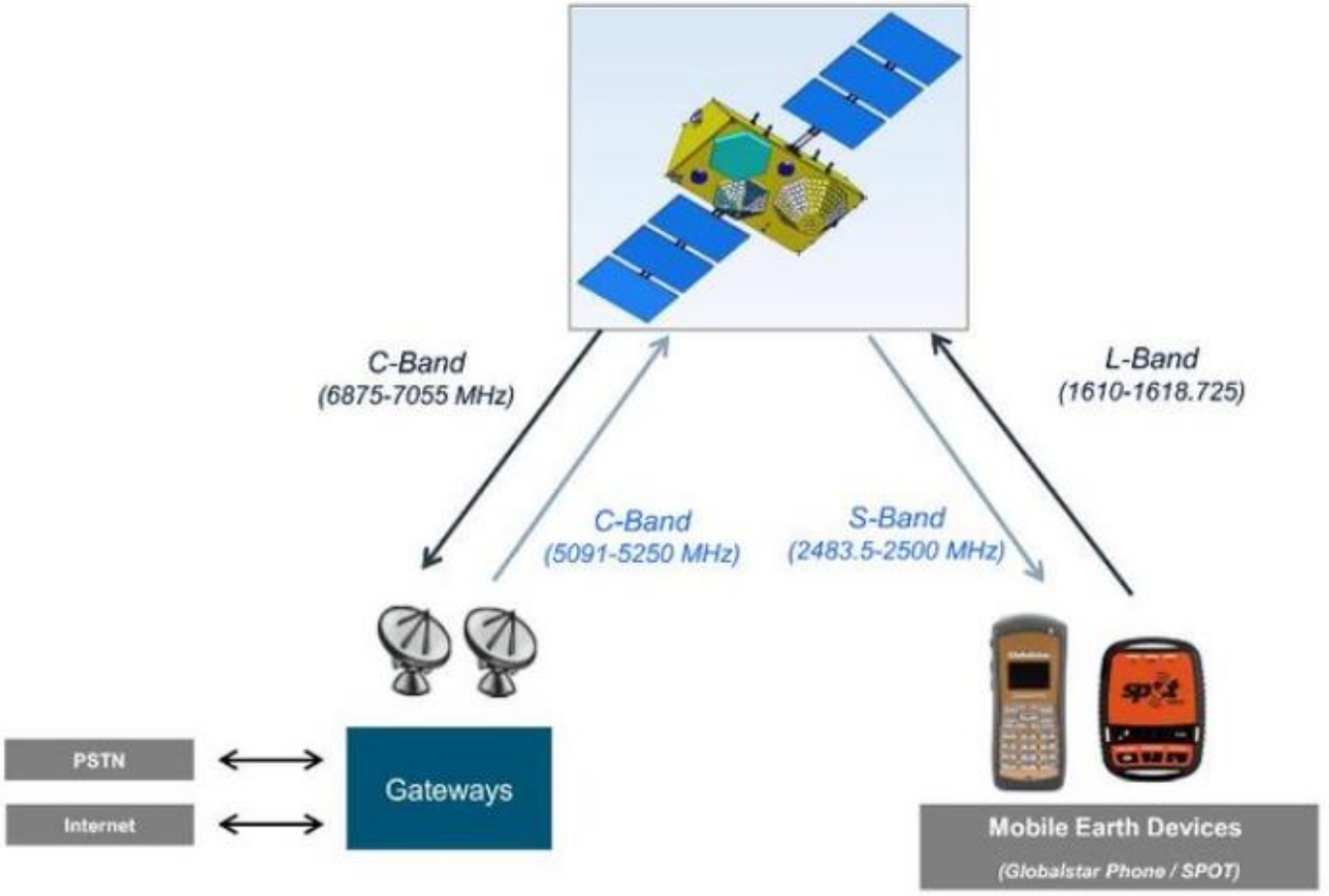
NGSO Mobile Globalstar Constellation

- LEO constellation at an altitude of 1410 km for mobile telephony and low-rate data services – Developed by Space System Loral, Qualcomm and Thales Alenia
- Satellites in inclined orbit (52 degrees inclination) over 8 planes, 114 min orbit
- Simple bent-pipe satellites (no ISL), several gateways not providing global coverage
- 1st generation constellation deployment completed in 2000 (48 satellites)
- 2nd generation put in operation in 2019 (24 satellites)



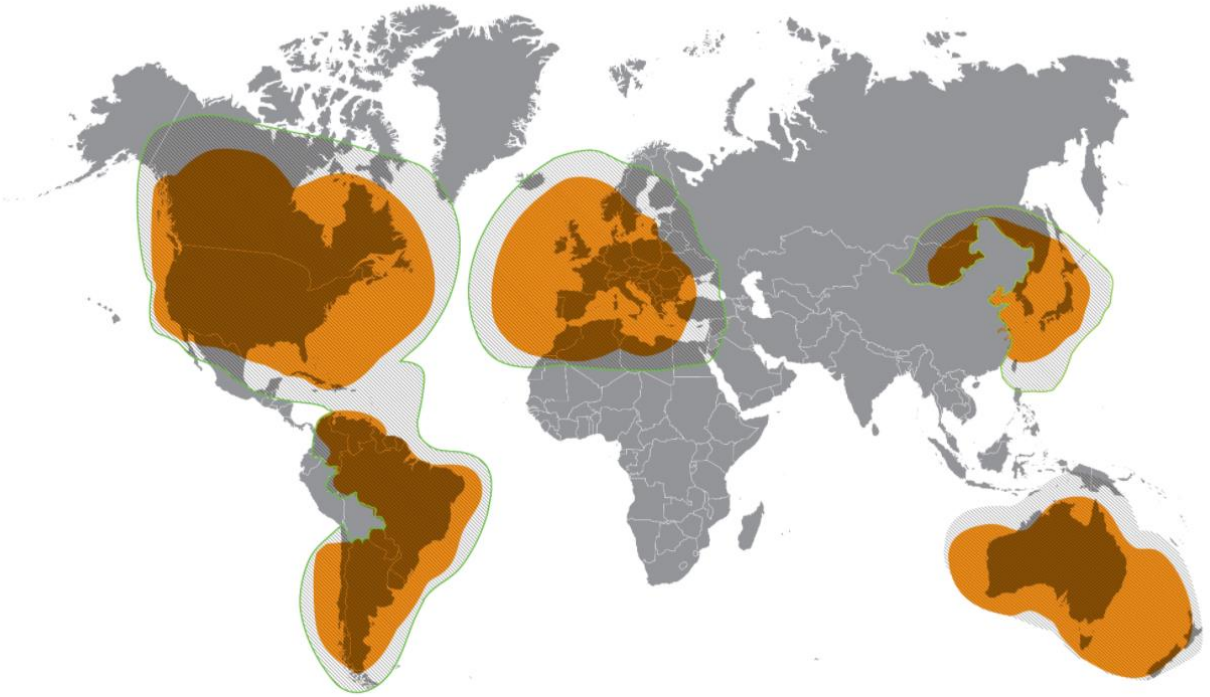
NGSO Mobile Globalstar Constellation

The Globalstar system architecture



NGSO Mobile Globalstar Constellation

The Globalstar system voice and data current coverage

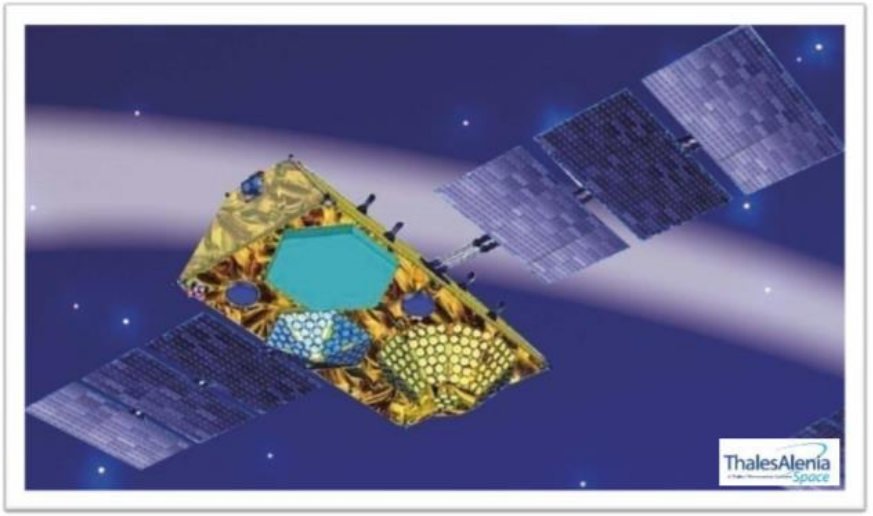


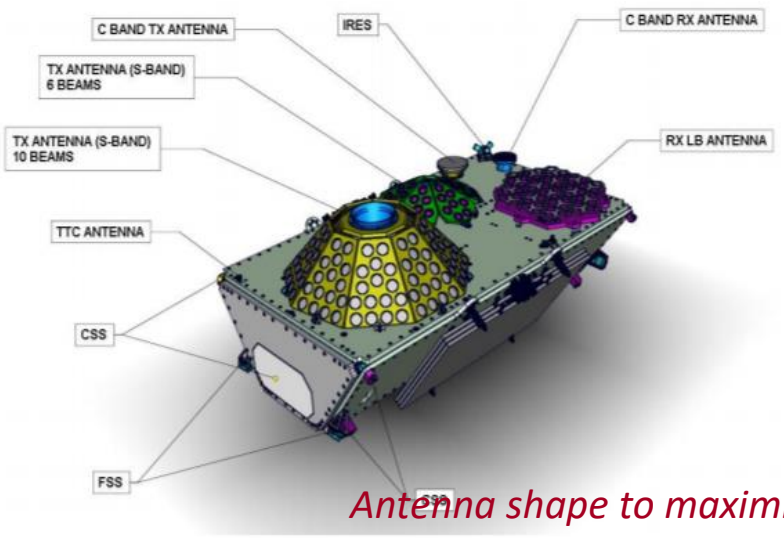
NB: Initial plans were showing much wider coverage thanks to a larger number of gateways across the world Now reduced due to the lack of national agreements/cost of the ground segment

NGSO Mobile Globalstar Constellation

The Globlastar 2nd generation spacecraft:

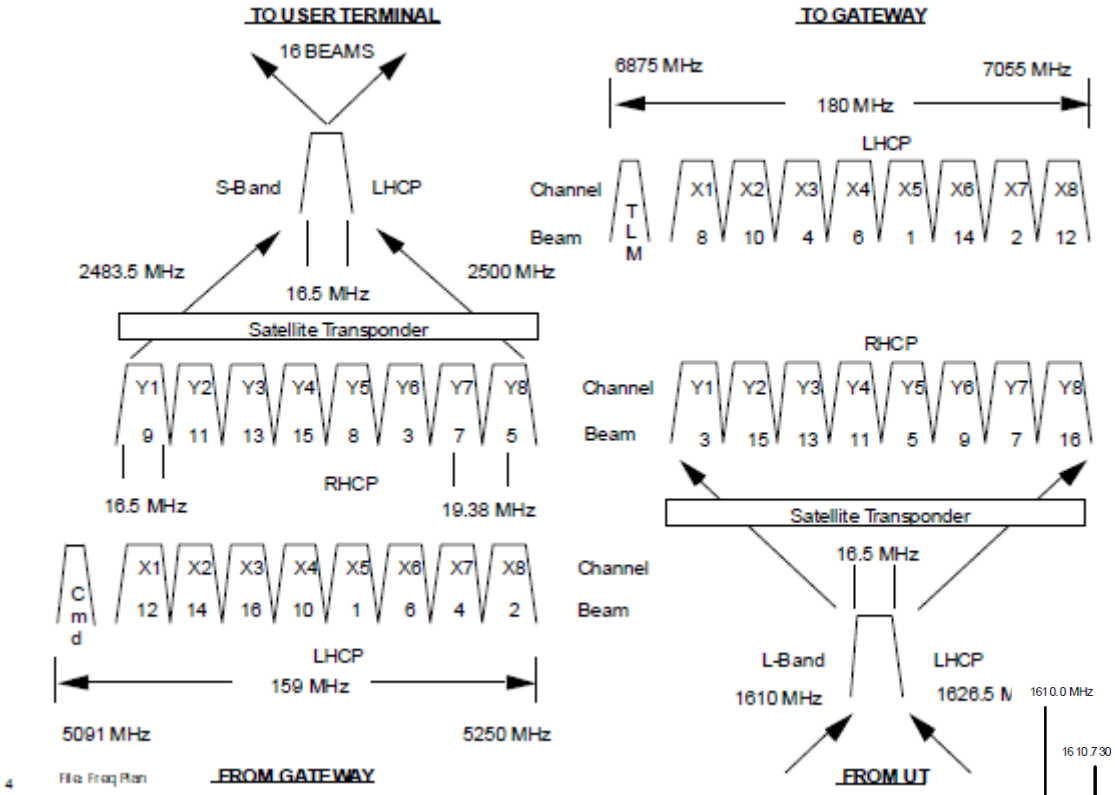
- Bent pipe payload – no regeneration / no ISL as in Iridium
- L/S-band separate direct-radiating array with analogue BFN and bent-pipe payload
- S-band Tx array split in two conformal DRAs (10+6 beams)
- L-band Rx array with single flat DRA
- 2 feeder link antennas for transmit/receive (C-band)





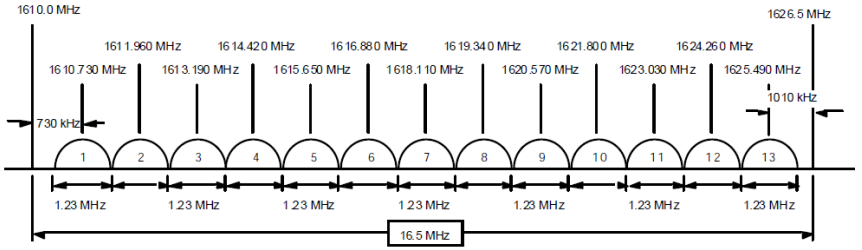
Antenna shape to maximize gain at lower elevations

NGSO Mobile Globalstar Constellation



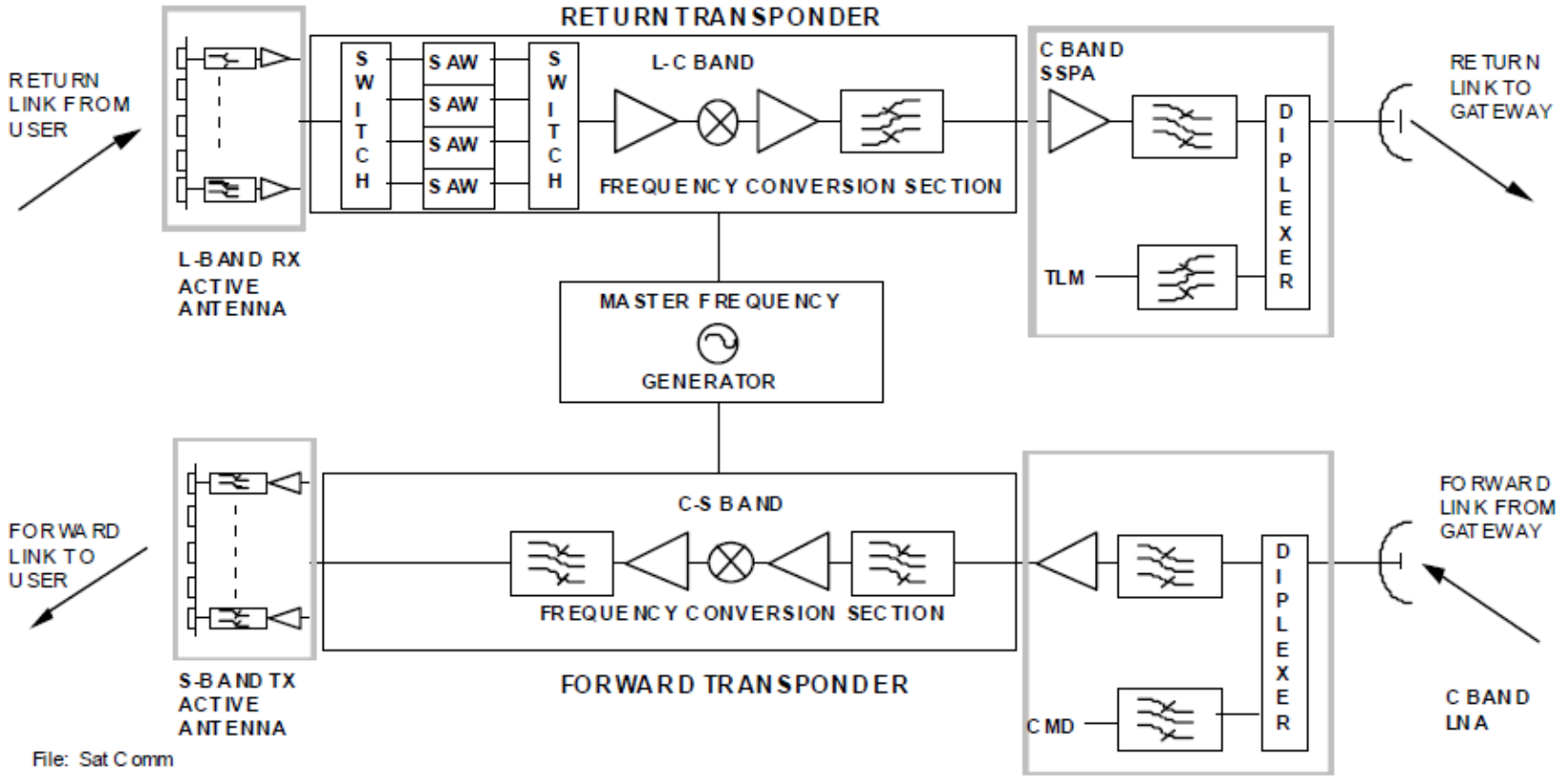
Globalstar frequency plan:

- Separate Tx (2.5 GHz) and Rx (1.6 GHz) satellite bands
- 13 FDM/CDM channels of 1.23 MHz in forward link in each beam
- 13 FDMA/CDMA channels of 1.23 MHz in the return link (see below)
- C-band FDM feeder link using two polarizations



NGSO Mobile Globalstar Constellation

The Globalstar payload:

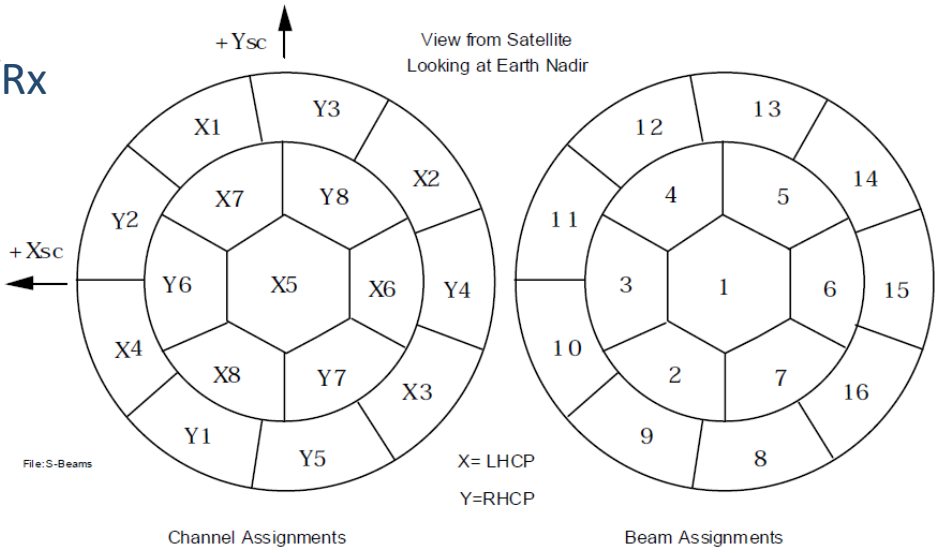


Active antenna allows to share the HPAs power among all beams => multi-carrier TXP operation
DRA SSPAs with variable operating point to maximize DC->RF efficiency conversion

