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A Thales / Finmeccanica Company

Aero**N**au**T**ic**A**l **RE**sources **S**atellite based

ANTARES System

5th December 2011

THALES

BS Navigation and Integrated Communications

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Introduction

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ANTARES project funded by European Space Agency within the Iris program.

Objective:

the development of a new Satellite based communication system for ATM (*)

- IRIS is dedicated ESA program to support SESAR (Single European Sky ATM Research) under the umbrella of the "Advanced Research in Telecommunication Systems" (ARTES) program, having the objective to design, develop, validate and standardize a satellite-based communication system for the provisioning of ATM safety communications, in accordance with the future ATM concept on the basis of the SESAR requirements
- SATCOM used as :
  - Redundant medium for the provision of Safety of life Air Traffic Services (ATS) and Aeronautical Operational Control (AOC) services over high density continental areas (ECAC)
  - Primary mean over remote and oceanic areas
- ANTARES will allow aviation to use Low cost SATCOM services

(*) "Air traffic management is about the procedures, technology and human resources which make sure that:

- ***aircraft are <u>guided safely</u> through the sky and on the ground and***
- ***airspace is managed to accommodate the <u>changing needs of air traffic</u> over time."***

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Phase B divided into:

- **Phase B1, to analyze requirements and provide options to SESAR.**
  Specific objectives are:
  - Consolidate Mission and System level Requirements with SESAR
  - Perform Design and Specification of the Communication Standard (CS)
  - Perform Initial Specification and Architectural Design of the Verification Test Bed (VTB)
  - Define System Architecture Options
  - Perform Initial Design of SPS and GS Elements for the above Options
  - Perform Initial Design of the UT and develop Proof of Concept
  - Perform Trade-offs among Architecture Options to define System Baseline Design
- **Phase B2 (to be kicked off) devoted to System and Segments consolidation and detailed design leading to Preliminary Design Reviews.**

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AEROCOM by satellites: State of the Art

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AEROCOM by satellites: State of the Art

Aeronautical Services via satellite

- **Main SATCOM systems used for Aeronautical Services: INMARSAT, IRIDUM, MTSAT**
  - **INMARSAT**
    - ✓ **Classic Aero services (Aero-L, Aero-I, Aero-H/H+)**
      High quality Voice, low-speed data and safety communications
    - ✓ **Swift64**
      Higher voice/data transmission rates (Packet data and ISDN at 64kbps per channel, up to 256 kbps by 5 channel bonding)
    - ✓ **SwiftBroadband**
      Simultaneous voice and broadband data (up to 432kbps per channel)
  - **IRIDIUM**
    Voice, Data, Faxing, Datalink, Flight Tracking (4.8 kbps voice and 2.4 kbps modem data)
  - **MTSAT**
    Standard Classic Aero Services (Voice and data communication services at 9600 bps)
- **Although all these systems already provide aeronautical services, only MTSAT was designed specifically for aeronautical purposes. All the other systems share some parts of their network (SPS and GS) with other applications.**

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AEROCOM by satellites: Evolution

- European Air Traffic is expected to double by 2020
- Existing communication protocols and associated satellite systems judged not suitable by EUROCONTROL and FAA (Federal Aviation Administration)
- Not designed to meet delay and availability requirements of continental airspace where the air traffic is dense
- Iridium and MTSAT communication systems do not provide sufficient bandwidth per aircraft. Iridium does not operate in a frequency band protected for aeronautical safety communications
- Cost of user terminals/communications for airlines is high

⬇

Two possible solutions under technology investigations in the frame of IRIS Program:

- New SATCOM system (ANTARES)
- Evolution of INMARSAT SBB (THAUMAS)

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ATM User Needs

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ATM User Needs (1/2)

- SESAR program highlighted the need to evolve from voice based communications toward data links between the aircraft flight management system and the ground Air Traffic Control (ATC) and Airline Operations Centre (AOC) systems.
- This has driven the requirement for a dual link solution which includes a terrestrial and a satellite-based component to guarantee the necessary availability, especially over dense traffic areas
- Performances of Air Traffic Services (ATS) and safety related Aeronautical Operational Control (AOC) communications as from FAA/EUROCONTROL COCR (Communication Operating Concept and Requirements for the Future Radio System)
- Traffic profile based on aircraft distribution scenarios from EUROCONTROL
  - PIAC (Peak Instantaneous Aircraft Counts) vs. Traffic Scenario
- Coverage: Iris focus on ECAC service area but the communication system designed is foreseen to become a worldwide standard (ICAO standardisation) for possible implementation of other compatible systems in the world.

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ATM User Needs (2/2)

ATS Data Performance Requirement

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95} – 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UT}	I_{UCT}	A_P	A_U
ACL	6.25	6.25	6.25	20.0	6.25	3.0	3.0	3.0	12.5	3.0	0.9995	1.0E-7	0.99999	0.999
ACM	6.25	6.25	6.25	20.0	6.25	3.0	3.0	3.0	12.5	3.0	0.9995	1.0E-7	0.99999	0.999
A-EXEC	-	2.0	2.0	2.0	-	-	1.65	1.65	-	-	0.9999999	1.0E-9	0.999999999	0.9999999
AIRSEP	-	-	-	-	9.75	-	-	-	-	5.0	0.9995	1.0E-7	0.99999	0.999
AIRSEP SURV	-	-	-	-	10.0	-	-	-	-	2.0	0.9995	1.0E-7	0.99999	0.999
AMC	10.0	10.0	10.0	-	30.0	8.0	8.0	8.0	-	20.0	0.995	1.0E-3	0.999	0.993
ARMAND	-	-	17.0	-	-	-	-	10.0	-	-	0.995	1.0E-3	0.999	0.99
C&P ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
C&P SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
COTRAC	-	9.75	9.75	20.0	9.75	-	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
D-ALERT	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-5	0.99999	0.999
D-ATIS	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
DCL	30.0	-	-	-	-	20.0	-	-	-	-	0.9995	1.0E-7	0.99999	0.999
D-FLUP	9.75	9.75	17.0	30.0	30.0	5.0	5.0	10.0	20.0	20.0	0.995	1.0E-3	0.999	0.99
DLL	6.25	9.75	17.0	30.0	30.0	3.0	5.0	10.0	20.0	20.0	0.9995	1.0E-7	0.99999	0.999
D-ORIS	-	9.75	9.75	30.0	30.0	-	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-OTIS	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-RVR	6.25	6.25	9.75	30.0	30.0	3.0	3.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
DSC	-	-	30.0	20.0	30.0	-	-	20.0	50.0	20.0	0.9995	1.0E-7	0.99999	0.999
D-SIG	17.0	17.0	-	-	-	10.0	10.0	-	-	-	0.995	1.0E-7	0.999	0.99
D-SIGMET	9.75	9.75	9.75	30.0	30.0	5.0	5.0	5.0	20.0	20.0	0.995	1.0E-7	0.999	0.99
D-TAXI	9.75	9.75	-	-	-	5.0	5.0	-	-	-	0.9995	1.0E-7	0.99999	0.999
DYNAV	-	-	17.0	30.0	-	-	-	10.0	20.0	-	0.995	1.0E-3	0.999	0.99
FLIPCY	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
FLIPINT	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-7	0.99999	0.999
ITP ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
ITP SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
M&S ACL	-	9.75	9.75	20.0	-	-	5.0	5.0	12.5	-	0.9995	1.0E-7	0.99999	0.999
M&S SURV	-	6.0	6.0	6.0	-	-	2.0	2.0	2.0	-	0.9995	1.0E-7	0.999	0.999
PAIRAPP ACL	-	9.75	-	-	-	-	5.0	5.0	-	-	0.9995	1.0E-7	0.99999	0.999
PAIRAPP SURV	4.0	4.0	-	-	-	1.2	1.2	-	-	-	0.99995	1.0E-7	0.999	0.999
PPD	17.0	17.0	17.0	30.0	30.0	10.0	10.0	10.0	20.0	10.0	0.995	1.0E-3	0.999	0.99
SAP	-	9.75	9.75	-	-	-	5.0	5.0	-	-	0.9995	1.0E-7	0.99999	0.999
SURV (ATC)	4.0	10.0	10.0	10.0	10.0	1.2	2.0	2.0	2.0	2.0	0.99995	1.0E-7	0.999995	0.9999
TIS-B	-	-	-	-	-	-	-	-	-	-	-	-	-	-
URCO	9.75	9.75	9.75	20.0	9.75	5.0	5.0	5.0	12.5	5.0	0.9995	1.0E-5	0.99999	0.999
WAKE	4.0	10.0	10.0	-	-	1.2	2.0	2.0	-	-	0.9995	1.0E-7	0.999	0.999

ATM user needs in terms of expiration time, latency, integrity, continuity and availability performances, are the system design drivers.

