SATCOM

Satellite Communication

Presented by

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ALTRAN on behalf of ENAC

Objectives

- List the principles of SATCOM in civil aviation

Outlines

- General Introduction
- Satellite in aeronautical communication
- Implementation
  - IMARSAT
  - IRIDIUM

Introduction

History

General Introduction

ENAC

中国民航大学

Civil Aviation University Of China

Introduction - History

1957 - Sputnik, first artificial satellite, Soviet Union

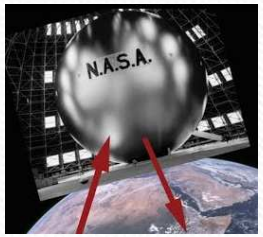
1960 - Echo 1, “satelloon”, first artificial communications satellite, NASA

1962 - Telstar, first live transatlantic television feed, NASA

1964 - Syncom 3, first geostationary satellite, NASA

1965 - Intelsat I, “Early Bird”, first commercial communications satellite

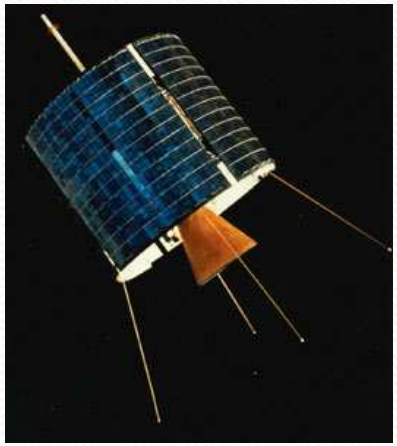
Sputnik



Echo 1

Telstar

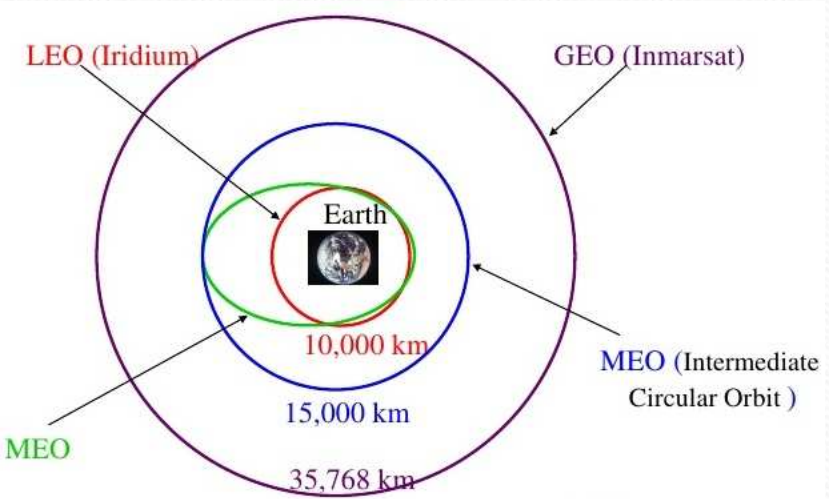
Syncom



Intelsat 1
“ Early Bird”

Introduction - Orbits

LEO : Low Earth Orbit
MEO : Medium Earth Orbit
GEO : Geostationary Orbit



Comparison	LEO	MEO	GEO
Orbit	500 - 1500 Km	6000 - 20000 Km	36000 Km
Coverage	small	large	global
Nb. Handovers	High	Low	Least (none)
Propagation	Least	High	Highest
Propagation delay	10 ms	80 ms	250 ms
Lifetime	Short (5-8years)	Long	Long (~15years)

Introduction - Constellations

- Constellation : A group of satellites, of a similar type and function, designed to be in similar, complementary, orbits for a shared purpose, under shared control
- Gain : Coverage
- LEO often deployed in constellations
- Examples: GPS,GLONASS,COMPASS (Beidou), …

Introduction - Frequency Bands

Band	Frequency Range	Total Bandwidth	General Application
L	1 - 2 GHz	1 GHz	MSS (Mobile Satellite Service)
S	2 - 4 GHz	2 GHz	MSS, NASA, deep space research
C	4 - 8 GHz	4 GHz	FSS (Fixed Satellite Service)
X	8 - 12.5 GHz	4.5 GHz	FSS military, terrestrial earth exploration and meteorological satellites
Ku	12.5 - 18 GHz	5.5 GHz	FSS, BSS (Broadcast Satellite Service)
K	18 - 26.5 GHz	8.5 GHz	FSS, BSS
Ka	26.5 - 40 GHz	13.5 GHz	FSS

- ITU (International Telecommunication Union) is in charge of Frequency Allocation

Introduction - Conclusion

- Advantages
  - Wide aera coverage (remote incl.)
  - Mobile and wireless communication
  - Cost of transmission independent of distance
  - High bandwidth
  - Uniform service / single service provider facility
  - …
- But
  - Costs
  - Lifetime
  - Propagation delay
  - ...