NGSO Mobile Globalstar Constellation

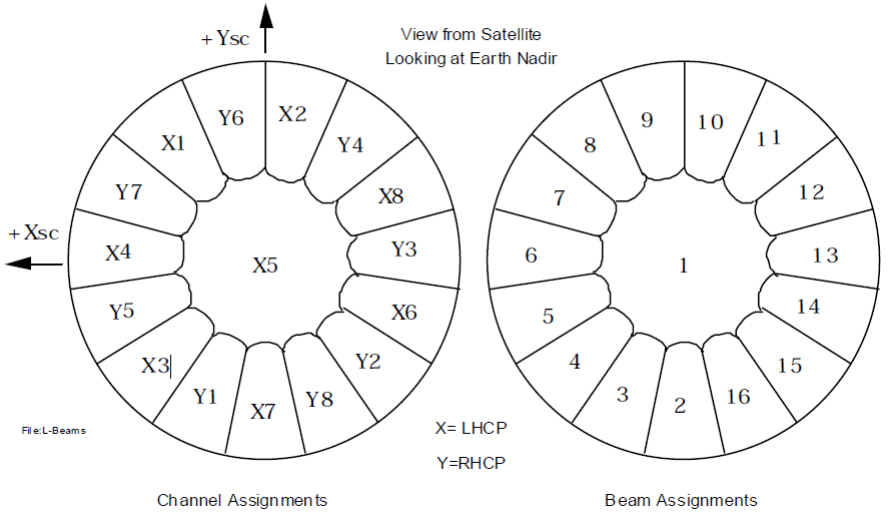
The Globalstar L/S-band antenna pattern:

- 16 non steerable beams non congruent Tx/Rx
- Field of view 108 degrees
- Minimum elevation angle 10 degrees
- Full frequency reuse in every beam



TRANSMIT ANTENNA PATTERN

RECEIVE ANTENNA PATTERN



- *Shape of the reverse link antenna beams to "equalize" the number of users/beam*
- *NO CONGRUENT FWD/RTN BEAMS ANTENNA PATTERN*

Legacy Products

Consumer / SPOT			Voice & Data / Duplex
SPOT Trace	**SPOT X**	**SPOT Gen4**	**GSP-1700**
			
• Tracking of assets beyond terrestrial coverage • Anti-theft device • Quick, easy, and inexpensive attachment to assets for both commercial and consumer applications	• Two-way messaging with SPOT tracking and emergency capabilities • Keyboard functionality • Send and receive SMS • Only fully integrated (single device) two-way messaging device on market • Bluetooth technology • Available in Jeep special edition device	• Next generation SPOT Satellite GPS Messenger • More tracking features with enhanced mapping interface • Improved product specs for water resistance • Available in Jeep special edition device	• Full voice / data capabilities • GSP-1700 -commercial / government market • Highest quality voice service

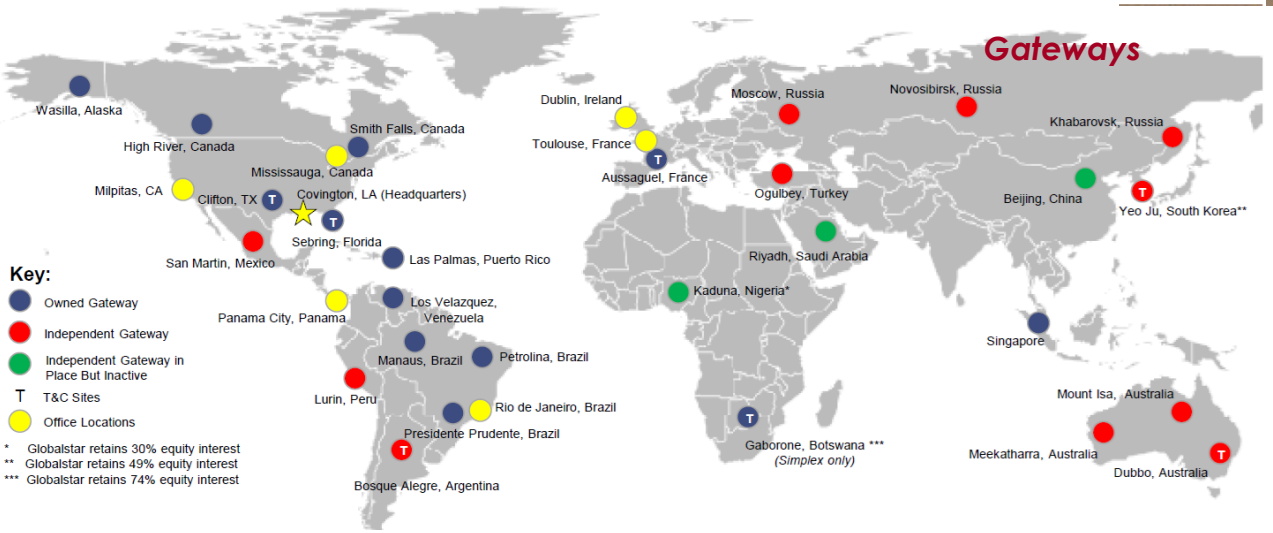
Commercial IoT Products

STX-3	SmartOne C	SmartOne Solar	ST100	ST150	Two-way Module
					Under development
• Company's smallest M2M satellite transmitter • Integrated by VARs and OEMs into M2M solutions	• Tracking of assets • Line powered or battery powered • Utilizes motion sensors and GPS to gather and transmit telemetry data	• Tracking of assets • Solar power recharges batteries providing 8+ years of usable service • Bluetooth capabilities for indoor tracking • ATEX and Intrinsically Safe certifications	• Launched in 2020 • Latest satellite transmitter designed for rapid development by 3rd party companies • Low costs, reliable, complete one-way data module • Battery and solar connections • Bluetooth technology	• Recently commenced production for both module and finished product form factors • Partner-friendly apps and edge computing capabilities • Board development refreshed from ground up	• Currently under development, expected launch in 2023 • Competitively positioned in all product specifications • Ability to track and control assets • Large established existing market

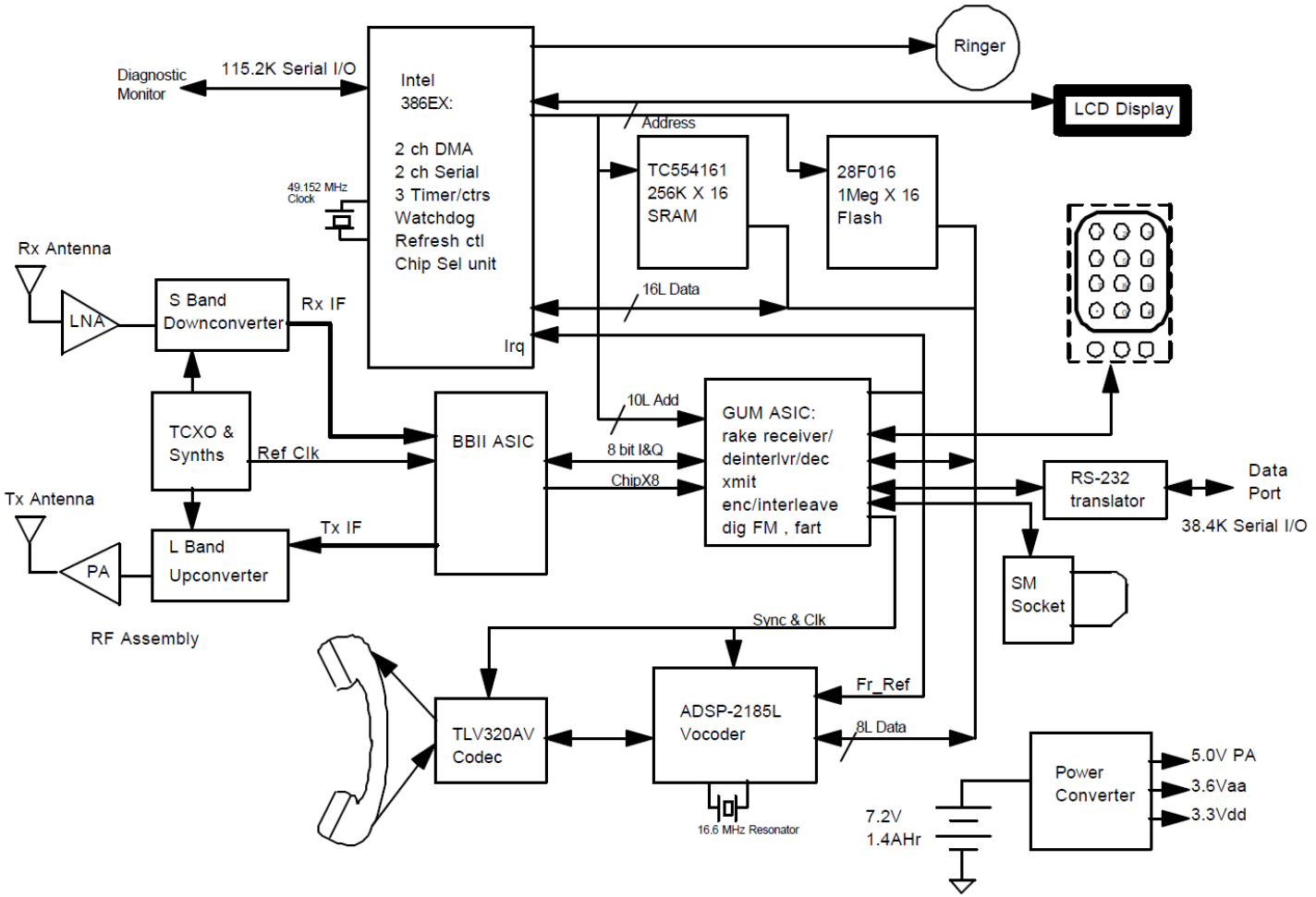
IoT is one of the main current Globalstar service on top of the more recent Apple direct-to-hand-held service (see later on)

NGSO Mobile Globalstar Constellation

The Globalstar ground segment gateways

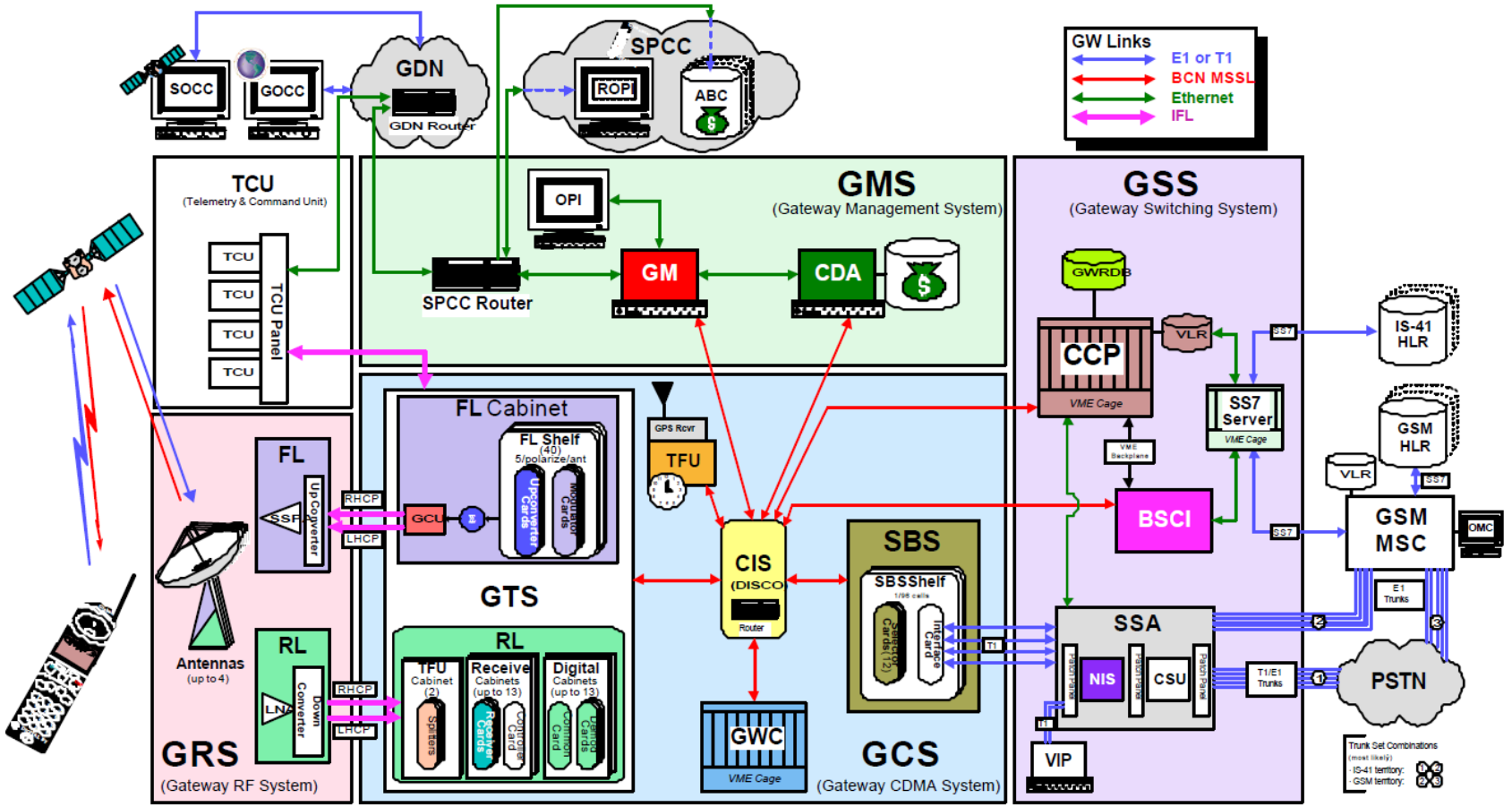


The Globalstar mobile user terminal



NGSO Mobile Globalstar Constellation

The Globalstar Gateway



NGSO Mobile Globalstar Constellation

The Globalstar Control Centre

NGSO Mobile Globalstar Constellation

The Globalstar air interface (IS-95 2G terrestrial standard derived):

- Up/downlink in frequency division multiplexing (more complex user terminal)
- CDM(A)/FDM(A) multiplexing allows full frequency reuse among the beams keeping traffic load modest - 13 (1.2288 kHz) channels (16.5 MHz total bandwidth)
- BPSK r=1/2 FEC for traffic channel plus CDM pilot (with beam unique PN sequence)/paging/sync channels

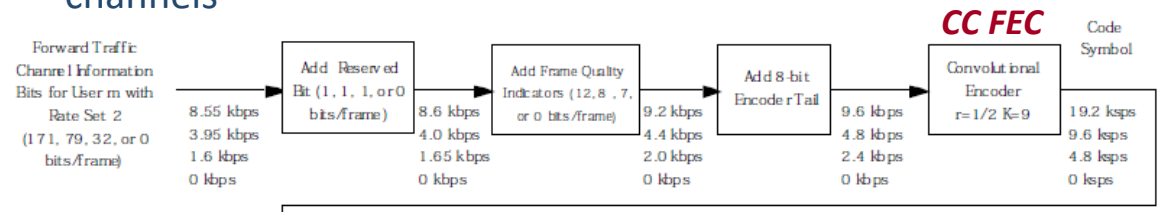


Table 4-1 Vocoder and Channel Rates

Configuration	Vocoder Rate	Channel Rate	Purposes
Rate 1	8,550	9,600	High Quality Option
Rate 1/2	3,950	4,800	Baseline Voiced
Rate 1/4	1,750	2,400	Baseline Unvoiced
Rate 1/8	800	1,200	Baseline Pauses/Background

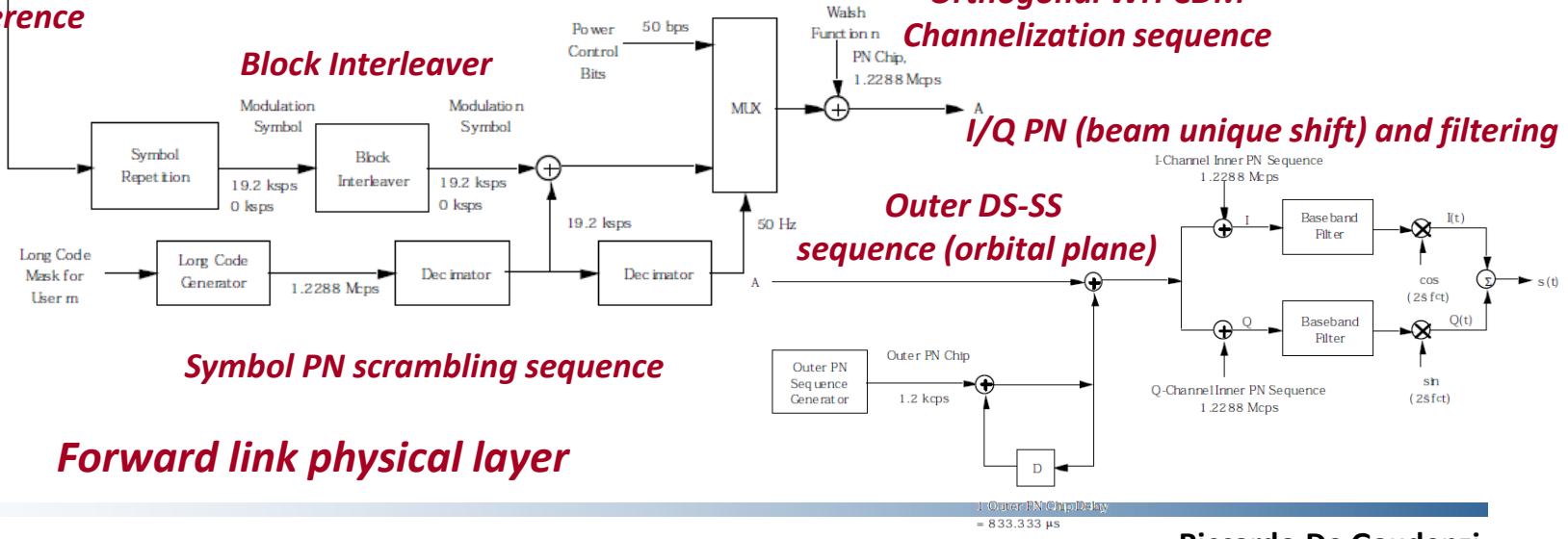
Variable rate bit rate vocoder to reduce MAI interference

Block Interleaver

Orthogonal WH CDM Channelization sequence

I/Q PN (beam unique shift) and filtering

Outer DS-SS sequence (orbital plane)



Symbol PN scrambling sequence

Forward link physical layer

NGSO Mobile Globalstar Constellation

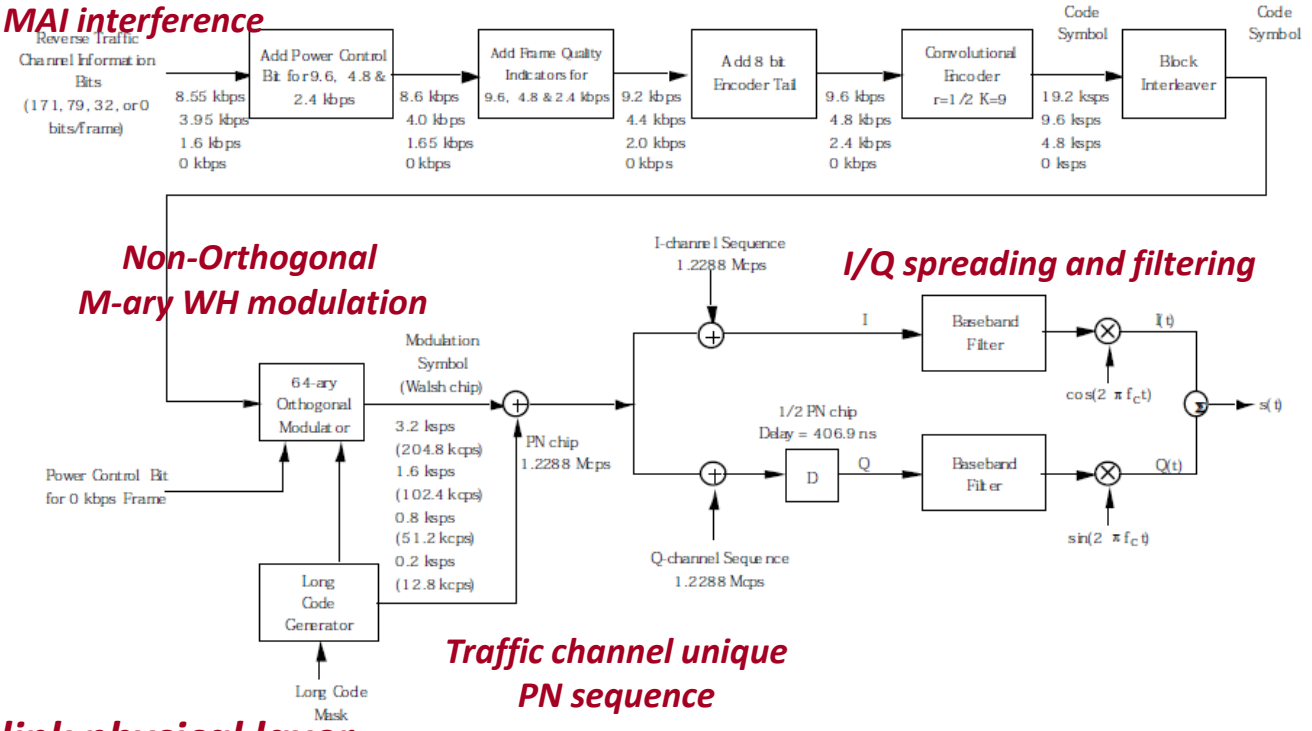
The Globalstar air interface (IS-95 derived):