AOC Data Performance Requirement

Service	Expiration Time RCTP (ET – 1 way)					Latency RCTP (TT_{95} – 1 way)					Continuity RCTP (per inst)	Integrity RCTP (per inst)	Availability RCTP (pFH)	
	APT	TMA	ENR	ORP	AOA	APT	TMA	ENR	ORP	AOA	C_{UT}	I_{UCT}	A_P	A_U
AOCDLL						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
CABINLOG						60.0	-	-	-	-		1.0E-3	0.999	0.99
ENGINE						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
FLTLOG						60.0	-	-	-	-		1.0E-3	0.999	0.99
FLTPLAN						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
FLTSTAT						30.0	30.0	30.0	60.0	60.0		1.0E-3	0.999	0.99
FREETXT						60.0	60.0	60.0	120.0	120.0		1.0E-3	0.999	0.99
FUEL						60.0	60.0	60.0	120.0	120.0		1.0E-3	0.999	0.99
GATES						30.0	30.0	30.0	60.0	60.0		1.0E-3	0.999	0.99
LOADSHT						30.0	30.0	-	-	-		1.0E-7	0.999	0.99
MAINTPR	Not Available					30.0	30.0	30.0	60.0	60.0	Not Available	1.0E-4	0.999	0.99
MAINTRT						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
NOTAM						60.0	60.0	60.0	120.0	120.0		1.0E-7	0.999	0.99
OOOI						30.0	-	-	-	-		1.0E-3	0.999	0.99
POSRPT						60.0	60.0	60.0	120.0	120.0		1.0E-4	0.999	0.99
SWLOAD						60.0	60.0	60.0	120.0	120.0		1.0E-9	0.999	0.99
TECHLOG						60.0	-	-	-	-		1.0E-4	0.999	0.99
UPLIB						60.0	60.0	60.0	120.0	120.0		1.0E-7	0.999	0.99
WXGRAPH						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
WXRT						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99
WXTEXT						30.0	30.0	30.0	60.0	60.0		1.0E-7	0.999	0.99

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ANTARES System Architecture

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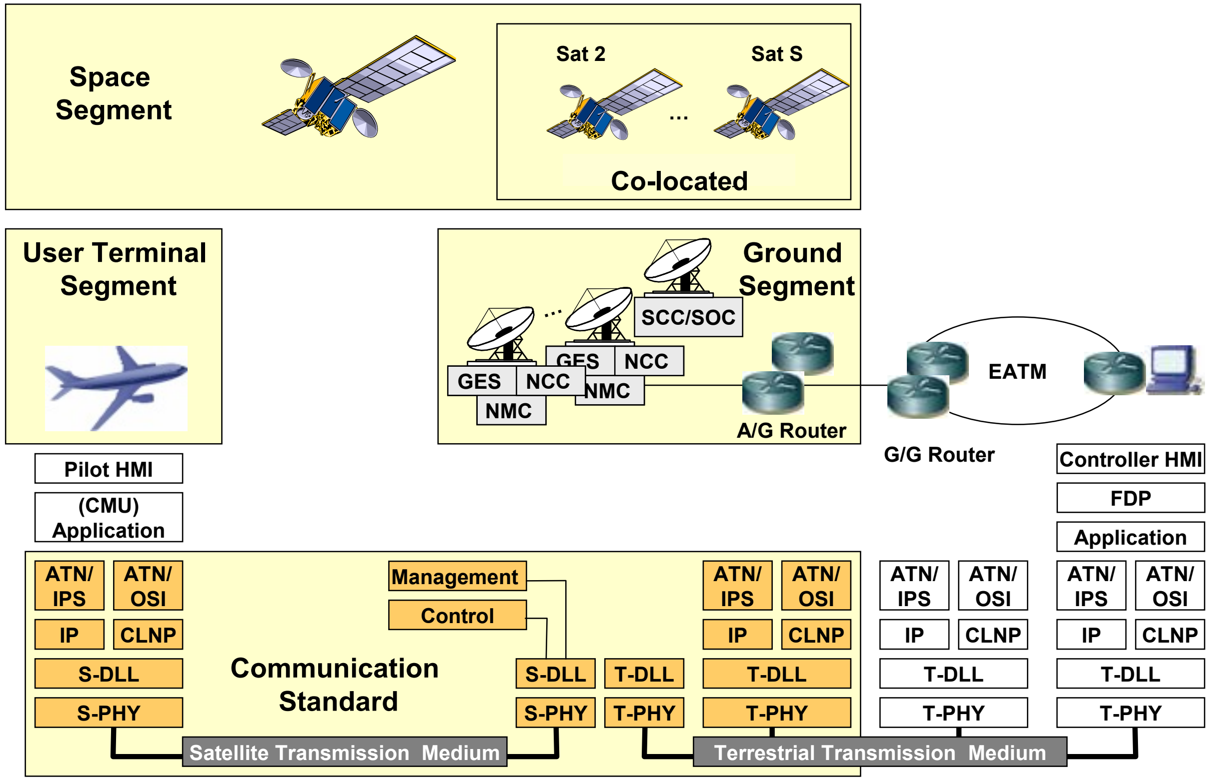
General ANTARES System Architecture

System architecture:

- **Physical elements**
  - Space segment
  - Ground segment
  - User terminal
- **Communication standard**
  - Comms functionality
  - Comms between system elements

with a given level of performance



"General" because includes several architecture options

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Main System Requirements driving the definition of the system

SYSTEM ARCHITECTURE & DESIGN

- Allowing incremental deployment of its elements or sub-elements
- Allowing to met service requirements during aircraft manoeuvring
- Providing linking and handover with other ATM regional services
  - Using the same Communication Standard and compatible user terminals
- Allowing static, semi-static and dynamic capacity and resources allocation between ground earth stations (GESs)
  - To cover traffic pattern changes during lifetime, daily and in case of system failures

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System Design Drivers (2/2)

Other important design drivers considered:

- **Communication Standard trade offs results and performances**
  - Return link modulation and coding
  - Multiple access
  - Driving overall system performance including link budget
  - System dimensioning (all system elements)
- **Aeronautical channel**
  - Physical layer performances and link budgets
- **(Low cost) user terminal performance and constraints (including antenna)**
  - Space segment dimensioning
  - System service area
- **Coverage**
  - Space and ground segments dimensioning
- **Availability requirements**
  - Redundancy for all system elements
- **Validation approach**
  - Overall system architecture and deployment evolution
- **Costs**
  - System dimensioning (all elements)

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Requirement Options

Uncertainty in key requirements for the following areas:

- Security (information security and transmission security)
- Number and type of applications/services
- Number of equipped aircraft as function of time
- Service provider configuration and associated G/S architecture
- User terminal performance - HPA power & antenna gain - linked to installation on board and selected technology

Requirement Option Name		Requirement Option Definition
RO1	**Information and Communication Security**	**Information and communications security capabilities** that are applied within the ANTARES system boundaries in order to mitigate the threats on informatics system and on communication devices or other electronic systems
RO2	**Transmission Security**	**Transmission security capabilities** that are applied within the ANTARES system boundaries, in order to mitigate the threats deriving from RF interference sources
RO3	**System Capacity**	**Information volume (Mbps)** entering the ANTARES System at network layer
RO4	**End User Terminal Capability**	Radiofrequency **transmission performance** (EIRP) of the end user terminal on-board the SATCOM equipped aircrafts
RO5	**Ground Segment Architecture**	**Topology** of the ground segment architecture

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System Architecture Options (1/2)

- **System Architecture Options (SAO) are originated from the combination the Requirement Option values**

  Wide set of theoretical SAOs

- **A highly representative subset of SAOs has been selected**
  - ✓ *Useful to highlight the impact of requirements variability*
  - ✓ *Appropriate for system dimensioning and specifications*