SATCOM (in aviation)

History

AMSS

Implementation

ENAC

中国民航大学

Civil Aviation University Of China

Satellite in Aeronautical Communication

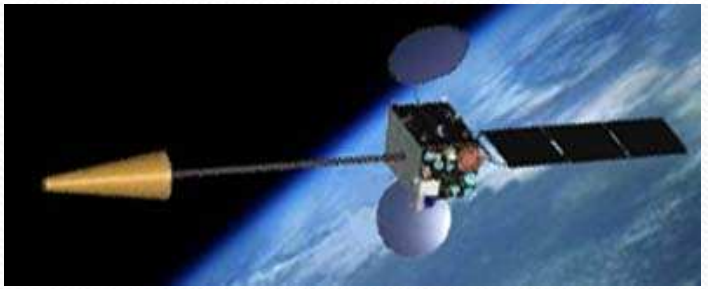
- History
  - 60's
    - Need for a long distance communication system
    - In replacement of vocal HF
    - NASA ATS 3 used for feasibility study
  - 1968 : ICAO launches ASTRA
    - Application of Space Techniques Relating to Aviation
  - 1974 AEROSAT
  - 1983 : FANS Committee starts
  - 1991(resp 1993) : FANS work approved by ANC

Satellite in Aeronautical Communication

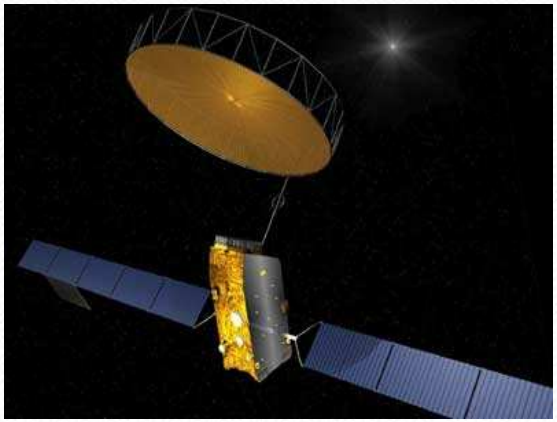
- History
  - Until 2007:
    - Only GEO satellites for AMSS
      - Limited to INMARSAT and MTSAT
  - Since 2007:
    - SARPs independent from LEO, MEO or GEO
      - Includes IRIDIUM

Satellites

Inmarsat 3



MTSAT - 2



Inmarsat 4

Iridium

SCOPE of SATCOM in ATM

- ICAO Standards and Recommended Practices (SARPs) : GEO and LEO systems
- Targeted at Oceanic and Remote areas
- Maybe a complement link for continental regions
- A/G Communication
- Service : voice , date or both

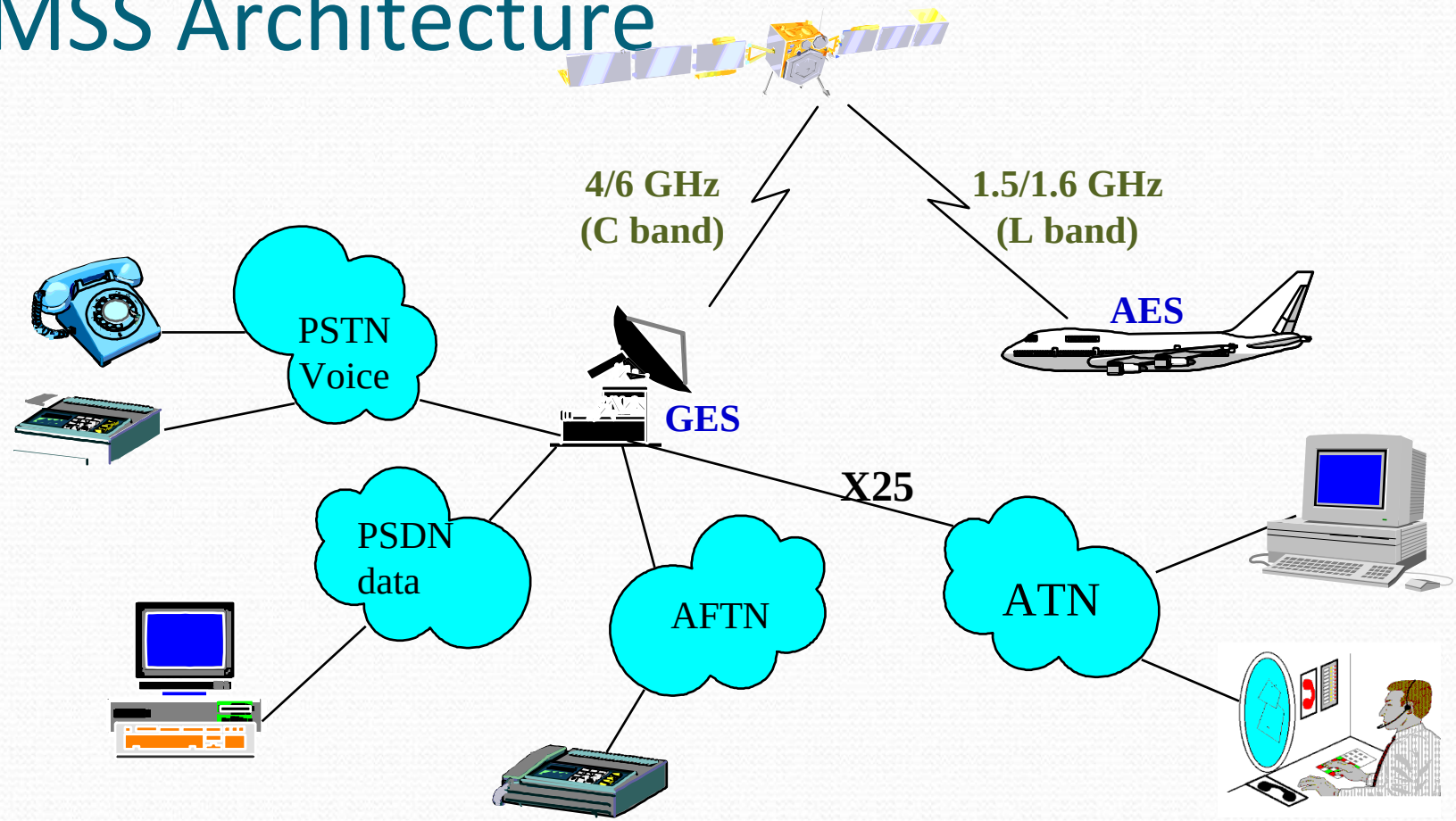
Communication service

- Packet mode
  - For data transmission only
- Circuit mode
  - Primarily for voice transmissions
  - May also be used for data transmission