- Up/downlink in frequency division multiplexing (more complex user terminal)
- M-ary WH CDMA for uplink with non coherent detection
- Rate ½ convolutional FEC with variable rate vocoder

Variable rate bit rate vocoder to reduce MAI interference

CC FEC

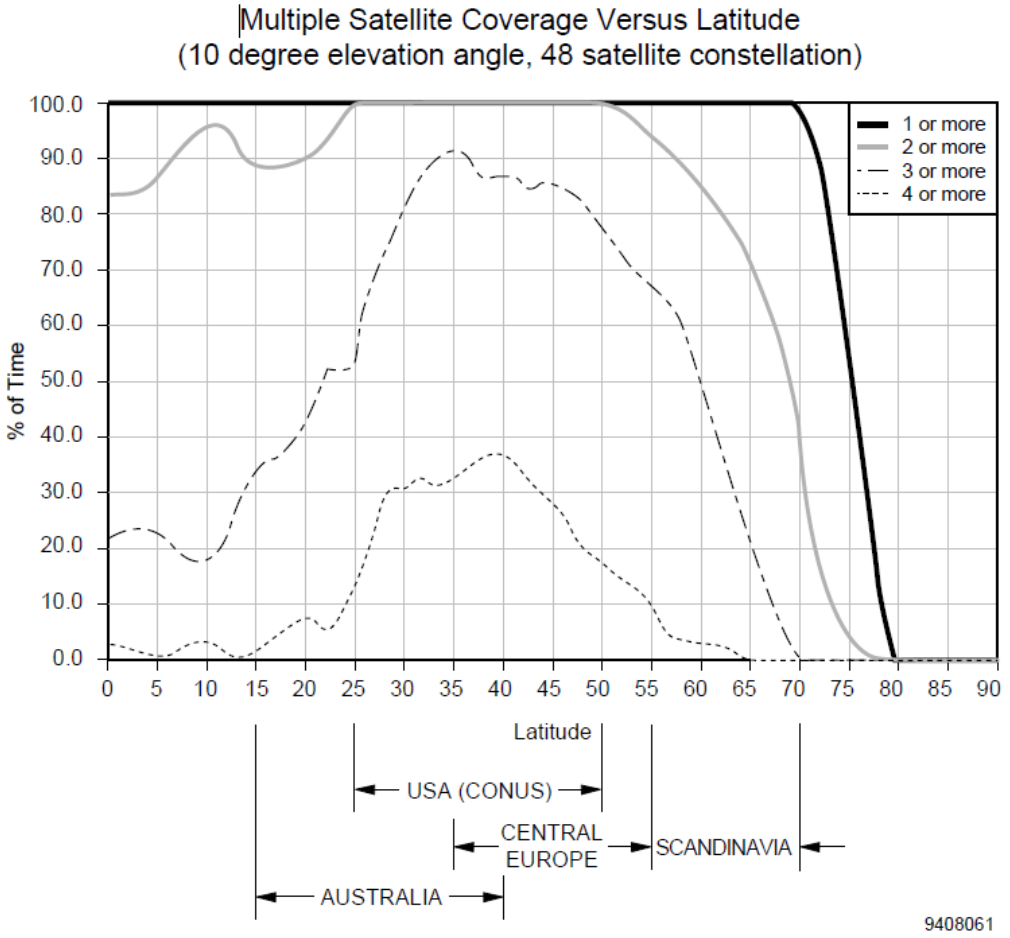
Block Interleaver



Return link physical layer

NGSO Mobile Globalstar Constellation

Satellite path diversity for communication quality and users' localization (RRM and billing) purposes (10 km accuracy)



NGSO Mobile Globalstar Constellation

The Globalstar spatial diversity capabilities thanks to CDM(A) and Full Frequency Reuse:

- Forward link spatial diversity with rake demodulator at the user terminal -> causing throughput reduction in the forward link but increased availability and fading margins
- Return link gateway rake combining of all useful signals coming from beams and satellites -> big gain in availability/transmit power reduction in particular at low mobile speeds
- Soft hand-off (make before it breaks) for QoS

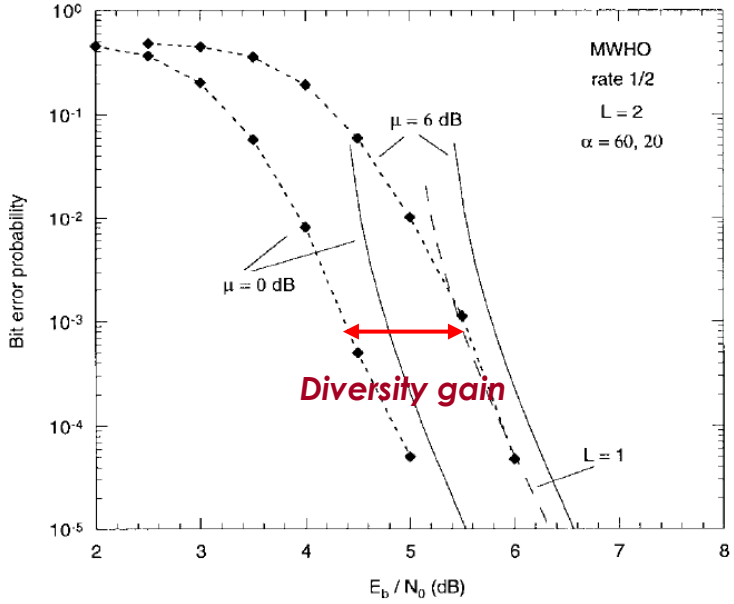
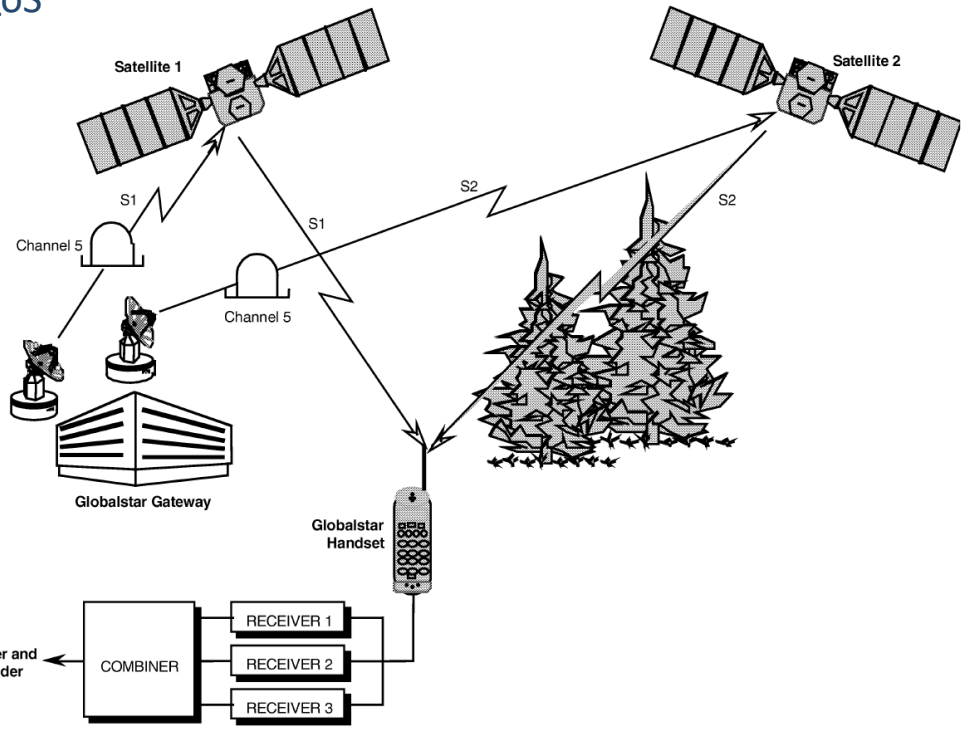


Fig. 7. Upper bounds for MWHO in a rural tree-shadowed environment for rate 1/2, with unbalanced links ($\alpha_1 = 60°, \alpha_2 = 20°$) and different values of the loading factor, μ. Single link performance for $\alpha = 60°$ is also shown for reference.



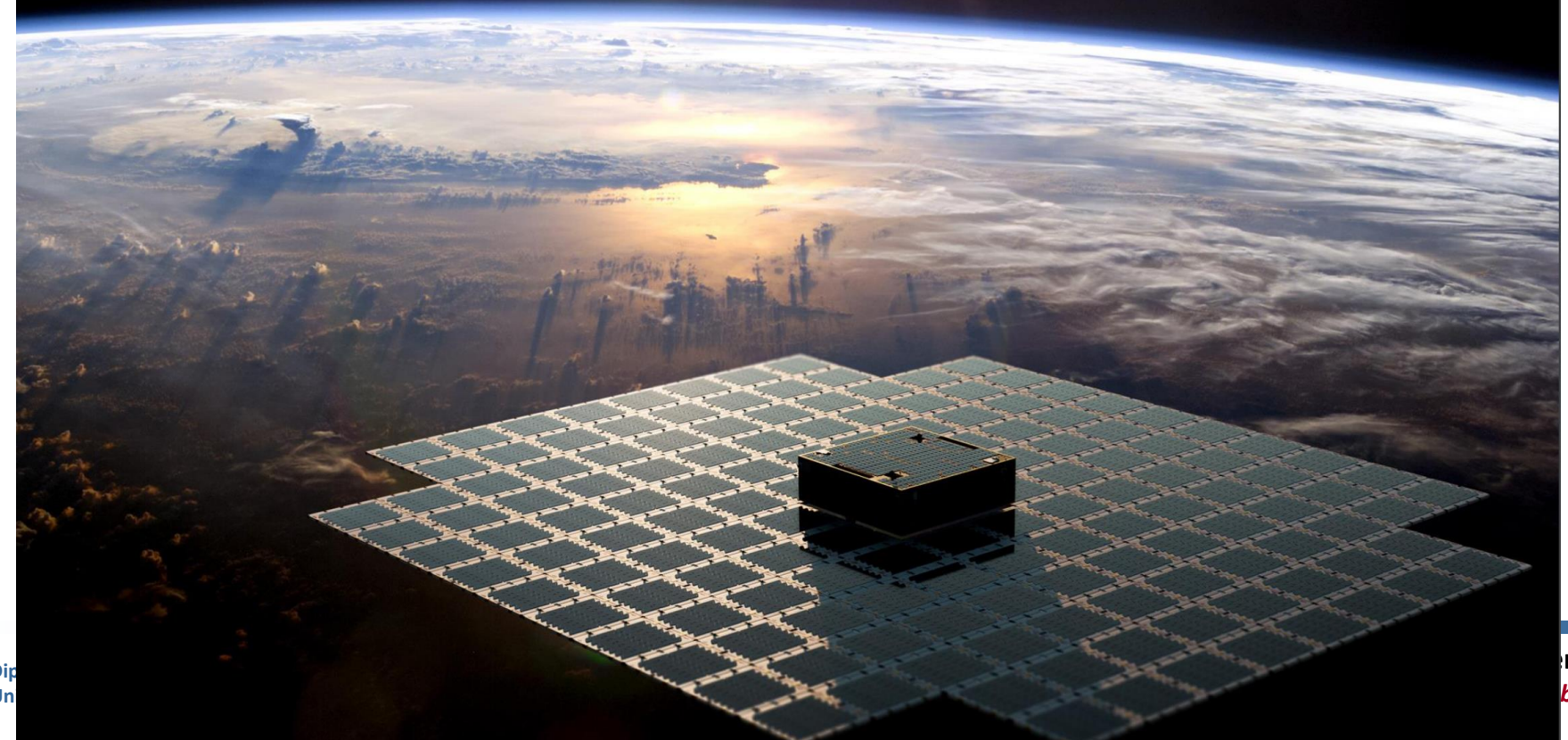
AST Mobile

Raised $850+ million to date to fund network build and technology with **2,600+ patent and patent-pending claims**

Signed agreements and understandings with **40+ mobile network operators** with **~2.4 billion existing subscribers**

Confirmed 4G capabilities and achieved **10+ mbps download speeds** to everyday smartphones directly from space

Fully-funded for operations of first **five commercial satellites** to offer **initial cellular broadband** service



AST Mobile

AST Mobile represents a new paradigm in mobile satcom

- 243 large LEOs satellites
- Direct access to terrestrial hand-held mobile phones with 4G services
- Use of terrestrial frequency bands to avoid PFD limits affecting MSS bands
- Very large (30x30 m) deployable phased arrays to support link budgets
- Solar generators opposite to the phased array antenna

Strategic Investors	Select MNO Partners
vodafone, AMERICAN TOWER, Rakuten, SAMSUNG NEXT, Bell	vodafone, AT&T, Bell, Rakuten, orange, Telefónica, MTN, Smart, LIBERTY LATIN AMERICA, africell, indosat ooredoo, TELECOM, Telstra, Telkomsel, smartfren., TIM, tigo, etisalat by e&, Globe, zain, stc

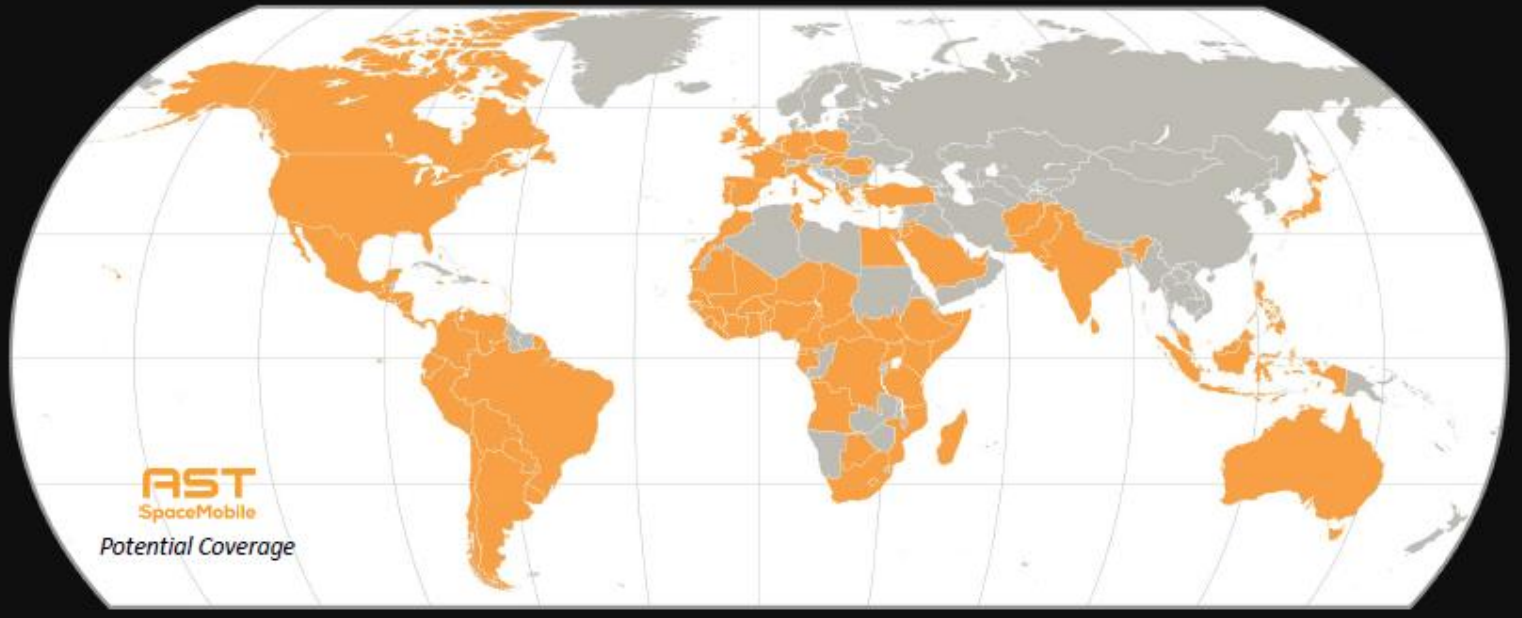
AST Mobile

Differentiated approach compared to existing space-based communications

	First & Only Broadband Direct To Mobile Phones	Direct via Proprietary Mobile Phones	Indirect via Complex, Expensive Hardware
	AST SpaceMobile 		
	Any standard mobile phone	Provider-specific satphones (~$1K)	Provider-specific antennas mounted on planes, ships, vehicles, buildings (~$1K-$200K+)
End Users	Mass market mobility and the unconnected	Narrowband service on satphones	Enterprise, Maritime, Aviation, Government, Residential
Market Size [1]	> $1 trillion	< $2 billion	< $20 billion

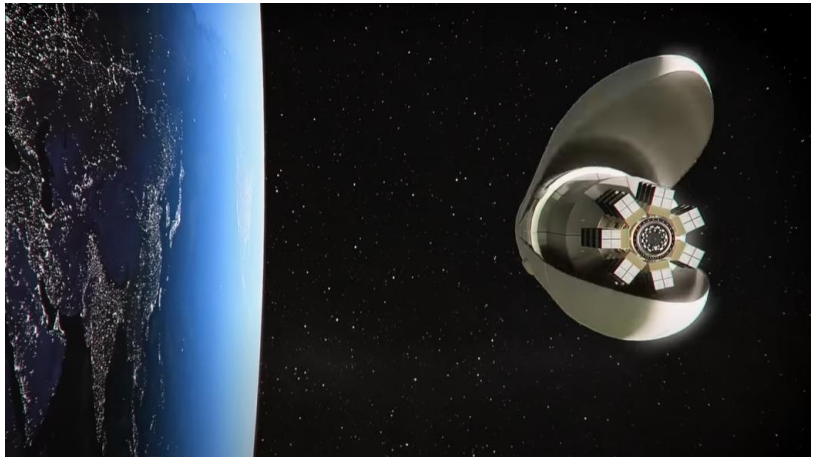
AST Mobile

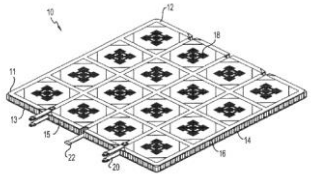
When operational, SpaceMobile service will be available to our MNO customers, a growing list of leading companies that have over 1.8 billion existing subscribers [1]



- ✓ Leverages existing 5.3 billion mobile phones and devices
- ✓ Super-wholesale revenue share model
- ✓ Direct-to-phone native cellular architecture
- ✓ Strategic relationship with Vodafone
- ✓ Drives new MNO revenue and reduced churn
- ✓ Easy sign-up for cellular subscribers