Five System Architecture Options (SAO) have been
- ✓ *Analysed*
- ✓ *Dimensioned*
- ✓ *Specified*
- ✓ *Assessed on the basis of suitably selected Figure of Merit*

A SAO "catalogue" is offered by the ANTARES project
- *Five solutions (Five complete sets of system and segment specifications)*
- *Assessment of each solution*
- *A communication standard suitable for all the solutions*
- *The most suitable solution to be selected by operators and aeronautical organizations*

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System Architecture Options (2/2)

- **System Architecture Option 1**
  1. Supporting a low capacity traffic
  2. Presenting high resistance to the interference
  3. Not implementing any specific information/communication security mechanisms
  4. Having a decentralised ground segment architecture
- **System Architecture Option 2**
  1. Supporting a medium capacity traffic
  2. Presenting high resistance to the interference
  3. Not implementing any specific information/communication security mechanism
  4. Having a decentralised ground segment architecture
- **System Architecture Option 3**
  1. As SAO 2, but with a centralised ground segment architecture
- **System Architecture Option 4**
  1. Supporting a medium capacity traffic
  2. Presenting high resistance to the interference
  3. Implementing specific information/communication security mechanisms
  4. Having a decentralised ground segment architecture
- **System Architecture Option 5**
  1. Supporting a very high capacity traffic
  2. Presenting high resistance to the interference
  3. Not implementing any specific information/communication security mechanisms
  4. Having a decentralised ground segment architecture.

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Communication Standard

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Communication Standard

- **One of the main objectives of the ANTARES project is the development and the validation of a new satellite-based Communication Standard for Air-Ground safety communications, valid worldwide and able to cope with future Air Traffic Control (ATC) and Airline Operational Control (AOC) communication needs.**

- **Communication Standard main features:**
  - ✓ meets the service requirements and traffic profiles from COCR
  - ✓ efficient use of limited L-band spectrum resources (spectrum reserved for AMS(R)S services)
  - ✓ meets the UT and aircraft constraints.
  - ✓ compatible with multiple satellite orbits (GEO, HEO and MEO) using the same user terminal
  - ✓ designed to cope with Aeronautical (mobile) environment
  - ✓ compatible with centralized and distributed GS architecture, allowing an incremental deployment
  - ✓ not relying on external navigation systems.
  - ✓ designed to be able to transport ATN/OSI or ATN/IPS flows, facilitating initial deployment.
  - ✓ optimized to support networks with large population of terminals and short message transmissions.

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FWD Link – Access Scheme and ModCod

- **FWD Link Multiple Access Scheme: MF-TDMA**
  - FWD link carriers (time-slots) are shared between GS elements
  - Forward link synchronization mechanism to assure timing alignment

- **FWD Link Physical layer**
  - Robust and flexible coding (IRA LDPC) and modulation schemes (MPSK)
  - Support of ACM to adapt the coding and modulation scheme to the channel propagation conditions maximizing the spectral efficiency
  - Channel interleaver to break the multipath fading correlation

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RTN Link – Access Scheme and ModCod

- **RTN Link Multiple Access** – two access schemes considered for trade off:
  - **MF-TDMA**
    - Random Access (RA) based on CRDSA (Contention Resolution Diversity Slotted ALOHA)
      - Enhanced slotted ALOHA scheme based on Interference Cancellation technique.
      - Robust coding (1/3) based on Turbo codes
    - DAMA
      - Several codings (Turbo codes) and O-QPSK modulation
      - Support of AC/DRA to adapt the coding and carrier rate to the channel propagation conditions and maximizing the spectral efficiency.
  - **A-CDMA**
    - Enhanced Spread Spectrum ALOHA based on Interference Cancellation Technique.
    - Control channel for synchronization.
    - Several Spreading Factors and burst lengths to adapt to the different services message lengths.
    - Robust coding (1/3) based on Turbo codes

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System Definition

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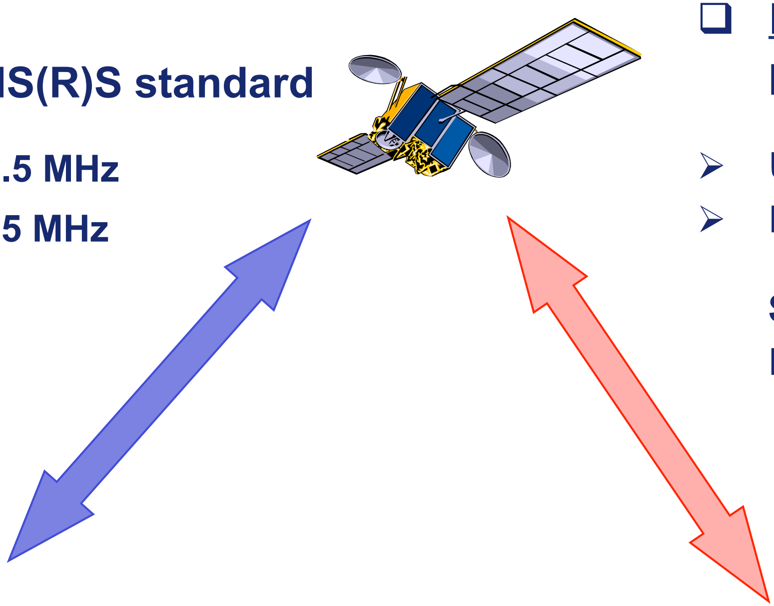
Frequency Bands

- **User link**
  L band as from AMS(R)S standard

- **Uplink: 1646.5 ÷ 1656.5 MHz**
- **Downlink: 1545 ÷ 1555 MHz**



- **Feeder link**
  Ku band as from FSS standard

- **Uplink: 14230 ÷ 14250 MHZ**
- **Downlink: 12730 ÷ 12750 MHz**

Selected on the basis of the analysis performed

- *Traded off wrt C, Ka, X bands*
- *Potentially being traded-off also with possible additional requirements issued in the future by Operators*

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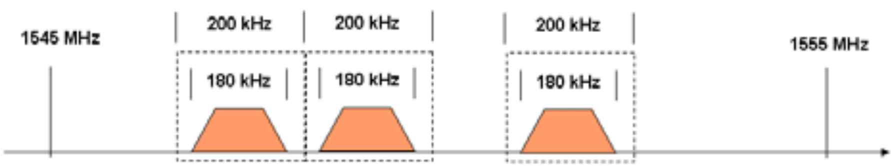
Bandwidth Constraints

- The overall L band available spectrum for user link is 10 MHz for both the uplink and the downlink

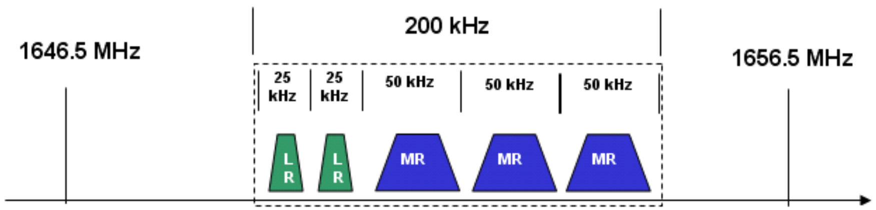
- L band spectrum allocated with maximum chunks of 200 kHz both uplink and downlink

FWD LINK



- **Single carrier per chunk on the downlink**
  Carrier bandwidth of 180 kHz (150 ksps symbol rate)
  Guard bands of 20 kHz

RTN LINK



- **Multiple carriers per chunk on the uplink**
  Three types of carriers are defined: Low Rate (LR), Medium Rate (MR) and High Rate (HR) Carriers

Carrier Type	Carrier BW (kHz)	Symbol, Rate (ksps)	Overall BW (kHz)
LR	19.2	16	25
MR	38.4	32	50
HR	57.6	48	75

Alternative frequency plan under analysis with increased guard bands to reduce adjacent channel interference and out of band emission

Carrier Type	Carrier BW (kHz)	Symbol, Rate (ksps)	Overall BW (kHz)
LR	19.2	16	33
MR	38.4	32	66
HR	57.6	48	99

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ANTARES Service Areas

The ANTARES service areas are:

- **ECAC area**

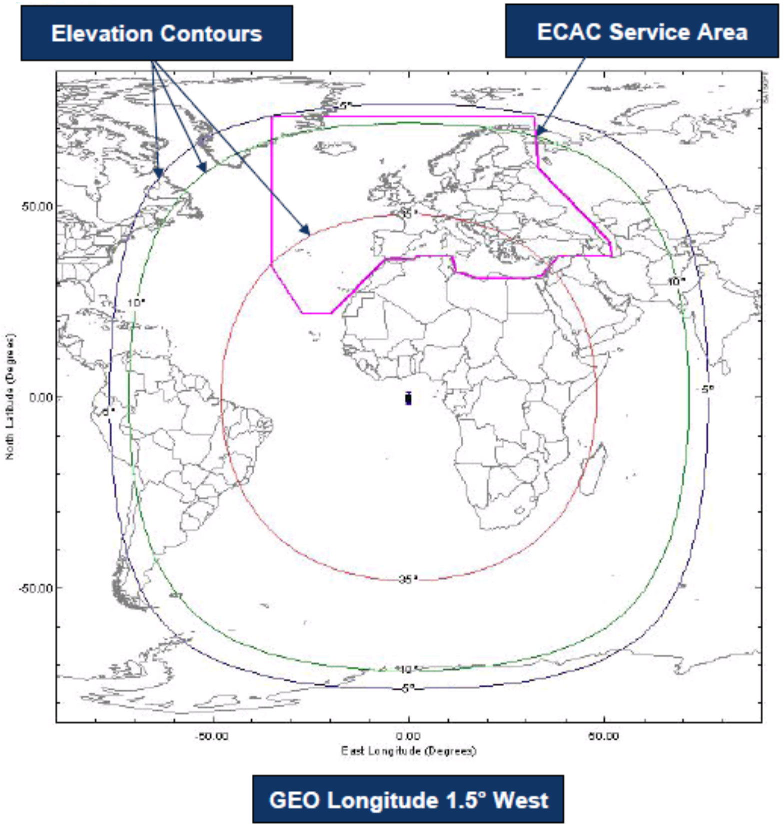
  Supported services

  - Air Traffic Services (ATS)
  - Airline Operational Control (AOC) services providing data communications services
  - Voice communications services (for emergency conditions)

- **Visual Earth area**

  Supported services

  - ADS-C service (Surveillance)



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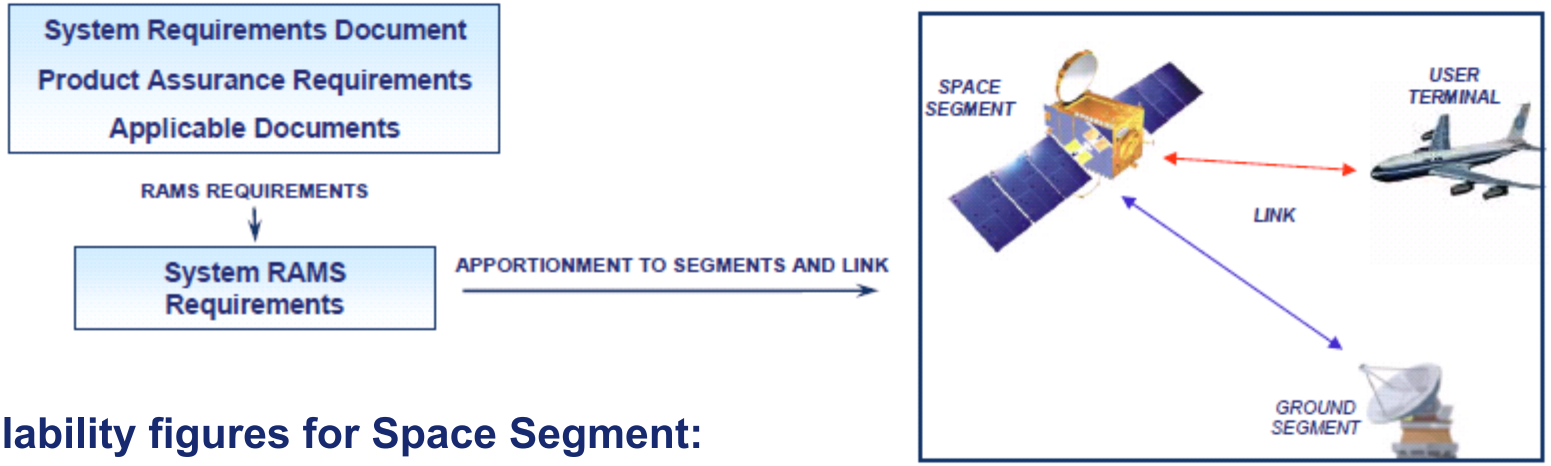
System Availability and Space Segment Availability



ANTARES System and Segments

- **TARGET availability figures for Space Segment:**
  - Availability of use of 99.80%
  - Availability of provision of 99.96%

- **SPS availability apportioned to:**
  - Satellite/platform (0.8)
  - ATM payload (0.95)

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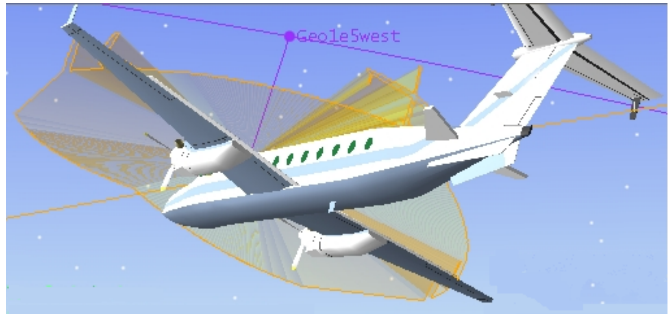
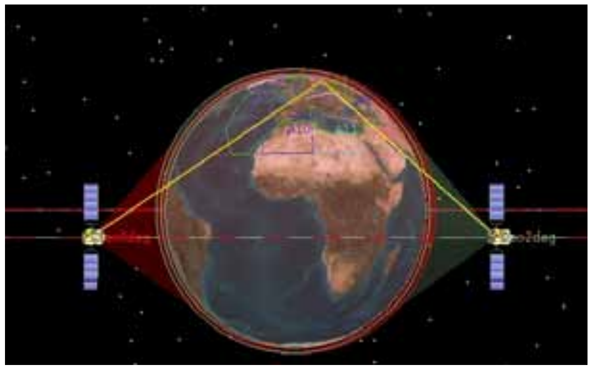
Aircraft Visibility Analyses

The aircraft visibility analyses aim at

- **Evaluating the geometrical availability of the link between aircraft and satellite**
  - Contribution to the overall system availability which may be offered to the aviation end-users
- **Identifying solution to increase satellite link geometrical availability**
  - System dimensioning to cope with real flight conditions
  - Number of antenna on the aircraft and location
  - Number of satellite simultaneously operating





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Multidimensional Link Budget (1/2)

- Link Analysis with multidimensional link budgets taking into account of:
  - **Different frequency reuse configurations**
  - **Dark sky vs. clear sky conditions**
    - Dark sky condition is evaluated for an availability of
      - ✓ 99.99% on the forward link
      - ✓ 99.95% on the return link
  - **Different UT antenna configurations**
    - Single antenna
    - Dual antenna
      - ✓ 45° offset
      - ✓ 20° offset
  - **Different carriers rate types and modulation/coding schemes**
    - Return Link
      - ✓ 16, 32, 48 ksps with O-QPSK and FEC (TCC) 1/4, 1/2, 1/3 and 2/3
    - Forward link
      - ✓ 150 ksps using QPSK, 8PSK and 16 APSK and FEC (LDPC) 1/4, 1/2, 1/3 and 2/3

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Multidimensional Link Budget (2/2)

Remarkable number of cases under analysis

- **4 cases of manoeuvres conditions (related to the banking angle)**
  - 0 degree (no banking)
  - 5 degree (low banking)
  - 15 degree (mid banking)
  - 30 degree (high banking)
- **GES pointing strategy and relevant de-pointing losses**
  - GES pointing to the centre of the SKBox where the satellite(s) is(are) (co-) located
  - GES specifically pointing each satellite
- **Different GES positions**
  - Fucino
  - Darmstadt
  - Tromsoe
- **Different aircraft categories**
  - Fixed-wings aircraft
    - Large aircraft represented by A380
    - Small aircraft represented by Dassault Falcon 100
  - Rotary-wings aircraft

