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Manual on the Aeronautical Mobile Satellite (Route) Service

Approved by the Secretary General
and published under his authority

First Edition — 2010

International Civil Aviation Organization

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FOREWORD

Satellite technology has a unique potential to satisfy many present and future communication, navigation and surveillance (CNS) needs. A key part of system improvement in the future is the introduction of air-ground digital communication services which could provide substantial benefits in air traffic services (ATS) efficiency and capacity, satisfying the needs of air traffic safety as well. Important system considerations include: worldwide interoperability; access by all classes of aeronautical users; the need to accommodate evolutionary system growth in terms of functional capability and capacity in an adaptive manner, considering different requirements in different areas; and the potential for taking advantage of satellite service capability from different service providers.

The Aeronautical Communications Panel (ACP) of the Air Navigation Commission has carried forward future air navigation systems planning that designated basic architectural concepts for using satellite communications, initially in oceanic and remote environments, and eventually in continental airspace. Progress in the development of satellite communications for aeronautical safety is made through the revision of Standards and Recommended Practices (SARPs) and guidance material by ICAO for the aeronautical mobile satellite (route) service (AMS(R)S) and through the interactions of ICAO with other international bodies to assure that resources are coordinated and available.

Accepting to largely replace voice communications with the application of data links to support ATS requires assurance that all relevant elements of data link network(s) and subnetworks (such as a satellite subnetwork) are properly coordinated and interoperable. AMS(R)S is considered a global satellite subnetwork of the aeronautical telecommunication network (ATN) that provides end-to-end voice and data connectivity among end-users, such as air traffic controllers, pilots and aircraft operators. Interoperability with the ATN is assured by means of a standardized architecture for all elements of the ATN, based on ICAO SARPs and guidance material.

The objective of this manual is to provide an overview of systems operating in the AMS(R)S and offer guidance on the consideration of satellite networks as a platform for AMS(R)S communications for the safety and regularity of flight. The AMS(R)S serves the safety, regularity and efficiency of flight by providing communications between the aircraft earth stations (AES) (on-board an aircraft) and ground earth stations (GES) through a satellite link.

This manual is to be considered in conjunction with the ICAO SARPs as contained in Annex 10, Volume III, Part I, Chapter 4. This manual provides implementation guidance for specific satellite systems operating in the AMS(R)S.

The AMS(R)S manual is divided into the following parts:

Part I – General information on AMS(R)S

Part I contains a general description of aeronautical mobile satellite communications including information on applications, user requirements, potential operational benefits, and information on standardization activities undertaken by ICAO and aviation industry bodies. Information on institutional guidelines related to AMS(R)S services, the SARPs and AMS(R)S spectrum availability is provided.

Part II – Iridium Satellite Network

Part II of the manual deals with aeronautical mobile satellite communications provided by the Iridium satellite network. Information is provided on the compliance with AMS(R)S SARPs and Iridium-specific performance parameters pertaining to minimum operation performance standards for avionics supporting next-generation satellite systems as specified in RTCA DO-262.

Part III – Inmarsat and MTSAT Classic Aero

Part III provides a technical overview and guidance material to ICAO Member States and the international civil aviation community on the “Classic Aero” aviation satellite system as operated globally by Inmarsat and regionally by the Japanese Civil Aviation Authority (JCAB) which provides AMS(R)S communications.

Part IV – Inmarsat SwiftBroadband (SBB)

Part IV deals with the SwiftBroadband Satellite (SBB) system operated by Inmarsat. A general overview is given and technical specifications are provided by reference. This is followed by a compliance matrix showing conformance with ICAO Standards and Recommended Practices (SARPs) and then general guidance on the use of the system, for ANSP and aircraft operators.

Comments on this manual would be appreciated from all parties involved in the development and implementation of global navigation satellite services (GNSS). These comments should be addressed to:

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ABBREVIATIONS AND DEFINITIONS

3G	Third generation (mobile telecommunications technology)
AAC	Aeronautical administrative communication
AAGW	ACARS aircraft gateway
A-BPSK	Aviation binary-phase shift keying
AC	Acquisition class
ACARS	Aircraft communications addressing and reporting system
ACCHL	Associated control channel, L Band
ACP	Aeronautical Communications Panel
ADS	Automatic dependent surveillance
ADS-C	Automatic dependent surveillance – contract
AEEC	Airline Electronic Engineering Committee
AES	Aircraft Earth station
AFC	Automatic frequency compensation
AGGW	ACARS ground gateway
AMCP	Aeronautical Mobile Communications Panel
AMS(R)S	Aeronautical mobile satellite (route) service
AMSS	Aeronautical mobile satellite service
ANSP	Air navigation services provider
AOC	Aeronautical operational control
AOR-E	Atlantic Ocean Region–East
AOR-W	Atlantic Ocean Region–West
APC	Aeronautical passenger communications
A-QPSK	Aviation quadrature-phase shift keying
ARC	Aviation review committee
ARINC	Aeronautical Radio Inc.
ARQ	Automatic repeat request
AT	AT (Attention) command set or Hayes command set
ATC	Air traffic control
ATM	Air traffic management
ATMC	Air traffic management centre
ATN	Aeronautical telecommunication network
ATNP	Aeronautical Telecommunication Network Panel
ATS	Air traffic services
ATSP	Air traffic service provider
BCH	Bose, Ray-Chaudhuri, Hocquenghem (a type of error control code)
BER	Bit error rate
BGAN	Broadband global area network
BPSK	Binary phase shift keying
CDF	Communication data field
C-Ch	Circuit switched channel in forward direction (to aircraft) and return direction (from aircraft)
CLI	Caller line identification
CN	Connectivity notification
CNS/ATM	Communication, navigation, surveillance/air traffic management
CNP	Communication network provider
COTS	Commercial, off-the-shelf

CPDLC	Controller-pilot data link communication
CRA	Central Reporting Agency
D-ATIS	Data link-automatic terminal information service
dB	Decibel (a ratio expressed as $10 \times \log_{\text{base}_10}$)
dBi	Decibel with respect to a isotropic antenna
dBic	Decibel with respect to a circularly polarized isotropic antenna
dBm	Decibel with respect to 1 milliwatt of power
dBW	Decibel with respect to 1 Watt of power
DCE	Data circuit-terminating equipment
DL	Downlink
DLS	Direct link service
DLMA	Data Link Monitoring Agency
DSP	Digital signal processor
DTE	Data terminal equipment
ECS	Earth terminal controller — communication sub-system
EIRP	Equivalent isotropically radiated power
ELGA	Enhanced low gain antenna
ET	Earth terminal
ETC	Earth terminal controller
ETS	Earth terminal controller — transmission sub-system
FAA	Federal Aviation Administration (United States)
FANS	Future air navigation system
FCC	Federal Communications Commission (United States)
FDMA	Frequency division multiple access
FEC	Forward error correction
FIR	Flight information region
FIS	Flight information services
FPL	Flight plan
GES	Ground Earth station
GNSS	Global navigation satellite system
GHz	Gigahertz: 10^9 Hz
GSM	Global system for mobile communications standard (Groupe special mobile)
G/T	Receiver gain-to-system noise temperature ratio
HF	High frequency
HGA	High gain antenna
HLE	Higher-level entity
HPA	High-power amplifier
Hz	Hertz (1 cycle per second)
ICAO	International Civil Aviation Organization
IGA	Intermediate gain antenna
IMEI	International mobile equipment identifier
IMSI	International mobile network subscriber identifier
IOR	Indian Ocean region
IP	Internet protocol
IPS	Internet Protocol suite
ISLLC	Iridium satellite
ISO	International Organization for Standardization
ISPACG	Informal South Pacific ATC Coordinating Group
ISU	Initial signal unit
ITU	International Telecommunication Union
ITU RR	International Telecommunication Union Radio Regulations
JCAB	Japanese Civil Aviation Bureau