Space segment from paper/rendering to reality





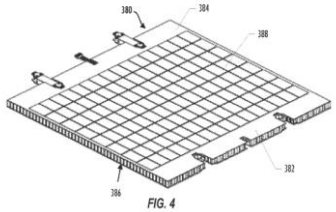


FIG. 4

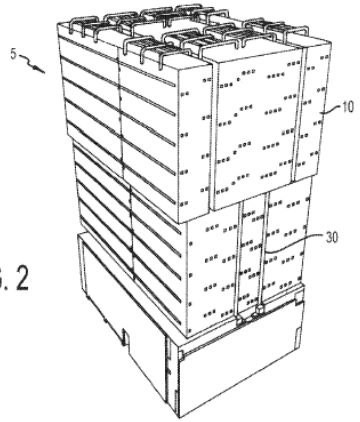
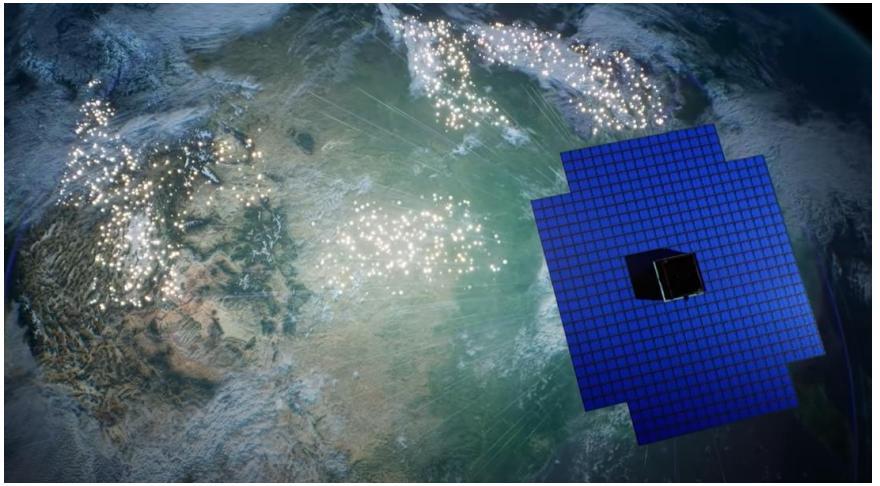


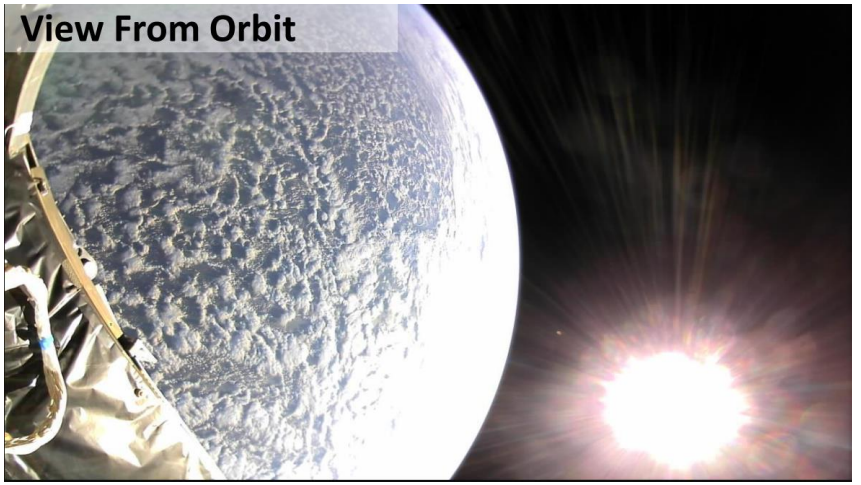
FIG. 2

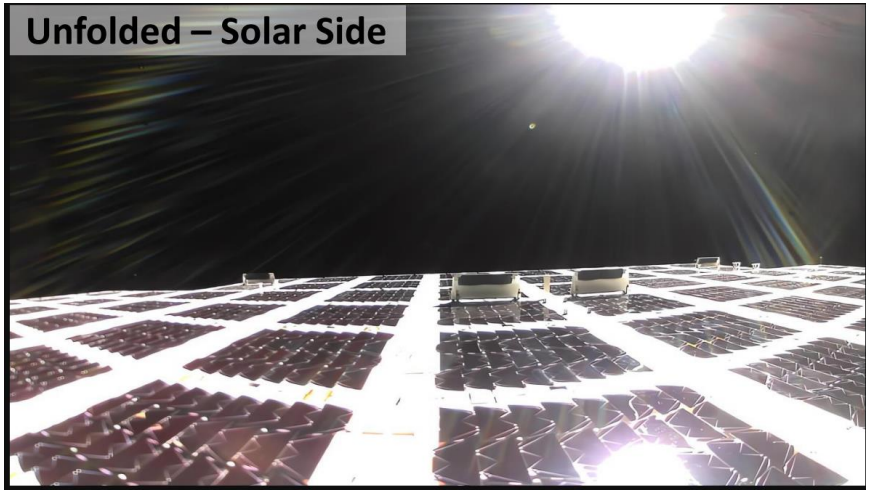


AST Mobile


The experimental AST Mobile Walker 3 satellite
Scaled down UHF Deployable Phased Array 8x8 m

Space segment from paper/rendering to reality: Blue Walker 3 experiment





Blue Walker 3 testing milestones:

April 2023
History made:
First-ever space-based voice calls using everyday smartphones

The first voice call was made from the Midland, Texas area to Rakuten in Japan over AT&T spectrum using a Samsung Galaxy S22 smartphone

June 2023
History made, again:
First-ever 4G LTE to everyday smartphones directly from space

Using AT&T cellular spectrum, we connected everyday smartphones to our BlueWalker 3 test satellite and recorded 4G LTE download speeds (with 5MHz carrier) of

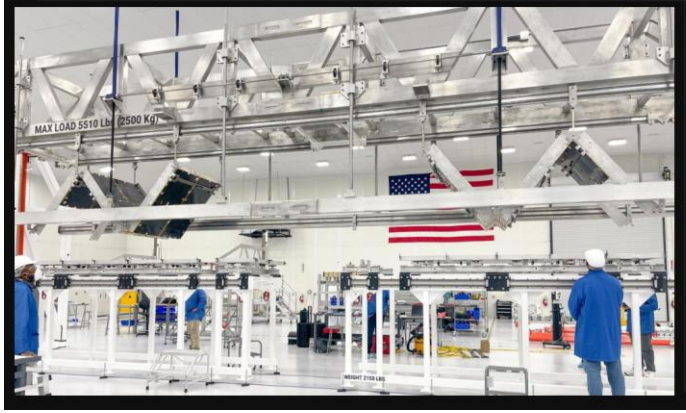
>10 Mbps

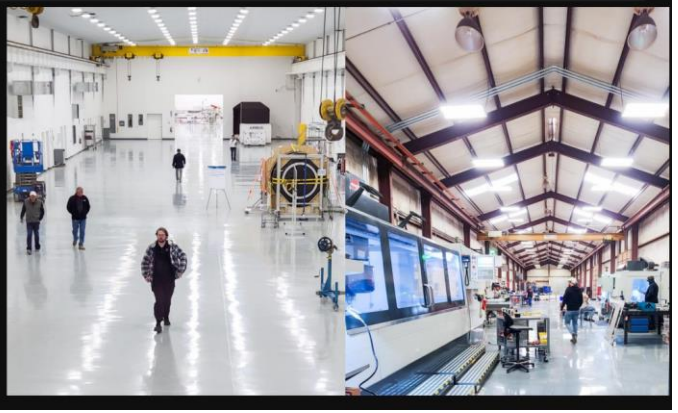
AST production facilities:

Two locations in Texas with combined 185,000 sq ft and potential capacity to produce up to 6 satellites per month using automated processes

Headquarters

Site 2



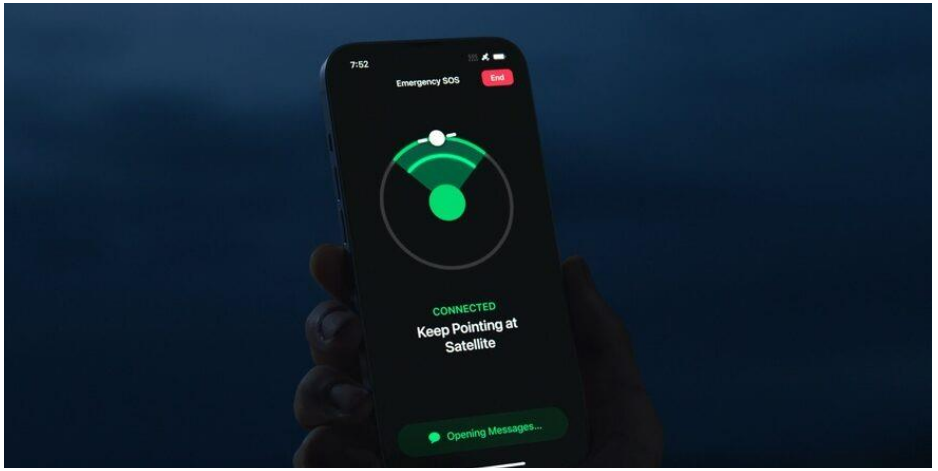


NGSO Mobile: Starlink/T-Mobile and Apple/Globalstar

Starlink 2G and T-Mobile
Will work on Starlink 2G satellites proprietary PHY
with a 25 sqm S-band (?) phased array

That connection should be enough to let you text, send MMS messages, and even use "select messaging apps" whenever you have a clear view of the sky, even if there's no traditional service available. According to a press release from T-Mobile, the "satellite-to-cellular service" will be available "everywhere in the continental US, Hawaii, parts of Alaska, Puerto Rico and territorial waters." The service is scheduled to launch in beta by the end of next year in "select areas," and Sievert says he hopes it will someday include data.

Apple iPhone 14 and Globalstar
Refurbished GS – proprietary PHY
200 (GS) + 300 (SSEG) MEURO investment



WASHINGTON — Apple formally announced its long-anticipated partnership with Globalstar Sept. 7 to provide satellite messaging services for new iPhones and becoming Globalstar's biggest customer.

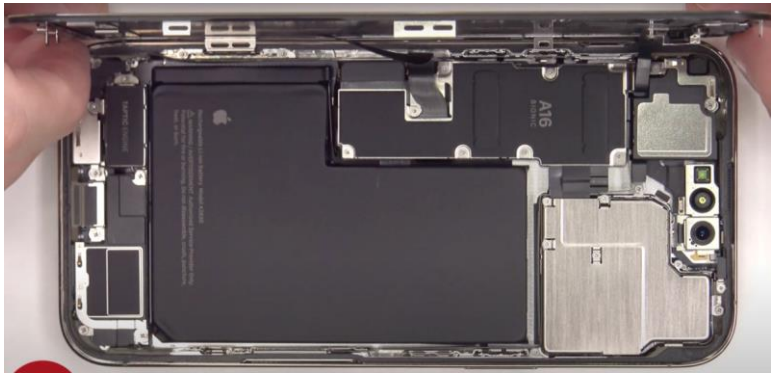
At an event to unveil new iPhone and other products, Apple said the new iPhone 14 series will include an "Emergency SOS" feature that will allow users to send emergency messages via satellite when out of terrestrial network coverage. Those services will start in November and will be available initially in the United States and Canada. Those services will be free for at least the first two years.

In the presentation, Apple emphasized the difficulty of providing connectivity via satellite for its phones. "The bandwidth is so limited that even sending a text message is a technical challenge," said Ashley Williams, manager of satellite modeling and simulation at Apple.

Welcome to the 1.5G era for satcom direct access to the mobile end user!
Small user HH phone antenna gain => low data rates for mass-market

Apple Direct to Hand-Held Mobile Service

- Apple invested 450 M$ to initiate this new service largely in the Globalstar ground infrastructure
- Full reuse of the existing Globalstar space segment with proprietary ad-hoc narrowband physical and upper layers – Qualcomm Snapdragon X65 chip
- The service exploits the Globalstar L (Tx) and S (Rx) bands for direct-to-hand-held communications with iPhones 14 & 15

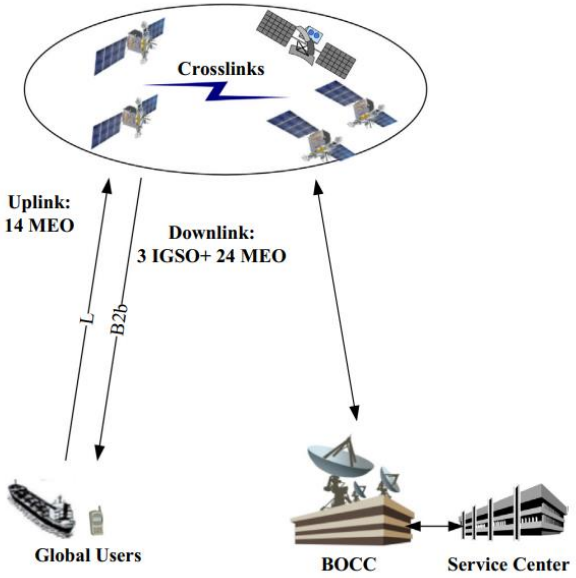


Apple Direct to Hand-Held Mobile Service

- New more powerful C-band gateways ground antennas
- New ground stations in Nevada and Hawaii, as well as existing facilities in Texas, Alaska, Florida, and Puerto Rico
- 17 new satellites planned to be launched by SpaceX paid by Apple in return of 85% Globalstar capacity exploitation

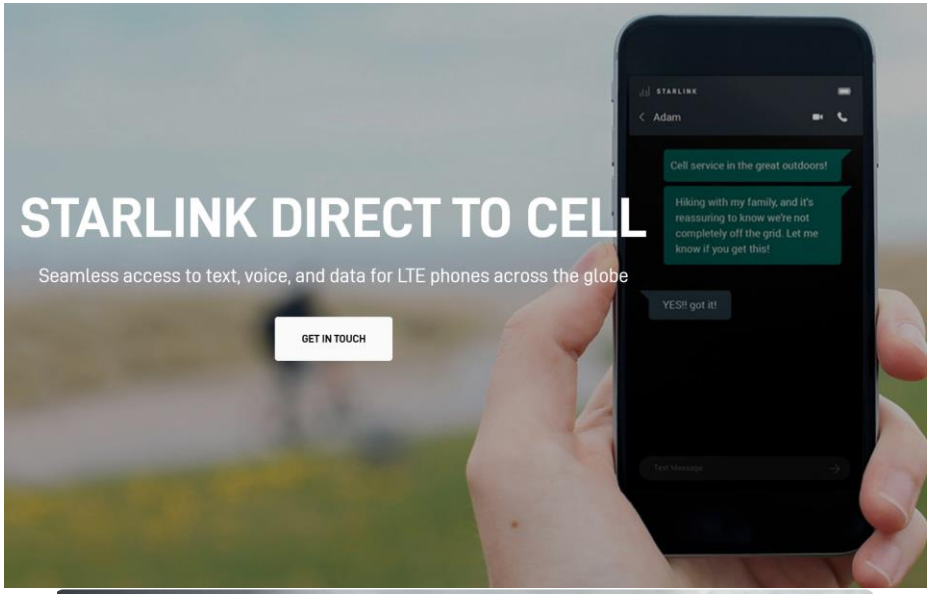
Chinese Beidou 3 and Huawei

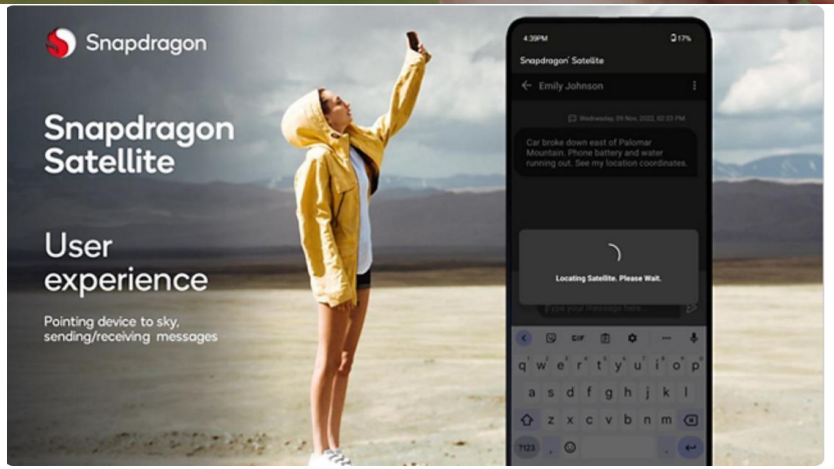
- Huawei Q3 2022 announced that the new Mate 50 mobile phone will support geo-localised SMS messaging via Beidou GNSS 24 MEO and 3 IGSO satellites
- 3W user equipment transmit RF power required
- A dedicated LEO Chinese telecom constellation is currently planned - 300 satellites in 2030 with a possible growth to almost 13000 satellites



More Direct to Hand-Held Mobile Service

- STARLINK direct to mobile service announced to start the new service in 2024
- No technical information available on the space segment that will be used
- Most likely Starlink Gen2 satellites support the mobile hand-held frequency band
- More terrestrial operators are joining T-mobile to offer this new service
- Iridium is planning to support direct to hand-held services in cooperation with Qualcomm and Garmin
- Snapdragon® Satellite offers truly global coverage from pole to pole and can support two-way messaging for emergency use, SMS texting, and other messaging applications
- Iridium frequency resources that can be dedicated to this new services are likely to be limited due to the large use by customers like US DoD

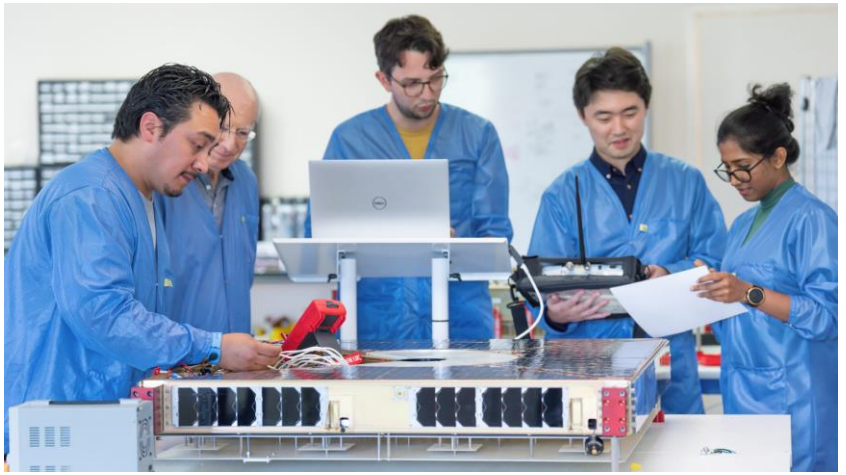




More Direct to Hand-Held Mobile Service

- Lynk has the license from FCC to operate in the UHF 4G/5G bands
- Two experimental satellites launched in 2020
- One more satellite launched in 2021 planning t to have 5000 if funding found
- Agreement with 25 operators for providing direct to hand-held service
- Initial service limited to messaging then voice and broadband
- Unclear funding situation and effective service start date

- Video: https://www.youtube.com/watch?v=nkH6VnxW5u8



PART 2 - GEOSTATIONARY MOBILE NETWORKS

GSO Mobile INMARSAT Constellation

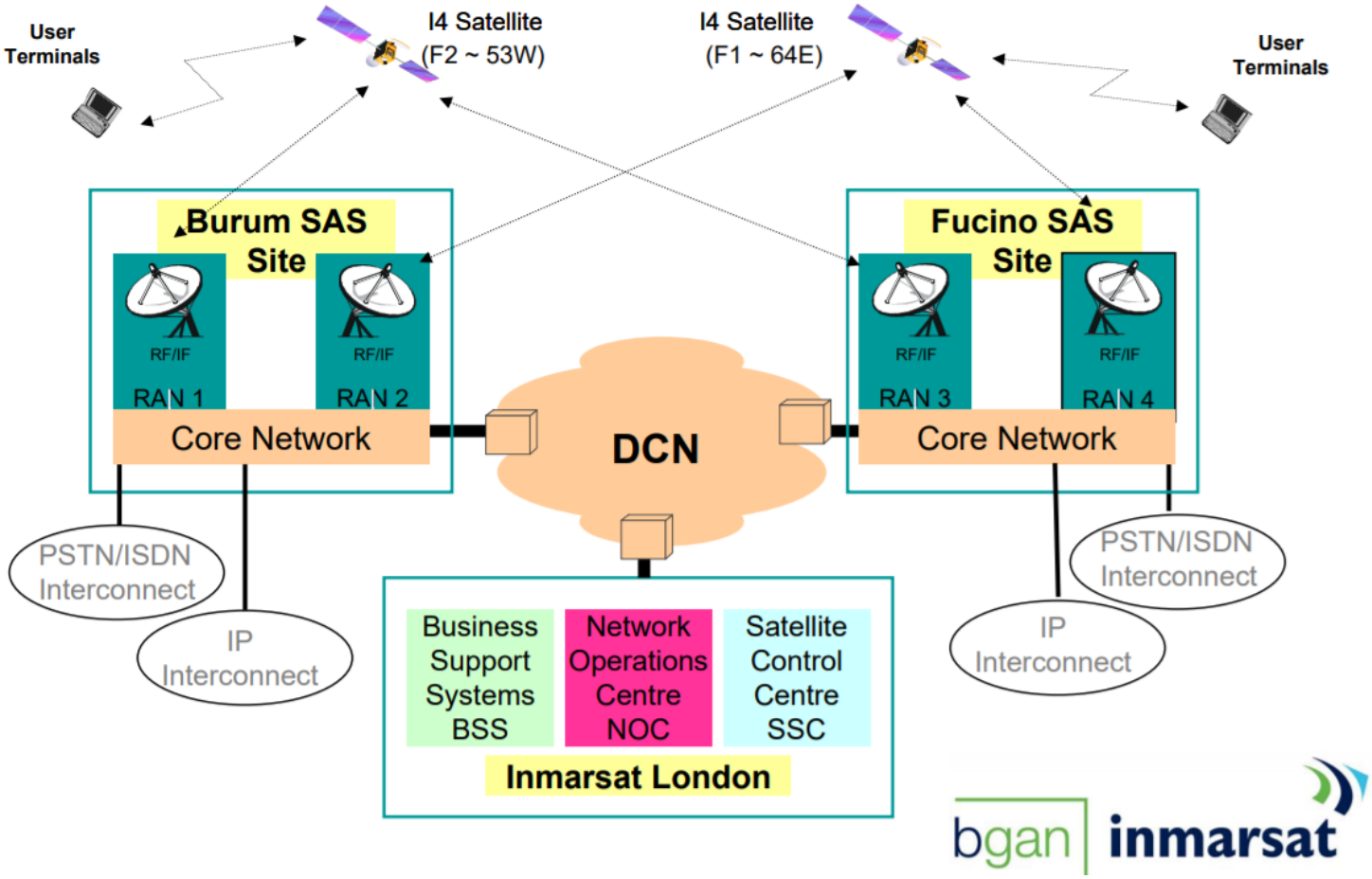
INMARSAT is the first satellite GSO mobile operator, est. 1979!