AMSS

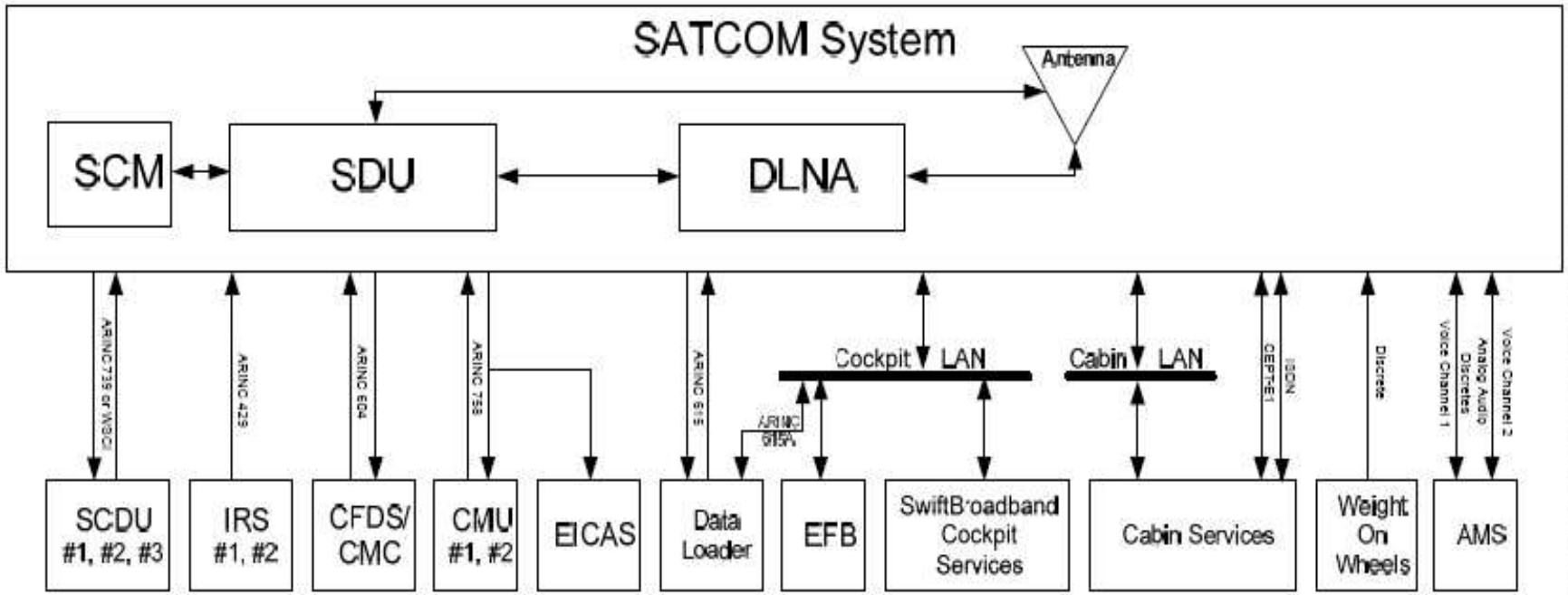
- Aeronautical Mobile-Satellite Service
- Defined by ICAO
- Annex-10 : general architecture , communication protocols
- System consists of 3 segments
  - Ground
  - Aerospace
  - Space (transparent from network func. point of view)
- Mobile earth station is located on board aircraft

AMSS Architecture



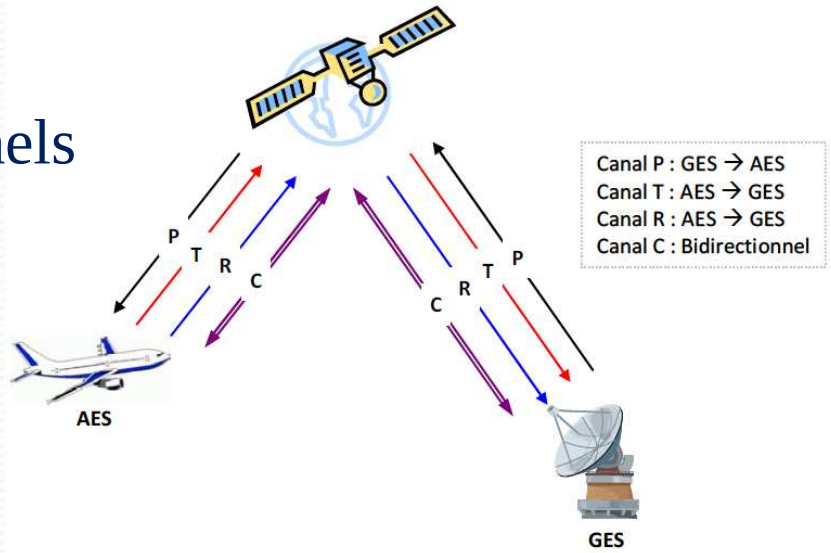
AES : Airborne Earth Station
GES: Ground Earth Station
ATN: Aeronautical Telecom Network
PSDN : Packet Switched Data Network
PSTN : Packet Switched Telephony Network
AFTN: Aeronautical Fixed Telecom Network