K	Kelvin
kbps	kilobits-per-second
kHz	kilohertz: 10^3 Hz
km/h	kilometres per hour
ksp/s	kilosymbols-per-second
LAC	Location area code
LBT	L-band transceiver
LEO	Low Earth orbit
LES	Land Earth station
LHC	Left-hand circular
LICI	Link interface control information
LIDU	Link interface data unit
LNA	Low-noise amplifier
LSDU	Link service data unit
LSU	Lone signal unit
MASPS	Minimum aviation system performance standards
MCDU	Multifunction control and display unit
MEO	Medium Earth orbit
MHz	Megahertz: 10^6 Hz
MLPPP	Multi-link point-to-point protocol
MMP	Meet-me-point
MO	Mobile originated
MOC	Message Origination Controller
MOPS	Minimum operational performance standards
MOS	Mean opinion score
ms	millisecond
MSC-MS	Mobile switching centre to mobile subscriber (signalling)
MSISDN	Mobile subscriber integrated services digital network number
MSS	Mobile satellite service
MST	Mountain Standard Time
MT	Mobile terminated
MTBF	Mean time between failures
MTSAT	Multifunctional transport satellite
MTSBD	Mobile terminated SBD message
MTTR	Mean time to repair
NASA	National Aeronautics and Space Administration (United States)
NGSS	Next-generation satellite system
NM	Nautical mile
NSAC	Network service access point
NVRAM	Non-volatile RAM
OCD	Oceanic clearance delivery
ORT	Owner requirements table
OSI	Open system interconnection
PBCS	Performance-based communications and surveillance
P-Ch	Packed switched channel in forward direction (to aircraft)
Pd	P-channel used for data
PDU	Protocol data unit
PIN	Personal identification number
POR	Pacific Ocean region
PPP	Point-to-point protocol
PSDN	Public switched data network
PSid	P-channel satellite ID

Psmc	P-channel used for system management functions
PSTN	Public switched telephone network
QOS	Quality-of-service
QPSK	Quadrature phase shift keying
RAN	Radio access network
RCP	Required communication performance
Rd	R-channel used for data
RER	Residual error rate
RF	Radiofrequency
RFU	Radiofrequency unit
RHC	Right-hand circular
RLS	Reliable link service
Rsmc	R-channel used for system management functions
RSP	Required surveillance performance
RTCA	Radio Technical Commission for Aeronautics
RUDICS	Router-based unrestricted digital interworking connectivity solution
s	second
SAR	Search and rescue
SARPs	Standards and Recommended Practices
SAS	Satellite access station
SBB	SwiftBroadband
SBD	Short burst data
SCA	Service control area
SCPC	Single channel per carrier
SDM	System definition manual (Inmarsat)
SDU	Satellite data unit
SEP	Short burst data, Earth terminal controller (SBD ETC) processor
SIM	Subscriber information module
SITA	Société Internationale de Télécommunication Aéronautiques
SNAC	Single number access code
SNAcP	Subnetwork access protocol
SNC	Sub-network connection
SNDCF	Subnetwork dependent convergence facility
SNOC	Satellite network operations centre
SNS	Subnetwork service
SNSDU	Sub-network service data unit
SP	Service provider
SPP	Short burst data post-processor
SSN	Satellite sub-network
SSNPDU	Satellite sub-network protocol data unit
SSR	Secondary surveillance radar
SSU	Subsequent signal unit
SU	Signal unit
T-Ch	Time division multiple access channel in return direction (from aircraft)
TCP/IP	Transport control protocol/Internet protocol
TDM	Time division multiplex
TDMA	Time division multiple access
TE	(User) Terminating equipment
TMSI	Temporary mobile subscriber identification
TSC	Technical support centre
TSO	Technical Standard Order (United States)
TTAC	Telemetry, Tracking and Control/Command

UL	Uplink
UMTS	Universal mobile telecommunications system
VDL	VHF digital link
VHF	Very high frequency
VoIP	Voice over Internet Protocol
VPN	Virtual private network
W	Watt

DEFINITIONS

AES. Aircraft Earth Station is the avionics on board an aircraft necessary for satellite communications. This includes modulator and demodulators, RF power amplifier, transmitter and receiver, and the antenna. Iridium AES may consist of multiple Satcom Data Units (SDU), or L-Band Transceivers (LBT), which a) serve as radio transceivers; b) provide the actual modem and signal processing functions, as well as Iridium satellite subnetwork protocol management including circuit-switched voice/data management; and c) provide data and voice interfaces with other aircraft systems.

Availability. The proportion of time a system is in a functioning condition which is computed as (Observation Time-Total Outage Time)/Observation Time.

GSM. Global System for Mobile communications is a sophisticated cellular system used worldwide which was designed in Europe. It uses a TDMA air interface.

Integrity. The probability of a message being received without undetected errors.

MOS. Mean Opinion Score provides a numerical measure of the quality of human speech at the destination end of the circuit. The scheme uses subjective tests (opinionated scores) that are mathematically averaged to obtain a quantitative indicator of the system performance.

To determine MOS, a number of listeners rate the quality of test sentences read aloud over the communications circuit by male and female speakers. A listener gives each sentence a rating as follows: (1) bad; (2) poor; (3) fair; (4) good; (5) excellent. The MOS is the arithmetic mean of all the individual scores and can range from 1 (worst) to 5 (best).

MTBF. Mean Time Between Failure is the “average” time between failure, the reciprocal of the failure rate in the special case when failure rate is constant. Calculations of MTBF assume that a system is “renewed”, i.e., fixed, after each failure and then returned to service immediately after failure.

MTTR. Mean Time to Repair is the average time required to perform corrective maintenance on a product or system. This kind of maintainability prediction analyses how long repairs and maintenance tasks will take in the event of a system failure.