Initially maritime/aeronautical service provision, Later BGAN for laptop 3G services & hand-held - 2022 1.4 B$ revenues and 316 MEURO CAPEX (L and Ka-band services)

The INMARSAT (London-based) L-band MSS system architecture:

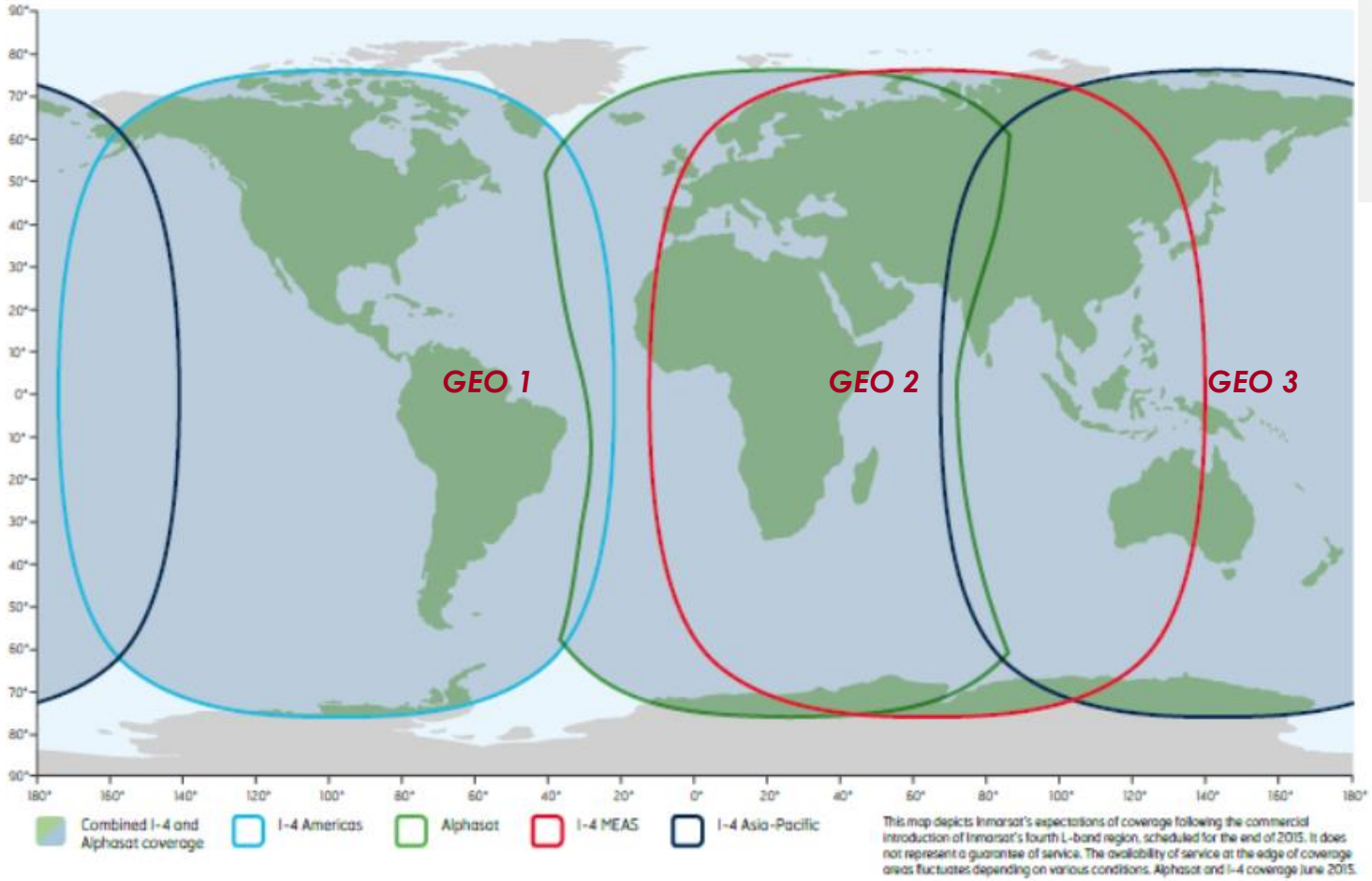
- GSO constellation composed of 2 INMARSAT IV plus 1 Alphasat satellites
- UMTS (3G) type of services to mobile terminals
  - Circuit-mode services up to 64 kbps (voice, video, FAX, messaging, data)
  - Packet mode services (up to 492 kbps)
- GSO orbit inclination allowed up to +/- 3 degrees to save station keeping fuel
- Regional and spot beams
- Three gateways
  (Hawaii, Netherlands, Italy)
  and four TT&C stations

GSO Mobile INMARSAT Constellation



GSO Mobile INMARSAT Constellation

INMARSAT L-band GSO fleet current coverage



ELERA (L-band[3])

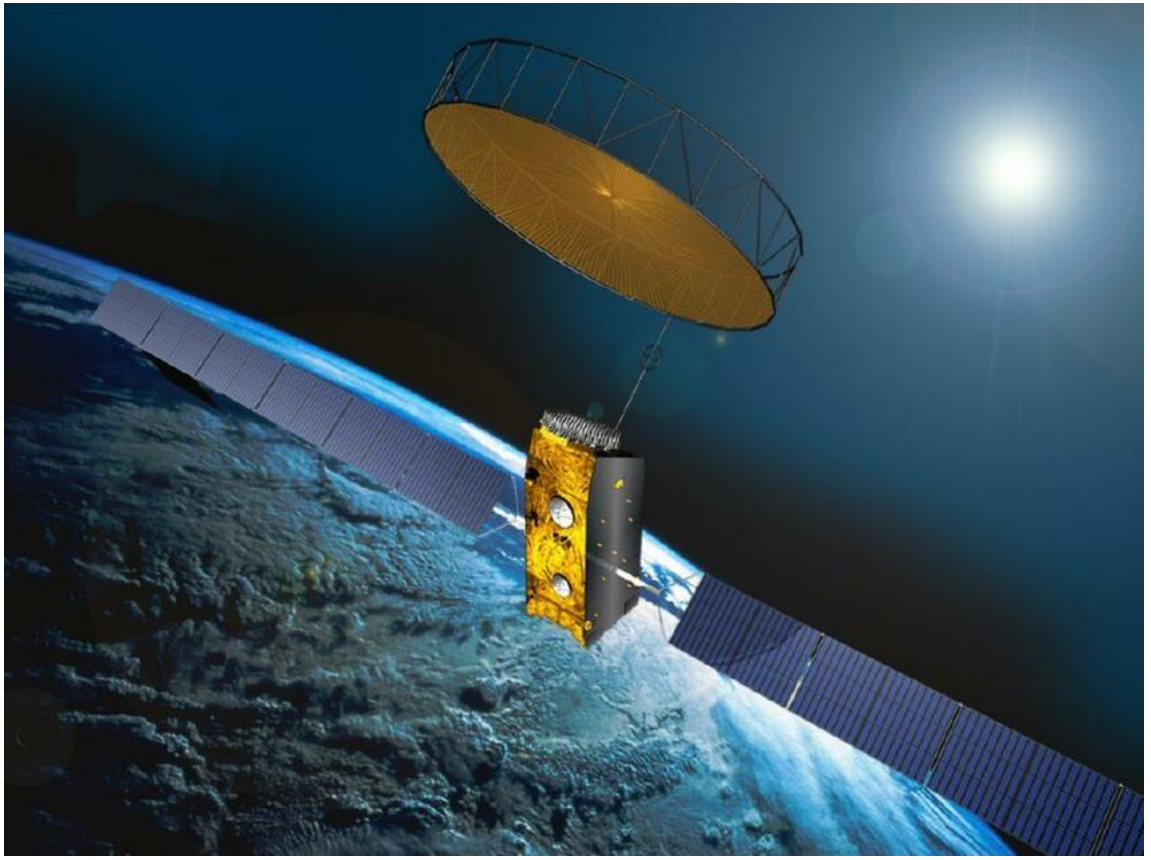
12 I-3 F1	16 I-4 F1	21 I-6 F1[4]
13 I-3 F2	17 I-4 F2	22 I-6 F2[5]
14 I-3 F3	18 I-4 F3	
15 I-3 F5	19 ALPHASAT I-4 F4	

INMARSAT is keeping legacy I-3 satellites on top of the I-4, I-5 and I-6

GSO Mobile INMARSAT Constellation

The INMARSAT 4 spacecraft (made by Airbus with ESA support):

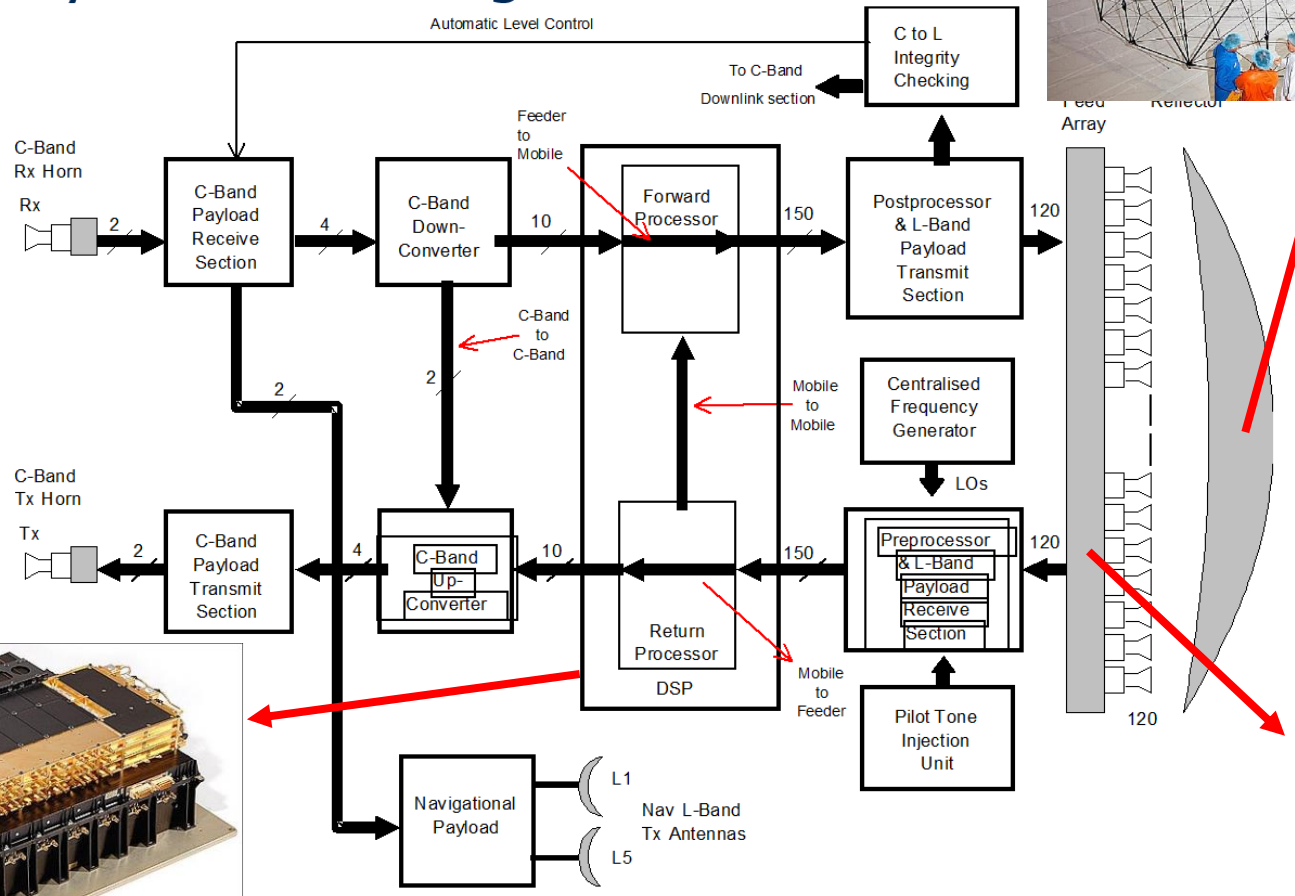
- L-band 9 m deployable antenna fed reflector (AFR) with digital transparent payload and DBFN
- C-band gateway feeder antennas
- Digital processor allows flexible frequency plan

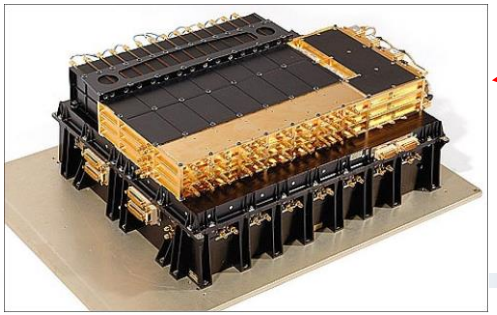


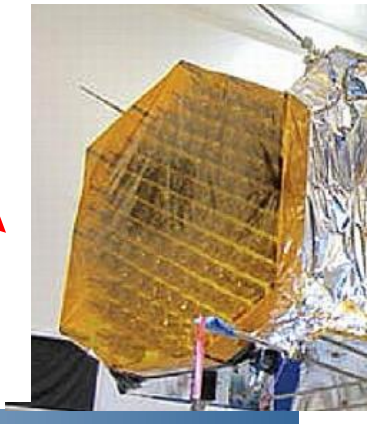
GSO Mobile INMARSAT Constellation

The INMARSAT IV payload:

I4 Payload Block Diagram



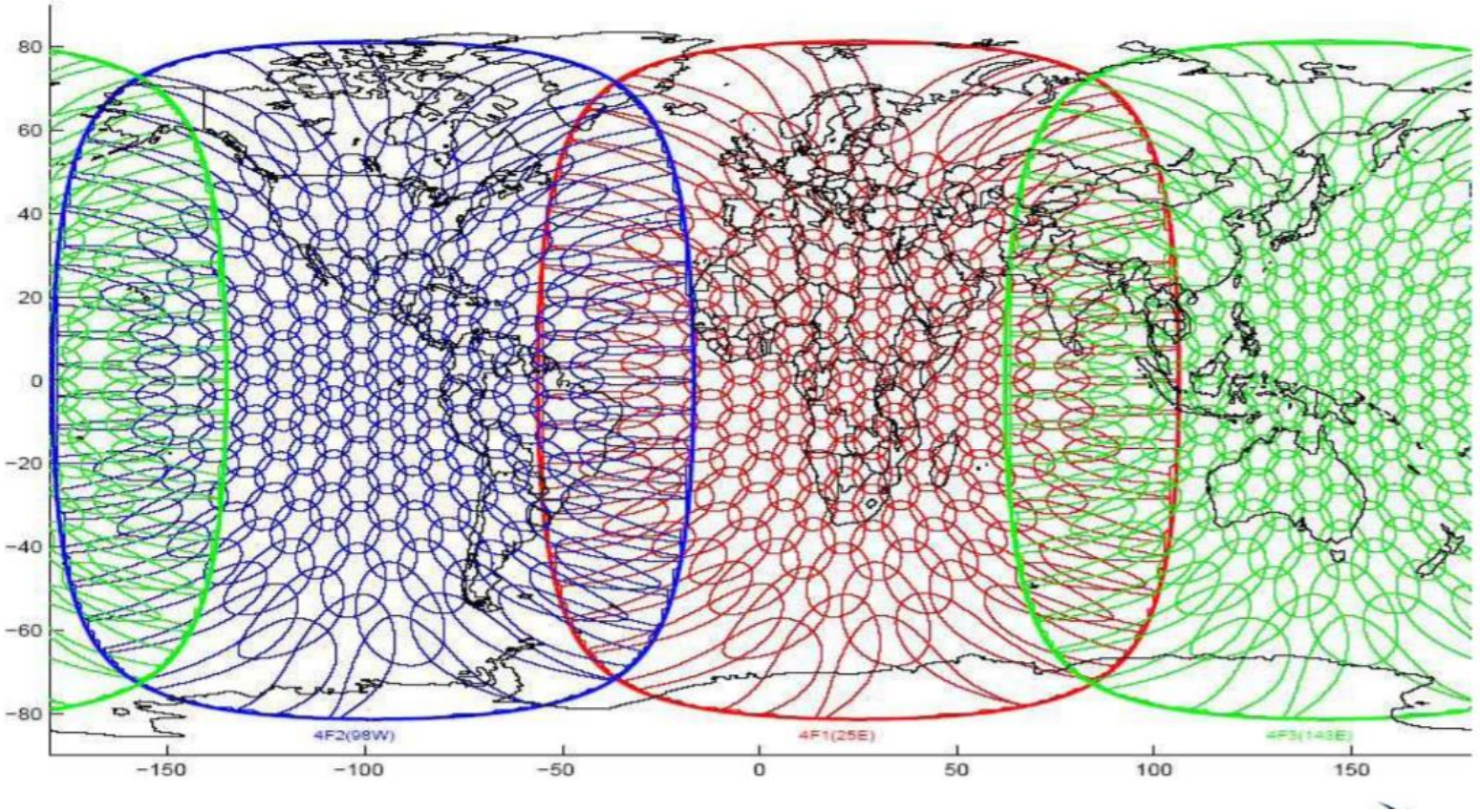




GSO Mobile INMARSAT Constellation

The INMARSAT IV L-band antenna pattern:

- Up to 256 re-configurable beams, 200 implemented by the ground segment
- 7 or 4 colours for frequency reuse configurable by the digital processor



GSO Mobile INMARSAT Constellation

The INMARSAT ground segment (user terminal and gateways)

User terminals

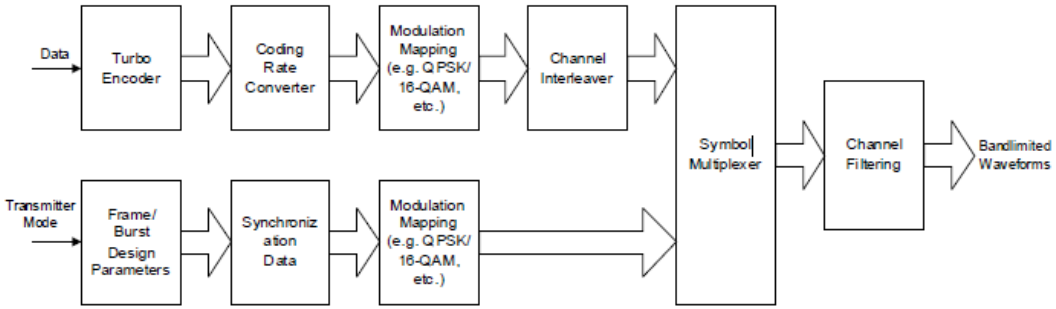
GSO Mobile INMARSAT Constellation

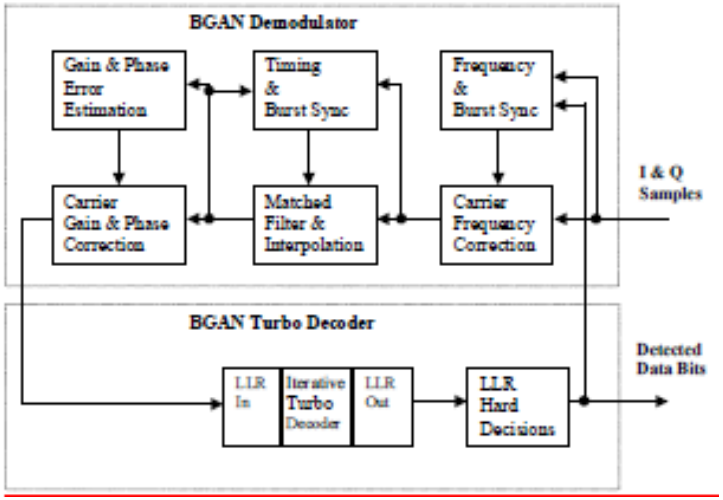
The INMARSAT control center

GSO Mobile INMARSAT Constellation

The INMARSAT L-band air interface follows a sub-set of the IAI-2 proprietary air interface

- MF-TDMA uplink/FDM-TDM downlink
- FWD: Up to 630 (200 kHz) carriers, data rates up to 512 kbps, 80 ms frame
- RTN: 25, 50, 100 or 200 kHz carriers, data rates up to 492.8 kbps, 5 or 20 ms frame
- Downlink QPSK and 16QAM, uplink $\pi/4$-QPSK and 16QAM [32QAM for HDR in Alphasat]
- Turbo code FEC with code rates 1/3 to 9/10





Thuraya (United Arab Emirates) L-band MSS regional system architecture

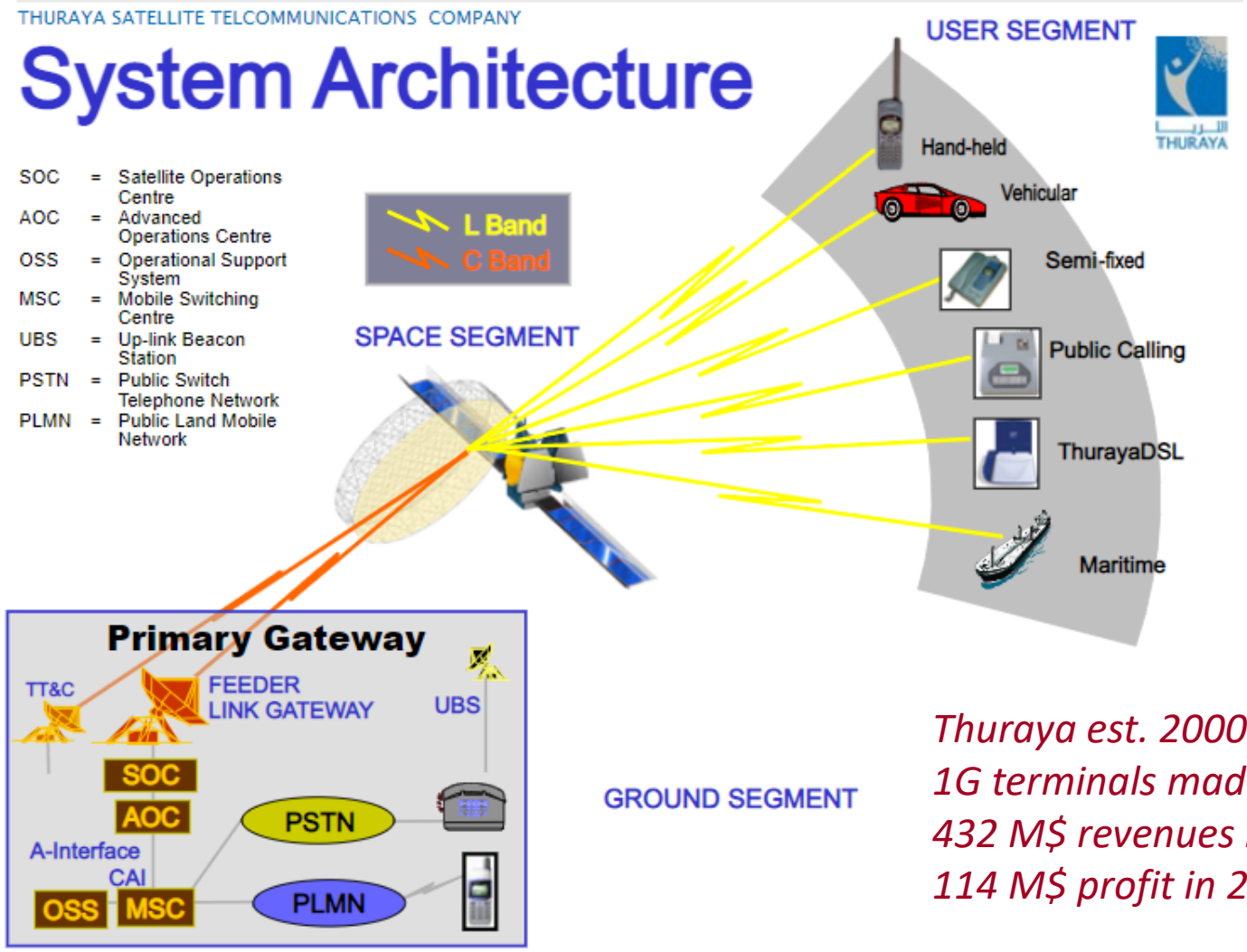
- GSO constellation composed of two satellites covering eastern hemisphere (2 more ordered)
- UMTS (3G) type of services to mobile terminals
  - Circuit-mode GSM-type voice services (up to 9.6 kbps)
  - Packet mode services (up to 444 kbps)
  - Streaming with up to 384 kbps
- GSO orbit inclination allowed up to +/- 6 degrees to save station keeping fuel
- Three gateways

GSO Thuraya Regional Mobile System

THURAYA SATELLITE TELCOMMUNICATIONS COMPANY

System Architecture

SOC = Satellite Operations Centre
AOC = Advanced Operations Centre
OSS = Operational Support System
MSC = Mobile Switching Centre
UBS = Up-link Beacon Station
PSTN = Public Switch Telephone Network
PLMN = Public Land Mobile Network



Thuraya est. 2000
1G terminals made in CH (Ascom)
432 M$ revenues in 2022
114 M$ profit in 2022

The Thuraya L-band GSO fleet current coverage

GSO Thuraya Regional Mobile System

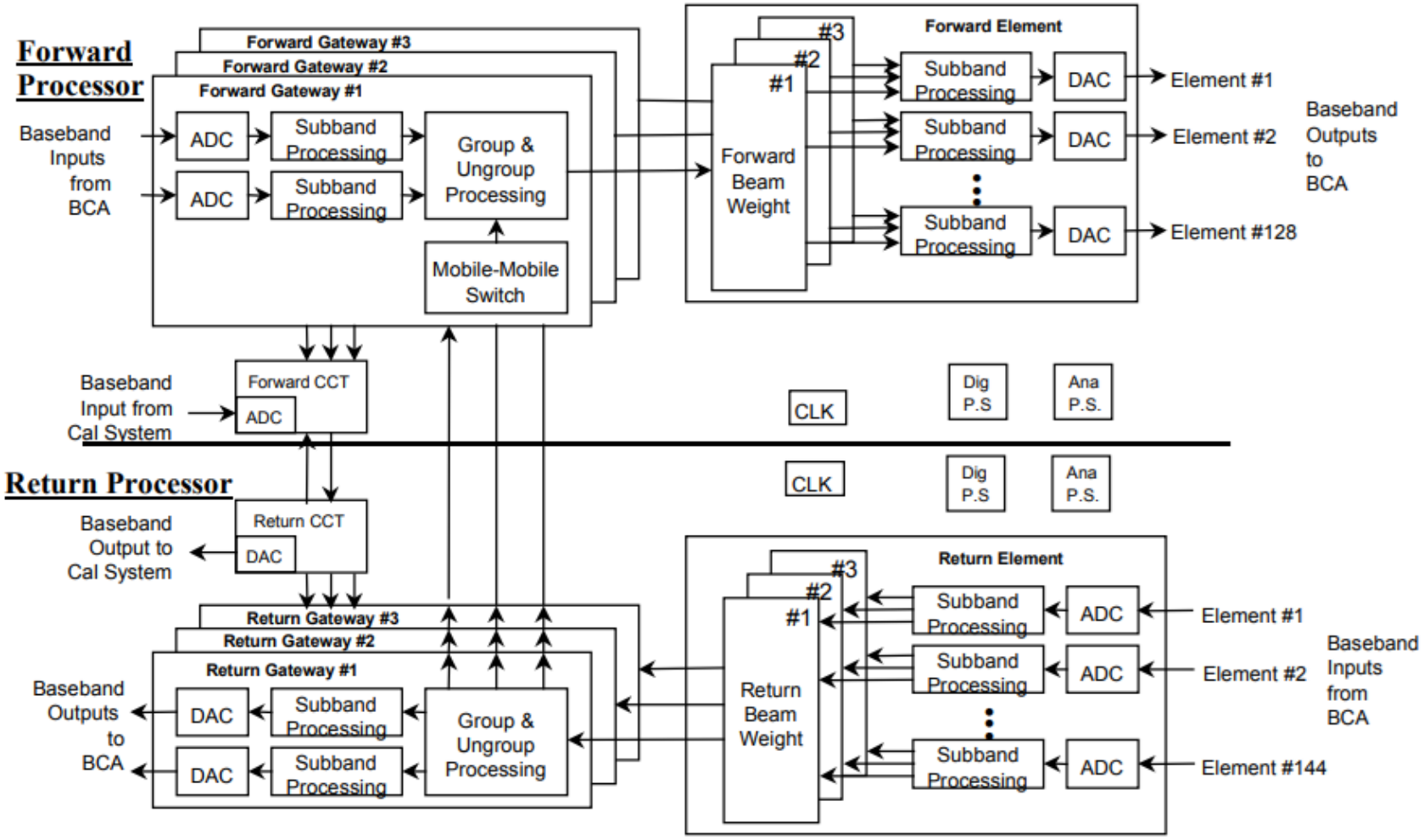
The Thuraya spacecraft

- L-band 12.25 m antenna fed reflector (AFR) with digital transparent payload (channelization and DBFN)
- C-band feeder link antennas
- Offset-fed phased-array of 128 elements
- Multi-matrix amplifiers

Thuraya 2/3

Thuraya 4/5

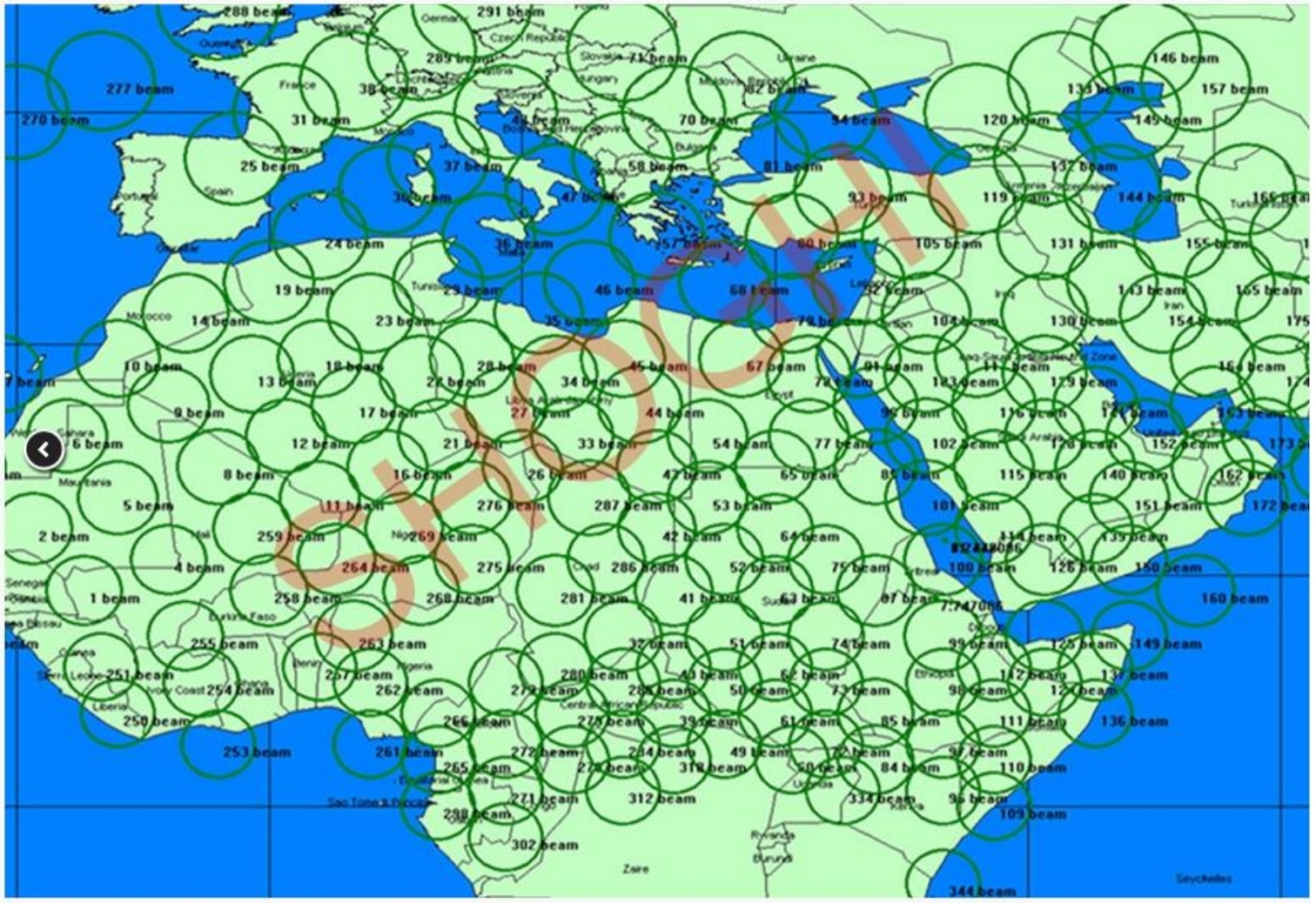
Thuraya processor



GSO Thuraya Regional Mobile System

Thuraya 2/3 antenna pattern

Up to 344 re-configurable beams (TBC)



GSO Thuraya Regional Mobile System

The Thuraya ground segment (user terminal and gateways)

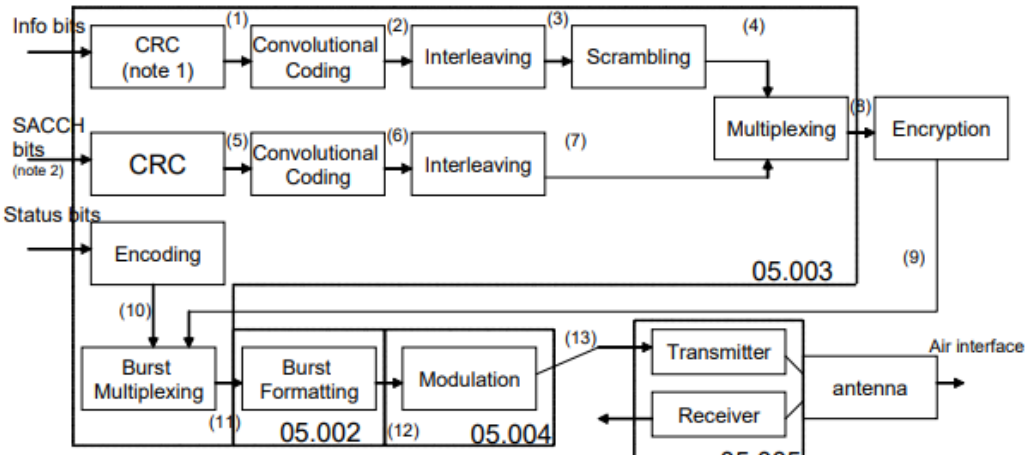
Strategic C-Band Only Thuraya Monitoring System

User terminals

GSO Thuraya Regional Mobile System

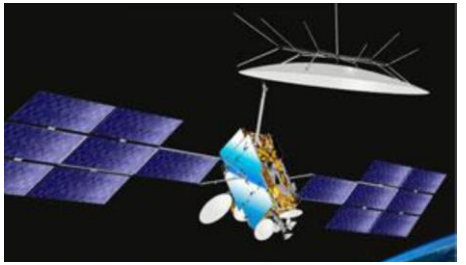
The Thuraya L-band air interface follows the ETSI GMR-1, release 2 public air interface

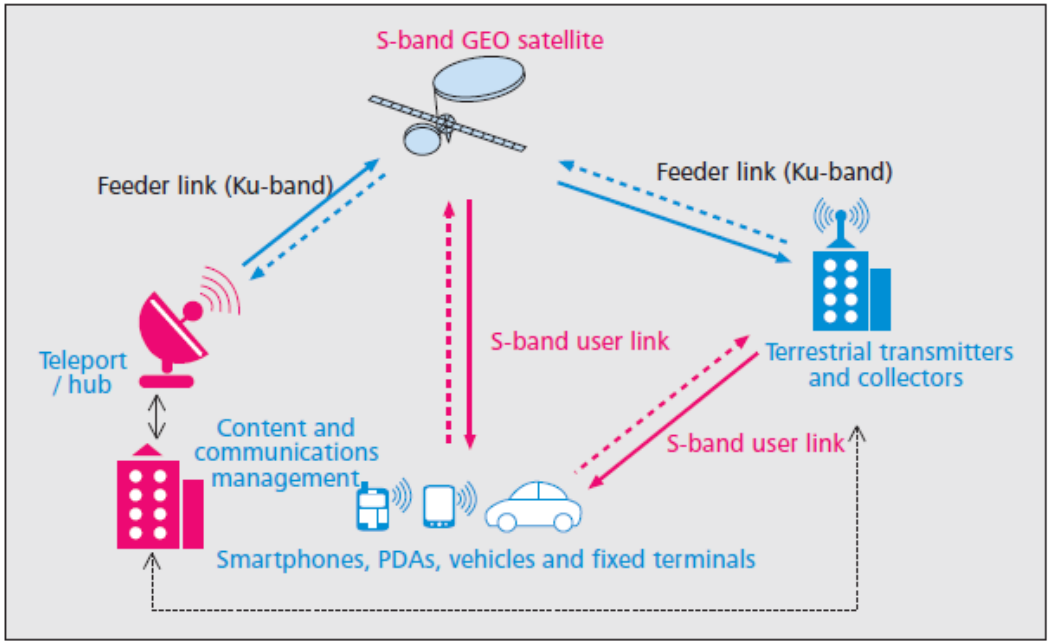
- MF-TDMA uplink/FDM-TDM downlink
- Up to 3140 (27.7 kHz) carriers, data rates up to 9.6 kbps, 40 ms frame
- Coherent π/4-QPSK
- Convolutional code FEC with code rate ½
- Localization with GPS in the UE