Onboard architecture



Transmission channels (Physical)

- P channel
  - From ground station to the aircraft
  - TDM (super frame lasts 8 sec –500 ms slots)
  - continuous transmission
  - Signaling data and user data
  - Synchronizes all the other channels
- R channel
  - From the aircraft to the ground
  - Slotted-ALOHA
  - Signaling data and user data
- T channel
  - From the aircraft to the ground
  - TDMA (Time Division Multiple Access) with reservation (contiguous slots allowed)
- C channel
  - Single circuit for voice and signaling



Connection establishment

- GES regularly sends data on P_{smc}
- AES receives these data
- AES request connection to the GES
- Depending on needs
  - Establish channels C and T
  - Establish level 3
  - …

Performances

- Connection establishment delay
  - 10 to 17 seconds from the aircraft
  - 9 to 11 seconds to the aircraft

Implementation

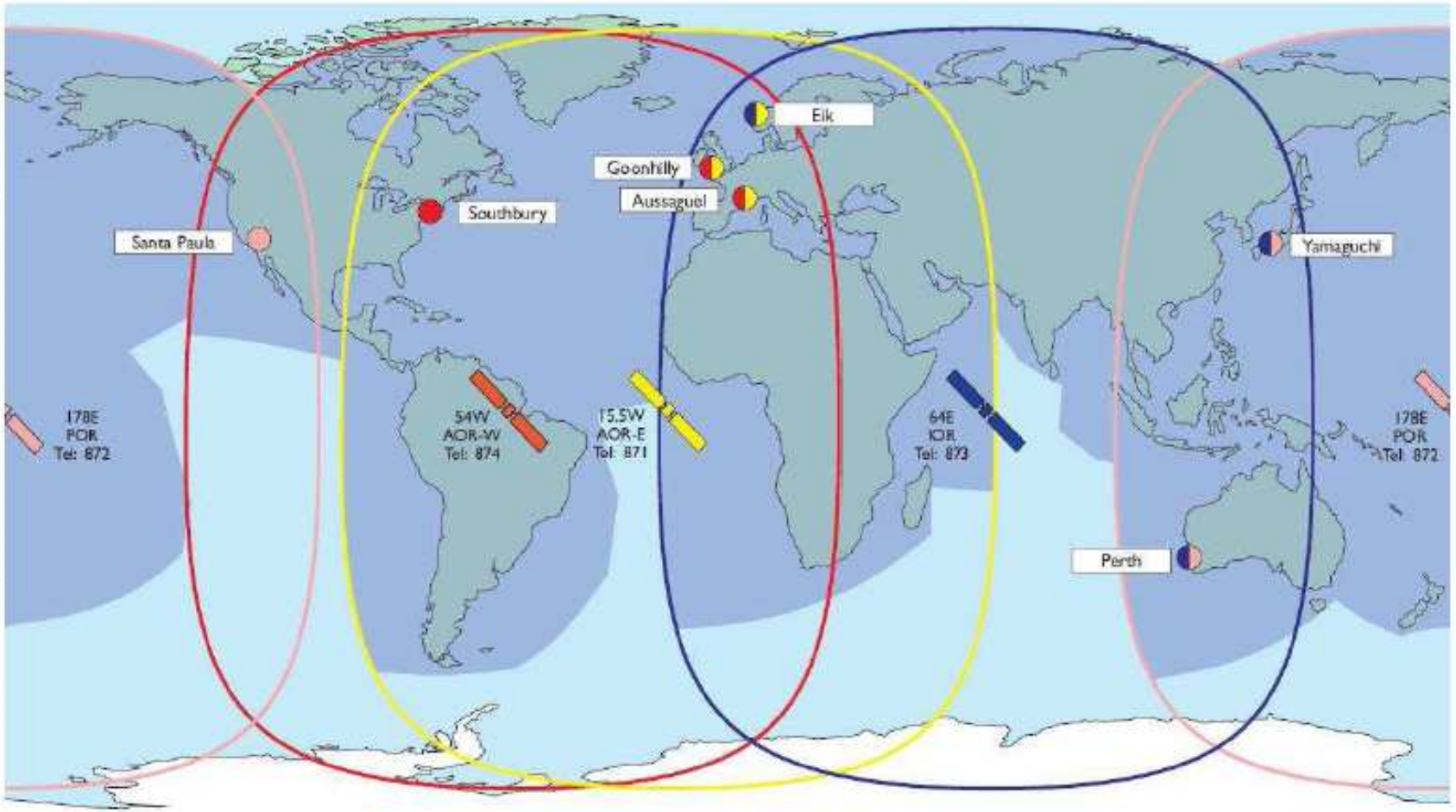
Inmarsat

- Founded in 1979
- International governmental organization
  - 75 members (at the beginning)
- Private company since1999
- GEO based
- Four generations : I-2 (not ope.), I-3, I-4 and I-6 (under construction)

Inmarsat

- In 2015 : 1.3 billion$ revenues (10% for aeronautical services, CAGR 10% for safety services)
- Inmarsat AMSS ‘safety services’ :
  - Fully managed ICAO SARPs compliant aeronautical services have been available since 1990
  - Approx. 7700 Aero L, I, H/H+ terminals currently activated
  - Classic Aero services (over I-3 and I-4 systems)
  - New concept : SwiftBroadband Safety services