Priority, Precedence and Pre-emption. Each element of the AMS(R)S Subsystem (including AESs, GESs and the constellation) shall conform with applicable International and National Radio Regulations and aviation regulations governing the precedence and protection of aeronautical mobile safety communications. Each AMS(R)S system shall address each requirement of this section in its system-specific normative attachment to this document with a complete description of the mechanisms enabling the system to meet the requirements.

Priority Levels. The AMS(R)S system and, as appropriate, its elements, shall support not fewer than three AMS(R)S priority levels at the subnetwork interfaces. If the system accepts non-safety blocks for transmission, at least one (lowest) priority level shall be added for non-safety traffic. If the system accepts blocks for transmission that contain either no priority indicator or a null priority indication, each such block shall be marked upon entry with a non-safety priority level and shall be treated as such in subsequent processing within the system. The AMS(R)S system shall forward a block priority indicator to the succeeding sub-system or end-user terminal.

Note.— For the purpose of this document the three AMS(R)S priorities are designated as:

*Distress/Urgency (highest safety priority), Flight Safety, and Other Safety (lowest safety priority).
Non-safety traffic is designated as Non-Safety.*

Precedence. Each AES and GES shall ensure that higher priority blocks are not delayed by the transmission and/or reception of lower priority messages.

Pre-emption. Lower priority messages shall be pre-empted, if necessary, to allow higher priority blocks to be transmitted and received.

Note 1.— For example, if a lower priority block is occupying limited AMSS resources when a higher priority block is received, then transmission of the lower priority block should be interrupted, if necessary and feasible, to permit transmission of the higher priority block.

Note 2.— The priority assigned to a voice or data block will be determined by the initiating user or by the terminal equipment.

Reliability. The probability that a satellite subnetwork actually delivers the intended message. The failure to deliver a message may result either from a complete breakdown of an essential component or because of detected errors which are unrecoverable.

Satellite Communications Service Provider. Typically provides the inter-working unit of the terrestrial sub-system as depicted in Figure 2-1 of Part I of this manual, within Segment C-D, which connects the satellite ground earth station, or Gateway, and the terrestrial network in support of AMS(R)S.

Satellite Network Operations Provider. Typically provides the satellite sub-system, as depicted in Figure 2-1 of Part I of this manual, within Segment B-C, which includes the satellite(s) and may or may not include the ground earth stations or Gateway.

Terrestrial Network Service Provider. Typically provides the aviation centric terrestrial sub-system, as depicted in Figure 2-1 of Part I of this manual, within Segment C-D, which provides connectivity to the end-users, such as ATS providers, airlines and flight departments.

**MANUAL ON THE
AERONAUTICAL MOBILE
SATELLITE (ROUTE) SERVICE**

Part I

General Information on AMS(R)S

Chapter 1

INTRODUCTION

1.1 Objectives

The objectives of this part of the manual are to provide an overview of the AMS(R)S and offer guidance on the consideration of satellite networks as a platform for AMS(R)S communications for the safety and regularity of flight. This manual is to be considered in conjunction with the ICAO SARPs as contained in Annex 10, Volume III, Part I, Chapter 4. Subsequent sections of this manual provide implementation guidance for specific satellite systems.

1.2 Scope

This part contains a general description of aeronautical mobile satellite communications including information on applications, user requirements, potential operational benefits and standardization activities undertaken by ICAO and aviation industry bodies. Information on institutional guidelines related to AMS(R)S services, the SARPs and AMS(R)S spectrum issues are also included.

1.3 Historical

1.3.1 In the 1960s, the civil aviation community began careful study of the practicability of using satellite communications to provide long-distance communications, primarily as a replacement for high frequency (HF) communications over oceanic and remote areas. Early experimentation focused on the use of the very high frequency (VHF) spectrum (118 to 136 MHz).

1.3.2 Using the NASA ATS 3 experimental satellite, the aviation community demonstrated the feasibility of VHF satellite-based communications in aviation. In 1968, ICAO established a panel of experts to explore the application of space techniques relating to aviation. This panel studied the technical characteristics of an aeronautical satellite system. At that time, the aviation community considered that an initial, low capacity satellite system could provide early relief to satisfy in particular the requirements for oceanic communications and would permit transition to a higher capacity satellite at a later stage as technology developed. These satellite systems were to operate in frequency bands, allocated on an exclusive basis to the AMS(R)S. Use of the bands for public correspondence (e.g. passenger communications) was not excluded.

1.3.3 During 1971–1973 and 1974–1975, several experiments were performed with the ATS 5 and ATS 6 satellites, respectively. These tests demonstrated that, at that time, it was feasible to use available technology to provide satellite communications to aircraft in the 1.5/1.6 GHz bands. A KC-135 aircraft was used to test the effect of direct path and multipath propagation with different antennas. Ranging and digital data demonstration tests were also performed. Aircraft tests were performed at various altitudes, elevation angles to the satellite and at various headings and speeds.

1.3.4 An international aeronautical satellite programme, AEROSAT, was devised in the early 1970s. AEROSAT was a programme to jointly plan, construct and manage a dedicated aeronautical experimental satellite system sponsored by Canada, the United States and the European Space Agency, representing several European nations, under a memorandum of understanding signed in August 1974. Its objective was to develop and launch several satellites to perform a variety of experiments to determine the preferred system characteristics of an operational system.

The satellites were to be launched in the late 1970s. However the satellite cost grew much larger than anticipated, and a downturn in worldwide economic conditions, along with the lack of the expected traffic growth, caused the airlines to withdraw their support.

1.3.5 From 1978 to 1982, the Aviation Review Committee (ARC) managed a broad study of alternative system improvements aimed at oceanic and remote overland areas, with the participation of more than twenty States and international organizations. The ARC identified the potential of automatic dependent surveillance (ADS) and air-ground satellite data link communications based on a space segment shared with other (non-aeronautical) communication services.

1.3.6 In November 1983, following the ARC conclusions and recommendations, the ICAO Council established the Special Committee on Future Air Navigation Systems (FANS) to "study technical, operational, institutional and economic questions, including cost/benefit effects relating to future potential air navigation systems". FANS tasks included studying the application of satellite technology in aviation. In 1988, the FANS Committee concluded its work and recommended to ICAO the adoption of the global CNS/ATM systems concept, largely based on satellite technology. The concept was consequently endorsed by the Tenth Air Navigation Conference in 1991.

1.3.7 The systems concept was further developed and refined by Phase II of the FANS Committee which concluded its work in 1993. Its work included a study of the necessary institutional arrangements, development of a global coordinated implementation plan, assessment of ongoing research and development activities, and development of guidelines for ATM evolution. Noting the fact that implementation activities had already begun, the name "global CNS/ATM systems concept" was changed to "CNS/ATM systems".

1.3.8 The future air navigation system was mainly based on:

- a) a global navigation satellite system (GNSS) to allow aircraft en route to determine their present position worldwide, based on signals transmitted by satellites;
- b) an aeronautical mobile satellite service (AMSS) interoperable with SSR Mode S data link and VHF data link, in the framework of the ATN; and
- c) ground-based ATM systems, including airspace management, flow management and ATS.

