Agenda Item 5: New material and Work Programme

SATCOM Communications:
Developments in Europe, NEXUS output and Way ahead in ICAO

(Prepared and presented by EUROCONTROL)

SUMMARY
This paper presents an update of the SATCOM developments particularly in the European context. It contains the outcome of the work undertaken in the NEXUS group to develop a proposal for ICAO to update of the current AMS(R)S SARPs to include performance based requirements that will be appropriate for the future applications and services. In addition the paper discussed the way ahead in ICAO for the SATCOM aspects and recommends the establishment under CP of a group to progress specifically the SATCOM aspects in ICAO.

ACTION
The Communications Panel (CP) is invited to 1) note the information presented in this paper, 2) discuss and agree the activities needed to be undertaken by ICAO and the CP in particular and 3) establish a working group to progress the SATCOM aspects, considering the outcome of the NEXUS group as provided in Appendices A and B.
1. **INTRODUCTION – PAST DEVELOPMENTS**

1.1 SATCOM communications is a key component of the current as well as the Future Aeronautical Communications Infrastructure (FCI). SATCOM, together with the terrestrial systems, is a critical enabler of the future concepts developed in the context of the SESAR, NextGEN and CARATS ATM modernisation programmes.

1.2 ACP WGW/2 meeting in 2008, discussed the FCI aspects and in particular for the satellite communications developed the following recommendation:

   **R3:** Recognising that satellite communications remain the prime candidate to support oceanic and remote environments and that the considered future satellite systems may also be able to support continental environments possibly complementing terrestrial systems, monitor and support developments that will lead to globally available ATS satellite communications.

1.3 In line with the ICAO/ACP and the FAA-EUROCONTROL Action Plan 17 recommendations for the future satellite communications, the EUROCONTROL NexSAT Group (http://www.eurocontrol.int/nexsat) addressed the need to update the existing AMS(R)S SARPS to include stringent performance requirements to support the emerging future operating concepts.

1.4 In Europe, satellite communications are considered as a complement to terrestrial systems in order to meet in the long term the future service provision performance requirements as well as in the short term to complement the VDL2 on-going implementation. In the context of SESAR the multilink concept is being analysed and developed and this concept considers both terrestrial and satellite communication systems as parts of the FCI.

1.5 The latency (delay) in particular requirements of the current AMS(R)S SARPs are rather relaxed (20 to 30 secs) and therefore the existing ICAO standardised SATCOM systems are not expected to meet the required performances of the future ATM services. However as the life time of the satellite based communication systems is limited by the lifetime of the host satellites, new satellite communication systems are expected to become available (also for aviation) with better performance. Therefore the NEXSAT group recommended the update of current SATCOM SARPS with more stringent performance requirement as well as to reflect the AMS(R)S SARPs evolution in new communication standards meeting the updated SARPS performance requirements.

1.6 It is noted that such an update would facilitate the usage of the satellite-based communications and enable the SATCOM systems to play an important role not only in the oceanic and polar environment but also in the continental environment in the future in conjunction with the terrestrial based systems.

1.7 Furthermore, the availability of a single global aviation standard for future aeronautical communications would facilitate the adoption and implementation of such a standard and discourage technology proliferation in general. In particular for the satellite communications, it is expected that the availability of such an open and global standard and its implementation in the future by different satellite service providers will facilitate interoperability and help boost avionics equipage (single SATCOM avionics equipment) and at the same time allow for multiple (regional and global) satellite communications service providers.

1.8 Considering also that in general ICAO aims to initiate standardisation activities when sufficient maturity and consensus has been achieved, NexSAT, in order to facilitate the AMS(R)S standardisation update, decided to create an ad-hoc subgroup of experts to support the preparation of a proposal to ICAO.

1.9 The subgroup established by NexSAT is referred to as the NEXUS group. NEXUS has been an open group, operating on the basis of expert voluntary contributions with the objective to deliver recommendations to ICAO and other interested parties (i.e. SESAR, ESA/IRIS, etc.).
The NEXUS activities have been facilitated by EUROCONTROL and there has been active participation and contributions from a number of interested parties including AENA (now ENAIRE), AVINOR, EADS Astrium (now Airbus Defence and Space), ESA, Frequentis, INDRA, Inmarsat, Rockwell Collins, Telespazio, Thales Alenia Space and others. The NEXUS work has to some extent been also followed by other regions and FAA, JCAB and ENRI in particular have been in the NEXUS distribution list.

2. **NEXUS ACTIVITIES**

2.1 NEXUS agreed the following stepped approach for the updates of the ICAO SATCOM material.

2.1.1 Step 1 – Development of a consolidated proposal to ICAO for an update of the existing AMS(R)S SARPs with stringent performance requirements required to support the future ATM concept in the 2020+ timeframe.

2.1.2 Step 2 - Provide a recommendation to ICAO for a candidate system supporting the updated AMS(R)S SAPRS (new part of the AMS(R)S Manual).

2.1.3 It is noted that the Step 1 outcome is technology independent (i.e. applicable to all technologies), and Step 2 is naturally technology dependent as it would identify a specific technology.

2.2 The NEXUS initial work focused in the definition of classes of service to define performance based requirements.

2.3 NEXUS also agreed that in any update of the SATCOM ICAO material, it is important to ensure that there is no impact on the continuity of service provision for existing standardised systems which are compliant with the current AMS(R)S SARPs. In addition, considering the significant capital investment required for any new satellite based communication systems and the time it takes to have new SATCOM developments, NEXUS decided to follow a pragmatic approach and aim to accommodate expected/likely evolutions of existing or firmly planned SATCOM developments.

2.4 At the beginning of the NEXUS work in 2010, there were two ICAO standardised SATCOM systems: Inmarsat I3 and Iridium. At that time Inmarsat was already offering (non safety) SATCOM services over its new operational SATCOM system (I4 or SwiftBroadband, SBB) and was expected to propose to ICAO to standardise SBB to support safety services. In addition at the same time, Iridium, had already started the firm planning of the new Iridium system (Iridium NEXT), and it was also expected to be interested to support safety services.

Note: It is noted that at the CP/1 meeting, INMARSAT has proposed to ICAO that SBB supports oceanic safety services (SB Safety) and Iridium is now increasingly more interested in the consideration of safety services for their new system.

2.5 Furthermore, considering also the life time of SATCOM systems and the interest to provide guidance to drive developments for new SATCOM systems, NEXUS agreed that it would be beneficial to provide performance requirements also for the next generations of SATCOM systems (after the Inmarsat SBB and Iridium Next).

2.6 Therefore, the NEXUS group proposed the establishment in the future ICAO SATCOM SARPS of 3 classes of performance (class A, B and C) for the aviation SATCOM systems (current and future) as follows:

2.6.1 Class C covers the performance requirements included in the current AMS(R)S SARPs and is applicable to systems already standardized in ICAO (such as Inmarsat Classic Aero,
MTSAT and Iridium) as well as the Inmarsat SB Safety system currently proposed for inclusion in the AMS(R)S Manual. Class C is effectively covering oceanic operations.

2.6.2 Class B covers more stringent (compared to Class C) performance requirements (such as the ones required by initial 4D) and will be applicable for existing SATCOM systems but which are currently not standardised by ICAO. These systems are the Iridium Next and the planned evolution of the Inmarsat SB safety to become a system supporting safety services in continental airspace and which in Europe is referred to with the commercial name “Precursor”. Class B requirements will cover oceanic as well as continental operations.

2.6.3 Class A covers more stringent (compared to Class B) performance requirements (such as those required by full 4D and by the SESAR/NextGEN/CARATS future concepts) and will be applicable to future SATCOM systems (not available today). Class A will also cover oceanic as well as continental operations. Class A performance requirements are expected to serve in particular as design guidelines for the definition and specification of future SATCOM systems to support the future aviation requirements, aiming to provide an agreed baseline of the desired performance targets.

2.6.4 The above three classes should not necessarily be linked directly with traffic levels in a particular domain, as it may be required for example also in low density traffic environments to apply stringent performance requirements for some of the applications. Therefore, classes A and B can be considered for providing support for both continental and oceanic airspaces.

2.6.5 Note: It was recently suggested that the above class names (A, B and C) maybe confused with the airspace classes. Therefore, if needed, the naming of the classes may be reconsidered to avoid ambiguity or confusion.

2.7 Apart from the classes of performance, NEXUS also agreed on a proposed structure (table of contents) for the future SATCOM SARPs considering the structure of the current SARPs, aiming to minimise the changes in the existing Annex 10 SATCOM material.

2.8 Following the agreement in the three classes of performance and the structure of the updated SARPs, the NEXUS work focused on the definition of the class B performance requirements. For the definition of class B, NEXUS aligned the work with the EUROCAE and RTCA WG78 and SC214 work describing the ATN Baseline 2 (ATN/B2) services.

2.9 NEXUS so far has only addressed the Step 1 activities and the Class B requirements. The Class A requirements work, as well as, the Step 2 work have not been addressed.

2.10 Various NEXUS partners took the lead in developing material for the different sections of the proposed structure of the updated SATCOM SARPS addressing the Class B requirements. Appendix A of this document incorporates the developed material in the form of a normal ICAO Proposal for Amendment (PfA) in order to better visualise the potential changes. In addition, in Appendix B, the original material provided by the NEXUS partners leading various sections (AENA/ENAIRE, EADS ASTRIUM/Airbus Defence and Space, INDRA, Inmarsat, Rockwell Collins, Telespazio, Thales Alenia Space) is provided for traceability purposes as well as for the explanatory material and/or justification of the proposals included in Appendix A.

2.11 The material in Appendix A (and Appendix B) is provided to ICAO to be used as input for the development of the final PfA to include the Class B performance requirements in the SATCOM SARPS.

Note: The material in Appendices A and B is currently undergoing a check by the NEXUS partners to ensure it has been correctly incorporated. If any changes will be required, updated versions of these Appendices will be resubmitted to ICAO for any future work in ICAO.
The NEXUS proposal for the most stringent performance requirements for Class B is summarised in the following table:

<table>
<thead>
<tr>
<th>Class of Service</th>
<th>RCTP&lt;sub&gt;AG&lt;/sub&gt;</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latency</td>
<td>Continuity</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Class B Safety</td>
<td>4.7</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.9</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.- Most stringent Class B safety services for Continental Airspace Domain

3. OTHER SATCOM ACTIVITIES IN EUROPE

3.1 In Europe, the European Space Agency (ESA) under the Iris Programme has been actively working to promote the use of satellite based communications. In summary, Iris has worked (and continues to work) in two areas. The first one is relevant to the Precursor (that is the evolution of the Inmarsat SBB system to become a SATCOM system supporting safety services both in oceanic and continental airspace to complement the VDL2 operations in Europe). The second one (referred to a Long Term SATCOM) is about the definition and validation of a new open standard for satellite communications and the facilitation of the eventual service provision.

3.2 In the context of SESAR, there are two projects about the satellite communications. One (P15.02.05) is linked with the Precursor activities and the other (P15.02.06) is linked with the Long Term SATCOM. Additional SATCOM activities are expected to be initiated in the context of the SESAR2020 framework.

3.3 In addition, and in response to the ongoing activities in Europe, EUROCAE has initiated a SATCOM task under the EUROCAE Working Group 82.

3.3.1 WG82 is aiming to develop MOPS and MASPS for both Class B and Class A satellite services. The WG82 ToRs, clarify that Class B aims to cover the performance of the existing systems (such as Precursor and Iridium NEXT) and Class A will capture the performance characteristics expected to be supported by future generations of SATCOM systems not yet available. The agreement in WG82 is to have a two-step development process providing the MASPS and MOPS for Class B by end of 2016 and the MASPS and MOPS for Class A by end of 2017.

3.4 Following discussions between EUROCAE and RTCA, WG82 is now working together with the RCTA SC222 and aim to jointly develop the Class B MOPS and MASPS and with the active support from INMARSAT and Iridium both INMARSAT Precursor and Iridium NEXT will be addressed. For Class B, in terms of requirements, WG82/SC222 is using the outcome of the EUROCAE WG78 / SC214 (EUROCAE ED-228 and ED-229) and is having the support of the SESAR project P15.02.05 and ESA IRIS Precursor project.

3.4.1 WG82 will continue with the Class A material and RTCA is invited to continue working jointly. In terms of Class A requirements, WG82 will base its work in the SESAR activities (projects P15.02.04 and P15.02.06) which define the expected future performance requirements (in coordination with NextGEN and FAA). In terms of technical specifications for the MOPS, WG82 is planning to use the ESA and SESAR sponsored work defining and validating a proposal for an open and flexible (i.e. potentially multiple constellations) standard to support these stringent requirements.
It is important to note that is already significant amount of material developed by ESA and in addition the ESA material is proposed as a starting point aiming to commonly agree on the supported requirements and the technical specs for the new standard(s) for Class A.

4. **ICAO INVOLVEMENT**

4.1 There is increasing interest and maturity of activities in relation to the satellite communications.

4.2 There are ongoing development, investigations and standardisation activities involving many actors such as Inmarsat, Iridium, EUROCAE, RTCA, ESA, NEXUS and SESAR. In these activities evolution of existing as well as new SATCOM technologies are being considered and/or specified. Figure 1 below identifies the applicable NEXUS class of performance for the past, current and likely future technological developments as well as identifies also the relevant ongoing standardisation involvement of EUROCAE and RTCA.

<table>
<thead>
<tr>
<th>Class C</th>
<th>Class B</th>
<th>Class A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inmarsat Classic Aero</td>
<td>INMARSPORT / ESA Precursor (Joint EUROCAE WG82 / RTCA SC222)</td>
<td>(ESA) Long term SATCOM (Joint EUROCAE WG82 and RTCA SC222 – tbc)</td>
</tr>
<tr>
<td>MTSAT</td>
<td>Iridium Next (Joint EUROCAE WG82 / RTCA SC222)</td>
<td></td>
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<tr>
<td>Iridium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INMARSAT SB Safety</td>
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</tbody>
</table>

**Figure 1: NEXUS Classes of Performance and Relevant Technologies**

4.3 Considering the various on-going activities in relation to SATCOM, it is now appropriate that ICAO is more actively involved and provides appropriate steering and guidance for the future SATCOM activities to ensure global applicability of any developed material.

4.4 Therefore, it is proposed that a dedicated COM Panel group (WGT, or another group under COM Panel) is established aiming to:

- progress the update of the SATCOM SARPS to include in a first step the Class B (or any other name if decided to change the naming) performance requirements,
- oversee the development of new parts of the ICAO SATCOM Manual to capture the new systems (IMARSAT Precursor) and Iridium Next, and
- coordinate as required with the EUROCAE and RTCA SATCOM activities.