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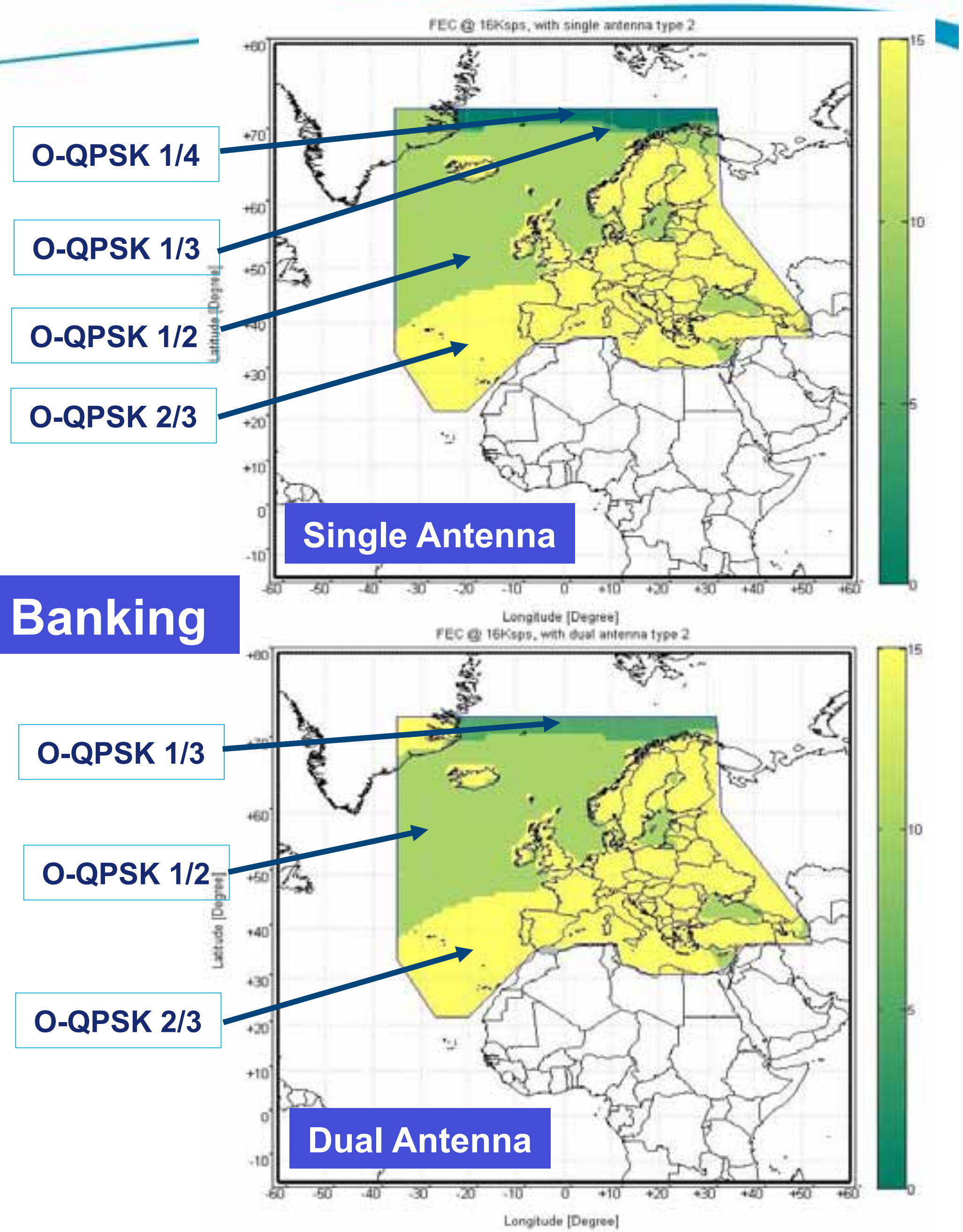
Example of Link Budget Results (1/2)

❑ Example of link budget results for

- ECAC service area
- Aircraft type: Airbus A380
- Single and dual (45° offset) antenna configuration
- Return link
- Two aircraft manoeuvring cases
  - No banking condition
  - Mid banking condition (15°)
  - High banking condition (30°)
- No frequency re-use
- GES in Fucino
- Dark sky
- Carrier rate: 16ksps

Legend	Modcod	Achievable Data rate (kbps)
0	O-QPSK 1/4	8.0
5	O-QPSK 1/3	10.6
10	O-QPSK 1/2	16.0
15	O-QPSK 2/3	21.3

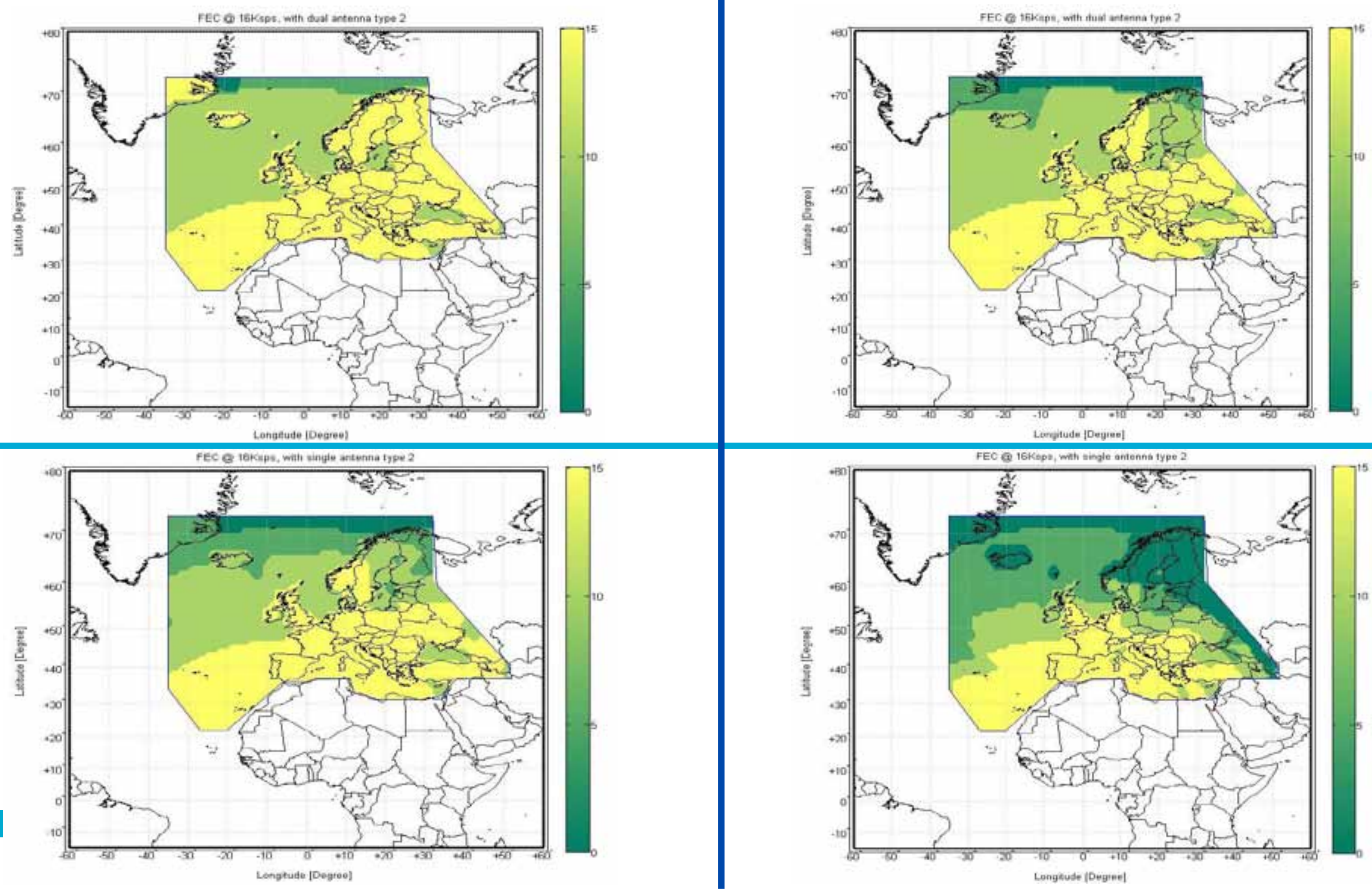
No Banking



Example of Link Budget Results (2/2)