1.3.9 Satellite systems were planned to be used firstly in large areas with a low density of air traffic such as remote and oceanic areas. In areas with higher air traffic density (e.g. terminal areas) compatible terrestrial-based systems were part of CNS/ATM.

1.3.10 This manual, which is an updated and enhanced version of the "Global Coordinated Plan for Transition to the ICAO CNS/ATM Systems" contained in the Report of the Fourth Meeting of the Special Committee for the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II) (Doc 9623), has been produced to include recently developed concepts and systems.

1.3.11 In its "Global Coordinated Plan for Transition to the ICAO CNS/ATM Systems" as contained in Doc 9623, the FANS Committee recognized that satellite technology had a unique potential to satisfy many present and future CNS needs. A key part of future system improvement would be the introduction of air-ground digital data communication services (data link firstly, to be followed by voice) which could provide substantial benefits in ATS efficiency and capacity, satisfying the need for improved air traffic safety as well. Important system considerations included worldwide interoperability, access by all classes of aeronautical users, the need to accommodate evolutionary system growth in terms of functional capability and capacity, consideration of different requirements in different areas, and the potential for taking advantage of satellite service capabilities offered by different service providers. Therefore, the committee defined the minimum necessary level of communication systems standardization to achieve the mentioned objectives and recommended the subsequent architecture in the FANS/4 Report.

1.3.12 Following Recommendation 7/1 (Development of SARPs and guidance material for aeronautical mobile satellite (R) service) from FANS/3, the Air Navigation Commission established in 1988 the Aeronautical Mobile Satellite Service Panel, to develop the SARPs and related guidance material based on the CNS/ATM concept developed by FANS.

1.3.13 The fourth meeting of the Aeronautical Mobile Communications Panel (AMCP/4, 1996) noted the near-future availability of non-geostationary-satellite systems (which were expected to provide mobile satellite communication services) as well as the potential for application of such services to a broad segment of the aviation community. The meeting considered the need to undertake a feasibility study of the potential of these systems for the provision of AMS(R)S. AMCP/5 (1998) concluded that the use of non-geostationary-satellite systems for AMS(R)S was feasible. Following AMCP/5 Recommendation 5/1, the panel developed specific draft SARPs and guidance material for such satellite systems. In 2003, the ACP which was created after a merging between the AMCP and the Aeronautical Telecommunications Network Panel (ATNP), started to review and combine the AMSS SARPs (specific to geostationary satellite systems such as Inmarsat and MTSAT) and the next-generation satellite systems SARPs. This work was completed in 2005 at the first meeting of the ACP Working Group of the Whole.

1.3.14 Amendment 82 to Annex 10, as adopted by Council in 2007, introduced for the first time generic SARPs for AMS(R)S which are independent of the technology employed within a satellite communications system, cover performance requirements for data and voice operations, and accommodate low Earth orbit (LEO), medium Earth orbit (MEO) and geostationary orbit constellations. The SARPs and guidance material for AMS(R)S were structured as directed by Assembly Resolution A35-14, Appendix A. Technical specifications were divided into a “core” SARPs element, complemented by additional material, as published in this manual, and by references to documents developed by recognized standards-making bodies (e.g. the International Telecommunication Union (ITU) and RTCA).

Chapter 2

SERVICES, USER REQUIREMENTS AND OPERATIONAL BENEFITS

2.1 SATELLITE COMMUNICATION SERVICES

General

2.1.1 Air traffic scenarios differ widely around the world and are likely to continue to do so in the future. Global ATM systems must therefore be able to deal with diverse air traffic densities and different aircraft types, with vastly different performances and equipment fit; these variations, however, should not lead to undue diversity and potential incompatibility in avionics and ground segments.

2.1.2 In general, as new CNS systems provide for closer interaction between the ground and airborne systems before and during flight, ATM may allow for more flexible and efficient use of airspace and thus enhance air traffic safety and capacity.

2.1.3 Aeronautical communication services are classified as:

- a) safety and regularity communications, AMS(R)S, requiring high integrity and rapid response:
 - 1) safety-related communications carried out by ATS for air traffic control (ATC), flight information and alerting; and
 - 2) communications carried out by aircraft operators, which also affect air transport safety, regularity and efficiency (aeronautical operational control (AOC) communications); and
- b) non-safety related communications:
 - 1) private correspondence of aeronautical operators (aeronautical administrative communications (AAC)); and
 - 2) public correspondence (aeronautical passenger communications (APC)).

Data communication

2.1.4 Since the earliest days of ATC, air-ground communication between the flight crew and the air traffic controller has been conducted through speech over radiotelephony on either HF or VHF. When radiotelephony channels become congested or, in the case of HF radio-telephone channels, during HF propagation disturbances, voice communication availability and reliability can decrease to a point where flight safety and efficiency may be affected.

2.1.5 Despite the introduction of Secondary Surveillance Radar (SSR) and VHF digital link (VDL), both of which include limited air-to-ground data transfer and provide controller workload relief, the burden of voice communication on the air traffic controller and the pilot is still high. Moreover, large areas of the world are beyond the coverage of SSR and VDL. In those remote and oceanic areas, both tactical communication and position reports are being exchanged over HF circuits with variable quality.

2.1.6 Experience has shown that factors on the ground limit the alleviation of shortcomings in the voice communication systems. In particular, the saturation of manual ATC capabilities creates strong pressure for automated assistance in ATS, and because of this, increasing levels of automation are being incorporated in aircraft systems. Achieving full potential benefits of automation requires an increased information flow between the aircraft and ground systems. Moreover, a digital data link is an essential element of an advanced automated ATC environment.

2.1.7 It is currently envisaged that future ATM systems (on the ground and in the aircraft) will make increased use of various and diverse physical links (e.g. HF data link, VHF data link and satellite data link) to allow for the (automatic) transmission of data from the aircraft to the ground and vice versa. Efficient use of the diverse links lends towards a more universal value of its supporting services. It therefore is to the advantage of service providers and users to support international standardization of these data links and their applications.

2.1.8 Many useful safety- and efficiency-related applications can be implemented using air-ground data links. In order to be used for safety-related services, an air-ground data link must have high integrity.

Voice communication

2.1.9 Despite the expected increased automation of data exchange between air and ground systems, the use of voice communication will remain imperative. Emergency and non-routine problems make voice communications a continuing requirement.

2.1.10 Aeronautical mobile services in continental areas continue to use VHF for line-of-sight voice communications. Oceanic and other remote areas at present rely on HF voice communications, which may require communication operators to relay communications between pilots and controllers.

2.1.11 A viable solution to overcome the limitations in current ATS and AOC voice communications, particularly in remote and oceanic areas, is the application of satellite-based communication systems.