4.5 It is highlighted that the task in the first bullet above, about the performance requirements, is technology independent. Furthermore, this work is very much related to the planned work of the CP Operations Working Group (OPWG) to update the ICAO PBCS Manual to include the ATN/B2 application requirements (as effectively the Class B requirements are using the RCP and RSP values of the ATN/B2 applications).

5. **ACTION BY THE MEETING**

5.1 The meeting is invited to:

(a) Note the information in this paper,

(b) discuss and agree in the activities needed to be undertaken by ICAO and the CP in particular
(2) establish a (or task an existing) a working group to progress the SATCOM aspects, considering the outcome of the NEXUS group as provided in Appendices A and B
APPENDIX A: Initial Draft for amending SATCOM SARPS to include Class B performance requirements

This Appendix provides a proposal for consideration and further discussions in ICAO aiming to eventually amend the current SATCOM SARPS (Annex 10, Volume 3, Part 1, Chapter 4) to include more stringent performance requirements to support the future NextGEN and SESAR concepts.

This proposal is based on the outcome of the NEXUS group and in addition contains further input and suggestions originating from EUROCONTROL for discussion in the COM Panel (CP).

Further work is required to finalise the proposal, including in particular the review of the proposed material and the resolution of the points identified by EUROCONTROL. Nevertheless, this initial proposal is presented in the traditional format of the ICAO PfAs to provide a better understanding on how the eventually amended SATCOM SARPS text could look like and to facilitate appropriate decisions for its finalisation.

In accordance with the ICAO PfA formatting principles, the text of the amendment is arranged to show deleted text with a line through it, new text highlighted with grey shading and issues/comments for resolution in CP, as shown below:

Text to be deleted is shown with a line through it.

New text to be inserted is highlighted with grey shading.

Text proposed by NEXUS to be deleted from SARPS

New text proposed by NEXUS to be inserted in SARPS

Issue/Comment raised by EUROCONTROL for further discussion and resolution in CP

ISSUE/COMMENT X
Describes an issue in relation to existing or proposed by NEXUS text for further discussion. Alternative proposals are provided where applicable.
AERONAUTICAL TELECOMMUNICATIONS

VOL III

DIGITAL COMMUNICATION SYSTEMS

(PART I : Digital Communication Systems)

CHAPTER 4. AERONAUTICAL MOBILE-SATELLITE (ROUTE)
SERVICE (AMS(R)S)

Note 1.— This chapter contains Standards and Recommended Practices applicable to the use of Aeronautical Mobile-Satellite (R) Service communications technologies. The Standards and Recommended Practices in this chapter are service- and performance-oriented and are not tied to a specific technology or technique.

Note 2.— Detailed Technical Specifications of AMS(R)S Systems are contained in the manual on AMS(R)S. This document also provides a detailed description of the AMS(R)S, including details on the Standards and Recommended Practices below.

ISSUE/COMMENT 1:
The eventually agreed changes may affect Annex 10/Vol 3/Part 1 (AMS(R)S SARPS) as well as Doc 9925 (AMS(R)S Manual). Therefore, to ensure consistency, changes may be needed also to Manual.
In addition, it is proposed that Annex 10/Vol3 and Doc9925 should be coordinated and synchronised with the ICAO PBCS Manual (Ed3.0 planned for publication in Q1 2016), the industry standards ED228/DO350 (SPR ATS-B2) and the under development EUROCAE/RTCA (tbc) SATCOM MASPS and MOPS (DO343A/EDxxx , …) to ensure consistency and to avoid confusions.

4.1 DEFINITIONS

Reading key: Definitions entitled in blue bold are intended to be used as parameters to define the classes of performances.

4D Trajectory: The 4D trajectory is:

• The lateral path consisting of route waypoints, and

• The vertical path consisting of the predicted altitude and vertical constraints, if any, at each of the waypoints forming the lateral path, and

• The predicted speed and speed constraints, if any, at each of the waypoints forming the lateral path, and

• The predicted time and time constraints, if any, at each of the waypoints forming the lateral path.

Availability The probability that an operational communication transaction can be initiated when needed (ICAO
Availability of use: The probability that the communication system between the two parties is in service when it is needed.

Availability of provision: The probability that communication with all aircraft in the area is in service.

Availability Ratio: defined by the following ratio (Observation Time - Total Outage Time)/Observation Time, with “Observation Time” being defined as the duration of the measurement period, and “Total Outage Time” being defined as the sum of the Service Outage Times over the Observation Time.

Call processing delay: The time delay for a GES (respectively, an AES) to present a call origination event to the terrestrial network interworking interface (respectively, to the AES interface) after a call origination event has arrived at the AES interface (respectively, at the terrestrial network interworking interface).

Classes of Performance. The following 3 classes of performance: A, B and C are defined for data and voice applications associated performance requirements:

• Class A corresponds to stringent performance requirements needed for the support of 4D trajectory services. Refer to section 4.6.4.1 for a detailed description of this class.

• Class B corresponds to medium performance requirements needed for the support of the services defined in the Data Communications Safety and Performance Requirements (SPR) documents (EUROCAE/RTCA WG78/SC-214). Refer to section 4.6.4.2 for a detailed description of this class.

• Class C corresponds to performances requirements inherited from AMS(R)S SARPs (Edition, date) and intended for systems compliant with these SARPs but not compliant with Class B nor Class A levels of performances. Refer to section 4.6.4.3 for a detailed description of this class.

Note: These classes are not necessarily corresponding to traffic levels (i.e. in low density traffic it may be required to apply stringent performance requirements for some of the applications).

Class of Service (CoS): A CoS is an attribute that is associated with an application transaction in order to notify the communication system with the Quality of Service required by the transaction.

• Multi Link CoS (ML CoS): for the ATS services/application that are the most critical in terms of safety impact, thus could require a configuration with multiple data links to meet the performance targets.

• Medium CoS (MD CoS): for the remaining ATS services/applications.

• Best Effort CoS (BE CoS): for AOC services/applications.

Communication Expiration Time (ET): The maximum time for the completion of the operational communication transaction after which the initiator should revert to an alternative procedure (ICAO doc 9869).

Connection Establishment Delay: Connection establishment delay, as defined in ISO 8348, includes a component, attributable to the called subnetwork (SN) service user, which is the time between the SN-CONNECT indication and the SN-CONNECT response. This user component is due to actions outside the boundaries of the satellite subnetwork and is therefore excluded from the AMS(R)S specifications.

Continuity of Service: specified performance (assuming the system was available when the transaction is initiated). The value for the continuity parameter is based on the acceptable probability of detected anomalous behaviours of the communication transaction. Detected anomalous behaviours include, but are not limited to (ICAO RCP Manual):

• Late transactions;

• Lost messages or transactions that cannot be recovered within the expiration time;

• Duplicate messages or transactions that are forwarded and/or used; and

• Uncorrected detected message errors.
Data Transfer Delay requirements are set by the need to assure that data link messages are delivered through the communications system in a timely manner. The measured transfer delay characteristics of a subnetwork and its elements are normally characterized by data which, plotted as a histogram, appear as an probability distribution having a biased offset (latency) from the zero value. The DO270 expresses three different values of transfer delay the latency, the mean value (transit delay) and the 95th-percentile value. These values are the minimum necessary to combine properly the delay data of individual elements, systems and subnetworks for aggregated delay values (e.g., for "end-through-end" delays). (RTCA DO 270).

Data Transfer Delay (95th percentile). The 95th percentile of the statistical distribution of delays for which transit delay is the average. This means a 95% of the messages sent must be received within this delay.

Transfer Delay is a measure of the time required for an information element to be transferred in one direction between the reference Points B and C of Figure 2-1, on a first-bit-in to last-bit-out basis. The Transfer Delay of a given block of data across an air/ground communications subnetwork depends on:

1. The length, type and priority of that block and all other blocks that constitute the instantaneous user traffic loading of the subnetwork -- the Traffic Model.
2. The subnetwork's throughput characteristics which are basically determined by its architecture, protocols, and the characteristics of its RF and Physical layer channel(s) — the Subnetwork Model.

Notes:
1. A number of the factors determining these characteristics are interdependent and can be different for the two directions of traffic flow (to-AES and from-AES).
2. It is assumed that an air/ground subnetwork's transfer delay characteristics will be established via high-fidelity simulations and/or analyses because fullscale measurements across the subnetwork under the various conditions are impracticable. The transfer delay verification procedures of Section 4 utilize certain subnetwork measurements intended to validate the simulations and/or analysis.[RTCA DO-270 Section 2.2.5.1 Transfer Delay]

Data Transfer Latency of the AMS(R)S System is defined under conditions of no user traffic loading other than the test block itself; however, normal system management traffic and protocol overhead traffic are expected to be present, due to management entities internal to the subnetwork. Thus, latency is the minimum delay that can be expected within the system, and accounts for the relatively fixed delay components such as propagation delay, component transmission speeds, and latent buffering.[RTCA DO-270 Section 2.2.5.1.4]

Data Transit Delay. in packet data system, the elapsed time between a request to transmit an assembled data packet and an indication at the receiving end that the corresponding packet has been received and is ready to be used.

Integrity. In accordance with DO-264, it is the acceptable rate of transactions that are completed with an undetected error. Undetected errors include, but are not limited to (ICAO RCP Manual):

• Undetected corruption of one or more messages within the transaction;
• Undetected misdirection of one or more messages within the transaction;
• Undetected delivery of message in an order that was not intended;
• Undetected delivery of a message after the communication

Integrity is the ability to guarantee that the information being transported through the communications means arrives exactly as it was sent.

Multi-User Service Outage: A Service Outage simultaneously affecting multiple users within a defined service volume.

Network (N). The word “network” and its abbreviation “N” in ISO 8348 are replaced by the word “subnetwork” and its abbreviation “SN”, respectively, wherever they appear in relation to the subnetwork layer packet data performance.

Operational Communication Transaction The process a human uses to send an instruction, a clearance, a flight information, and/or a request. The procedure is completed when that human is confident that the transaction is complete (ICAO doc 9869).
Pre-emptive access. An access technique which allows the termination without warning of the transmission of lower priority messages to let higher priority messages be transmitted.

Priority Access: An access technique which requires each message to be given a level of priority depending on the data transfer delay requirement associated with the service.

Required Communication Performance (RCP). A statement of the performance requirements for operational communication in support of specific ATM functions. (ICAO)

RCP Type. A label (e.g. RCP 240) that represents the values assigned to RCP parameters for communication transaction time, continuity, availability and integrity.

Required Communication Technical Performance (RCTP). The portion of the (intervention) transaction time that does not include the human times for message composition, operational response, and recognition of the operational response.

RCTP. The symbol used to designate required communication technical performance.

RCTP CSP. The summed critical transit times for an ATC intervention message and a response message, allocated to the CSP system.

Residual Error Rate. The ratio of incorrect, lost and duplicate subnetwork service data units (SNSDUs) to the total number of SNSDUs that were sent.

Service Outage Time: The time the service is not meeting a specified performance of Quality of Service. RTCA DO-270 considers two types of outages:

• Single-User Service Outage
• Multiple-User Service Outage

Single-User Service Outage A Service Outage affecting any single user aircraft within a defined service volume

Spot Beam. Satellite antenna directivity whose main lobe encompasses significantly less than the earth’s surface that is within line-of-sight view of the satellite. May be designed so as to improve system resource efficiency with respect to geographical distribution of user earth stations.

SubNetwork (SN). See Network (N).

SubNetwork Service Data Unit (SNSDU). An amount of subnetwork user data, the identity of which is preserved from one end of a subnetwork connection to the other.

Susceptibility The cumulative relative change in its noise temperature due to interferences a receiver can tolerate.

Total Voice Transfer Delay. The elapsed time commencing at the instant that speech is presented to the AES or GES and concluding at the instant that the speech enters the interconnecting network of the counterpart GES or AES. This delay includes vocoder processing time, physical layer delay, RF propagation delay and any other delays within an AMS(R)S subnetwork.

Note.— The following terms used in this chapter are defined in Annex 10 as follows:

• Aeronautical telecommunication network (ATN): Volume III, Chapter 1.
• Aeronautical mobile-satellite (route) service (AMS(R)S): Volume II, Chapter 1.1.
• Aircraft earth station (AES): Volume III, Chapter 1.
• Ground earth station (GES): Volume III, Chapter 1.
• Subnetwork layer: Volume III, Chapter 6.1.

Transaction: a two-way operational communication process (e.g., Controller and pilot, pilot and pilot, or Controller and Controller). It contains the outgoing request message, the Controller or pilot response time and
the incoming response message. Communications exchanges that have multiple responses, i.e., the STANDBY, followed by the operational response, are treated as two transactions. (DO-264)

**Transaction time.** The time needed by a pilot and a Controller to exchange a pair of messages. This time represents the sum of the delivery time of incoming and outgoing messages and the Controller or pilot response time.

**Voice Access Delay** The one-way user-to-user delay starting with the voice initiation event (e.g. Push-To-Talk signal event) and ending with audio appearing at the remote end of the link, but excluding any human response times (COCR v2.0).

**Voice Channel Setup Delay** Time needed by the system to establish a path between users, prerequisite for voice access and communications (COCR v2.0).

**Voice Latency** The one-way user-to-user between analogue system interfaces (HMIs) after the audio path has already been established (COCR v2.0).

### ISSUE/COMMENT 2
The proposed definitions of the parameters require a review to ensure completeness, relevance and consistency with the ICAO PBCS Manual and the industry standards ED228/DO350 (SPR ATS-B2) and the under development EUROCAE/RTCA SATCOM MASPS and MOPS

Example 1: SATCOM link supports the ATS, AOC (and the future AIS/MET) applications. The mentioning of 4D Trajectory, although key, is one of the many services, therefore it is questionable if we need to provide a definition.

Example 2: Definition of RCP and RSP, Availability (use, provision, ratio). For Availability, only $A_{CSP}$ and $A_{AIR}$ are relevant to the AMS(R)S.

Example 3: The definition of Classes of performance for SATCOM should be linked with the RCP and RSP spec, e.g. Class B SATCOM is compliant to RCP130 and RSP160 and Class C is compliant to RCP240/400 and RSP180/400.

Example 4: The PBCS Manual, DO343A and ED228/DO350 use delay values, associated with 2 Continuity percentiles (95% and 99.9%), while Annex 10 and Doc 9925 defines 2 delay values, corresponding to the 95% value (data transfer delay) and average value (data transit delay). Moreover, Annex 10 and Doc9925 apply a statistical distribution for the existing values (which?).

Example 5: Definition Classes of Service (CoS). The notion of CoS is planned to be used in the long-term time-frame. Given the high degree of inmaturity, introduction of CoS needs to be further discussed.

### 4.2 GENERAL

4.2.1 Any mobile-satellite system intended to provide AMS(R)S shall conform to the requirements of this chapter.

4.2.1.1 An AMS(R)S system shall support packet data service, or voice service, or both.

4.2.2 Requirements for mandatory carriage of AMS(R)S system equipment including the level of system capability shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment. A level of system capability shall include the performance of the AES, the satellite and the GES.