Mid Banking (15°) | **High Banking (30°)**

Dual Antenna | **Single Antenna**



Ground Segments

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Main Ground Segment Requirements

- **Two main alternative configurations are envisaged for the ground segment**
  - Centralized: single Satellite Service Provider (SSP) scenario
  - Distributed: multiple SSP scenario
- **SSP carrier sharing and no carrier sharing policies are considered for distributed scenario**
- **RF requirements**
  - EIRP density 40 dBW/KHz
  - Antenna size 6 m
  - G/T 32.8 dB/K (clear sky)
- **Ground segment architecture shall be robust to the following events:**
  - Failure events
    - ✓ GES failure
    - ✓ NCC failure
    - ✓ Satellite failure
  - Fault free events
    - ✓ GES unavailability due to rain event (tropospheric event)
    - ✓ NCC unavailability due to rain event (tropospheric event)
    - ✓ GES unavailability due to sun outage event
    - ✓ NCC unavailability due to sun outage event

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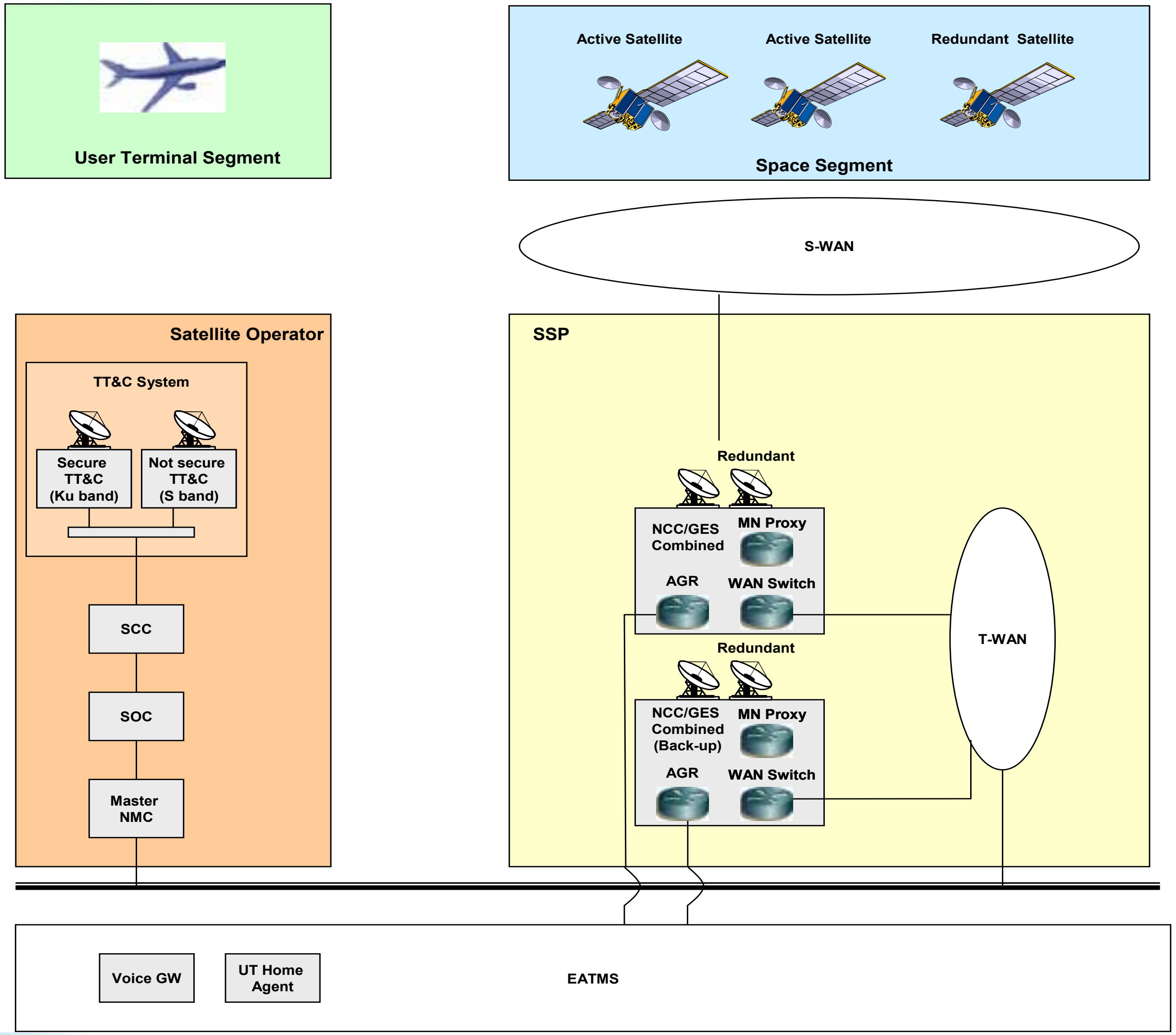
Ground Segment: Centralised Architecture



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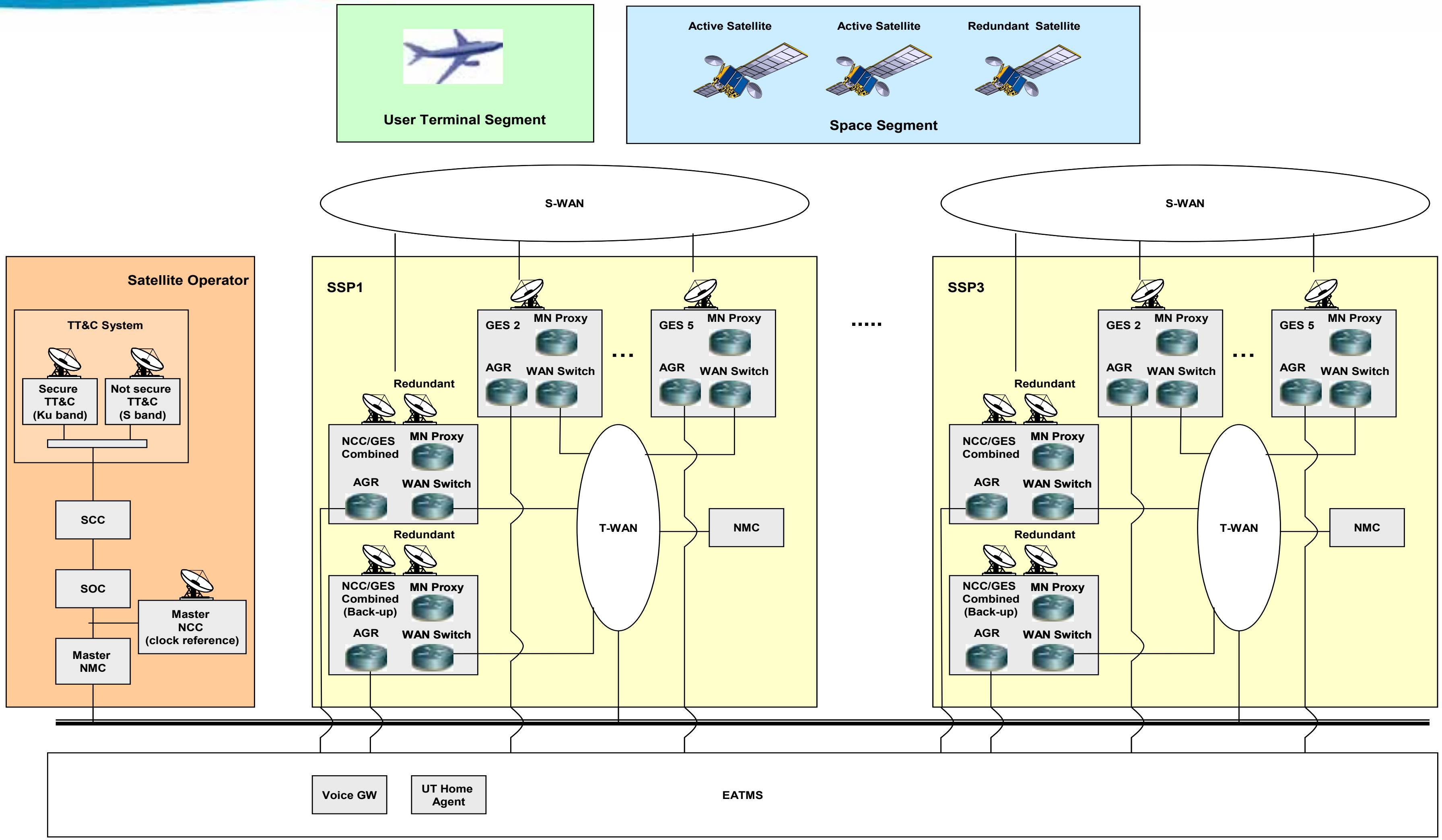
Ground Segment: Decentralised Architecture