Air traffic services (ATS)

2.1.12 An important application of satellite technology to civil aviation is the provision of communication services for ATS purposes, particularly in remote and oceanic areas, covering, inter alia, flight information service, alerting service and ATC service including area, approach and aerodrome control services. Especially in such areas, ATS will benefit significantly from the use of satellite systems for the delivery of services over the services provided by HF and VHF. Satellite-provided ATSS offer both cost-savings and service quality enhancements. For example, whereas HF services can be unreliable due to propagation conditions and limited bandwidth, and VHF communication systems do not have extended coverage, satellite services can overcome most of these limitations. Moreover, satellite services are global in nature and may include coverage of both the North and South Poles. The provision of ATS in oceanic airspace differs in many aspects from that provided over land areas. Oceanic flights are conducted in airspace where no sovereign rights are exercised and where normally, in that airspace, more than one State is concerned with the provision of ATS. Therefore the planning of ATS for such operations is a matter of international concern. The development and implementation of the ICAO air navigation plans and the provision of ATS for such areas is entrusted by ICAO to designated States based on regional air navigation agreements. Additional information is contained in the *Manual of Air Traffic Services Data Link Applications* (Doc 9694).

Air traffic control services

2.1.13 The main objectives of the ATC services are to prevent collisions between aircraft, and between aircraft and obstructions in the manoeuvring area, and to expedite and maintain an orderly flow of air traffic. These objectives can be achieved by applying separation between aircraft and by issuing clearances to individual flights as close as

possible to their stated intentions, taking into account the actual state of airspace utilization and within the general framework of measures for the control of air traffic flow when applicable.

Flight information services (FIS)

2.1.14 FIS provide flight crews with compiled meteorological and operational flight information specifically relevant to the departure, approach and landing phases of flight.

Alerting services

2.1.15 The objective of the alerting service is to enable flight crews to notify appropriate organizations regarding aircraft in need of search and rescue aid and to assist such organizations as required.

Automatic dependent surveillance (ADS)

2.1.16 The introduction of satellite communication technology, together with sufficiently accurate and reliable aircraft navigation, e.g. by GNSS, presents ample opportunity to provide better surveillance services mostly in areas where such services lack efficiency — in particular over oceanic areas and other areas where the current systems (i.e. radars) prove difficult, uneconomical, or even impossible to implement.

2.1.17 ADS is an application whereby the information generated by an aircraft's on-board navigation system is automatically relayed from the aircraft, via satellite data link, to the ATS and displayed to the air traffic controller on a display similar to radar. The aircraft position report and other associated data can be derived automatically, and in almost real-time, by the ATC system, thus improving its safety and performance efficiency. Ground-to-air messages also will be required to control the ADS information flow.

Controller-pilot data link communication (CPDLC)

2.1.18 One of the keys to the future ATM system lies with the two-way exchange of data, both between aircraft and the ATC system and between ATC systems. CPDLC is a means of communication between controller and pilot, using data link for ATC communications.

2.1.19 The CPDLC application provides the ATS facility with data link communications services. Sending a message by CPDLC consists of: 1) selecting the addressee; 2) selecting and completing, if necessary, the appropriate message from a displayed menu or by other means which allow fast and efficient message selection; and 3) executing the transmission. The messages defined herein include clearances, expected clearances, requests, reports and related ATC information. A "free-text" capability is also provided to exchange information not conforming to defined formats. Receiving the message will normally take place by display and/or printing of the message.

2.1.20 CPDLC will remedy a number of shortcomings of voice communication, such as voice channel congestion, misunderstanding due to bad voice quality and/or misinterpretation, and corruption of the signal due to simultaneous transmissions.

Automated downlink of airborne parameter services

2.1.21 The automated downlink of information available in the aircraft will support safety services. Such service may, for example, help detect inconsistencies between ATC-used flight plans and the flight plan activated in the aircraft's flight management system. Existing surveillance functions on the ground can be enhanced by downlinking of specific tactical flight information such as current indicated heading, air speed, vertical rate of climb or descent, and wind vector.

Aeronautical operational control communications (AOC)

2.1.22 Aeronautical operational control is a safety service and is defined in Annex 6 — *Operation of Aircraft*. Operational control provides for the right and duty of the aircraft operator to exercise authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of flight.

2.1.23 Operational control communications accommodate the functions of airline dispatch and of the flight operations department but may also interface with other airline departments such as engineering, maintenance and scheduling, in exercising or coordinating related functions.

2.1.24 Current experience with AOC shows that a significant number of messages are exchanged using data communications. AOC voice, however, will continue to be required. Based on expected increases in air traffic, AOC data communications will further grow as the result of both the increase in number of messages per aircraft and of the size and characteristics of the message content. AMS(R)S can assist in performing functions such as:

- exceptional situation handling (aircraft/flight emergencies etc.);
- flight planning;
- weather information;
- airport/airways operational information;
- flight crew scheduling;
- aircraft engine monitoring;
- in-flight maintenance problem reporting and solving; and
- aircraft schedule.

2.1.25 Such AOC functions may operate via air-ground voice and data communications either through the cockpit crew or directly with airborne sensors or systems.

Non-safety services

2.1.26 Non-safety services include AAC and APC. Non-safety communication services may be authorized by administrations in certain frequency bands allocated to the AMS(R)S as long as they cease immediately, if necessary, to permit transmission of messages for safety and regularity of flights (i.e. ATS and AOC, according to priorities 1 to 6 of Article 51 of the ITU Radio Regulations).

2.2 USER REQUIREMENTS

2.2.1 Air-ground satellite data communication plays a key role in the functional improvement of existing and new ATM functions, particularly in remote and oceanic areas.

2.2.2 In order to fulfil these operational requirements, these ATM functions require a certain level of quality of communication services. This level is specified in the communication, technical and operational characteristics required by the SARPs.

2.2.3 Satellite voice communications continue to be used, particularly in non-routine and emergency situations, and offer improved voice quality over HF-voice.

2.2.4 ATM-related communications (voice and data) are given high priority in transit through the satellite system and the ATN, as appropriate. The satellite system architecture supports ATS needs for handling both data and voice.

2.2.5 AMS(R)S requirements are to be derived from these characteristics, in terms of service reliability, availability, etc., to achieve the required standards of service. Primary service requirements for AMS(R)S are highlighted in the following subparagraphs.

Performance criteria for end-to-end applications

2.2.6 The aeronautical satellite communication system will support the categories of AMS(R)S communications according to the appropriate performance, integrity and availability criteria, taking into account a gradual increase in communication needs. Systems which allow for step-by-step and evolutionary implementation and growth are desirable.

2.2.7 AMS(R)S system performance parameters as defined in SARPs are provided for the ATN satellite subnetwork (see Figure 2-1 between points B and D for packet mode, and Figure 2-2a between points B and C for circuit mode services). Additional information on ATN end-to-end performance between user terminals is contained in the *Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) using ISO/OSI standards and protocols* (Doc 9880).