4.2.3 The agreements indicated in 4.2.2 shall provide at least two years’ notice of mandatory carriage of airborne systems.
4.2.4 **Recommendation.**—Civil aviation authorities should coordinate with national authorities and service providers those implementation aspects of an AMS(R)S system that will permit its worldwide interoperability and optimum use, as appropriate.

### 4.3 RF CHARACTERISTICS

#### 4.3.1 Frequency bands

Note.—ITU Radio Regulations permit systems providing mobile-satellite service to use the same spectrum as AMS(R)S without requiring such systems to offer safety services. This situation has the potential to reduce the spectrum available for AMS(R)S. It is critical that States consider this issue in frequency planning and in the establishment of national or regional spectrum requirements.

4.3.1.1 When providing AMS(R)S communications, an AMS(R)S system shall operate only in frequency bands which are appropriately allocated to AMS(R)S and protected by the ITU Radio Regulations.

#### 4.3.2 Emissions

4.3.2.1 The total emissions of the AES necessary to meet designed system performance shall be controlled to avoid harmful interference to other systems necessary to support safety and regularity of air navigation, installed on the same or other aircraft.

*Note 1.— Harmful interference can result from radiated and/or conducted emissions that include harmonics, discrete spurious, intermodulation product and noise emissions, and are not necessarily limited to the “transmitter on” state.

*Note 2.— Protection requirements for GNSS are contained in Annex 10, Volume I.*

4.3.2.2 **INTERFERENCE TO OTHER AMS(R)S EQUIPMENT**

4.3.2.2.1 Emissions from an AMS(R)S system AES shall not cause harmful interference to an AES providing AMS(R)S on a different aircraft.

*Note.— One method of complying with 4.3.2.2.1 is by limiting emissions in the operating band of other AMS(R)S equipment to a level consistent with the intersystem interference requirements such as contained in RTCA document DO-215. RTCA and EUROCAE may establish new performance standards for future AMS(R)S which may describe methods of compliance with this requirement.*

#### 4.3.3 Susceptibility

4.3.3.1 The AES equipment shall operate properly in an interference environment causing a cumulative relative change in its receiver noise temperature (∆T/T) of 25 per cent.

### 4.4 PRIORITY AND PRE-EMPTIVE ACCESS

4.4.1 Every aircraft earth station and ground earth station shall be designed to ensure that messages transmitted in accordance with Annex 10, Volume II, 5.1.8, including their order of priority, are not delayed by the transmission and/or reception of other types of messages. If necessary, as a means to comply with the above requirement, message types not defined in Annex 10, Volume II, 5.1.8 shall be terminated even without warning, to allow Annex 10, Volume II, 5.1.8 type messages to be transmitted and received.
4.4.2 All AMS(R)S data packets and all AMS(R)S voice calls shall be identified as to their associated priority.

4.4.3 Within the same message category, the system shall provide voice communications priority over data communications.

4.5 SIGNAL ACQUISITION AND TRACKING

4.5.1 The AES, GES and satellites shall properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 15800 km/h (80960 knots) along any heading.

4.5.1.1 Recommendation.— The AES, GES and satellites should properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 283000 km/h (15600 knots) along any heading.

4.5.1.2 Recommendation.— The AES, GES and non GEO satellites should properly acquire and track service link signals with a relative speed implying a Doppler Shift of ± 60 kHz at the maximum uplink carrier frequency (L band) along any heading.

Note.— the ground speed for the AES acquisition and tracking of the satellite signal has to be considered only for GEO satellites. In case of non GEO satellites, the AES and GES acquisition and tracking of the satellite signal shall consider a relative speed of a maximum of 30 000 km/h (i.e. LEO constellation).

4.5.2 The AES, GES and satellites shall properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 0.6 g.

4.5.2.1 Recommendation.— The AES, GES and satellites should properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 1.2 g.

4.6 PERFORMANCE REQUIREMENTS

4.6.1 Designated operational coverage

4.6.1.1 An AMS(R)S system shall provide AMS(R)S throughout its designated operational coverage (DOC).

4.6.1.2 An AMS(R)S system shall provide AMS(R)S as a primary means of communications in Oceanic, Remote and Polar areas of the designated operational coverage (DOC) for the classes of performances it corresponds to, namely either class A or B or C.

4.6.1.3. An AMS(R)S system ensuring class B performance shall provide the performance required for being used as supplemental means of communications for en-route (ENR) airspace and for Terminal Manoeuvre Area (TMA) airspace of the designated operational coverage (DOC).

4.6.1.4 An AMS(R)S system ensuring class A performance can be used as primary data link communication system of a multilink operation concept in communications for en-route (ENR) and Terminal Manoeuvre Area (TMA) of the designated operational coverage (DOC).

4.6.1.5 An AMS(R)S system ensuring class A performance shall provide the performance required for being used as in Stand Alone as primary means of communications for en-route (ENR) or for Terminal Manoeuvre Area (TMA) of the designated operational coverage (DOC).
4.6.2 Failure notification

4.6.2.1 In the event of a service failure, an AMS(R)S system shall provide timely predictions of the time, location and duration of any resultant outages until full service is restored.

Note.— Service outages may, for example, be caused by the failure of a satellite, satellite spot beam, or GES. The geographic areas affected by such outages may be a function of the satellite orbit and system design, and may vary with time.

4.6.2.2 The system shall annunciate a loss of communications capability within 30 seconds of the time when it detects such a loss.

4.6.3 AES requirements

4.6.3.1 The AES shall meet the relevant performance requirements contained in 4.6.4 and 4.6.5 for aircraft in straight and level flight throughout the designated operational coverage of the satellite system.

4.6.3.1.1 Recommendation.— The AES should meet the relevant performance requirements contained in 4.6.4 and 4.6.5 for aircraft attitudes of +20/-5 degrees of pitch and +/−25 degrees of roll throughout the DOC of the satellite system.

4.6.4 Packet-Data Classes of performance for Data and Voice applications

4.6.4.1 Class of performance A requirements

NOTE: Class A requirements are not matured and are left for addressing in the future. At this stage only a placeholder is provided.

4.6.4.1.1 Class A packet data service performance requirements

4.6.4.1.2 Class A voice service performance
4.6.4.2 Class of performance B Performance

4.6.4.2.1 An AMS(R)S system compliant with the class of performance B shall be a technical enabler for all modules within the ICAO Aviation System Block Upgrades\(^1\) and 2 concerning the A/G Data-Link services being standardized in ED 228/DO 350.

\textit{Note 1: Initial Operating Capability (IOC) dates for Blocks 1 and 2 are foreseen by 2018 and 2023 respectively.}

4.6.4.2.2 An AMS(R)S system compliant with the class of performance B shall allow to:

i. Support the operational concepts defined in the ICAO Blocks 1 and 2 that relied on the A/G Data-Link services being standardized in EUROCAE ED 228/DO 350.

ii. Offer additional capacity to complement terrestrial infrastructure (e.g. VDL mode 2) in terms of total communication bandwidth and alleviate congestion of other bands in the spectrum.

iii. Extend the geographical coverage of the terrestrial infrastructure mainly to ORP areas.

\textbf{ISSUE/COMMENT 4}
It is suggested to review para 4.6.4.2 (e.g. the mentioning of ASBU blocks and complementing VDLM2 maybe better to remove is irrelevant).

It might be more appropriate to state the linkage of RCP/ RSP specs and SATCOM classes (see also ISSUE 3 in section 4.6.4).

4.6.4.2.1 Class B packet data service performance

4.6.4.2.1.1 An AMS(R)S system compliant with the class of performance B shall meet the following performance requirements for safety of life services:

<table>
<thead>
<tr>
<th>Continental Airspace Domain (APT, TMA, ENR-1)</th>
<th>RCP(_{130})</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Service</td>
<td>Latency 95%</td>
<td>Continuity</td>
</tr>
<tr>
<td>Class B Safety _1</td>
<td>4.7</td>
<td>8.9</td>
</tr>
<tr>
<td>Class B Safety _2</td>
<td>49</td>
<td>57.7</td>
</tr>
<tr>
<td>Class B Safety _3</td>
<td>119</td>
<td>137.7</td>
</tr>
<tr>
<td>Class B Safety _4</td>
<td>83</td>
<td>167.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oceanic and Remote Airspace Domain (ENR-2)</th>
<th>RCP(_{400})</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Service</td>
<td>Latency 95%</td>
<td>Continuity</td>
</tr>
<tr>
<td>Class B Safety _1</td>
<td>49</td>
<td>57.7</td>
</tr>
<tr>
<td>Class B Safety _2</td>
<td>119</td>
<td>137.7</td>
</tr>
<tr>
<td>Class B Safety _3</td>
<td>83</td>
<td>167.7</td>
</tr>
<tr>
<td>Class B Safety _4</td>
<td>83</td>
<td>167.7</td>
</tr>
</tbody>
</table>

Table 3.- Safety Class B services for Oceanic and Remote Airspace Domain (ENR-2).

<table>
<thead>
<tr>
<th>Class B</th>
<th>Safety: 0.9995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency: N/A</td>
<td></td>
</tr>
<tr>
<td>ADS-C (RSP400)</td>
<td></td>
</tr>
</tbody>
</table>

### ISSUE/COMMENT 5:
This section is the core part of Annex 10/Vol3/Part1 and requires a thorough review to ensure consistency and avoid duplication with under development EUROCAE and RTCA SATCOM MASP and MOPS.

From boundary perspective, the proposal has considered the A/G part of the AMS(R)S system, which constitutes only a portion of the AMS(R)S. Both ICAO Doc 9925 and DO343A define the AMS(R)S as the SSP + CNP.

A clear delineation of the AMS(R)S boundary is provided in DO343A/Fig 1-2. The consequence is that ICAO docs and industry standards are no longer aligned.

From values perspective, although the values correctly were derived from ED228/DO350, class B should be limited to the RCP130 and RSP160 spec. (RCP240/400 are class C).

To ensure alignment from boundary and perf perspective, it is highly recommended to develop SATCOM Class B perf in line with DO343A, which is currently being updated for incorporating Class B perf requirements.

Regarding the delay values in support of RCP specs there is a mismatch with respect to the current specifications provided in section 4.6 and the current definitions, provided in section 4.1; For RCP, the Tables correctly represent the 95% and 99.9% two-way delay values, while the definitions in section 2 are ‘Average’ and 95%. Although the definitions are not clear the aspect of 1-way vs 2-way, it appears from the current specifications in section 4.6 (and Doc 9925) that the average and 95% delay values, are 1-way. However it should be emphasised that 95% and 99.9% two-way delay values for RCP are consistently applied in the PBCS manual and industry standards.

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**Note1:** The boundaries of the SATCOM domain (Air/Ground) can be defined as follows:

- **From physical point of view,** between A/G router in Ground Domain to airborne router on-board the aircraft. The performance contributions associated with the A/G router are excluded from the SATCOM domain allocated performance.

- **From logical point of view,** at the boundary between the internetworking and intranetworking layers of the reference protocol stack.

The SATCOM domain is equivalent to the portion of the ACSP domain (as considered by the ED228/DO350) allocated to the Air/Ground side.

**Note2:** According to the ED228/DO350, the performance allocation for Latency to the SATCOM assumes that the component delays are distributed independently and log-normally with a probability density distribution of the sum of independent lognormal random variables. (see attachment 0.4 – section 4.1.1). This assumption is only applicable to continental airspace (i.e. APT, TMA and ENR-1) whereas for oceanic airspace (i.e. ENR-2) the rationale provided in the GOLD is still valuable where technical delays follow an arithmetic summation to give the RCTP value.
Note3: The latency values are specified for one-way transaction (i.e. RCTP1W value for the one-way or transfer transaction). The RCTP1W values are set equal to half the statistical sum of the RCTP2W values for each segment (see attachment 0.4 – section 4.1.1).

Note4: As assumption for setting the performances allocation to G/G segment, PENS has been considered as the G/G segment.

The G/G segment-allocated values have been set to 500 ms for Class B Safety_1 and to 1 s for the remaining ones. These figures are based on the current Service Level Agreement for PENS (see attachment 0.4 – section 4.1.3).

The A/G segment-allocated values figures have been worked out as the points containing in the assumed distribution taking into account the aforementioned G/G segment-allocated values (see attachment 0.4 – section 4.1.2).

Note5: According to ED228/DO350, the performance allocation for Continuity assumes a 99.9% value for all A/G Data-Link services (see attachment 0.4 – section 4.3).

Note6: According to ED228/DO350, the performance allocation for Availability assumes an equalled allocation to both A/G and G/G segments (see attachment 0.4 – section 4.2).

Note7: According to the EO228/DO350/ED228/DO350, there is no allocation of Integrity to the SATCOM as the requirement is wholly satisfied by the end-to-end mechanism (Protected Mode) in the aircraft and the ATS. However ED228/DO350 notes that in formulating contract terms with the ACSP, the ATSP and/or operator may specify an integrity value and other related criteria (e.g. residual error rate), as appropriate, for the network, including subnetworks, that will ensure acceptable data integrity, consistent with the assumptions used to define the end system provisions, e.g. CRC or Fletcher’s checksum (see attachment 0.4 – section 4.4).

Note8: FIS application has been removed from ED228/DO350 work. The removal of FIS application from Class B definition does not preclude from supporting those FIS services relying on ATN and targeting the same timeframe as Class B (e.g. D-OTIS) by a Satellite Communication system in compliance with Class B as long as the bandwidth demanded by FIS services is supported. This is because FIS services are expected to be less performance demanding (except for bandwidth) than the services covered in ATN-Baseline 2. The main reason why FIS application is considered out of scope of ED228/DO350 are as follows:

- Other groups, notably RTCA SC-206, actively defining FIS services are on a different publication schedule than ED228/DO350 (for instance the newer services D-HZWX and D-RVR) are still under development without foreseen operational validation activities.

- Low need for integration with other cockpit systems (e.g. FMS) whereas ATS applications in the scope of ED228/DO350 (CM, CPDLC and ADS-C) all involve interactions with the FMS (or other cockpit systems).

- There is not the same need for processing rules as CPDLC, then FIS services are better suited to be defined in a document that takes this need for flexibility into consideration.

**ISSUE/COMMENT 6:**
The notes 1 to 8 are explanatory notes to Table 1 and 2. In relation to ISSUE 5, a review of the notes is required.
Since the FIS application has been removed from ED228/DO350, it should be discussed if it is better to remove Note 8.
Continental Airspace Domain (APT, TMA, ENR-1)

<table>
<thead>
<tr>
<th>Class of Service</th>
<th>Latency</th>
<th>RCTP (99%)</th>
<th>Availability (provision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B</td>
<td>4.7</td>
<td>N/A</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

Table 4.- Best Effort Class B services for Continental Airspace Domain (APT, TMA, ENR-1).