Converage


Elk
Goonhilly
Aussaguel
Southbury
Santa Paula
Yamaguchi
178E
POR
Tel: 872
54W
AOR-W
Tel: 874
15.5W
AOR-E
Tel: 871
64E
IOR
Tel: 873
178E
POR
Tel: 872
Perth

Offered services

- I-3 and I-4 – “Classic Aero” services/ICAO compliant
  - Aero L – Low gain antenna
    - 600 to 1200 bit/s
    - 1 single voice channel
  - Aero I – Intermediate gain antenna (I-3 regional beams)
    - multi-channel voice
    - 4,8 Kbit/s in circuit mode
  - Aero H/H+ High gain antenna: H with global coverage, H+ with beam
    - 10,5 Kbit/s in circuit mode
    - 9.6 Kbps per channel for multi-channel voice
    - Fax

ICAO channels

Service	Antenna	C-Channels Supported	P Channels Supported	R Channels Supported	T Channels Supported
Aero-L	LGA	None	600*, 1200	600*, 1200*	600#, 1200#
Aero-H	HGA	21000	600*, 1200	600*, 1200*	600#, 1200#
Aero-I	IGA	8400	600*, 1200	600*, 1200*	600#, 1200#
Aero-H+	HGA	21000, 8400	600*, 1200, 10500	600*,1200*, 10500	600#,1200#, 10500

* : mandatory

: only mandatory if AES provides data packet service

Proposed services

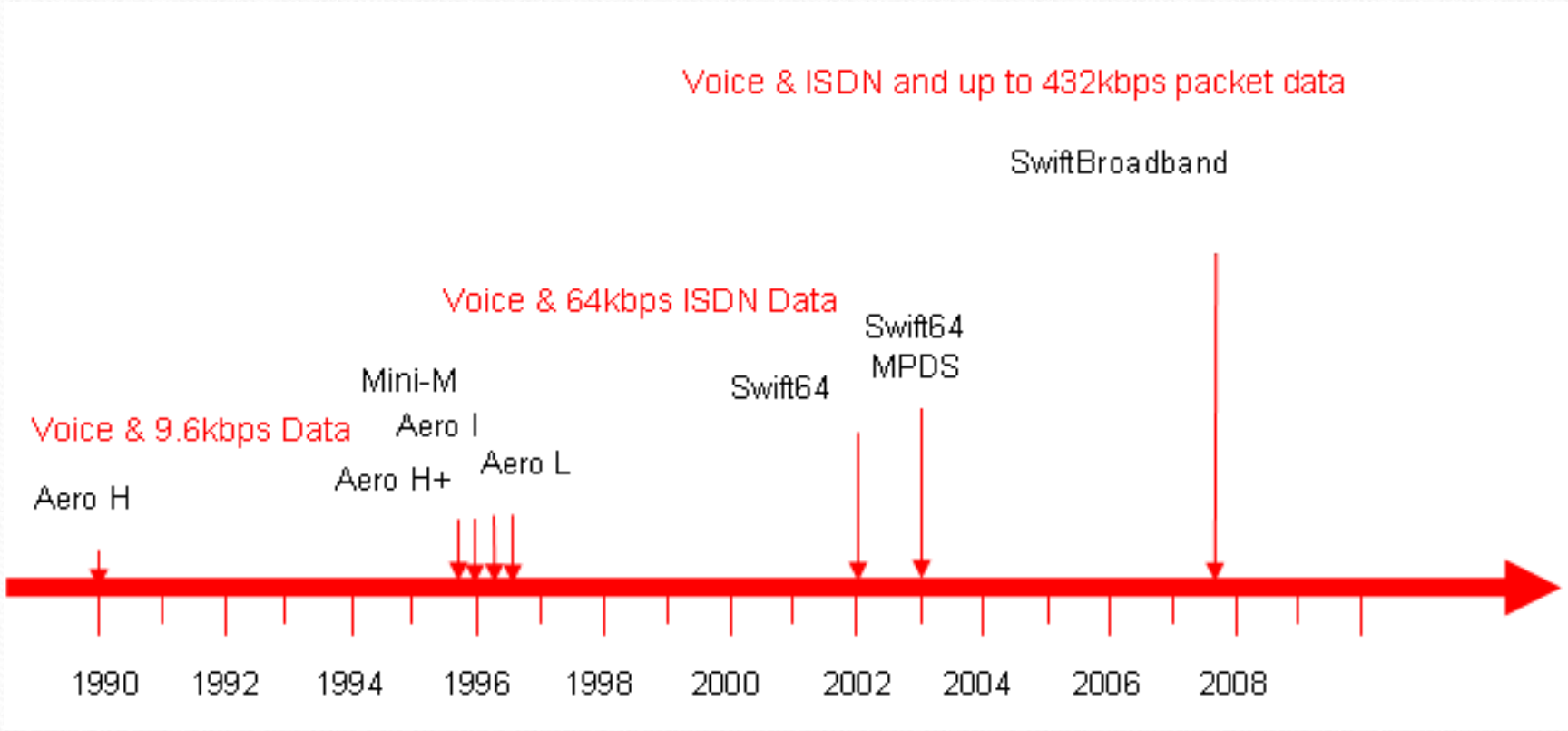
- Swift64 (I-3)
  - Since 2002
  - 64 Kbit/s per channel
  - ISDN supported (channel allocation: per user)
  - IP allowed