2.2.8 AMS(R)S data services are based primarily on the use of packet data communications. The packet mode structure of the system and its four subsystems is shown in Figure 2-1. The AMS(R)S circuit mode service primarily serves voice but also supports continuous data and facsimile services where these services are needed and appropriate. The system structure for circuit mode services is depicted in Figures 2-2a and 2-2b.

2.2.9 Measures of the service quality of the end-to-end system including the AMS(R)S subnetwork are detailed in the following subparagraphs.

Minimum available throughput

2.2.10 Throughput is defined as the amount of user data (per time unit) which can be transferred over the available links between the AES and the GES. The message transfer frequency (i.e. number of ADS reports per time unit), together with message length (i.e. number of bits in the ADS report) and the protocol overhead, determine the required throughput for ADS messages.

Maximum data transit delay

2.2.11 The satellite data transit delay for packet data communications is defined as the time between sending and receiving a message within the satellite system, using the AMS(R)S. In addition, ATN data transit delays (when the message is further sent through the ground-based ATN) need to be considered. Maximum data transit delay requirements are derived from the required communication performance (or RCP) parameters (i.e. time between generating and sending airborne data and receiving the data for processing on the ground).

Priority

2.2.12 Each AMS(R)S communication transaction is assigned a priority. This priority is dependent on the information type and is assigned by the associated user application in accordance with the internationally defined priorities in Annex 10.

2.2.13 The ATN sequences messages in order of priority. The AMS(R)S will provide a sequencing mechanism that complies with the priority assigned to a message.

Reliability/integrity

2.2.14 The AMS(R)S will have the integrity and reliability required for provision of safety communication. Users must be able to pass their messages reliably, regardless of the position or situation of the aircraft, with rapid access and minor transmission delay, but at an economical rate.

2.2.15 Reliability is defined as the probability that a satellite subnetwork will actually deliver the intended message within a set amount of time. The failure to deliver a message may result either from a complete breakdown of an essential component or because of detected errors which are unrecoverable.

2.2.16 Integrity is defined as the probability a message will be received without undetected errors.

2.2.17 It is necessary to establish performance standards for reliability, continuity and integrity of service for the space segment, ground stations and associated facilities. This will require application of ICAO SARPs and certification.

2.2.18 The consequences of loss of a satellite in an aeronautical air-ground communication system would be severe unless an adequately rapid changeover to back-up facilities could be achieved. However, the history of satellite communication has shown that, once operating in orbit, satellites are extremely reliable. Both satellite and ground equipment changeover will need to occur within a very short time, depending on the critical nature of the safety service being supported. This implies that a mature system may require either hot stand-by redundancy of both space segment and earth station or alternative strategies relating to both space and earth segment facilities and equipment. Such strategies would need to ensure that the loss of one satellite would cause minimum disturbance to communication traffic and allow timely restoration of full services.

2.2.19 GES mean time between failures (MTBF) will be high and mean time to repair (MTTR) will be low, employing hot stand-by and uninterruptible power supplies to ensure AMS(R)S continuity. Moreover system performance will be further enhanced due to the availability of technical support, e.g. logistics and maintenance staff.

2.2.20 The AES will also be able to cope adequately with a satellite failure, for example, by rapid acquisition of the signal from an alternate satellite or by tracking the signals from more than one satellite at all times.

2.2.21 Requirements for changeover time will be related to such parameters as the needed surveillance update rate in those cases where, for example, the communication system is supporting ADS.

2.2.22 As with all the avionics, the AES will be designed so that the MTBF is as long as possible whereas the MTTR is as short as possible. These two requirements will apply to essential airborne units such as the satellite data unit, communication management unit, beam steering unit and the antenna sub-system. This may be achieved by main/hot stand-by configuration of the critical units stated above, as well as automated changeover mechanisms within each unit.

Protection

2.2.23 Protection is defined as the degree to which unauthorized parties are prevented from interfering with data transfer over the satellite subnetwork.

2.2.24 For safety communications, the AMS(R)S will provide, at a minimum, protection against modification, addition or deletion of user data.

2.2.25 Measures need to be provided to grant protection from intentional and other harmful interference resulting from malfunction of AES, GES (also referred to as Gateways), satellites, or from sources outside the system.

Figure 2-1
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Figure 2-2 a)
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Figure 2-2 b)
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2.2.26 As an additional level of protection, critical services provided from an interfered satellite could be transferred to another satellite, if necessary by pre-empting lower priority services. Frequency management will be carried out automatically from ground control.

2.2.27 System performance monitoring in real time will be necessary at appropriate locations. Additionally, some protection from intentional jamming will be achieved with spot-beam systems as the effect will be limited to the beam containing the interfering signal with minimal effect on adjacent beams.

Minimum area of connectivity

2.2.28 Operationally required connectivity determines the designated operational coverage area and may influence the location of GESs. In general, satellite systems are intended to provide long-distance connectivity in areas which, for technical and/or economical reasons, cannot be serviced by terrestrial aeronautical air-ground communication systems.

2.2.29 In particular, connectivity is required between aircraft flying in oceanic airspace and oceanic area control centres. Additionally, remote areas require connectivity through satellite systems with area control centres. Connectivity requirements can, when technology permits, include other airspace, including continental airspace with high-density air traffic and area control centres.

Costs and benefits

2.2.30 The initial cost of AES equipment varies widely depending on the class of service provided, e.g. core capability, data rate and voice capability. Moreover, aircraft operators have an interest in keeping the cost and quantity of onboard equipment to a minimum. Any onboard equipment requirements should appropriately weigh costs and benefits ensuring that the minimum communications service standards are met and taking into account the desire for minimizing cost.

Interoperability

2.2.31 The AMS(R)S must be compatible and interoperable with external aircraft and ground systems and also must co-exist with other aviation data links in order to achieve significant cost and operational benefits. Prerequisites for interoperability are:

- a) the definition of standard protocols at the network interface layer; and
- b) a global addressing plan.

2.2.32 To achieve this interoperability, ICAO has defined a particular network protocol architecture through which various networks, including AMS(R)S, Mode S and VDL, can communicate. This is known as the ATN. Details can be found in Doc 9880.

2.3 OPERATIONAL SCENARIOS AND ANTICIPATED BENEFITS

General

2.3.1 The application of AMS(R)S in oceanic and remote areas should provide improved communications, surveillance and procedures. This will lead to improved safety, increased airspace efficiency including a potential for reduced separation, improved meteorological information, and reduced flight time, based on the use of more efficient flight profiles.

2.3.2 A reduction of longitudinal and lateral separation between aircraft requires enhanced CNS capabilities in air traffic systems and on board those aircraft. Enhanced CNS systems provide controllers with automated tools such as conflict prediction and reporting to assist in separation assurance and with tools to better monitor flight plan conformance. Enhanced communication and surveillance systems also enable controllers and pilots to better communicate and manage weather deviations and contingency situations such as aircraft turn-backs and diversions.