Oceanic and Remote Airspace Domain (ENR-2)

<table>
<thead>
<tr>
<th>Class of Service</th>
<th>Latency</th>
<th>RCTP (99%)</th>
<th>Availability (provision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B</td>
<td>49</td>
<td>N/A</td>
<td>Efficiency: 0.999995</td>
</tr>
<tr>
<td>Class B</td>
<td>119</td>
<td>N/A</td>
<td>Efficiency: 0.999995</td>
</tr>
<tr>
<td>Class B</td>
<td>83</td>
<td>N/A</td>
<td>Efficiency: 0.999995</td>
</tr>
<tr>
<td>Class B</td>
<td>269</td>
<td>N/A</td>
<td>Efficiency: 0.999995</td>
</tr>
</tbody>
</table>

Table 5.- Best Effort Class B services for Oceanic and Remote Airspace Domain (ENR-2).

Note 1: When the safety analysis does not require the definition of a continuity value and an expiration time, this datalink service is considered as a best effort service. Non-safety of life services (e.g. AOC) are considered as best effort (see attachment 0.4 – section 5.2).

ISSUE / COMMENT 7:
It is understood that regularity and non-safety of life services are meant to be AIS/MET and AOC services.

For AIS/MET, it should be emphasized that a modernization, incl the specification of performance requirements (AIS/MET SPR standard), is ongoing by WG76.

Initial proposals have been made by SESAR project 15.2.4 (refer to Deliverable D3 and D4) for consideration by WG76.

While it may be useful to incorporate performance requirements on the AMS(R)S for the support of AIS/MET and AOC services, it is worthwhile to note that DO343A does not specify AMS(R)S performance requirements in support of AIS/MET and AOC.

Concerning AOC services, no industry standard exists for the specification of performance requirements. For this, deliverable 4 of SESAR/P15.2.4 may be used as initial input for further discussion.

The notion of Best Effort CoS does not exist (yet). As stated in ISSUE 2, the use of CoS should be a long-term plan.
4.6.4.4.2 Class B voice service performance

TBD

4.6.4.3 Class of performance C requirements

4.6.4.3.1 Class C Packet data service performance

4.6.4.1 If the system provides AMS(R)S packet data service, it shall meet the standards of the following subparagraphs.

   Note.— System performance standards for packet data service may also be found in RTCA Document DO-270.

4.6.4.1.1 An AMS(R)S system providing a packet data service shall be capable of operating as a constituent mobile subnetwork of the ATN.

   Note.— In addition, an AMS(R)S may provide non-ATN data functions.

4.6.4.1.2 DELAY PARAMETERS

   Note.— The term “highest priority service” denotes the priority which is reserved for distress, urgency and certain infrequent network system management messages. The term “lowest priority service” denotes the priority used for regularity of flight messages. All delay parameters are under peak-hour traffic loading conditions.

4.6.4.1.2.1 Connection establishment delay. Connection establishment delay shall not be greater than 70 seconds.

   4.6.4.1.2.1.1 Recommendation.— Connection establishment delay should not be greater than 50 seconds.

4.6.4.1.2.2 In accordance with ISO 8348, data transit delay values shall be based on a fixed subnetwork service data unit (SNSDU) length of 128 octets. Data transit delays shall be defined as average values.

4.6.4.1.2.3 Data transit delay, from-aircraft, highest priority. From-aircraft data transit delay shall not be greater than 40 seconds for the highest priority data service.

   4.6.4.1.2.3.1 Recommendation.— From-aircraft data transit delay (95th percentile), shall not be greater than 80 seconds for the highest priority data service.

4.6.4.1.2.4 Data transit delay, to-aircraft, highest priority. To-aircraft data transit delay shall not be greater than 12 seconds for the highest priority data service.

   4.6.4.1.2.4.1 Recommendation.— To-aircraft data transit delay (95th percentile), should not be greater than 28 seconds for the highest priority data service.

4.6.4.1.2.5 Data transfer delay (95th percentile), from-aircraft, highest priority. From-aircraft data transfer delay (95th percentile), shall not be greater than 80 seconds for the highest priority data service.

   4.6.4.1.2.5.1 Recommendation.— From-aircraft data transfer delay (95th percentile), should not be greater than 40 seconds for the highest priority data service.
4.6.4.1.2.5.2 **Recommendation.**— Data transfer delay (95th percentile), from-aircraft, lowest priority. From-aircraft data transfer delay (95th percentile), should not be greater than 60 seconds for the lowest priority data service.

4.6.4.1.2.6 Data transfer delay (95th percentile), to-aircraft, highest priority. To-aircraft data transfer delay (95th percentile), shall not be greater than 15 seconds for the highest priority data service.

4.6.4.1.2.6.1 **Recommendation.**— Data transfer delay (95th percentile), to-aircraft, lowest priority. To-aircraft data transfer delay (95th percentile), should not be greater than 30 seconds for the lowest priority data service.

4.6.4.1.2.7 Connection release delay (95th percentile). The connection release delay (95th percentile) shall not be greater than 30 seconds in either direction.

4.6.4.1.2.7.1 **Recommendation.**— The connection release delay (95th percentile) should not be greater than 25 seconds in either direction.

4.6.4.1.3 **INTEGRITY**

4.6.4.1.3.1 **Residual error rate, from-aircraft.** The residual error rate in the from-aircraft direction shall not be greater than $10^{-4}$ per SNSDU.

4.6.4.1.3.1.1 **Recommendation.**— The residual error rate in the from-aircraft direction should not be greater than $10^{-6}$ per SNSDU.

4.6.4.1.3.2 **Residual error rate, to-aircraft.** The residual error rate in the to-aircraft direction shall not be greater than $10^{-6}$ per SNSDU.

4.6.4.1.3.3 **Connection resilience.** The probability of a subnetwork connection (SNC) provider-invoked SNC release shall not be greater than $10^{-4}$ over any one-hour interval.

**Note.**— Connection releases resulting from GES-to-GES handover, AES log-off or virtual circuit pre-emption are excluded from this specification.

4.6.4.1.3.4 The probability of an SNC provider-invoked reset shall not be greater than $10^{-1}$ over any one-hour interval.

4.6.4.3.2 **Class C Voice service performance**

4.6.5 **Voice service performance**

4.6.5.1 If the system provides AMS(R)S voice service, it shall meet the requirements of the following subparagraphs.

**Note.**— ICAO is currently considering these provisions in the light of the introduction of new technologies.

4.6.5.1.1 **CALL PROCESSING DELAY**

4.6.5.1.1.1 **AES origination.** The 95th percentile of the time delay for a GES to present a call origination event to the terrestrial network interworking interface after a call origination event has arrived at the AES interface shall not be greater than 20 seconds.

4.6.5.1.1.2 **GES origination.** The 95th percentile of the time delay for an AES to present a call origination event at its aircraft interface after a call origination event has arrived at the terrestrial network interworking interface shall not be greater than 20 seconds.
4.6.5.1.2 *VOICE QUALITY*

4.6.5.1.2.1 The voice transmission shall provide overall intelligibility performance suitable for the intended operational and ambient noise environment.

4.6.5.1.2.2 The total allowable transfer delay within an AMS(R)S subnetwork shall not be greater than 0.485 seconds.

4.6.5.1.2.3 **Recommendation.**— Due account should be taken of the effects of tandem vocoders and/or other analog/digital conversions.

4.6.5.1.3 *VOICE CAPACITY*

4.6.5.1.3.1 The system shall have sufficient available voice traffic channel resources such that an AES- or GES-originated AMS(R)S voice call presented to the system shall experience a probability of blockage of no more than $10^{-2}$.

*Note.— Available voice traffic channel resources include all pre-emptable resources, including those in use by non-AMS(R)S communications.*

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**ISSUE /COMMENT 8**

It should be emphasized that recently voice performance specifications have been published in the PBCS manual (RCP400/V and RSP400/V). Possibly, additional voice performance requirements may be found in the SATCOM Voice Guidance Guidance Manual (SVGM).

Suggested to consider if changes are required considering the availability now of this material.

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### 4.6.5 Handover

*Note.— Two different kind of handover are foreseen for the ATM communication systems:
Intra-segment (between elements of the same AMS(R)S ) and Inter-segment ( between satellites belonging to different AMS(R)S, and between different ATM system (i.e. satellite and terrestrial link))

*The intra-segment handover is addressed in the present SARP while the inter-segment handover is out of scope.*

4.6.5.1 The AMS(R)S System shall assure handover procedures among different elements of the same SATCOM system and different regional systems using the same communication standard.

4.6.5.2 The AMS(R)S System shall support handovers within the System without service interruption or performance reduction caused by the System during and after the handover.

4.6.5.3 The AMS(R)S System shall ensure that the performance and safety requirements are identical before and after handover within the same airspace domain.

*Note 1: A handover can happen also when an aircraft is changing airspace moving from one airspace to another one. If the second airspace has the same performance and safety requirements of the previous one, in this case the requirement is applicable. If the second airspace has different performance and safety requirements with respect to the previous one, the performance and safety requirements of the second airspace are requested.*

4.6.5.4 The AMS(R)S System shall be able to carry out handover procedures independently from any navigation.

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2 The requirement is limited to intra-segment (i.e. same communication standard used by different AMS(R)S (e.g. GEO, HEO, LEO).
systems.

Note 2: COM, NAV and SUR currently do not operate as an integrated whole for safety reasons; CNS domains separation ensures that if the NAV fails, aircraft are still capable of COM and SUR. For example if US DoD GPS navigation system will be not available for military reasons, communication datalink will be still available.

4.6.5.5 No loss of communication shall be induced by a failure in the handover procedure

4.6.5.6 Recommendation — The AMS(R)S communication standard should be designed to support handover (intra-segment handover) without service interruption.

4.6.5.7 Recommendation — Any possible combination of the following handover scenarios should be supported:

- Handover between two channels assigned to the same GES
- Handover between two channels assigned to different GES
- Handover between two channels provided through different satellite antenna beams
- Handover between two channels provided through different satellites owned by the same satellite service provider
- Handover between channels provided through different satellites owned by different satellite service providers

4.6.6 Security

 ISSUE /COMMENT 9

The issue of security and the security requirements that need to be supported is a wider issue in aviation as well as ICAO, and no final decisions have been taken. An analysis was provided to NEXUS in relation to the security aspects for an IP based system. This analysis identified a list of 20 potential security recommendations for discussion in NEXUS. As the subjects needs further discussion and decisions need to be considered in general for the new communications systems, including SATCOM, the NEXUS material is provided in Appendix B7 for further consideration. Therefore, it is recommended to discuss further in ICAO the content of section 4.6.6 considering also the analysis of Appendix B7.

4.6.6.1 The system shall provide features for the protection of messages in transit from tampering.

4.6.6.2 The system shall provide features for protection against denial of service, degraded performance characteristics, or reduction of system capacity when subjected to external attacks.

Note.— Possible methods of such attack include intentional flooding with spurious messages, intentional corruption of system software or databases, or physical destruction of the support infrastructure.
4.6.6.3 The system shall provide features for protection against unauthorized entry.

Note.— These features are intended to provide protection against spoofing and “phantom controllers”.

4.7 SYSTEM INTERFACES

4.7.1 An AMS(R)S system shall allow subnetwork users to address AMS(R)S communications to specific aircraft by means of the ICAO 24-bit aircraft address.

Note.— Provisions on the allocation and assignment of ICAO 24-bit addresses are contained in the Appendix to Chapter 9.

4.7.2 Packet data service interfaces

4.7.2.1 If the system provides AMS(R)S packet data service, it shall provide an interface to the ATN/OSI, the ATN/IPS or both.

Note.— The detailed technical specifications related to provisions of the ATN/OSI-compliant subnetwork service are contained in Section 5.2.5 and Section 5.7.2 of Doc 9880 — Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN) (in preparation).

Note.— The detailed technical specifications related to provisions of the ATN/IPS-compliant subnetwork service are contained in Part I of Doc 9896 – Manual for the ATN using IPS Standards and Protocols.

4.7.2.2 If the system provides AMS(R)S packet data service, it shall provide a connectivity notification (CN) function.

4.7.3 Voice service interfaces

TBC
APPENDIX B: Original Contributions of the NEXUS partners

Appendix B1: Input from EADS ASTRIUM for section 4.1 Definitions

4.1 DEFINITIONS

**Reading key:** Definitions entitled in blue bold are intended to be used as parameters to define the classes of performances.

**4D Trajectory:** The 4D trajectory is:
- The lateral path consisting of route waypoints, and
- The vertical path consisting of the predicted altitude and vertical constraints, if any, at each of the waypoints forming the lateral path, and
- The predicted speed and speed constraints, if any, at each of the waypoints forming the lateral path, and
- The predicted time and time constraints, if any, at each of the waypoints forming the lateral path.

**Comment:** Definition above taken from PU-10 SPR, Chapter 1

**Availability** The probability that an operational communication transaction can be initiated when needed (ICAO doc 9869).

**Availability of use:** The probability that the communication system between the two parties is in service when it is needed.

**Availability of provision:** The probability that communication with all aircraft in the area is in service.

**Comment:** Two definitions above taken from COCRv2

**Availability Ratio** defined by the following ratio \(\frac{\text{Observation Time} - \text{Total Outage Time}}{\text{Observation Time}}\), with “Observation Time” being defined as the duration of the measurement period, and “Total Outage Time” being defined as the sum of the Service Outage Times over the Observation Time.

**Call processing delay:** The time delay for a GES (respectively, an AES) to present a call origination event to the terrestrial network interworking interface (respectively, to the AES interface) after a call origination event has arrived at the AES interface (respectively, at the terrestrial network interworking interface).

**Classes of Performance:** The following 3 classes of performance: A, B and C are defined for data and voice applications associated performance requirements.

- **Class A** corresponds to stringent performance requirements needed for the support of 4D trajectory services. Refer to section 4.6.4.1 for a detailed description of this class.

- **Class B** corresponds to medium performance requirements needed for the support of the services defined in the Data Communications Safety and Performance Requirements (SPR) documents (EUROCAE/RTCA WG78/SC-214). Refer to section 4.6.4.2 for a detailed description of this class.

- **Class C** corresponds to performance requirements inherited from AMS(R)S SARPs (Edition, date) and intended for systems compliant with these SARPs but not compliant with Class B nor Class A levels of performances. Refer to section 4.6.4.3 for a detailed description of this class.
CLASS OF SERVICE (CoS) : A CoS is an attribute that is associated with an application transaction in order to notify the communication system with the Quality of Service required by the transaction.

Multi Link CoS (ML CoS): for the ATS services/application that are the most critical in terms of safety impact, thus could require a configuration with multiple data links to meet the performance targets.

Medium CoS (MD CoS): for the remaining ATS services/applications.