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Space Segment

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System Design Options & SPS Design Options

- Three SPS design options have been studied each of them relevant to different traffic profiles (*):
  - ✓ **Low traffic profile**
    - Total L-Band Bandwidth in Forward is 762 KHz
    - Total L-Band Bandwidth in Return is 800 KHz
  - ✓ **Medium Traffic Profile**
    - Total L-Band Bandwidth in Forward is 2200 KHz
    - Total L-Band Bandwidth in Return is 925 KHz
  - ✓ **High traffic profile**
    - Total L-Band Bandwidth in Forward is 4800 KHz
    - Total L-Band Bandwidth in Return is 1850 KHz
- Additional SPS design option for medium traffic profile has been studied with SCPA (Single Carrier Per Amplifier) payload
- Option to add surveillance service over the visible Earth has been studied on top of all options above (Single Global Beam)
- The SPS supports single carrier per chunk in the FWD link and multicarrier per chunk in the RTN link (see pg. 36)

(*) from Phase B1 currently under revision

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User Link Coverage: ECAC Area

User link at L Band:

Mobile Forward Link frequency band [1545 MHz ÷ 1555 MHz]
Mobile Return Link frequency band [1646.5 MHz ÷ 1656.5 MHz]

EIRP and G/T at L band

FWD single carrier/EIRP: 48.3 dBW
RTN G/T requirement: 2.5 dB/°K

Feeder link at Ku Band

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Payload Design Options

Option	Low traffic profile	Medium traffic profile	High traffic profile
Option 1	**Architecture:** • SCPC with HPAs drive in saturation • High Power OMUX • 5 spot beams in SFPB configuration **Antenna Farm:** • Two L band Tx/Rx antennas D=3.7 m rigid reflector possibility of foldable tips • 1 Ku band Tx/Rx antenna **Remark:** **requires predefined frequency plan**	**Architecture** **TARGET BASELINE** • Multiport amplifier (MPA) • 16 feed array cluster or 12 feed array • 5 spot beams **Antenna Farm** • 1 Tx + 1 Rx L band antennas D=3,7*2.5 m rigid trimmed reflector • 1 Ku band Tx/Rx antenna **Flexibility on traffic management and frequency plan**	***Load sharing approach:*** • *Same payload as per Medium traffic profile* • *Design to 50% Approach in order to accomplish High traffic profile*
Option 2		**Architecture** • **SCPC with HPAs drive in saturation** • **High Power OMUX** • **5 spot beams in SFPB configuration** **Antenna Farm** • **Two Tx/Rx antennas D=3,7 m rigid reflector** • **possibility of foldable tips** • **1 Ku band Tx/Rx antenna** **Remark:** **requires constraints & predefined freq. plan**	

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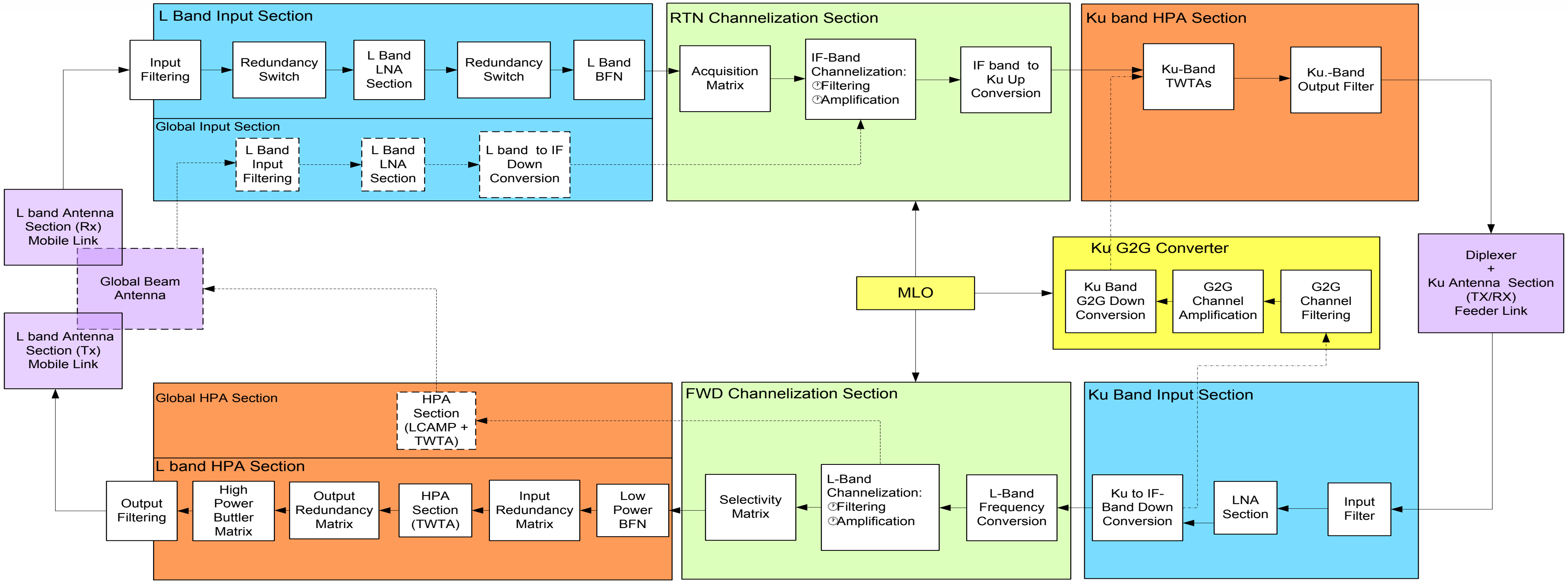
Baseline Payload Architecture



FWD and RTN ATM Payload composed of:

- Two large L band Semi-active Antennas Multi-Spot beam elliptical trimmed reflector (1 RX And 1 TX)
- 1 Ku band Single beam antenna (TX and RX)
- 1 On board transparent digital processor for the FWD and RTN channelization section
- Multi-port amplifier at L Band with parallelized TWTAs
- L band LNA assy and receiving Beam Forming Network
- Ku band Receiver

Additional Global and G2G repeaters (depending on option)

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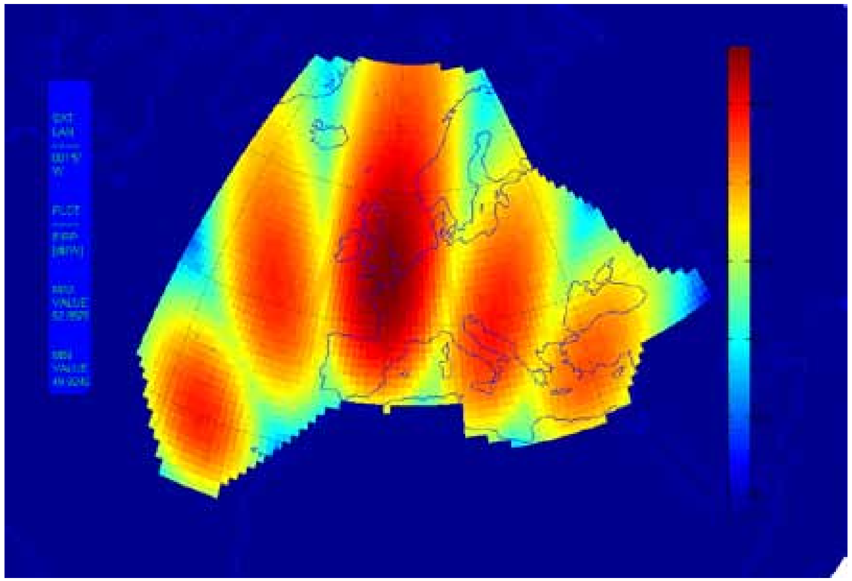
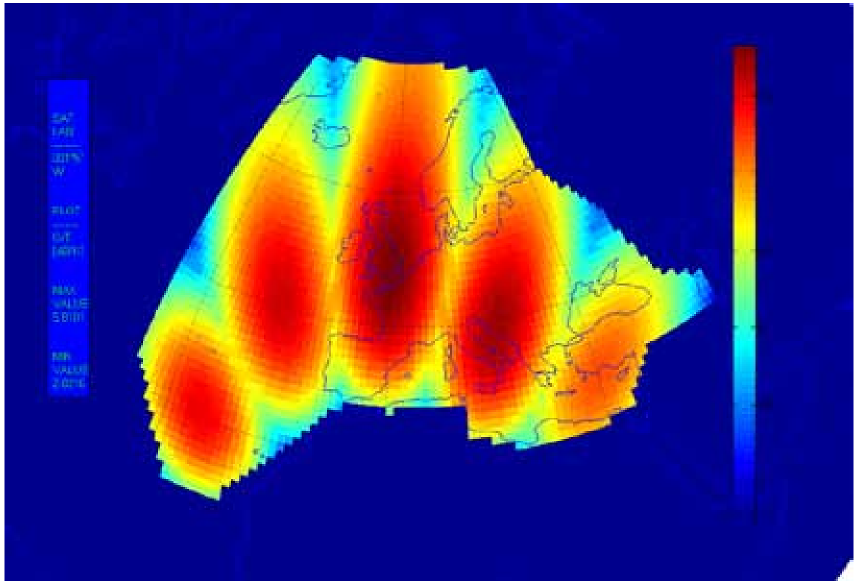
Main Payload Performance