2.3.3 Flight planning plays an important role in operations over oceanic airspace. Theoretically, the flight path from departure aerodrome to destination, along a great circle, would give the minimum distance track. However, wind speeds and directions and other meteorological aspects such as temperature, areas of clear air turbulence, etc., affect flight times and therefore the optimum flight paths vary considerably from day to day. Additionally, the free choice of the desired flight path may be restricted by the need to maintain a particular flight level, MACH number or a specific track in an organized track system.

2.3.4 Fuel cost is a dominant part of the total cost of flight operations and is especially significant for long-distance flights. ATC can assist in fuel conservation and gas emissions reduction by accepting a pilot's request for a change of the current flight plan (if the traffic situation permits) which is normally a result of a change in the operational factors affecting the efficiency of the flight.

2.3.5 For aircraft equipped with it, ADS allows automatic reporting of the aircraft's current position, based on information generated by an on-board navigation system, via satellite data link, to ATS. Using automated ATM systems together with graphical situational displays and the ability to interface with CPDLC, air traffic controllers will be in a position to control traffic in oceanic and remote areas almost in real time. These will change the way controllers in these areas work by moving them from a flight data strip and mental traffic picture to real-time "viewing" of traffic.

2.3.6 If there is any controller instruction/clearance to be passed on to the cockpit, the controller can use CPDLC to relay information such as climb, descent, maintain a particular MACH speed, etc. The total transaction time using satellite communication may be significantly less than when using HF.

High air traffic density oceanic areas

2.3.7 Currently, in certain parts of the world, controllers in oceanic airspace rely on infrequent position reports that are manually read by the pilot from the airborne navigation equipment. The position reports are then transmitted on a communications medium (HF radio) to a receiving operator. The communications operator transcribes a teletype message from the voice report and sends it to the oceanic area control centre. Finally the teletype message is printed at the oceanic area control centre and manually delivered to the controller.

2.3.8 At present, these manually-based operations are expected to be fully automated with the use of AMS(R)S. Due to the gradual progress in the airborne equipment, space segment, and ground segment (i.e. the transition from the low speed data link to the high speed data link and the gradual increase of satellite communication equipage), ATC systems are expected to evolve.

2.3.9 The AMS(R)S in oceanic areas with high air traffic density will provide capability for rapid access communications between the ground and the aircraft for both data and voice. This system will be able to accommodate ADS.

2.3.10 The evolution of ATM resulting from AMS(R)S (data and voice communications environment) is characterized by the improvement of traffic monitoring (surveillance accuracy), trajectory prediction, and conflict search and resolution, including short-term conflict alert, and will in addition permit improvement of existing flight planning procedures.

2.3.11 Consequently, a reduction of longitudinal and lateral separation, an increase of tactical conflict resolution and better accommodation of optimal routes are expected.

Low air traffic density oceanic/continental en-route areas

2.3.12 AMS(R)S in oceanic and continental en route areas with low air traffic density shall provide the capability of rapid access communications between the ground and aircraft for both data and voice. The satellite communication service will be able to accommodate ADS.

2.3.13 The evolution of ATM resulting from AMS(R)S (data and voice communications environment) is characterized by the improvement of traffic monitoring (surveillance accuracy), trajectory prediction, conflict detection and resolution, and flight planning procedures. As a consequence, there will be an increase in tactical conflict resolution and improved accommodation of optimal routes.

High air traffic density continental en-route areas

2.3.14 AMS(R)S in high air traffic density continental en-route areas will provide the capability of immediate access communications between the ground and aircraft for both data and voice and will coexist with the VHF voice and data service. AMS(R)S will be able to accommodate ADS but also, as a surveillance system, will coexist with the SSR Mode A, C and S.

2.3.15 The evolution of ATM will include increased accommodation of optimum routes, accommodation of 3D navigation (improved definition of vertical profiles), 3D planning capability based on actual aircraft performance, advanced data communications exchange capability between ATC centres, trajectory prediction for flexible routing, improved conflict search and computer generated resolution advisory, improved short-term conflict alert and resolution, air-ground data link communication capability, and improved trajectory prediction based on actual aircraft performance. All of this could be enhanced to accommodate 4D capabilities (where time is the fourth dimension of air navigation, negotiated between air and ground).

Terminal areas

2.3.16 AMS(R)S may be applied to terminal areas with low density traffic to provide the capability for immediate access communications between ground and aircraft for both data and voice. It may coexist with VHF voice and data, as well as SSR services.

Chapter 3

STANDARDIZATION ACTIVITIES

3.1 GENERAL

In addition to the definition of SARPs by ICAO, as described in 4.3 of the following chapter, standardization activities by other bodies are taking place. Documents which define technical aspects of the individual aeronautical satellite system (including the functional requirements of GES and AES) are developed and maintained by the satellite sub-system operator.

3.2 AEEC (ARINC) CHARACTERISTICS

Airlines, air transport equipment manufacturers and aviation service providers support the Airline Electronic Engineering Committee (AEEC) in developing systems and/or equipment to support industry standardization of common avionics signal characteristics, equipment mounting and inter-equipment signal interfaces. ARINC 741, 761 and 781 are examples of system-level specifications that define, in detail, form, installation, and wiring and operational capability of the equipment and any interchangeability. In addition, there are a number of specifications, such as ARINC 429, that define, in detail, standardized data bus, interface or protocol requirements, which are used by system-level specifications, such as the aforementioned 741, 761 and 781. Avionics manufacturers and service providers shall make every attempt to subscribe to the pertinent standards and specifications in order to provide the highest degree of system and service commonality as possible.

3.3 MINIMUM OPERATIONAL PERFORMANCE STANDARDS (MOPS)

3.3.1 MOPS are the standards by which the airworthiness and functional performance of avionics equipment and installed systems are determined in the United States. They are developed in the public domain by RTCA and then adopted by the U.S. FAA as basic technical standards for equipment certified under their Technical Standard Order (TSO) programme. MOPS are used by manufacturers for bench, installation and flight testing. Other States have similar equipment approval procedures, often based on the RTCA MOPS or similar standards produced by other organizations.

3.3.2 RTCA has developed DO-262, "Minimum Operational Performance Standards for Avionics Supporting Next-Generation Satellite Systems." Guidance on aeronautical mobile satellite service end-to-end system performance can be found in DO-215A.

3.4 MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS (MASPS)

3.4.1 RTCA also develops MASPS which specify characteristics useful to designers, installers, manufacturers, service providers and users of systems intended for operational use within a defined airspace. The MASPS describe the system (subsystems/functions) and provide information needed to understand the rationale for system characteristics, operational goals, requirements and typical applications. Definitions and assumptions essential to proper understanding

of the MASPS are provided as well as minimum system test procedures to verify system performance compliance (e.g. end-to-end performance verification).