Communication Expiration Time (ET) The maximum time for the completion of the operational communication transaction after which the initiator should revert to an alternative procedure (ICAO doc 9869).

Connection Establishment Delay. Connection establishment delay, as defined in ISO 8348, includes a component, attributable to the called subnetwork (SN) service user, which is the time between the SN-CONNECT indication and the SN-CONNECT response. This user component is due to actions outside the boundaries of the satellite subnetwork and is therefore excluded from the AMS(R)S specifications.

Continuity of Service. specified performance (assuming the system was available when the transaction is initiated). The value for the continuity parameter is based on the acceptable probability of detected anomalous behaviours of the communication transaction. Detected anomalous behaviours include, but are not limited to (ICAO RCP Manual):

- Late transactions;
- Lost messages or transactions that cannot be recovered within the expiration time
- Duplicate messages or transactions that are forwarded and/or used; and
- Uncorrected detected message errors

Data Transfer Delay requirements are set by the need to assure that data link messages are delivered through the communications system in a timely manner. The measured transfer delay characteristics of a subnetwork and its elements are normally characterized by data which, plotted as a histogram, appear as an probability distribution having a biased offset (latency) from the zero value. The DO270 expresses three different values of transfer delay the latency, the mean value (transit delay) and the 95th-percentile value. These values are the minimum necessary to combine properly the delay data of individual elements, systems and subnetworks for aggregated delay values (e.g., for "end-through-end" delays). (RTCA DO 270).

Data Transfer Delay (95th percentile). The 95th percentile of the statistical distribution of delays for which transit delay is the average. This means a 95% of the messages sent must be received within this delay.

Transfer Delay is a measure of the time required for an information element to be transferred in one direction between the reference Points B and C of Figure 2-1, on a first-bit-in to last-bit-out basis. The Transfer Delay of a given block of data across an air/ground communications subnetwork depends on:

1. The length, type and priority of that block and all other blocks that constitute the instantaneous user traffic loading of the subnetwork -- the Traffic Model.
2. The subnetwork's throughput characteristics which are basically determined by its architecture, protocols, and the characteristics of its RF and Physical layer channel(s) — the Subnetwork Model.

Notes:
1. A number of the factors determining these characteristics are interdependent and can be different for the two directions of traffic flow (to-AES and from-AES).
2. It is assumed that an air/ground subnetwork's transfer delay characteristics will be established via high-fidelity simulations and/or analyses because fullscale measurements across the subnetwork under the various conditions are impracticable. The transfer delay verification procedures of Section 4 utilize certain subnetwork measurements intended to validate the simulations and/ or analysis.[RTCA DO-270 Section 2.2.5.1 Transfer Delay]
Data Transfer Latency of the AMS(R)S System is defined under conditions of no user traffic loading other than the test block itself; however, normal system management traffic and protocol overhead traffic are expected to be present, due to management entities internal to the subnetwork. Thus, latency is the minimum delay that can be expected within the system, and accounts for the relatively fixed delay components such as propagation delay, component transmission speeds, and latent buffering. [RTCA DO-270 Section 2.2.5.1.4]

Data Transit Delay. In packet data system, the elapsed time between a request to transmit an assembled data packet and an indication at the receiving end that the corresponding packet has been received and is ready to be used.

Integrity. In accordance with DO-264, it is the acceptable rate of transactions that are completed with an undetected error. Undetected errors include, but are not limited to (ICAO RCP Manual):

- Undetected corruption of one or more messages within the transaction;
- Undetected misdirection of one or more messages within the transaction;
- Undetected delivery of message in an order that was not intended;
- Undetected delivery of a message after the communication

Integrity is the ability to guarantee that the information being transported through the communications means arrives exactly as it was sent.

Comment: Definition above is suggested by ESA with original definition taken from COCRv2

Multi-User Service Outage: A Service Outage simultaneously affecting multiple users within a defined service volume.

Network (N). The word “network” and its abbreviation “N” in ISO 8348 are replaced by the word “subnetwork” and its abbreviation “SN”, respectively, wherever they appear in relation to the subnetwork layer packet data performance.

Operational Communication Transaction The process a human uses to send an instruction, a clearance, a flight information, and/or a request. The procedure is completed when that human is confident that the transaction is complete (ICAO doc 9869).

Pre-emptive access. An access technique which allows the termination without warning of the transmission of lower priority messages to let higher priority messages be transmitted.

Priority Access: An access technique which requires each message to be given a level of priority depending on the data transfer delay requirement associated with the service.

Required Communication Performance (RCP). A statement of the performance requirements for operational communication in support of specific ATM functions. (ICAO).

RCP. A statement of the performance requirements for operational communication in support of specific ATM functions (ICAO doc 9869)

RCP Type. A label (e.g. RCP 240) that represents the values assigned to RCP parameters for communication transaction time, continuity, availability and integrity.

Required Communication Technical Performance (RCTP). The portion of the (intervention) transaction time that does not include the human times for message composition, operational response, and recognition of the operational response.

RCTP. The symbol used to designate required communication technical performance.

RCTP_{CSP}. The summed critical transit times for an ATC intervention message and a response message, allocated to the CSP system.

Residual Error Rate. The ratio of incorrect, lost and duplicate subnetwork service data units (SNSDUs) to the total number of SNSDUs that were sent.
**Service Outage Time:** The time the service is not meeting a specified performance of Quality of Service. RTCA DO-270 considers two types of outages:

- Single-User Service Outage
- Multiple-User Service Outage

**Single-User Service Outage** A Service Outage affecting any single user aircraft within a defined service volume.

**Spot Beam.** Satellite antenna directivity whose main lobe encompasses significantly less than the earth’s surface that is within line-of-sight view of the satellite. May be designed so as to improve system resource efficiency with respect to geographical distribution of user earth stations.

**SubNetwork (SN).** See **Network (N).**

**SubNetwork Service Data Unit (SNSDU).** An amount of subnetwork user data, the identity of which is preserved from one end of a subnetwork connection to the other.

**Susceptibility** The cumulative relative change in its noise temperature due to interferences a receiver can tolerate.

**Total Voice Transfer Delay.** The elapsed time commencing at the instant that speech is presented to the AES or GES and concluding at the instant that the speech enters the interconnecting network of the counterpart GES or AES. This delay includes vocoder processing time, physical layer delay, RF propagation delay and any other delays within an AMS(R)S subnetwork.

*Note.*— The following terms used in this chapter are defined in Annex 10 as follows:

- Aeronautical telecommunication network (ATN): Volume III, Chapter 1.
- Aeronautical mobile-satellite (route) service (AMS(R)S): Volume II, Chapter 1.1.
- Aircraft earth station (AES): Volume III, Chapter 1.
- Ground earth station (GES): Volume III, Chapter 1.
- Subnetwork layer: Volume III, Chapter 6.1.

**Transaction:** a two-way operational communication process (e.g., Controller and pilot, pilot and pilot, or Controller and Controller). It contains the outgoing request message, the Controller or pilot response time and the incoming response message. Communications exchanges that have multiple responses, i.e., the STANDBY, followed by the operational response, are treated as two transactions. (DO-264)

**Comment: Definition above taken from COCRv2**

**Transaction time.** the time needed by a pilot and a Controller to exchange a pair of messages. This time represents the sum of the delivery time of incoming and outgoing messages and the Controller or pilot response time.

**Voice Access Delay** The one-way user-to-user delay starting with the voice initiation event (e.g. Push-To-Talk signal event) and ending with audio appearing at the remote end of the link, but excluding any human response times (COCR v2.0).

**Voice Channel Setup Delay** Time needed by the system to establish a path between users, prerequisite for voice access and communications (COCR v2.0).

**Voice Latency** The one-way user-to-user between analogue system interfaces (HMIs) after the audio path has already been established (COCR v2.0).
Appendix B2: Input from TAS-I for section 4.5 Signal Acquisition and Tracking

Section 4.5 SIGNAL ACQUISITION AND TRACKING

“4.5.1 The AES, GES and satellites shall properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 1 800 km/h (972 knots) along any heading.”

Replace yellow text with “From 1 500 Km/h to 1 800 Km/h”.

“4.5.1.1 Recommendation.— The AES, GES and satellites should properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 3 000 km/h (1 600 knots) along any heading.”

Replace yellow text with “From 2 800 km/h to 3 000 km/h”.

Add new recommendation:

4.5.1.2 Recommendation.— The AES, GES and non GEO satellites should properly acquire and track service link signals with a relative speed implying a Doppler Shift of ± 60 kHz at the maximum uplink carrier frequency (L band) along any heading.

Since the speed figures are referred to a ground speed considerably lower than the non-GEO satellite speed, we propose the following note to this recommendation:

Note: the ground speed for the AES acquisition and tracking of the satellite signal has to be considered only for GEO satellites. In case of non GEO satellites, the AES and GES acquisition and tracking of the satellite signal shall consider a relative speed of a maximum of 30 000 km/h (i.e. LEO constellation).

Justification

Speed values have been selected thank to some considerations on the aircraft technology trends for the civil market (business, passengers and cargo) and also considering a possible provision of the service to the military context.

Currently, civil aircraft fly at a speed less than 1000 Km/h (620 mph) as the Airbus 300, Boeing 747 that can fly up to 988 Km/h (613 mph).

In the recent past few supersonic civil aircrafts have been designed and operative, i.e. the Air Concorde flying at maximum speed of 2179 Km/h (1351 mph) or 2.05 mach and the Tupolev TU-144 flying at a maximum speed of 2500 Km/h (1550 mph) or 2.35 mach. These supersonic aircrafts have been withdrawn due to the high noise pollution.

Current trends in the aircraft market for the next future foresee the supersonic technology applied in the business jet aircrafts. Aircrafts as the Aerion Supersonic Business Jet will fly at speed up to 1 840 km/h (1116 mph) or 1.5 mach.

Today these speed values are considered and superseded in the military air traffic where it is possible to reach a speed up to 2.5 mach.

Starting from the above technological considerations, a main issue arises about the Signal Acquisition and Tracking related to the Non-GEO constellation (MEO, LEO, HEO) serving northern and polar areas. Indeed the SATCOM Operational concept is investigating the service provision in these areas.

In this case the system shall be able to handle large Doppler shift. Doppler shift is function of the relative speed of AES, Satellite and their angle of view and trajectories (and also frequency).

This phenomenon is more evident in case of non-GEO constellation where the satellites have a high relative speed respect to the ground.

A HEO constellation is foreseen to cover the north and polar area and LEO is the Non-GEO Satellite with the highest tangential velocity (28000 km/h).

Considering the Minimum elevation angle for satellite coverage of 5 deg, we can consider as worst case the nominal AES speed. The satellite’s relative speed depends from the angle between the component in line of sight (LoS) and the tangential velocity vector. Of course with a good constellation's design the minimum “angle LoS” may increase then the satellite’s maximum relative velocity decreases.

However a more robust system is suitable in order to face an event of a significant malfunction failure. As worst case a cumulative relative velocity is around 30000 km/h.

Under this condition the maximum uplink carrier frequency (L band) Doppler Shift is ±60 kHz.

The following figure shows the relationship between the Doppler Shift and the aircraft’s elevation angle.
Appendix B3: Input from Telespazio for section 4.6.1 Designated Operational Coverage

Section 4.6.1 Designated Operational Coverage

4.6.1.1 An AMS(R)S system shall provide Aeronautical Communication Services throughout its designated operational coverage (DOC).

4.6.1.2 An AMS(R)S system shall provide AMS(R)S as a primary means of communications in Oceanic, Remote and Polar areas of the designated operational coverage (DOC) for the classes of performances it corresponds to, namely either class A or B or C.

4.6.1.3 An AMS(R)S system ensuring class B performance shall provide the performance required for being used as supplemental means of communications for en-route (ENR) airspace and for Terminal Manoeuvre Area (TMA) airspace of the designated operational coverage (DOC).

4.6.1.4 An AMS(R)S system ensuring class A performance can be used as primary data link communication system of a multilink operation concept in communications for en-route (ENR) and Terminal Manoeuvre Area (TMA) of the designated operational coverage (DOC).

4.6.1.5 An AMS(R)S system ensuring class A performance shall provide the performance required for being used as in Stand Alone as primary means of communications for en-route (ENR) or for Terminal Manoeuvre Area (TMA) of the designated operational coverage (DOC).
Appendix B4: Input from ENAIRE for section 4.6.4.2 Performance requirements for Class B

4.6.4.2 Class of performance B Performance

4.6.4.2.0.1 An AMS(R)S system compliant with the class of performance B shall be a technical enabler for all modules within the ICAO Aviation System Block Upgrades1 and 2 concerning the A/G Data-Link services being standardized in ED 228/DO 350.

Note 1: Initial Operating Capability (IOC) dates for Blocks 1 and 2 are foreseen by 2018 and 2023 respectively.

4.6.4.2.0.2 An AMS(R)S system compliant with the class of performance B shall allow to:

i. Support the operational concepts defined in the ICAO Blocks 1 and 2 that relied on the A/G Data-Link services being standardized in EUROCAE ED 228/DO 350.

ii. Offer additional capacity to complement terrestrial infrastructure (e.g. VDL mode 2) in terms of total communication bandwidth and alleviate congestion of other bands in the spectrum.

iii. Extend the geographical coverage of the terrestrial infrastructure mainly to ORP areas.

4.6.4.2.1 Class B packet data service performance

4.6.4.2.1.1 An AMS(R)S system compliant with the class of performance B shall meet the following performance requirements for safety of life services:

<table>
<thead>
<tr>
<th>Continental Airspace Domain (APT, TMA, ENR-1)</th>
<th>RCTP&lt;sub&gt;AG&lt;/sub&gt;</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Service</td>
<td>Latency</td>
<td>Continuity</td>
</tr>
<tr>
<td>Class B Safety_1</td>
<td>4.7</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>11.9</td>
<td>0.99975</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oceanic and Remote Airspace Domain (ENR-2)</th>
<th>RCTP&lt;sub&gt;AG&lt;/sub&gt;</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of Service</td>
<td>Latency</td>
<td>Continuity</td>
</tr>
<tr>
<td>Class B Safety_2</td>
<td>49</td>
<td>0.999</td>
</tr>
<tr>
<td>Class B Safety_3</td>
<td>119</td>
<td>0.999</td>
</tr>
<tr>
<td>Class B Safety_4</td>
<td>83</td>
<td>0.999</td>
</tr>
<tr>
<td>Class B Safety_5</td>
<td>269</td>
<td>0.999</td>
</tr>
</tbody>
</table>

Table 6.- Safety Class B services for Continental Airspace Domain (APT, TMA, ENR-1).

Table 7.- Safety Class B services for Oceanic and Remote Airspace Domain (ENR-2).