Proposed services

- SwiftBroadband (constellation of 3 I-4)
  - IP-based voice and data
  - up to 650 Kbit/s per channel
  - Commercial name: BGAN
  - Inmarsat is owner and operator of the ground stations

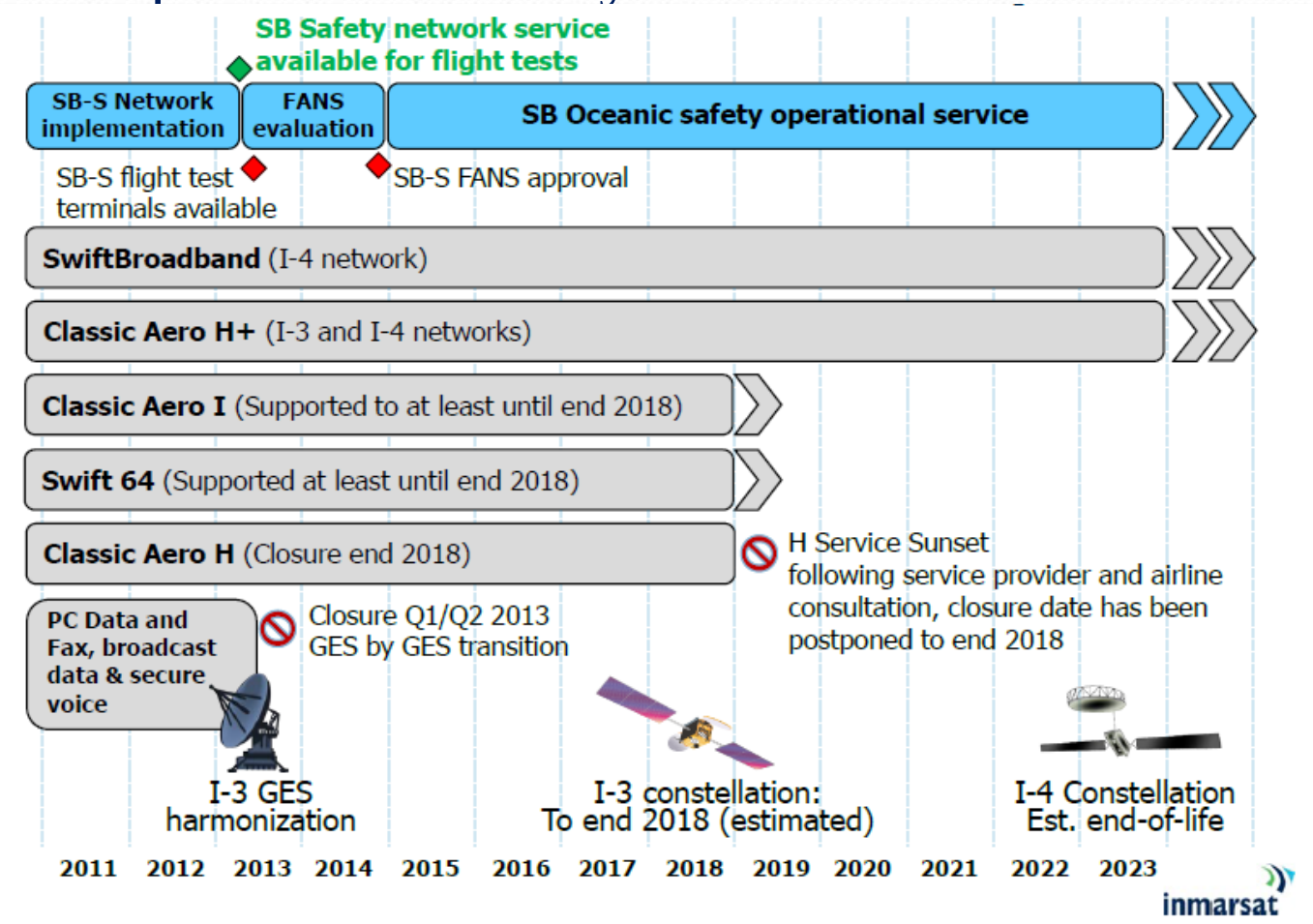
Proposed services

- Timeline of of Inmarsat's Aeronautical Services

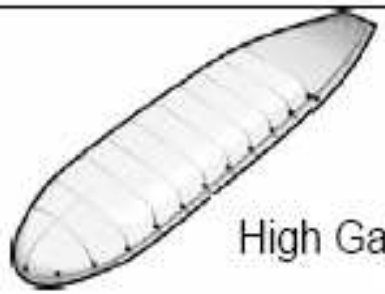


Proposed services

- Roadmap of AERO safety services



Antennas

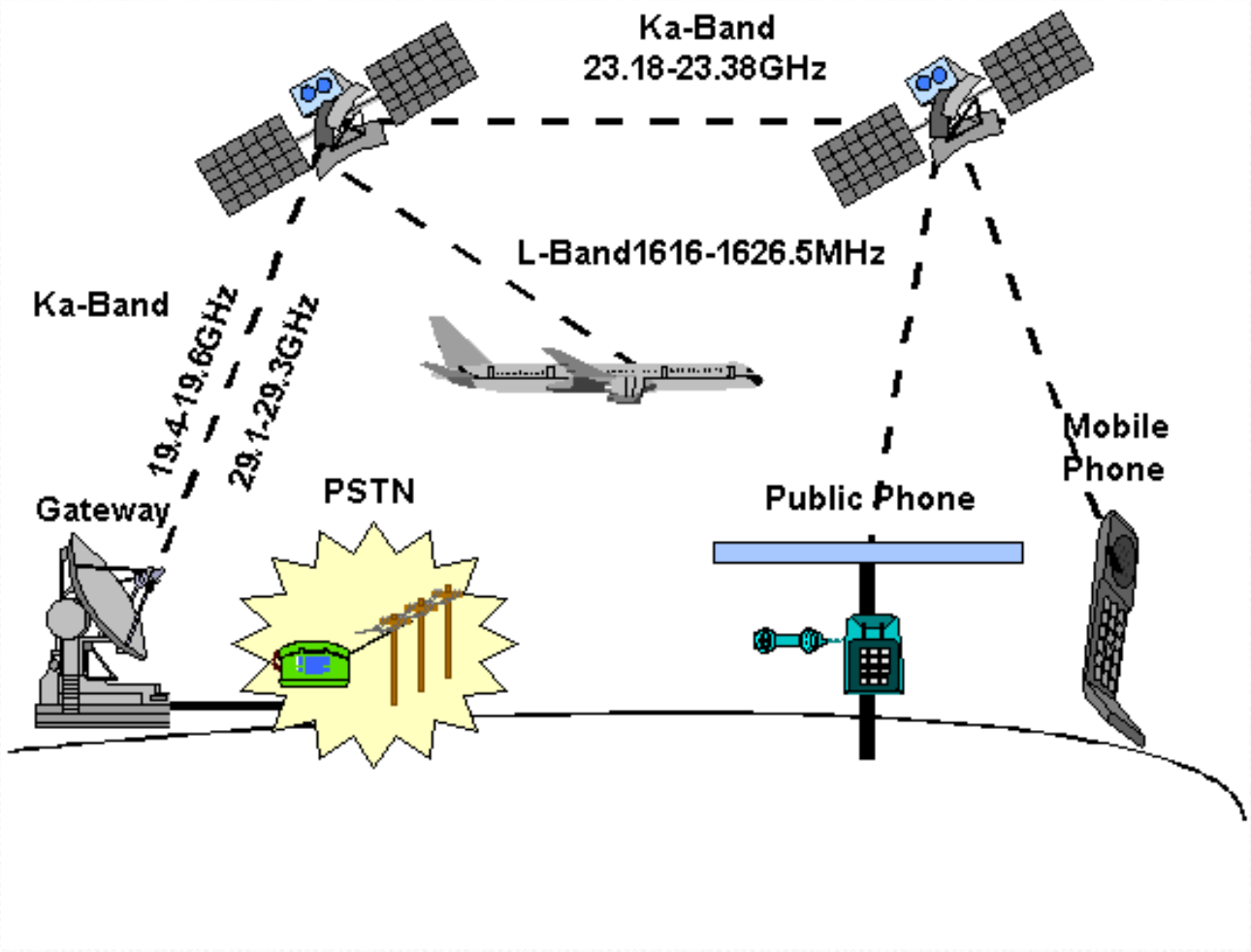
Classic/Swift 64	Antenna Type	SwiftBroadband (bearer rates)
Swift64 – Regional Beams 64 kpps ISDN and MPDS Aero H/H+ in Global beam Voice, fax, PM data Safety services support	 High Gain	High Gain – Class 6 UT 266 – 500 kbps Rx 332 – 492 kbps Tx Voice, fax PM data Safety Services potential
Aero-I – Regional Beam voice Global beam for 2.4 kbps fax and data 4.8 kbps X.25 PM data Safety services support	Intermediate Gain 	Intermediate Gain – Class 7 UT 200 – 344 kbps Rx 192 – 332 kbps Tx Voice, fax PM data Safety Services Potential
Aero-L – Global data only 1.2 kbps PM Data Safety services support	Low gain 	Low gain – Class 4 UT 36 – 50 kbps Rx 21 – 55 kbps Tx Voice, PM data. Safety services potential