S-band Solaris Satellite / Terrestrial Hybrid Network

- Joint Eutelsat/SES Solaris joint-venture to provide broadcasting/interactive services to mobile (vehicular) users using S-band
- EC dedicated frequency allocation next to terrestrial 3G networks at 2.2 and 2.0 GHz
- Prototypes and large experimentation performed in Europe





Field trials in Pisa

S-band Solaris Satellite / Terrestrial Hybrid Network

- Bent-pipe payload with linguistic beams over Europe launched in 2009 (12 m reflector)
- ETSI DVB-SH/S-MIM open air interface
  - DVB-SH is FDM/TDM standard optimized for mobile broadcasting and interactive service
  - S-MIM complements DVB-SH for high efficiency bursty return link (1000 times more efficient than ALOHA) using an adaptation of 3GPP W-CDMA with Successive Interference Cancellation for packet collision resolution
- The partly unsuccessful large reflector deployment led to the commercial project failure

SPACENEWS

Eutelsat W2A's S-band Antenna Malfunctions

by Peter B. de Selding — May 14, 2009

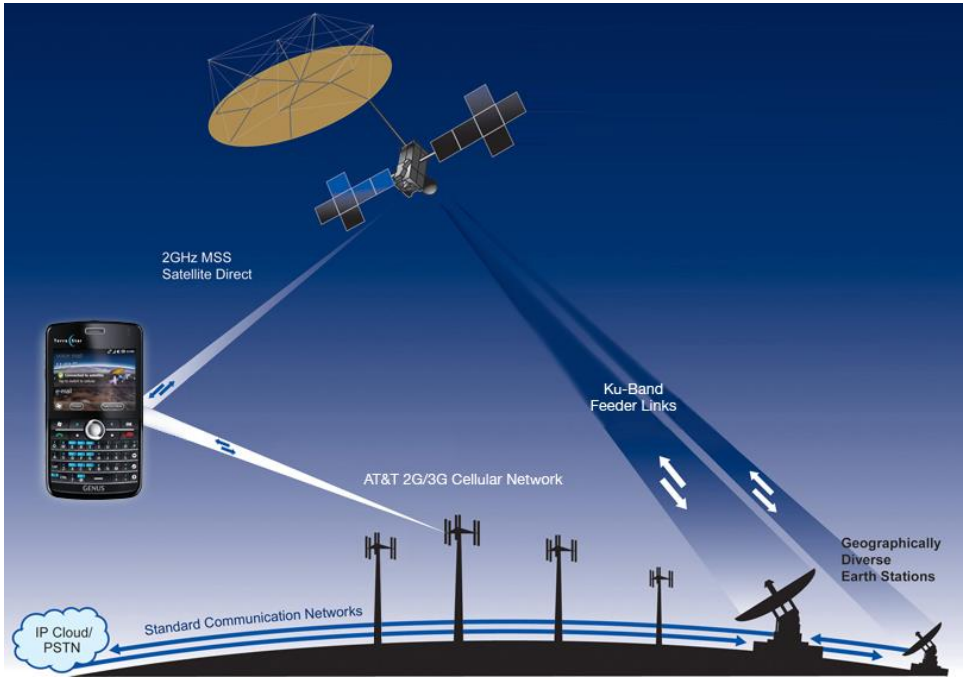
KOUROU, French Guiana — The 12-meter-diameter S-band antenna aboard the Eutelsat W2A satellite launched April 4 has suffered an anomaly that may reduce its ability to provide service across Europe as required by its regulatory license, one of two granted May 14, according to industry officials.

The antenna, built by Harris Corp. of Melbourne, Fla., was successfully deployed in orbit April 9. But in-orbit tests in the last four weeks have turned up a hardware glitch whose consequences are not yet known, according to Solaris Mobile, a joint venture that was formed to sell S-band satellite services to government and commercial users in Europe.

- Frequency sold to Echostar and Solaris company terminated

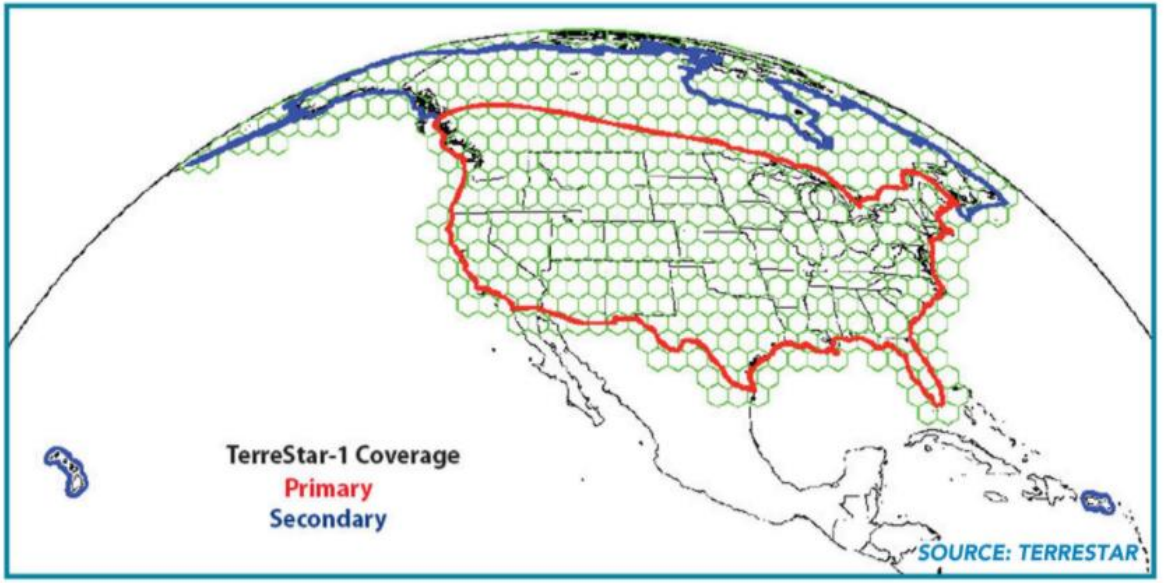
GSO Terrestar/Echostar Regional Mobile System

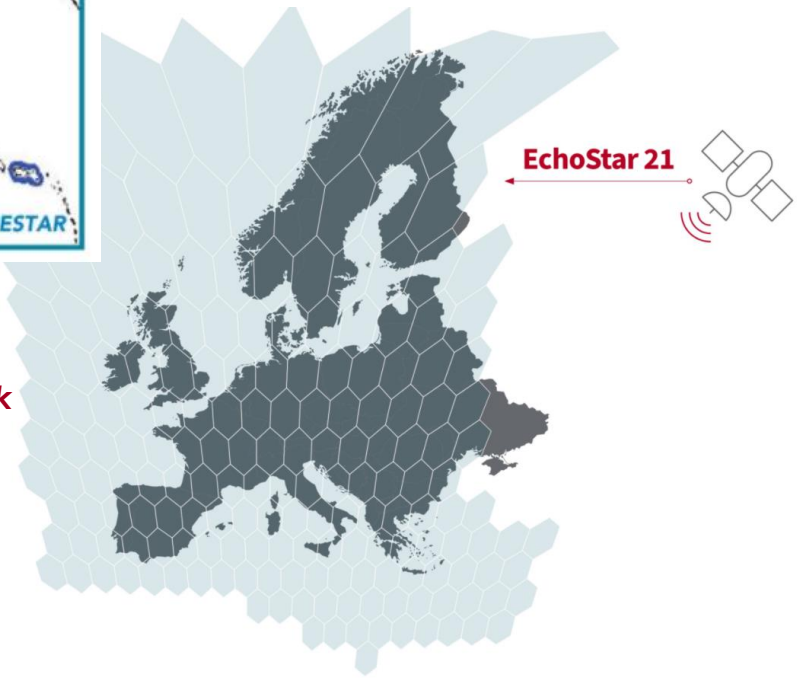
- US company founded in 2002 planning an hybrid satellite/terrestrial (ATC-CGC) network development over US operating at S-band
- Company went bankrupt in 2010, bought by EchoStar Mobile who launched EchoStar 21 in 2017 planning EU coverage (with the former Solaris (Eutelsat/SES) mobile CGC EU license)
- Planned services: 3G like IP–based voice, data and video
- Extensive terrestrial Ancillary Terrestrial Communication (ATC) network as per FCC license
- Dual-mode satellite/terrestrial phones with terrestrial size/look



GSO Terrestar/Echostar Regional Mobile System

The Terrestar 1 and Echostar 21 coverage (550 ground beams)





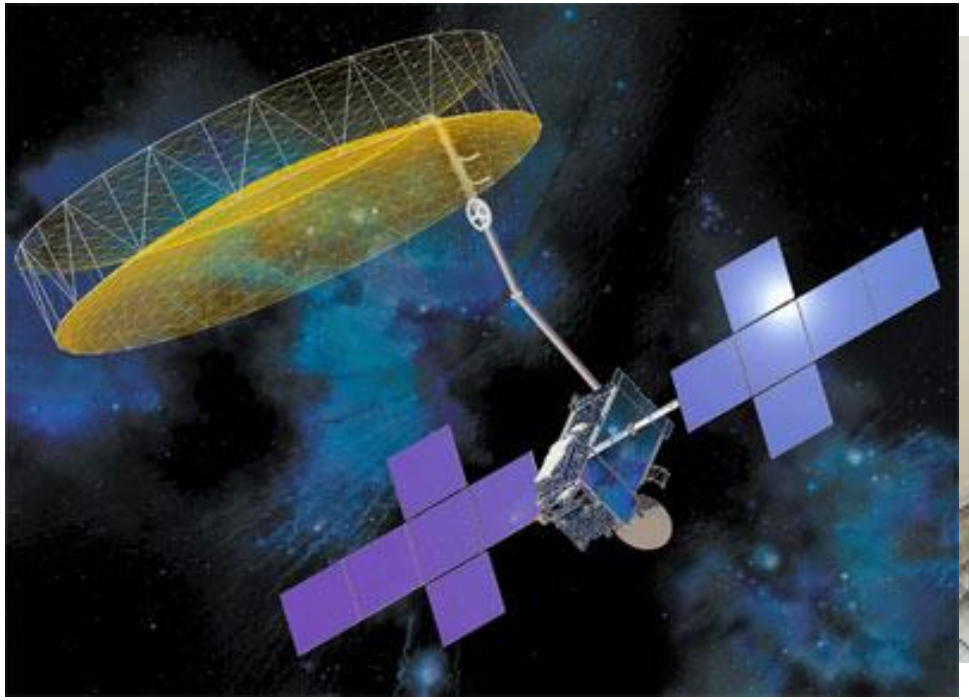
EchoStar 21 moved to Europe reusing the Solaris (Eutelsat/SES) S-band license given by the EU for Satellite/terrestrial ATC network
The Solaris joint venture failed after partially unsuccessful S-band antenna deployment

Not much commercial use reported to date

GSO Terrestar/Echostar Regional Mobile System

The Terrestar 1/Echostar 21 spacecraft:

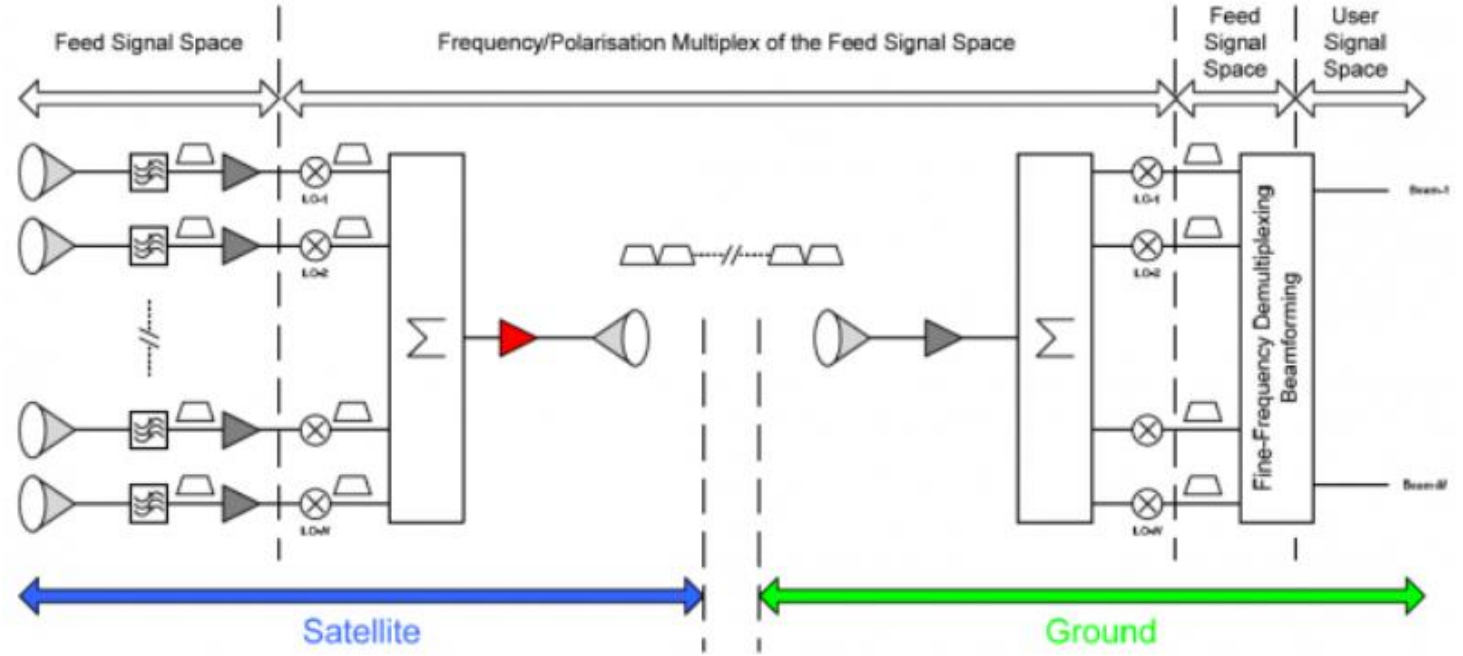
- S-band 18 m antenna fed reflector (AFR) with digital transparent payload (channelization and DBFN)
- Ku-band feeder link antenna with on-ground beam forming (OGBFN)
- Inclination allowed up to +/- 6 degrees, 20 ground beacons for spacecraft pointing using the OGBFN



GSO Terrestar/Echostar Regional Mobile System

The Terrestar payload and OGBFN:

- One 18 m reflector fed by three distinct arrays of 78 elements (1) and 8 elements (2)
- Simple bent-pipe payload architecture thanks to the OGBFN approach
- Larger feeder link bandwidth required – calibration of the RF chains from antenna feeds to the gateway required
- TWTAs for the HPAs (instead of SSPAs)



GSO Terrestar/Echostar Regional Mobile System

The Terrestar ground segment (user terminal and gateways)

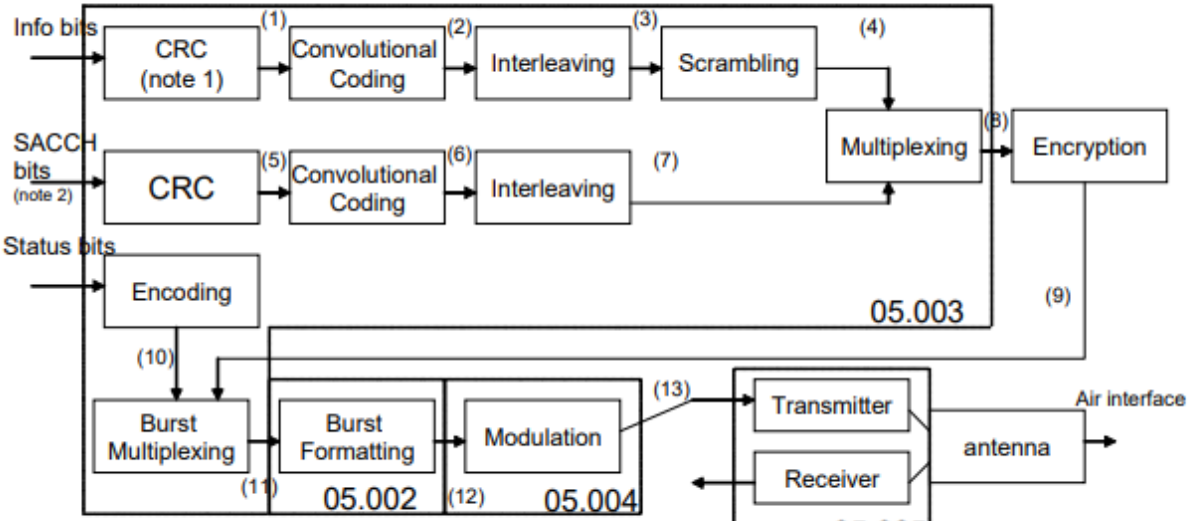
User terminal

Feeder link ground station

GSO Terrestar/Echostar Regional Mobile System

The Terrestar S-band air interface follows the ETSI GMR-1, release 3 public air interface

- MF-TDMA uplink/FDM-TDM downlink
- W-CDMA (3G) for the ATC/CGC

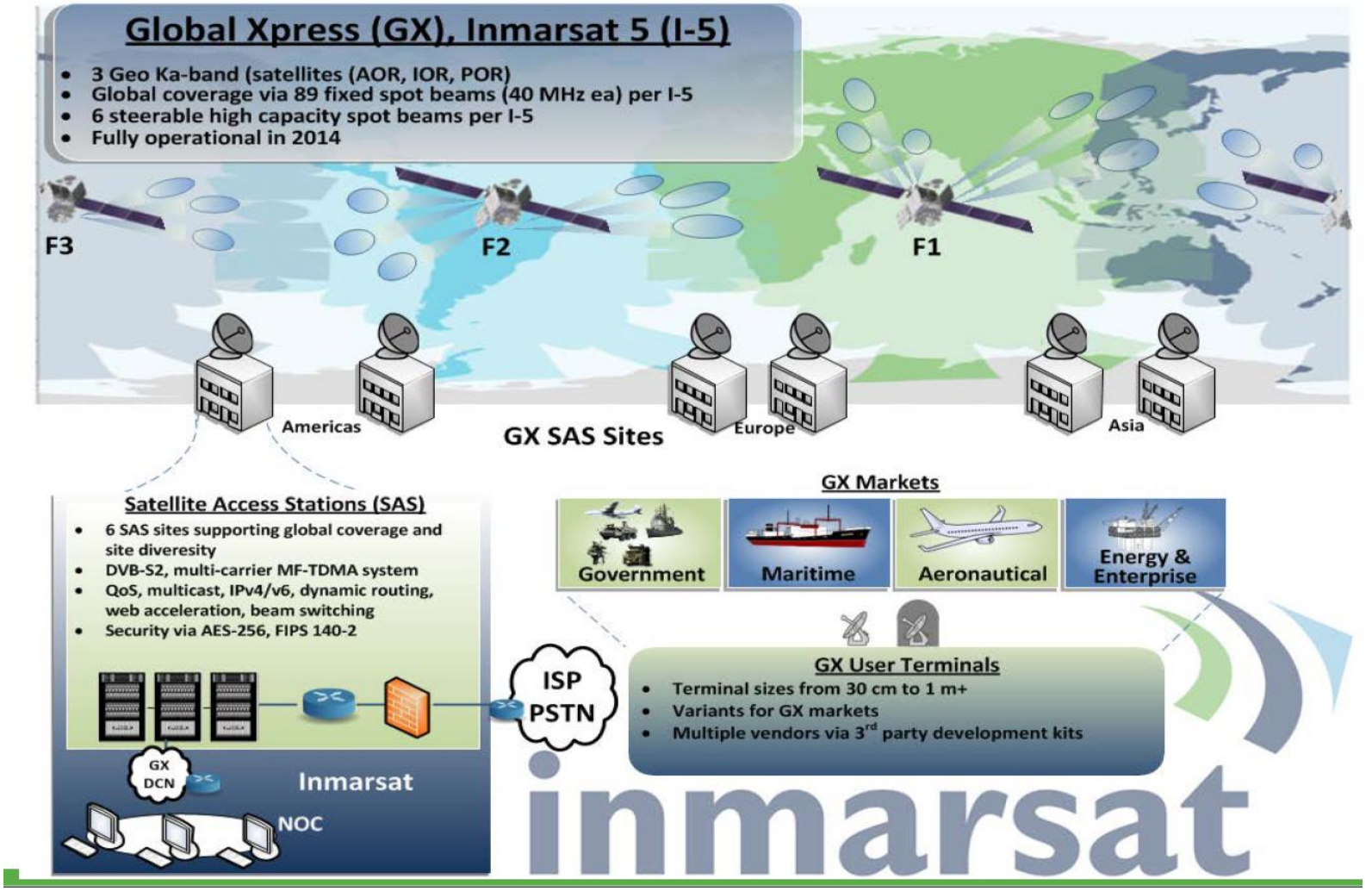


GSO INMARSAT Global Xpress Mobile Broadband Constellation

The INMARSAT (London-based) Global Xpress Ka-band system:

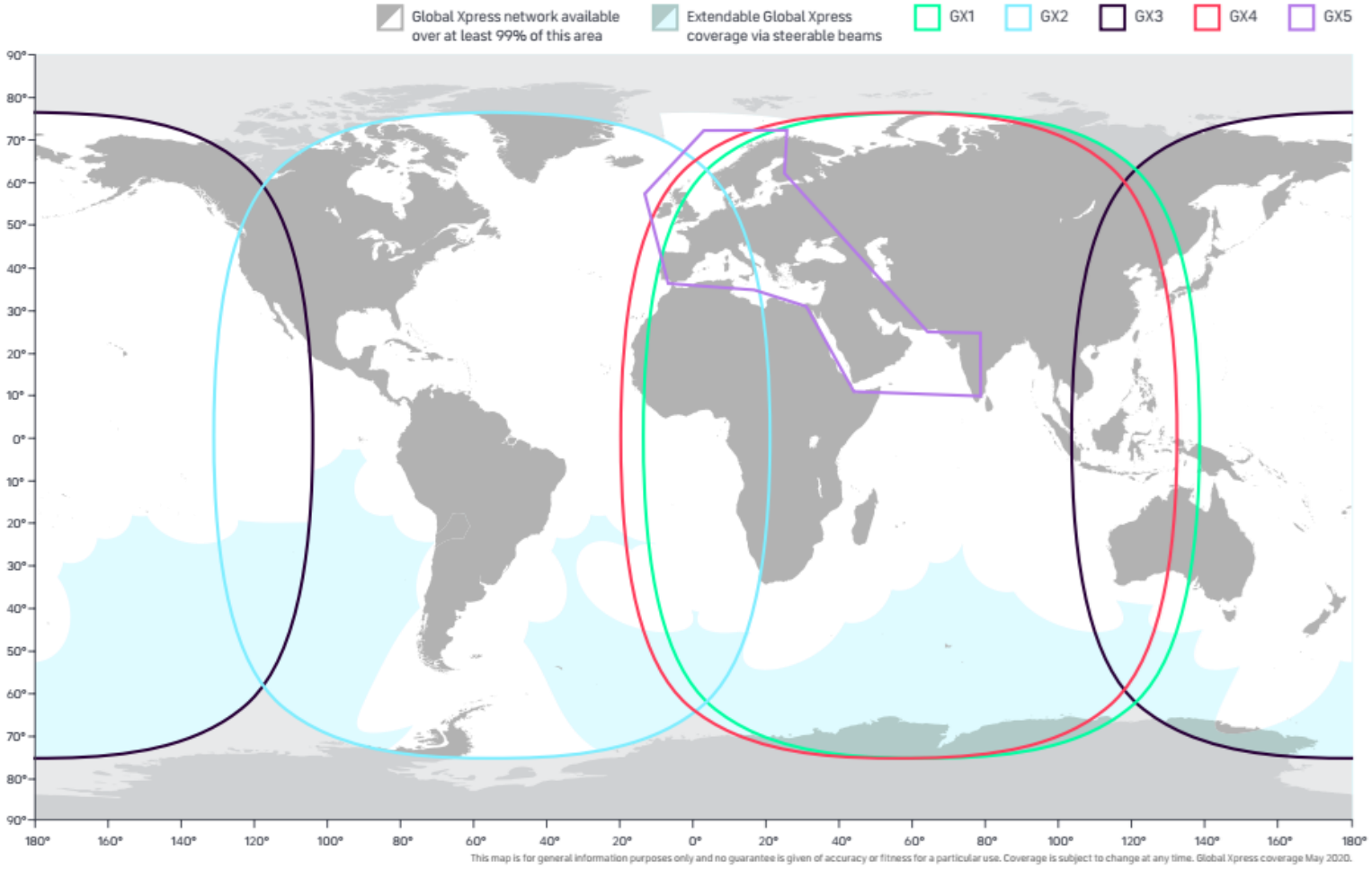
- GSO constellation composed of 4 INMARSAT-5 satellites (2 extra HEO satellites planned)
- Broadband VSAT type of services to fixed and mobile terminals
  - Voice over Internet Protocol (VoIP) support and managed VoIP service
  - Video teleconferencing
  - Branch office applications (e.g. VPN access, SAP, Citrix, email)
  - Real-time video and audio streaming
  - Real-time interactive collaboration and situational awareness
  - High-speed broadband for internet access
  - High-speed file transfer
  - Video surveillance
- 89 spot beams/satellite (72 active max), six steerable high-capacity beams
- Two steerable gateway beams (smaller size)
- 2 diversity GW/SAT (Italy, Greece, USA, Canada, New Zealand), 4 TT&C stations

GSO INMARSAT Global Xpress Mobile Broadband Constellation



GSO Global Xpress Mobile Broadband Constellation

INMARSAT Global Xpress GSO fleet current coverage



GSO Global Xpress Mobile Broadband Constellation

The INMARSAT 5 spacecraft

Six larger reflectors for HCP spot

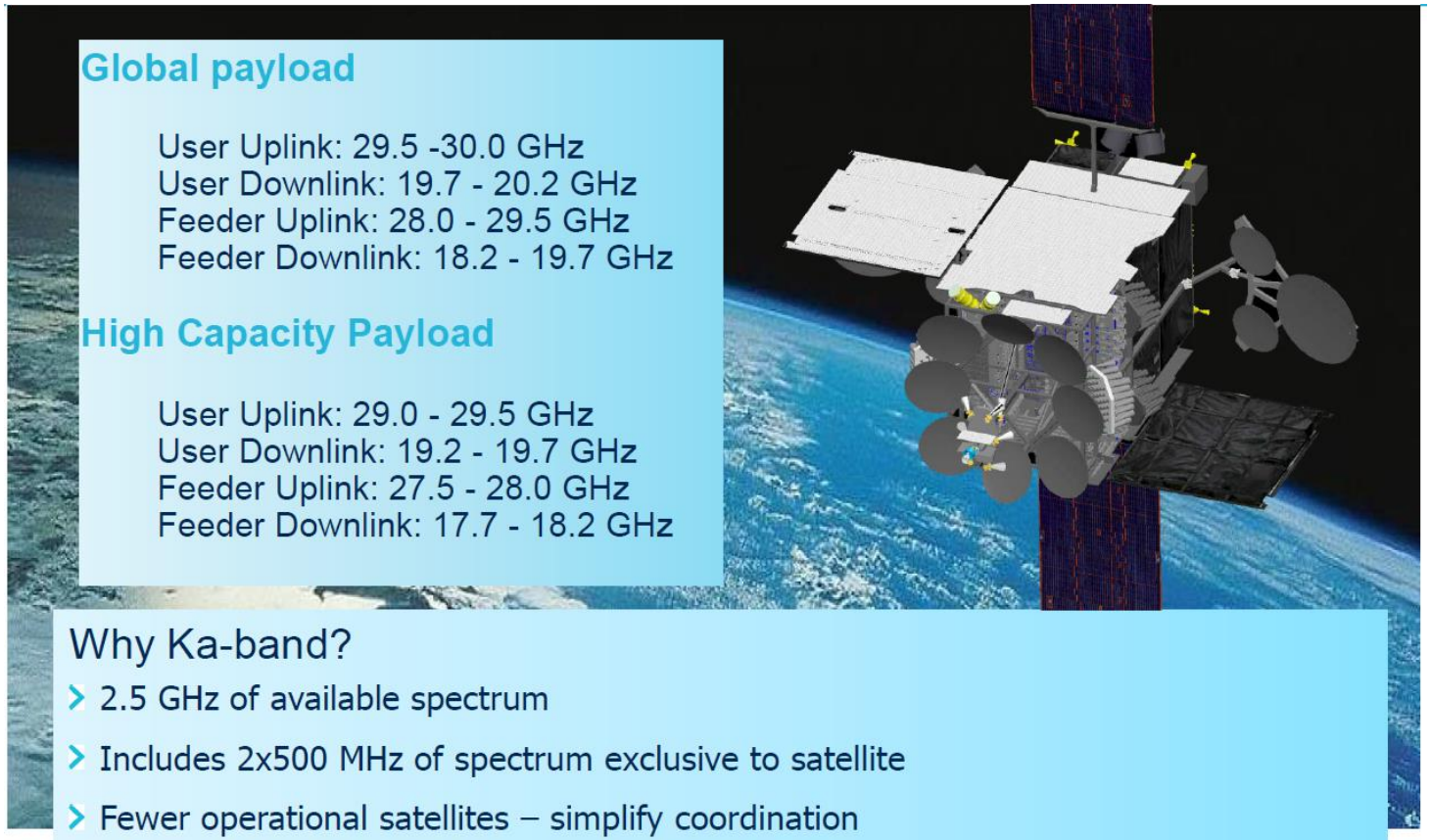
- Two Ka-band feeder link antennas small reflectors
- Three + three side reflector for user link (2 Tx, 4 Rx)

Dip. Ingegneria dell'Informazione
University of Pisa, Italy

GSO Global Xpress Mobile Broadband Constellation

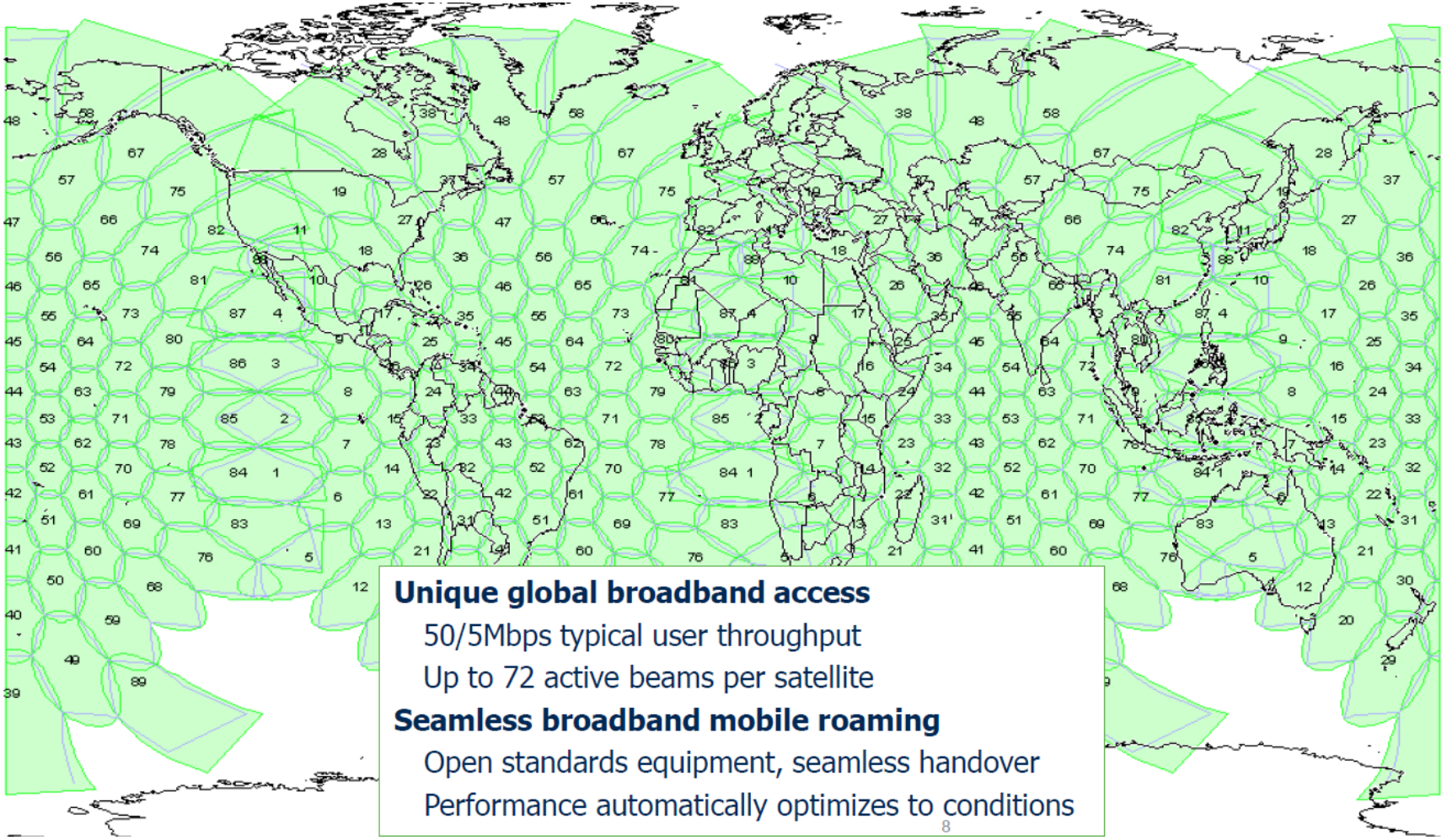
The INMARSAT 5 payload: Bent pipe with single feed-per-beam antenna

- 61 TWTAs forward link, 6 TWTAs in the return link



GSO Global Xpress Mobile Broadband Constellation

INMARSAT Global Xpress GSO fleet current coverage



Unique global broadband access

- 50/5Mbps typical user throughput
- Up to 72 active beams per satellite

Seamless broadband mobile roaming

- Open standards equipment, seamless handover
- Performance automatically optimizes to conditions

GSO Global Xpress Mobile Broadband Constellation

The INMARSAT Global Xpress ground segment (user terminal and gateways)

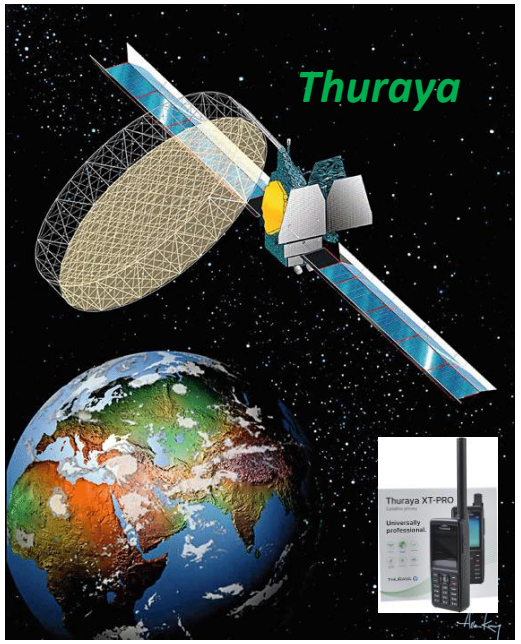
User terminals

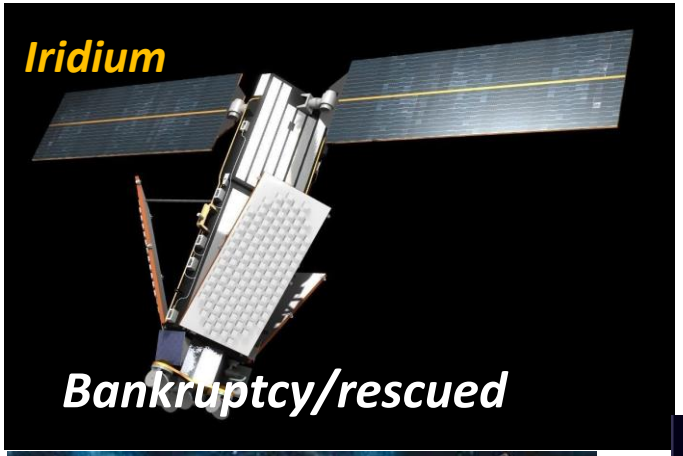
GSO Global Xpress Mobile Broadband Constellation

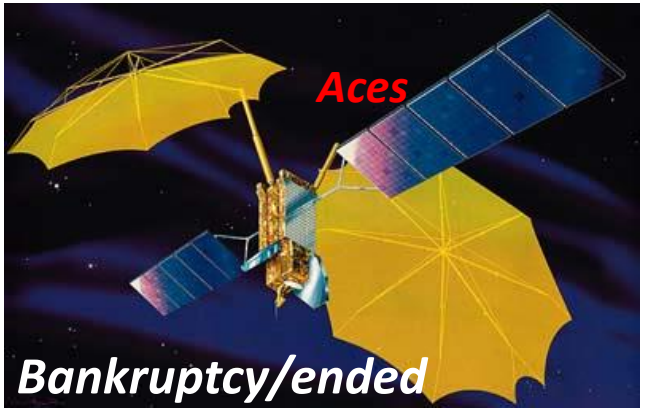
The INMARSAT Global Xpress air interface follows the DVB-S2(X) air interface in the forward link and a proprietary iDirect MF-TDMA return link air interface similar to DVB-RCS2

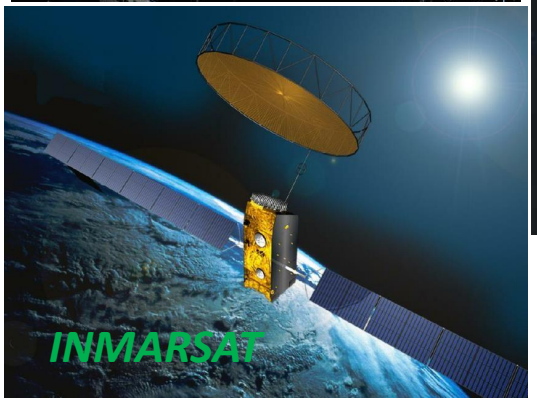
- FDM/TDM downlink with ACM 32/40 MHz channels, QPSK, 8PSK, 16APSK
- MF-TDMA uplink with ACM 32/50 MHz, BPSK, QPSK, 8PSK
- Feeder uplink fading counteracted with power control and spatial diversity
- User forward link fading mitigation based on DVB-S2 ACM (15 dB range)
- User return link fading mitigation: moderate uplink power control, ACM, baud rate reduction

Mobile Satellite Communication – Risky business?









Mobile Systems Takeaways 1/2

- **GSO and NGSO Mobile Satellite Networks are trying to complement terrestrial networks**
  - Satellite wide coverage is an asset to complement terrestrial coverage cost
  - Unique role for military, exploration and emergency situation
  - Current capabilities more suitable for niche professional applications
  - New initiatives like AST Mobile, Apple/Globalstar, T-Mobile/Starlink, Iridium/Qualcomm may drastically change the picture

Mobile Systems Takeaways 2/2

- **Key challenges:**
  - Satellite is struggling to provide satisfactory Q.o.S. and data rates in mobile conditions
  - Standard terrestrial user terminal has major link budget limitations due to the mobile antenna low-gain (in particular for hand-held)
  - Large satellite antenna aperture may compensate for the poor user terminal performance but making space segment bulkier and more expensive
  - PFD limitations in satellite frequency band are no allowing to increase the data rates unless reuse of terrestrial bands
  - Complex national licensing and frequency coordination processes
  - Radio resource management challenging considering the uneven traffic
  - Conventional business case difficult to close for both GSO and NGSO but in particular for the latter – new entrants cooperating with MNOs may have better success