Note 1: The boundaries of the SATCOM domain (Air/Ground) can be defined as follows:

- From physical point of view, between A/G router in Ground Domain to airborne router on-board the

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Appendix B

APPENDIX B: NEXUS PARTNERS INITIAL CONTRIBUTIONS

The aircraft. The performance contributions associated with the A/G router are excluded from the SATCOM domain allocated performance.

- From logical point of view, at the boundary between the internetworking and intranetworking layers of the reference protocol stack.

The SATCOM domain is equivalent to the portion of the ACSP domain (as considered by the ED228/DO350) allocated to the Air/Ground side.

Note2: According to the ED228/DO350, the performance allocation for Latency to the SATCOM assumes that the component delays are distributed independently and log-normally with a probability density distribution of the sum of independent lognormal random variables. (see attachment 0.4 – section 4.1.1). This assumption is only applicable to continental airspace (i.e. APT, TMA and ENR-1) whereas for oceanic airspace (i.e. ENR-2) the rationale provided in the GOLD is still valuable where technical delays follow an arithmetic summation to give the RCTP value.

Note3: The latency values are specified for one-way transaction (i.e. RCTP_{1W} value for the one-way or transfer transaction). The RCTP_{1W} values are set equal to half the statistical sum of the RCTP_{2W} values for each segment (see attachment 0.4 – section 4.1.1).

Note4: As assumption for setting the performances allocation to G/G segment, PENS has been considered as the G/G segment. The G/G segment-allocated values have been set to 500 ms for Class B Safety_1 and to 1 s for the remaining ones. These figures are based on the current Service Level Agreement for PENS (see attachment 0.4 – section 4.1.3).

The A/G segment-allocated values figures have been worked out as the points containing in the assumed distribution taking into account the aforementioned G/G segment-allocated values (see attachment 0.4 – section 4.1.2).

Note5: According to ED228/DO350, the performance allocation for Continuity assumes a 99.9% value for all A/G Data-Link services (see attachment 0.4 – section 4.3).

Note6: According to ED228/DO350, the performance allocation for Availability assumes an equalled allocation to both A/G and G/G segments (see attachment 0.4 – section 4.2).

Note7: According to the EO228/DO350ED228/DO350, there is no allocation of Integrity to the SATCOM as the requirement is wholly satisfied by the end-to-end mechanism (Protected Mode) in the aircraft and the ATS. However ED228/DO350 notes that in formulating contract terms with the ACSP, the ATSP and/or operator may specify an integrity value and other related criteria (e.g. residual error rate), as appropriate, for the network, including subnetworks, that will ensure acceptable data integrity, consistent with the assumptions used to define the end system provisions, e.g. CRC or Fletcher’s checksum (see attachment 0.4 – section 4.4).

Note8: FIS application has been removed from ED228/DO350 work. The removal of FIS application from Class B definition does not preclude from supporting those FIS services relying on ATN and targeting the same timeframe as Class B (e.g. D-OTIS) by a Satellite Communication system in compliance with Class B as long as the bandwidth demanded by FIS services is supported. This is because FIS services are expected to be less performance demanding (except for bandwidth) than the services covered in ATN-Baseline 2. The main reason why FIS application is considered out of scope of ED228/DO350 are as follows:

- Other groups, notably RTCA SC-206, actively defining FIS services are on a different publication schedule than ED228/DO350 (for instance the newer services (D-HZWX and D-RVR) are still under development without foreseen operational validation activities)

- Low need for integration with other cockpit systems (e.g. FMS) whereas ATS applications in the scope of ED228/DO350 (CM, CPDLC and ADS-C) all involve interactions with the FMS (or other cockpit systems)

- There is not the same need for processing rules as CPDLC, then FIS services are better suited to be defined in a document that takes this need for flexibility into consideration

4.6.4.2.1.2 An AMS(R)S system compliant with the class of performance B shall meet the following performance requirements for regularity and non-safety of life services:

Appendix B 8
### Continental Airspace Domain (APT, TMA, ENR-1)

<table>
<thead>
<tr>
<th>Class of Service</th>
<th>Latency 95%</th>
<th>Continuity</th>
<th>Availability (provision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B Best Effort _1</td>
<td>4.7</td>
<td>N/A</td>
<td>0.99975</td>
</tr>
</tbody>
</table>

#### Table 8.- Best Effort Class B services for Continental Airspace Domain (APT, TMA, ENR-1).

### Oceanic and Remote Airspace Domain (ENR-2)

<table>
<thead>
<tr>
<th>Class of Service</th>
<th>Latency 95%</th>
<th>Continuity</th>
<th>Availability (provision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B Best Effort _2</td>
<td>49</td>
<td>N/A</td>
<td>Efficiency: 0.99995 Safety: 0.9995</td>
</tr>
<tr>
<td>Class B Best Effort _3</td>
<td>119</td>
<td>N/A</td>
<td>Efficiency: N/A Safety: 0.9995</td>
</tr>
<tr>
<td>Class B Best Effort _4</td>
<td>83</td>
<td>N/A</td>
<td>Efficiency: 0.99995 Safety: 0.9995</td>
</tr>
<tr>
<td>Class B Best Effort _5</td>
<td>269</td>
<td>N/A</td>
<td>Efficiency: N/A Safety: 0.9995</td>
</tr>
</tbody>
</table>

#### Table 9.- Best Effort Class B services for Oceanic and Remote Airspace Domain (ENR-2).

**Note 1:** When the safety analysis does not require the definition of a continuity value and an expiration time, this datalink service is considered as a best effort service. Non-safety of life services (e.g. AOC) are considered as best effort (see attachment 0.4 – section 5.2).

### Guidance Material in support of section 4.6.4.2

#### 1 Assumptions

The main assumptions for the allocation approach used in the performance allocation to A/G segment are:

- The approach for Class of Performance B is based on the work currently being undertaken by WG78/SC214 that has been tasked with the standardization of the advanced A/G Data-Link services for both continental (namely APT, TMA and ENR-1) and Oceanic, Remote & Polar (namely OPR and known as ENR-2) domestic airspaces. These standards are intended to provide a viable migration path from the early data communication operations to the advanced TBO supported by ATN B2 to enable Europe and US to converge position on Data-Link Services. According to the European ATM Master Plan these advanced A/G Data-Link services correspond to the medium term Air/Ground Data-Link services for SESAR Step 1 and map to ICAO Blocks 1 and 2.

- The COCR study in its Phase 1 also addresses the definition of medium term Air/Ground Data-Link services, but this work does not seem so aligned with the concepts being defined under SESAR and NextGen.
2 Allocation Approach for ATC services (Tables 1 and 2)

2.1 Latency

2.1.1 Rationale

The Performance Assessment for Latency herein used assumes that the component delays are distributed independently and log-normally with a probability density distribution of the sum of independent lognormal random variables.

The rationale for using a lognormal distribution in the quantitative transaction time allocation process is the following:

- It is the statistical allocation used by WG78/SC214 having replaced the exponential distribution by lognormal in the time allocation process as the latter has the following advantages over the former:
  - Higher accuracy. Since lognormal distribution is a two-parameter function while exponential distribution is a single-parameter function, lognormal distribution has more flexibility to model real measurement data. Therefore, use of lognormal distribution will increase the requirement accuracy; and
  - Simple computation. The distribution of the sum of lognormal random variables can be simply computed using a closed-form formula.

- It is a distribution that allows to calculate delay performances by means of well-defined mathematical calculations that facilitate the quantitative analysis which produces the assigned allocations.

- This statistical allocation relies on the assumption that component delays are independent, e.g., a long delay in one element is not likely to coincide with a long delay in the next element resulting in larger allocated element delays that will be more practical to achieve without impacting the overall transaction time requirement.

The Performance Assessment is relied on the following allocation approach:

- The latency specification highly depends on the complexity and size of the message used for each Data-Link Application transaction. In all the concerned cases it is possible to simplify this specification assuming an arithmetic halving for the uplink and downlink delays. This assumption allows to specify the latency for one-way transition i.e. per message. Herein an analysis of each case is provided along with the type of transaction used for the latency specification:
  - For CPDLC, all the RCP-types are specified for the exchange transactions (one opening message in the forward direction and one closing response message in the return direction) taking the most common message size i.e. 2Kbytes as basis for the performance assessment. For timing allocations to downlink and uplink an arithmetic halving can be assumed so that the latency allocated to uplink and downlink is ½ of the values specified for the exchange transaction. Concluding that the delays for all CPDLC cases can be specified per message (i.e. one-way transaction).
  - For ADS-C the RSP180 and 400 are specified for transfer transactions (one message in the forward direction i.e. Next periodic/event report) whereas the RSP120 is specified for exchange transition (one opening message in the forward direction and one closing response message in the return direction i.e. ADS-C request and Single/1st Periodic/Baseline report). For all of the cases a 2Kbyte EPP report, containing the basic data and EPP data of 20 waypoints, is taken as basis for the performance assessment. For the single/1st periodic/Baseline reports (i.e. the only case of ADS-C exchange transaction), an arithmetic halving can be assumed for the uplink and downlink delays. Concluding that the delays for all ADS-C cases can be specified per message (one-way transaction).
  - The RCTP values derived for the ACSP domain by the WG78/SC214 have been statistically allocated to the two following segments assuming a lognormal PDF:
    - A/G segment i.e. the boundaries correspond to the FRS as defined by the COCRv2.
    - G/G segment (i.e. from G/G router interfacing with the ATSU domain to A/G router in the ACSP domain).

- The figures allocated to G/G segment have been set to values established empirically as explained in section 2.1.3. From these G/G segment-allocated values the figures allocated to A/G segment have been worked out as the points containing in the assumed statistical distribution so as to fit such a distribution. Therefore taking into account the aforementioned approach, the applicable formulas are the following:

\[ Lognormal probability density function (pdf) : [1] \]
\[ Cumulative distribution function (cdf) : [2] \]

[3]
Since \( T \) is log-normally distributed, then \( \ln(T) \) is normally distributed. The normal distribution parameters and are actually the arithmetic mean and variance of \( \ln(T) \), i.e.:

\[ \text{E}(Z) \]

where \( \text{E}(Z) \) is the expected value of the random variable \( Z \), and \( \text{Var}(Z) \) is the variance of random variable \( Z \).

The expected value of a random variable (RV) is actually the mean or average of the random variable. The variance of a RV is the mean of the squared deviation of that RV from its expected value or average.

The arithmetic mean and variance of the lognormal random variable \( T \) are:

\[ \text{E}(Z) \]

The lognormal distribution parameters and can be obtained from its arithmetic mean and variance by:

\[ \text{E}(Z) \]

Since the performance requirements are specified in two percentiles, i.e. 99.9th and 95th percentiles and the lognormal distribution is a two-parameter function, then it can exactly match these two percentiles.

For a log-normally distributed random variable, if the ( \( m \))-th percentile is \( \bar{p} \), and the ( \( m \)) -th percentile is \( \bar{p} \), from the lognormal quartile function, we have the following equations:

\[ \text{E}(Z) \]

Solving the above equations, we get the corresponding lognormal distribution parameters and as:

\[ \text{E}(Z) \]

Given and , the above equation becomes:

\[ \text{E}(Z) \]

Let be independent lognormally distributed random variables, i.e., The arithmetic mean and variance of each lognormal RV are:

\[ \text{E}(Z) \]

Let random variable be the sum of the independent lognormal distributed random variables, i.e.,

\[ \text{E}(Z) \]

In order to compute the distribution function of random variable, it is commonly assumed that the sum of independent lognormal RVs can be approximated as another lognormal RV, i.e., by matching mean and variance.

For the sum of independent random variables, the mean of the sum equals the sum of means of the individual RVs, and the variance of the sum equals the sum of variances of the individual RVs, i.e.,

\[ \text{E}(Z) \]

The lognormal distribution parameters of RV \( Y \) can be obtained by:

\[ \text{E}(Z) \]

Substituting Equations (10) and (12) into the Equation (13) yields:

\[ \text{E}(Z) \]

Equation (14) is the closed-form formula for computing the distribution of the sum of lognormal random variables, which can be used for quantitative performance requirement allocation.

### 2.1.2 Calculations

The Latency allocated to A/G segment is worked out using the formulas shown from [1] to [14] in the following way:

1. Taking and from values derived by WG78/SC214,
2. Working out the lognormal distribution parameters and using [9]
3. Working out the lognormal distribution parameters and using [10]
4. Setting and to the empirical values as explained in section 2.1.3,
5. Working out lognormal distribution parameters and using [9],
6. Working out the lognormal distribution parameters and using [10],
8. Working out lognormal distribution parameters and using [10] as follows:
9. Working out and using [9], as follows:

### 2.1.3 Estimation of figures allocated to Ground/Ground Segment

In the particular case of the SATCOM, we can assume that the total one-way delay for the G/G side will consist of the addition of two terms: one for the core network (i.e. PENS) and the other one for the access line (i.e. PENS-GES).

In the context of SESAR, performance requirements for the Ground/Ground segment are being defined so as to support the services envisaged in the medium and long term. More precisely such a Ground/Ground segment corresponds to the PENS that is the underlying IP-based network devoted to be the future ground-ground backbone of the new EATMN.

The requirements to be included within the Service Level Agreement (SLA) that shall be met by the PENS are currently being specified, so as to support the new services being defined in SESAR. According to that Service Level Agreement, the maximum Network Round Trip for PENS has been established to the value of 300 ms (so the maximum one-way delay could be assumed 150 ms).

For the specific case of SATCOM, the access line from the GES to the PENS can be considered as the bottleneck in the Ground/Ground domain. Two different factors mainly determine the impact of the access line on the total latency: on the one hand the throughput and on the other hand the distance/hops from the GES to the nearest PENS node.
Due to the number of heterogeneous networks existing nowadays it is hard to derive figures for the G/G segment. According to the current state of art of the G/G networks and the expected evolution in the coming years, the following one-way delay values (TT 95%) have been deemed justified and feasible in order to cover the most disadvantageous scenarios in the medium term:
- 500 ms for the most restrictive classes of service
- 1 s for the other classes of service

2.2 Availability

2.2.1 Rationale

The Performance Assessment for Availability herein used assumes the same rationale followed in WG78/SC214 for the availability calculation:

- Availability of provision is evaluated only over the ATSU and ACSP. Hence, APROVISION = AATSU X AACSP
- As both services must be equally available, the requirement may be simply allocated equally to both ATSU and ACSP i.e. AACSP = AATSU = A(PROVISION)

The applicability to availability allocation to A/G and G/G segments is a matter of judgment and should also take into account the impact of a particular allocation. For example, for an A/G, the issue is about whether single, dual or even triple coverage is required. The A/G allocation may be adjusted to avoid “pushing” the A/G into the next higher category when a small increase in the G/G availability would also achieve the same effect. However as a general approach and applying the aforementioned rationale used in WG78/SC214 for ATSU and ACSP, it makes sense to follow the same approach, i.e. assuming a 50% error contribution of both A/G and G/G segments to the Availability allocated to ACSP domain.