Implementation

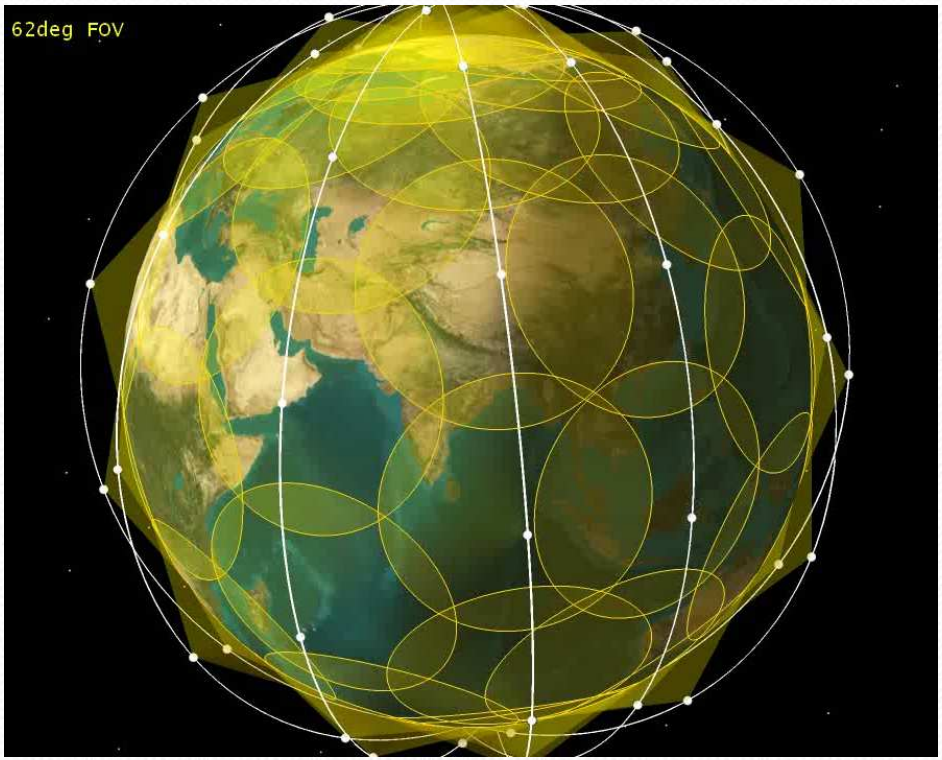
Iridium

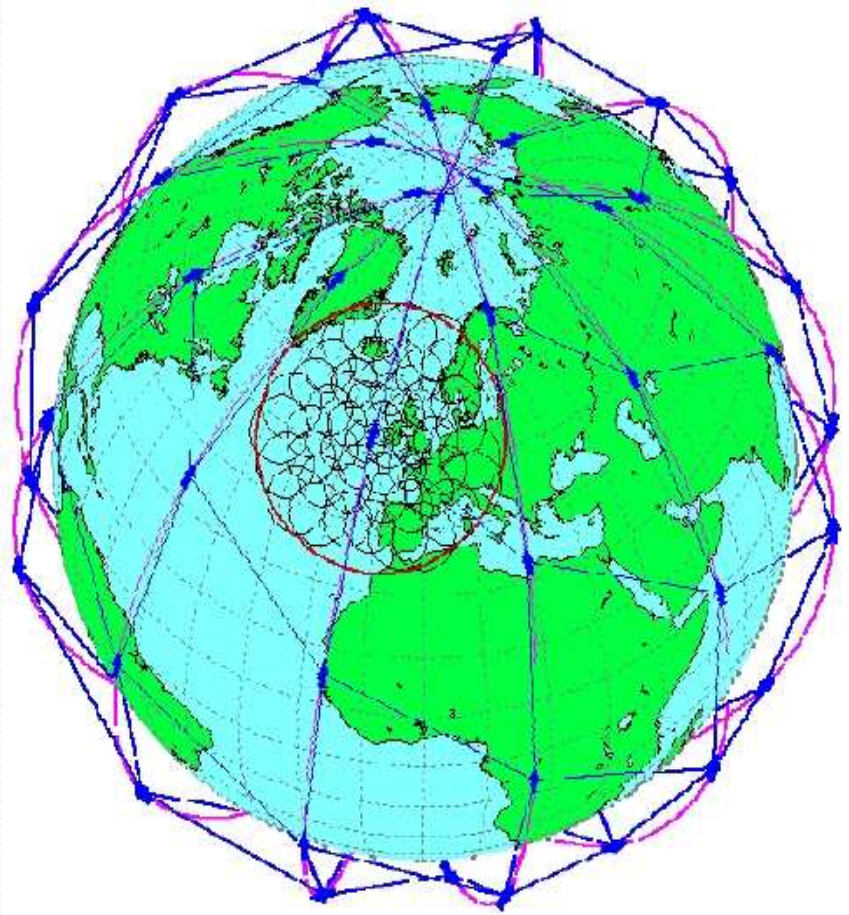
- Founded in 1998, bankrupt nine month later and restarted in 2001. In 2015 : 411.4 million$ revenues
- Designed with 77 satellites
  - Hence the name Iridium
- Now 66 active on 6 orbital planes (30° apart)
- Global coverage (LEO : ~780 km)
- Initial aim: mobile phones (MOTOROLA)
- Communication between satellites
  - Rapid handoffs and Doppler shifts
  - Required only 2 ground stations
    - 1 reserved for military communications

Iridium - System overview



Constellation





Provided service

- Connection oriented
  - Data rate: 2400 bits/s
  - Voice
    - Strong vocoding (AMBE), MOS = 3,5
      - To be compared with GSM: MOS = 3,5
    - MOS = Mean Opinion Score
- New mode (packet)
  - SBD : Short Burst Data
    - Transfer of messages of up to 1900 bytes
    - Data rate: 1200 bits/s

Provided service

- Latency:
  - About 0,5 s for data (128 bytes)
  - Less than 0,38 s for voice
- Integrity
  - RER for 128 bytes: 3.10-7
- Connection delay: < 20s
- Low retrofit costs compared to others (< 50 k$)

Offers

- SITA
  - 80 % of the aeronautical SATCOM market
  - Iridium for AOC since 2008
  - Mainly Inmarsat
  - AIRCOM global offer
    - IP connectivity over Swift64/SwiftBroadband for airlines
- ARINC
  - GLOBALink offer
  - Inmarsat Classic Aero (Aero L/I/H/H+)

Obstacles

- Cost
- Market for passengers to be demonstrated
  - Example: Connexion By Boeing
    - 1 milliard US $ invested from 2000 to 2006
    - Annual cost: 150 millions US $
    - Hardly 156 equipped aircraft – 11 airlines
    - Halted mid august 2006

Conclusion

- The principles of SATCOM
- The problem of costs

Bibliography

- Annex 10 – Volume 3 – Chapter 4
- Manual for AMS(R)S
- ARINC 781 : Aviation Satellite Communication System