- ✓ **Single carrier EIRP Performance over ECAC Area**
  - **49.9 dBW minimum**
  - **52.85 dBW Maximum**
- ✓ **Single carrier G/T Performance over ECAC Area**
  - **2.82 dB/K minimum**
  - **5.81 dB/K Maximum**





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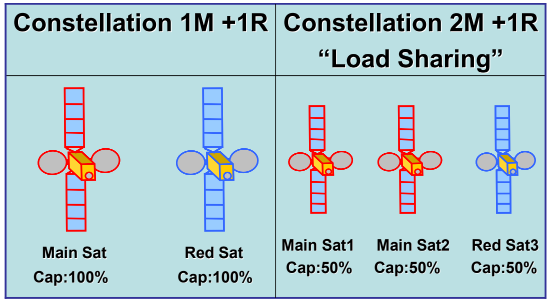
Selected Satellite Geostationary constellations for SAOs

Two design option alternatives have been considered

- No load sharing
  - Each satellite is designed to carry 100% of the total system capacity
  - Space segment configuration for availability requirements
    - 2 in orbit cold redundant satellites
    - 1 on ground spare satellite
- Load sharing 50%



SAO	Space Segment Option	Number of Satellites Composing the Space Segment Constellation	Commercial Platform	Coverage Areas
SAO 1	SPS-A	3 satellites: (1 main in-orbit + 1 in-orbit cold redundant + 1 on-ground spare)	SmallGEO Luxor (OHB) Or SpaceBus Class B (Thales Alenia Space)	Repeater for ATM service over ECAC + visual Earth area
SAO 2/3/4	SPS-B	3 satellites: (1 main in-orbit + 1 in-orbit cold redundant + 1 on-ground spare)	SpaceBus Class C (Thales Alenia Space)	Repeater for ATM service over ECAC + visual Earth area
SAO 5	SPS-C	4 satellites: (2 main in-orbit + 1 in-orbit cold redundant + 1 on-ground spare)	SpaceBus Class C (Thale Alenia Space)	Repeater for ATM service over ECAC + visual Earth area

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User Terminal Segment

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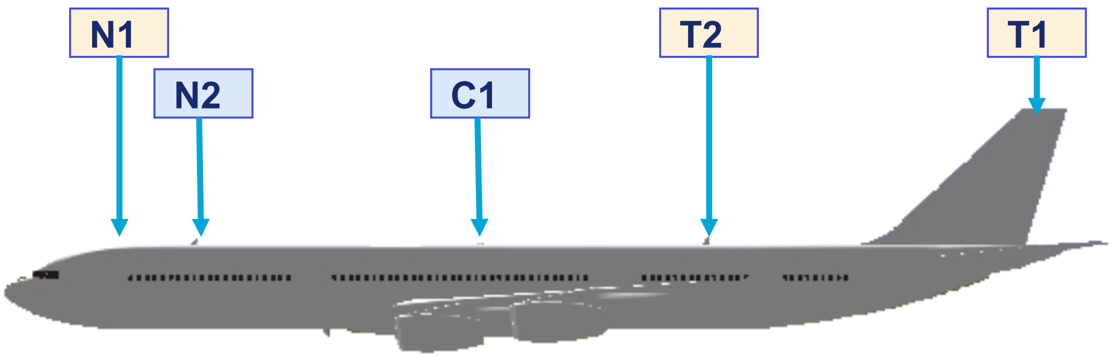
Main User Terminal Requirements (1/2)

- **Low cost, low gain and low drag antenna**
- **Low mass/volume, no forced air-cooling on-board avionics**
- **UT architecture design based on ARINC 741, 761, 781 recommendations**
- **Different configuration options for the UT design are envisaged to take into account aircraft installation constrains and operational conditions**
  - Radiofrequency and baseband redundancy
  - Single antenna mounted on the top of the fuselage
  - Dual antenna mounted 20° offset w.r.t. zenith above airframe
    - A 45° offset configuration has been investigated as well
  - Two positions identified: N2 and C1 in the picture
    - N1, T1 and T2 position have been investigated as well



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Main User Terminal Requirements (2/2)

- **Maximum two carriers to be supported on the forward link**
  - Target requirement

- **High Power Amplifier (HPA) power**
  - ~30 W at the HPA output
  - Resulting from the thermal analysis assuming
    - Passive cooling
    - 100% duty cycle
  - Taking into account HPA input-output performance and relevant operating point
  - Taking into account tolerances, uncertainties and margins

- **The final configuration trade-off will based on the outcomes of**
  - Link design
  - Visibility analysis

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ANTARES conclusions

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Iris/ANTARES: Major Benefits

- **ATM - Dedicated Satellite Communication System**

  Purposely designed for the services safety of life communication (ATS/AOC) with a high reliability and availability performances and therefore conforming with the imposed requirements as reflected and captured in applicable specification requirements, namely:

  - SRD Requirements
  - COCR Performance Requirements

- **Safety of life Applications Rigorously Provisioned by:**

  - Extensive and Comprehensive RAMS Analyses and Concerned Requirements both at System and Segments levels
  - Requested Services Availability Through a Dedicated and On – Purpose S/L Constellation
  - Satisfactory Design Level Allocation (for S/W and H/W)
  - Communication Standard Design to Meet Availability and Integrity Requirements

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Iris/ANTARES: Major Benefits

- **Low Cost User Terminal**

  A satellite based system designed to minimise the complexity and cost of the airborne terminal (AERO L type) suitable for most aircraft categories

- **Open Communication Standard**

  Communication Standard fully devoted to the avionics needs:

  - Designed to achieve the performances required for the Single European Sky new services, in continental and oceanic airspace, minimizing the spectrum usage
  - Specification made available to any interested party worldwide
  - Suitability with all types of aircrafts including rotary-wing
  - Very large networks with high number of aircrafts
  - Interoperability with different S/L Network, e.g. HEO-MEO

- **Optimized Throughput by Efficient Use of Communication Resources**
  - Resources Dynamic Assignment
  - Use of Adaptive Waveforms

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Iris/ANTARES: Major Benefits

- Use of both Centralized and De-Centralized GS Architectures to be selected depending on Service Providers needs.
- Allow a fully committed ATM Mission (Primary Mission) by avoiding possible priority conflicts wrt other missions sharing same S/L resources.
- ATM Traffic Variation Properly Fitted Accommodating:
  - Varying Traffic Distribution Over Service Area
  - Overall Traffic Growth
  - Satellite Constellation deployment based on incremental traffic needs reducing commercial risks
- Flexible Allocation and Reconfiguration of Frequency Plan
- Payload Multi-Port Architecture and IF Digital Processing allowing:
  - Power – to – beams allocation flexibility
  - Frequency plan flexibility to cope with variation of traffic demand
- Overall System dimensioned for Low Cost Avionics by appropriately optimizing System, Space Segment, Ground Segment, UT and Communication Standard features.

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Thank You!

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