According to WG78/SC214, AACSP and AATSU are derived from the formula:
Where:
“Planned Hours of Operation” are specified by the ATSU and are evaluated on an operational sector hour basis. Usually, “Planned hours of Operation” for systems are based on 24 x 7 operation.

“Maximum accumulated unplanned outage time (min/year)” is the maximum time of the sum of unplanned service outage durations over a period of time (i.e. 1 year). Hence over a 12-month period, it is measured in minutes /year by accumulating only the duration times for unplanned service outages greater than the unplanned service outage duration limit during any 12-month period. The accumulation is performed separately for each relevant operational airspace or FIR.

Concerning unplanned service outages for the ATSU and ACSP, the following four parameters are relevant:
- Unplanned service outage duration (min)
- Maximum number of unplanned service outages
- Maximum accumulated unplanned service outage time (min/yr)
- Unplanned service outage notification delay (min)

On the other hand the availability value specification is aligned with GOLD so as to smooth the integration of performances within Polar, Oceanic & Remote airspace domain. GOLD specifies APROVISION distinguishing between safety and efficiency wherever it has been determined to be beneficial (e.g. Polar, Oceanic & Remote domain). Then the specification of APROVISION for the environment ENR-2 indicates the distinction between safety and efficiency when applicable.

2.2.2 Calculations

Following the rationale explained above the applicable formula for availability allocated to A/G segment is worked out as follows:
AAG = AGG = ACSP A where AACSP = AAG X AGG

2.3 Continuity

2.3.1 Rationale

In WG78/SC214, continuity denotes the probability that a transaction is completed within the expiration time i.e. latency as referred to herein. As stated in WG78/SC214, there are system (e.g. congestion, normal packet errors/drops or system failure) and human contributors to continuity failure. It is assumed that the dominant form of failure in meeting continuity is the congestion and normal packet errors/drops. Therefore, continuity may remain fixed over all components when using the statistical distribution so the allocation to each component is made purely by the time.

Regarding the unit in which continuity is expressed, since neither Continuity nor its corresponding latency alone can be seen separately but as combination of both, they are specified in the same unit. Then if latency is expressed in either one-way or two-way transactions, then the corresponding continuity for such latency will refer to the percentile of succeeded one-way or two-way transactions respectively within the concerned latency.

2.3.2 Calculations
In the WG78/SC214, the 99.9% value is set as the Continuity figure for all medium term A/G Data-Link services. This means the latency corresponding to all A/G Data-Link services can be exceeded at most once for one thousand invocations of the transaction.

2.4 Integrity
2.4.1 Rationale
According to the WG78/SC214, there is no allocation of Integrity to the SATCOM as the requirement is wholly satisfied by the end-to-end mechanism (Protected Mode) in the aircraft and ATSU. However WG78/SC214 notes that in formulating contract terms with the ACSP, the ATSP and/or operator may specify an integrity value and other related criteria (e.g. residual error rate), as appropriate, for the network, including subnetworks, that will ensure acceptable data integrity, consistent with the assumptions used to define the end system provisions, e.g. CRC or Fletcher’s checksum.

2.4.2 Calculations
N/A.

3 Allocation Approach for non-safety of life services
3.1 Rationale
Best-effort classes of service only provide requirements for latency (TT 95%)

4. Class of performance B requirements
4.1 Class of performance B (safety of life services)
Table 1 and 2 above show the assignment of RCP and RSP types to the different safety applications / services as proposed by the WG78/SC214.

4.2 Class of performance B (non-safety of life services)
When the safety analysis does not require the definition of a continuity value and an expiration time, this datalink service is considered as a best effort service. Non-safety of life services (e.g. AOC) are considered as best effort. In this case the objective is to comply with the TT 95% parameter in nominal conditions and to provide best effort in case of increased link loading. Therefore, best effort classes of service, shown on Tables 3 and 4 above, only provide requirements for latency (TT 95%) and availability based on the results derived from the classes of service defined for safety of life services:

5 Definitions
5.1 Environmental Types and Characteristics
The airspace environments used by WG78/SC214 as the basis for assessing and establishing operational, safety, performance requirements are the following four airspace definitions:

- APT (Airport): The APT airspace consists the airport surface and immediate vicinity around the airport, typically an area 10 miles in diameter and up to ~5000’ above ground level (agl).
- TMA (Terminal Maneuvering Area): TMA airspace is a volume of controlled airspace set up at the confluence of airways in the vicinity of one or more major airports to protect traffic climbing out from and descending into the airports. It is shaped like an upside down wedding cake, in that the layers gradually get larger. The typical separation minima in this airspace are 3NM, appropriate vertical and/or visual separation as required.
- ENR-1 (En-route): The ENR-1 airspace is a volume of controlled airspace that encloses the flight paths above and between airports where air traffic service in TMA is provided. Jet routes and airways are typically used to traverse the en-route airspace structure. The typical separation minima in this airspace are 3NM, 5NM, appropriate vertical and/or visual separation as required.
- ENR-2 (En-route): The ENR-2 airspace is a volume of controlled airspace that is characterized by the use of procedural control and the lack of ATS surveillance service. The airspace is typically characterized by the use of flex tracks and customized trajectories rather than the use of fixed jet routes and airways. The typical separation minima in this airspace are 100NM lateral, 1000ft (RVSM) as required.

Assumptions regarding aircraft capacity, flight duration, the number of aircraft a controller manages per hour and aircraft equipage rate for the four above airspaces is reflected in the following table. The purpose behind these assumptions is to quantify the amount of data messages to characterize controller/flight crew workload which is used for the safety and performance assessments used by WG78/SC214.
5.2 Transactions Types and Characteristics
WG78/SC124 identifies the following transition types:

1. Exchange transaction (two-way transitions)
This is an interaction between peer parties (an initiator and a responder) that includes two operational messages: one opening message in the forward direction and one closing response message in the return direction.

2. Extended transaction (two-way transitions)
This is an interaction between peer parties (an initiator and a responder) that includes three or more operational messages: one opening message in the forward direction, one or more interim response messages in the return direction, e.g., a standby or processing notification message, and one closing response message in the return direction.

3. Transfer transaction (one-way transition)
This is an interaction between peer parties (an initiator and a recipient) that includes one operational message: one message in the forward direction.

6 Recommendation
The NEXUS group is recommended to take note of the proposal included in this note and provide comments.

7 References
[1] Draft proposal for the AMS(R)S SARPS amendment - NEXUS WG - v0.6
[2] Required Communication Performance DOC 9869, ICAO
[4] Quality of Service Requirements - Project SESAR P15.2.4 ET (Task EWA03-T1-D1) – Ed 00.00.17, Sep 2011
[5] Classes of Service - Project SESAR P15.2.4 ET (Task EWA03-T1-D2) - Ed 00.00.10, Sep 2011
Appendix B5: Input from TAS-I for section 4.6.5 Handover

4.6.5 Handover

Note.— Two different kind of handover are foreseen for the ATM communication systems:
Intra-segment (between elements of the same AMS(R)S) and Inter-segment (between satellites belonging to different AMS(R)S, and between different ATM systems (i.e. satellite and terrestrial link)).
The intra-segment handover is addressed in the present SARP while the inter-segment handover is out of scope.

4.6.5.1 The AMS(R)S System shall assure handover\(^4\) procedures among different elements of the same SATCOM system and different regional systems using the same communication standard.

4.6.5.2 The AMS(R)S System shall support handovers within the System without service interruption or performance reduction caused by the System during and after the handover.

4.6.5.3 The AMS(R)S System shall ensure that the performance and safety requirements are identical before and after handover within the same airspace domain. Note 1

4.6.5.4 The AMS(R)S System shall be able to carry out handover procedures independently from any navigation systems. Note 2

4.6.5.5 No loss of communication shall be induced by a failure in the handover procedure

4.6.5.6 Recommendation.— The AMS(R)S communication standard should be designed to support handover (intra-segment handover) without service interruption.

4.6.5.7 Recommendation.— Any possible combination of the following handover scenarios should be supported:

- Handover between two channels assigned to the same GES
- Handover between two channels assigned to different GES
- Handover between two channels provided through different satellite antenna beams
- Handover between two channels provided through different satellites owned by the same satellite service provider
- Handover between channels provided through different satellites owned by different satellite service providers

Notes:

Note 1: A handover can happen also when an aircraft is changing airspace moving from one airspace to another one. If the second airspace has the same performance and safety requirements of the previous one, in this case the requirement is applicable. If the second airspace has different performance and safety requirements respect the previous one, the performance and safety requirements of the second airspace are requested.

Note 2: COM, NAV and SUR currently do not operate as an integrated whole for safety reasons. CNS domains separation ensures that if the NAV fails, aircraft are still capable of COM and SUR. For example if US DoD GPS navigation system will be not available for military reasons, communication datalink will be still available

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\(^4\) The requirement is limited to intra-segment (i.e. same communication standard used by different AMS(R)S (e.g. GEO, HEO, LEO).
Appendix B6: Input from INDRA for section 4.7 System Interfaces

4.7 SYSTEM INTERFACES (Review on Sections 4.7.1 and 4.7.2)

Review of Interface and Addressing Requirements

1 Introduction
This attachment is devoted to explain the approach used in the review of system interface (section 4.7 of [RD-1]) and packet data service interface requirements (section 4.7.2 of [RD-1]) and to reflect the conclusions from this analysis.

2 Assumptions
The Ground/Ground segment is assumed to be based on either ATN/IPS or ATN/OSI. Aspects related to multilink may have an impact on interface requirements. The current version of this document does not address this point, but it will be considered in future versions, once the multilink concept has reached a more mature status.

3 System Interfaces (§4.7, §4.7.1)
3.1 Analysis of existing requirement
The existing requirement establishes a link between the subnetwork link layer address and the ICAO 24-bit address. It does not depend on the network layer stack (IP or OSI) used above the link layer.

3.2 Proposal
It is proposed to keep the requirement as it is. However, the requirement may be revised or removed if it can be demonstrated that applications are already able to address aircraft unequivocally just by using the ICAO 24-bit address at application level.

4 Packet Data Service Interfaces (§4.7.2)
4.1 Analysis of existing requirements
The current specification refers to the ATN/OSI technical manual (sections 5.2.5 and section 5.7.2 of Doc 9880 [RD-3]), which defines the requirements for ATN/OSI mobile subnetworks. The specification should be extended / revised in order to consider also ATN/IPS. Requirements for ATN/OSI subnetworks identified in the sections indicated above address the following:
- Byte/code independence. Transparent transfer of ISO/IEC 8473 (CLNP) or ISO/IEC 9542 (ES-IS) data packets (§5.2.5.1.2, §5.7.2.1.4).
- Indication of the available QoS of the subnetwork, in order to support routing decisions (§5.2.5.1.3.1).
- Unequivocal identification of attached ATN routers (§5.2.5.1.4.1).
- Capability to perform internal routing between attached entities based on their subnetwork addresses (§5.2.5.1.5.1).
- If a subnetwork supports several priorities, invocation of required subnetwork priority (relative importance of data, used for prioritization) (§5.2.5.2.2.1).
- Recommendation: Invocation of required QoS (refers to transit delay, RER, cost,…) (§5.2.5.2.3.1).
- Support for a connection-oriented subnetwork (for all mobile subnetworks):
  - Well-defined start & end of a connection (§5.2.5.2.4.1).
  - Reliable, sequenced transfer of data packets (§5.2.5.2.4.1).
- Attachment on Interfaces and Addressing concerning Sections 4.7.1 and 4.7.2
  - Invocation of the QoS of the connection (if provided per connection) (§5.2.5.2.4.2).
  - Notification of connectivity changes (JOIN/LEAVE) (§5.2.5.2.5.1, §5.2.5.2.5.1.1, §5.2.5.2.5.1.2).
  - Minimum delay of a LEAVE event, according to supported ATSC class (§5.2.5.2.5.1.2.1).
- Recommendation to provide a capability for segmentation & reassembly (but requirement is not quantitative) (§5.2.5.2.6.1).

4.2 Review approach
The following documents are considered relevant for the review of packet data service interface requirements for IPS:
- Manual for the ATN using IPS Standards and Protocols (Doc 9896)
- RFC 2460 - Internet Protocol, Version 6 (IPv6) Specification
- RFC 3819 - Advice for Internet Subnetwork Designers
- RFC 4861 - Neighbor Discovery for IP version 6 (IPv6)
Moreover, the following additional documents are considered relevant for the specific review of addressing aspects:
- RFC 4291: IP Version 6 Addressing Architecture
- RFC 4862 - IPv6 Stateless Address Autoconfiguration (SLAAC)

Finally, review of IPv6 link layer specifications for existing subnetworks is considered useful, as for example:
- RFC 2464 - Transmission of IPv6 Packets over Ethernet Networks
- RFC 5121 - Transmission of IPv6 via the IPv6 Convergence Sublayer over IEEE 802.16 Networks

4.3 Analysis of ATN/IPS requirements placed on sub-networks
The IPv6 protocol stack as specified in the ATN/IPS manual [RD-1] is characterized by the following:
- IPv6 assumes that subnetworks transfer packets transparently between nodes.
- It requires that subnetworks mark the beginning and end of each variable-length asynchronous IP packet.
- IPv6 requires a minimum MTU of 1280 bytes (RFC 2460). RFC2460 recommends that subnetworks are configured with an MTU of 1500 octets or greater, to accommodate possible encapsulations (i.e., tunneling) without incurring IPv6-layer fragmentation.
- Multicast is a standard feature of IPv6, used for key protocols as address configuration and link-layer address discovery. Multicasting is considerably more efficient when a subnetwork explicitly supports it. In particular, multicast should also be properly supported from an addressing point of view (e.g., by supporting L2 address filters for multicast).
- In order to improve TCP performance, subnetworks shall minimize delay, delay variance, and packet loss as much as possible. As these parameters may be related, it is advisable that subnetwork designers provide as much flexibility as possible in the implementation of these mechanisms and provide access to them when defining QoS classes.
- In order to improve TCP performance, subnetwork implementers should try to avoid packet reordering whenever possible, but not if doing so compromises efficiency, impairs reliability, or increases average packet delay.
- Link-layer event notifications can help IP detect configuration changes (e.g., related to mobility) and complement network-layer indications. The link-layer events that are considered most useful are the link up events, link down events and, as indicated in RFC 3775, link-layer indications in case of L3 handovers.

Attachment on Interfaces and Addressing concerning Sections 4.7.1 and 4.7.2

- A subnetwork can offer multiple services (with different QoS guarantees) to the IP layer, which can then determine which flows use which subnet service. QoS in the ATN/IPS is based on the DiffServ model and requires support for EF (RFC 3246) and AF PHBs (RFC 2597).

IPv6 supports stateless (RFC 4862) and stateful (RFC 3315) address configuration methods. It requires a unique 64-bit interface identifier to form link-local addresses (with prefix FE80::/64) and statelessly auto-configured addresses. This identifier may either be automatically generated (e.g., from the link-layer address), obtained from a DHCPv6 server, automatically established randomly, or assigned manually.
- RFC4861 defines a Source/Target Link-layer Address option used in Router Solicitation, Router Advertisement, Neighbor Solicitation, Neighbor Advertisement and Redirect messages to support address resolution. This option is link specific.
- IPv6 headers may be compressed using the ROHC framework (RFC 4995, now RFC 5795). ROHC places a set of requirements on the underlying link layer.

This means that the following requirements are placed on a subnetwork and the associated system:
- It shall provide a framed interface capable of carrying asynchronous, variable-length IP datagrams.
- It shall transfer IP datagrams transparently from one node attached to the subnetwork to another.
- It shall support a MTU of 1280 bytes. It is recommended to support at least a MTU of 1500 bytes.
- If supported, it shall allow invocation of QoS / priority mechanisms. This may be done by directly inspecting the network and upper layer headers of the IPv6 packet to be transmitted.
- If Voice over IP services are supported, then it shall provide support for the implementation of the EF PHB, for example, by proper implementation of MAC priority and error control mechanisms.
- It shall provide support for the implementation of the AF PHB, with possibly several AF classes and drop precedences, for example, by proper implementation of MAC priority and error control mechanisms.
- It shall support link layer UP and DOWN events. It should also support link layer indications in case of a L3 handover.
- It shall provide support for the generation of a unique EUI-64 format based interface identifier based on the subnetwork link-layer address. Other methods for interface identifier generation (e.g., use of random interface identifiers, as defined in RFC4941) shall also be possible. The EUI-64 format based interface identifier might include the ICAO 24-bit aircraft ID.
- The link-layer specification shall specify length and content of the Source/Target Link-layer Address option used in Router Solicitation, Router Advertisement, Neighbor Solicitation, Neighbor Advertisement and Redirect messages transmitted over the subnetwork.
- If ROHC is supported, then the following applies to the subnetwork:
  - It shall provide a logical point-to-point channel between the IP interfaces of two communicating network elements.
  - It has to allocate one link-layer payload type for ROHC and be able to distinguish the ROHC packet boundaries.
  - It must provide the means to establish header compression channel parameters defined in section 5.1.2 of RFC 5795. This can be achieved through a negotiation mechanism, static provisioning, or some out-of-band signalling.
  - It shall not duplicate ROHC packets.
  - It is recommended that the subnetwork provides native support for multicast.

Attachment on Interfaces and Addressing concerning Sections 4.7.1 and 4.7.2
- It is recommended that the subnetwork avoids packet reordering.

4.4 Proposal
Section 4.7.2 of the SARPS shall be updated as follows:
If the system provides AMS(R)S packet data service, it shall provide an interface to the ATN/OSI, the ATN/IPS or both.

Note.- The detailed technical specifications related to provisions of the ATN/OSI-compliant subnetwork service are contained in Section 5.2.5 and Section 5.7.2 of Doc 9880 – Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN).


If the system provides AMS(R)S packet data service, it shall provide a connectivity notification function. It should be noted that, whereas section 5.2.5 of the ATN/OSI manual explicitly identifies the requirements for the subnetwork, Part I of ATN/IPS manual just references directly or indirectly the different RFCs that finally contain the requirements identified before. However, this should be enough from a requirement specification point of view.

5 Recommendation
The NEXUS group is recommended to take note of the proposal included in this note and provide comments.

6 References
[RD- 1] Draft proposal for the AMS(R)S SARPS amendment - NEXUS WG - v0.4
Security considerations – Material for section 4.6.6

The material for this section is an analysis provided by Rockwell Collins in relation to the security aspects for an IP based system. The issue of security and the security requirements that need to be supported is a wider issue in aviation as well as ICAO, and no final decisions have been taken. Therefore the material in this section is provided for further consideration.

Security

Goal: The goal of this section is to define a set of security standards and practices which can be applied to off-aircraft IP communications networks, including satellite communication systems, to produce a secure system.

Overview: Information Security is based on three primary attributes associated within the end-to-end communications channel: Integrity, Confidentiality and Availability.

These attributes are required to be extended throughout the entire network, and must be guaranteed both within the processing nodes, and across borders or interfaces. The security of the network as a whole, and all of its interfaces, must be considered in order to define & create a secure system. This of course is the concept that the chain is only as strong as its weakest link.

The scope of this document is to identify and secure the IP information network from the on board router through the off-aircraft communication terminal (e.g. Satcom) line replaceable unit (LRU).

Security Definitions-

Integrity: Integrity is the ability for the information being transported through the communications means that it is guaranteed to arrive exactly as it was sent. Any changes to the information, unintentional or otherwise, must be detectable so the end systems can disregard and resend the suspect packages. This is generally accomplished by using a data integrity solution at the application level. A key (CRC) may be created that can be used at the receiving end to verify the data arrived and was reassembled correctly. In this case however, it will be very important to show that the data and associated key have taken different paths to the receiving system. These different paths may include physically different communications means, or different encryption keys for each data type. The reasoning for this data path difference is to mitigate the risk of any vulnerability or failure that could allow the data to be changed without detection.

Confidentiality: Confidentiality is at its basics, ensuring that information cannot be intercepted and/or used by an unintended party. This attribute goes beyond just protecting the stream of information while it is being transported via the communications means. It includes areas such as information that seems benign, but has potential to be used in unintended ways. An example of benign information may be an IP addressing scheme that is exposed via an uncontrolled log file or display system. Information of this type may be one piece that could be used to plan an attack on the IP network. No information must be allowed to leave the end-to-end system without direct controls and authorization. Encryption schemes are often used to help ensure confidentiality. Again a weakness to these schemes can be the management of the encryption keys.
Availability: This attribute is of course well understood in the aviation environment and is generally accepted as “mean availability” as it applies to safety. In this security discussion it will be understood to be “instantaneous availability”. Availability as it applies to this security topic could be expressed in a case where a subsystem becomes unavailable; there can be no implications or exposures of services, data or resources within the remaining subsystems.

In the security realm, availability is also discussed where an attack from an external domain or attacker makes resources, services or other elements unavailable. Where this is always a concern, this type of a non-availability event is the result of the lack of security within the system, not actually causing the system to be non-secure.

Security Topics:
Trust: is a property whereby the receiving system is guaranteed the Integrity of the communications data of the sending system. Trust is a system of its own and typically is inherited by lower levels of subsystems from their higher levels, up to a trusted root. Within this hierarchical system, lower level subsystems may or may not know about, or trust other systems at their own level. Trust is always granted from the higher level system to one or more lower level subsystems. In other words, a lower level subsystem is never considered a trusted part of this common network.

This trust system also flows within a trusted domain. This is where all services and resources within the domain are trusted by one other.

Domain Segregation: The assurance that information and services at one level, are not exposed to attacks from a lower level. A failure of domain segregation may expose higher level systems to data integrity, confidentiality and availability.

Encryption: Encryption is used to help ensure and implement several of these security attributes. Many different types of encryption are available and the correct type must be used for the intended role. A primary method of compromising an encryption scheme is for the encryption keys to be exposed outside of the authorized user domain. Again, key management is paramount to ensure a trustworthy encryption system is guaranteed.

Industry Resources-
The security characteristics describe here apply to both an LRU level subsystem, such as ARINC 781, and at the aircraft system level, such as ARINC 664.

Other industry players exist at the higher level for larger end-to-end systems that is not included in this discussion. This would include Satellite services providers, ground station terminations and so on.

ARINC Characteristic 781-6: ARINC 781, (MARK 3 AVIATION SATELLITE COMMUNICATION SYSTEMS), has been one of the original specifications which includes from its original publication, a dedicated section on security. Over the years, this security section has grown significantly where it now includes a reference design for security elements to ensure domain segregation within the LRU. This reference design may be considered by NEXUS as the LRU requirements are being developed.

ARINC Characteristic 664 Part 5: ARINC 664 Part 5, (AIRCRAFT DATA NETWORK PART 5 NETWORK DOMAIN CHARACTERISTICS AND INTERCONNECTON), concerned on higher level topics that can
include an entire end-to-end system, but generally ends at the aircraft system level. It also includes a very good starting point for those wishing to gain a much broader understand of security topics.

**ATA Specification 42:** Air Transport Association of America, Inc. (Aviation Industry Standards for Digital Information Security), is a definition of an identity management solution, based on Public Key infrastructure (PKI) technology with a ‘chain of trust’ to a Certification Authority (CA).

**Aircraft Domain Definitions**
The standard Aircraft Domain reference model is found in ARINC 664, Part 5, “Network Domain Characteristics and Interconnection” as depicted in the following figure. The requirements will be associated within this domain reference model. The two primary Domains of discussion in this paper are the Aircraft Control Domain (ACD) and the Airline Information Services Domain (AISD).

**Security Certification**
The RTCA and EUROCAE are developing standards for ‘Aeronautical Systems Security’ (ED202A/DO326A) and they will likely be imposed for certifying the NEXUS SATCOM sub-system (LRU).

The ED202A/DO326A will augment current guidance for aircraft certification to handle the information security threats to aircraft safety. It adds data requirements and compliance objectives, as organized by generic activities for aircraft development and certification, to handle the information security threats to aircraft safety and is intended to be used in conjunction with other applicable guidance material.
The key point is that the security architecture will drive the security functional and assurance objectives. These objectives will be defined once a security risk assessment has been performed. The primary indicator if this effort will be required is to determine if the SATCOM provides services to more than one security domain, or is connected to more than one domain within the aircraft. The assumption is that if the SATCOM provides services only to the Aircraft Control Domain (ACD), then minimal security requirements will be levied on the aircraft level SATCOM.

**Security Requirements**

**Asset Requirements:**

**SR01** - All Security Functions within the LRU shall be clearly identified, described and specified.

**SR02** - All Security Assets relating to the LRU, (both internal and external), shall be clearly identified and handled from a security prospective (i.e., level of protection for these assets should be defined in accordance with the security needs of such assets).

**SR03** - Domains of all security levels connected to the LRU shall be clearly identified.

**Functionality Requirements:**

**SR04** - At a minimum, the following security functions shall be included in the LRU.

- Security segregation of domains
- Filtering and anti-DoS protection
- Security audit and logging
- Security integrity for Field Loadable Software (FLS)

**SR05** - All services, protocols and ports which are not required by the LRU shall be disabled.

*Note: This is a principle requirement known as “security hardening” of the platform.*

**SR06** - Data segregation shall be guaranteed between the Aircraft Control Domain (ACD) and all other lower security domains which are connected to the LRU.

**SR07** - The LRU shall have a Protected mode of operation defined which will support the required minimum set of functionality for the required Safety of Flight.

**SR08** - Security Functions and Assets shall be monitored and reported on by a Security Monitoring mechanism located on the ACD part of the LRU.

**SR09** - Log files from the Security Monitoring mechanism shall be handled in secure form separately from the maintenance logging system.

**SR10** - The Security Monitoring mechanism shall be a component within the ACD.
SR11 - Misconfigurations and or failures identified by the Security Monitoring function shall result in the LRU locking out the affected function and putting the LRU into the defined Protected mode of operation.

SR12 - All functionality within the LRU providing ACD services shall be guaranteed to be unaffected by any attacks or data inputs from lower trusted domains.

SR13 - Functionality required to guarantee the Protected mode of operation shall reside within the ACD.

Examples-
- LRU Dataloading functionality shall be controlled and monitored by the ACD.
- LRU aircraft inputs (i.e. discretes, A429, power, etc.) shall be controlled and monitored by the ACD.
- The Security Monitoring mechanism

SR14 - Functionality required to service less protected operational functionality may be controlled by the AISD or PIESD (Domains).

Examples-
- Off aircraft TCP data channels for EFB and or flight crew data in the AISD.
- Off aircraft TCP data channels for cabin and or passenger data in the PIESD.

SR15 - The Security Functions shall be controlled on the LRU ACD part.

SR16 - The LRU and its Security Functions shall be resilient against potential attacks (flooding conditions, fuzzing etc.).

Note: defense in depth principle should be applied by implementing security protections on both non-ACD and ACD sides.

LRU Identity and Security Key Management:

Security Keys may be required within the LRU to provide assurance of the LRU’s identity within the aircraft and to the ground network. Security Key management is assumed to be a function external to the LRU and would likely be consistent with the ATA Specification 42. If LRU identity guarantees are required by the Aircraft or Network Systems, LRU requirements would need to flow from that higher System down to the SATCOM sub-system.

SR17 - If Security Keys are required within the System, the LRU shall provide a secure method of key management over the lifetime of the LRU. This is to include key exchange and key invalidation or destruction.
LRU Controls:

**SR18** - Any LRU command and or control messages which do not originate from within the ACD shall be authenticated using robust authentication scheme to communicate with the LRU.

*Note: Secure control methods such as SSL or SNMP v3 may be acceptable implementations for this requirement.*

**SR19** - The LRU shall reject all non-authenticated command and control messages which originate outside the ACD.

The LRU may accept all messages, encrypted or otherwise, which originate from within the ACD (Trusted).

**SR20** - Services within the LRU AISD that interface with untrusted domain and that are exposed to potential threats shall be hardened using the state-of-the-art protocols and technology (ex: SNMP V3 with USM and VACM)

Appendix A – Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACD</td>
<td>Aircraft Control Domain</td>
</tr>
<tr>
<td>AISD</td>
<td>Airline Information Services Domain</td>
</tr>
<tr>
<td>ATA</td>
<td>Air Transport Association</td>
</tr>
<tr>
<td>CA</td>
<td>Certification Authority</td>
</tr>
<tr>
<td>CRC</td>
<td>Cyclic Redundancy Check</td>
</tr>
<tr>
<td>DoS</td>
<td>Denial of Service</td>
</tr>
<tr>
<td>EFB</td>
<td>Electronic Flight Bag</td>
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<tr>
<td>EUROCAE</td>
<td>European Organization for Civil Aviation Equipment</td>
</tr>
<tr>
<td>FLS</td>
<td>Field Loadable Software</td>
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<tr>
<td>IP</td>
<td>Internet Protocol</td>
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<tr>
<td>LRU</td>
<td>Line Replaceable Unit</td>
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<tr>
<td>PIESD</td>
<td>Passenger Information and Entertainment Services Domain</td>
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<tr>
<td>PKI</td>
<td>Public Key Infrastructure</td>
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<tr>
<td>RTCA</td>
<td>Radio Technical Commission for Aeronautics</td>
</tr>
<tr>
<td>SNMP v3</td>
<td>Simple Network Management Protocol, version 3</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>USM</td>
<td>User-based Security Model</td>
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<tr>
<td>VACM</td>
<td>View-based Access Control Module</td>
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