3.4.2 RTCA has developed MASPS DO-270 for “AMS(R)S as used in Aeronautical Data Links.”

3.5 SATELLITE SYSTEM ACCESS APPROVAL

Satellite sub-system operators require ground and aircraft earth station equipment to perform in accordance with their system access standards. Thus, it will be necessary for equipment manufacturers to obtain system access approval from those system operators in whose systems they expect their equipment to function. With respect to AES, where components are procured from different manufacturers and installed on board an aircraft by an aircraft manufacturer or the owner, the burden of obtaining system access approval from satellite sub-system operators may fall on the aircraft manufacturer or owner.

3.6 AVIONICS AND CERTIFICATION

Avionics

3.6.1 Various avionics manufacturers are active in the field of the satellite AMS(R)S avionics. At the request of airlines, aircraft manufacturers who produce long range wide body aircraft are presently accepting options for satellite AMS(R)S installations on new aircraft.

Airworthiness certification

3.6.2 AMS(R)S aeronautical equipment cannot be operated unless certified as airworthy by the authorized agency of the State of its manufacture and, depending on treaty arrangements the State has with others, it must also be certified by the equivalent agencies of other States. The standards by which airworthiness is determined include RTCA MOPS, as noted above, and similar specifications produced by other international bodies such as EUROCAE or by the certification agencies themselves.

Type acceptance

3.6.3 With respect to radio transmission characteristics, type acceptance procedures are prepared by communications regulatory agencies, e.g. in the United States, the Federal Communications Commission (FCC), and are conducted by manufacturers to assure that potential radiated interference is within specified limits. The technical characteristics of type acceptance are closely related to MOPS and their testing.

Licensing and permits

3.6.4 An important function in the operation of radio is the control and regulation of the radio equipment in the aircraft. Correct operation of equipment in approved frequency bands and on assigned, operational frequencies must be assured throughout an aircraft's flight on national or international journeys. Performance standards for both telecommunication and air safety requirements are the means used to achieve conformity with international rules.

3.6.5 Individual AES are, by their nature, airborne radio stations; therefore, they are expected to require some form of licensing by national radio regulatory authorities. Operator (e.g. pilot) permits may also be required.

3.7 TERRESTRIAL SUB-SYSTEM SERVICE PROVIDERS

ICAO policy states that institutional arrangements should not prevent competition among different service providers. It is therefore inferred that the AMS(R)S would be offered to States, civil aviation administrations, airlines and others by more than one service provider.

Chapter 4

ICAO ACTIVITIES

4.1 INSTITUTIONAL ARRANGEMENTS

The institutional aspect of ATS communications by satellites is complex because State liability is concerned. The following guidelines were stressed by ICAO's Tenth Air Navigation Conference:

Guideline a): *Universal accessibility to air navigation safety services must be available without discrimination.*

This guideline is one of the fundamental principles underlying the philosophy of ICAO as the specialized agency of the United Nations for civil aviation. The application of the future CNS systems must not change this guideline, and, at this stage, it appears that it will not create new problems in this regard.

Guideline b): *The rights and responsibilities of States to control operations of aircraft within their sovereign airspace must not be compromised.*

This guideline is a fundamental tenet of international civil aviation philosophy, but it raises questions concerning the ability to utilize the "universal" capability of aircraft inherent in the application of modern technology. Satellite technology, in particular, makes it possible to improve the efficient utilization of airspace and the economic operation of international flights across political boundaries. One of the foremost challenges of the future is likely to be to find practical ways to utilize these potential improvements without imposing unacceptable conditions regarding the sovereignty of national airspace. For example, where a State provides ATS communications through another State's GES and other facilities, arrangements should avoid subordination of that State's ATS service.

Guideline c): *Arrangements must preserve, facilitate and not inhibit ICAO responsibility for the establishment of appropriate Standards, Recommended Practices and procedures in accordance with Article 37 of the Convention on International Civil Aviation.*

Article 37 of the Convention on International Civil Aviation recognizes the specialized safety needs of aircraft operations and designates ICAO as the body responsible for the adoption and application of air navigation safety Standards embodied in the technical Annexes to the Convention. ICAO has long recognized the desirability, particularly for economic reasons, of aligning its technical Standards as closely as possible with similar specifications being developed by other international standardization bodies but has always retained its authority to diverge from other similar international technical standards should the need arise. The reasons for the inclusion of Article 37 in the Convention still exist, and ICAO is vigilant in carrying out its mandate in this area of activity.

Guideline d): *Arrangements must ensure the ability to protect safety communications from harmful interference.*

As the electromagnetic spectrum becomes more intensely used, the incidence of harmful interference to aircraft safety services has increased alarmingly, and it would appear prudent to assume that this trend will continue and probably accelerate in the future. In modern satellite technology, and particularly on questions concerning use of the electromagnetic spectrum, there are strong pressures to ensure that non aviation users conform to critical specifications dictated by the safety requirements of the civil aviation community. The most effective place to deal with harmful interference is at its source, and ICAO has been doing its best to ensure that acceptable levels are established for spurious emissions allowable from activities in the electromagnetic spectrum of a growing number of users. The future

CNS system will utilize previously unexploited parts of the electromagnetic spectrum, and may be susceptible to new forms of harmful interference, so continuing efforts in coordination, research, application and regulatory enforcement will be required to retain established safety criteria. Arrangements should ensure that continuous oversight and control of the area's spectrum use be conducted so that harmful interference can be quickly detected and corrected.

Guideline e): *Arrangements must be adequately flexible to accommodate presently defined services and a range of future services.*

As in the introduction of any new system, users require assurance that there will be no degradation of existing services. Possibilities for additional services need to be introduced, and such additions need to be implemented with minimum disruption to existing systems. Furthermore, institutional and organizational arrangements must also ensure the required flexibility. Safety message priority must be assured.

Guideline f): *Arrangements must facilitate the certification by States of those service providers whose services comply with ICAO Standards, Recommended Practices and procedures for the aeronautical mobile satellite (R) service (AMS(R)S).*

The certification process should ensure that services provided meet the appropriate ICAO SARPs as well as any State requirements such as financial responsibility, competence and capacity.

Guideline g): *Institutional arrangements should not prevent competition among different service providers that comply with ICAO SARPs.*

This guideline seeks to encourage competition in the provision of aeronautical mobile satellite service. In some areas, however, ATS administrations may wish to select and regulate the satellite system to be used, for reasons such as the existence of contracts with service providers, or special interfaces with service providers that operate through a particular satellite system.

Guideline h): *ICAO's responsibility for coordination and use of AMS(R)S spectrum allocations must continue to be recognized.*

Where ICAO plays a role in the coordination and use of radio frequency spectrum within the aeronautical community, the ITU is responsible for the international allocation, coordination, registration and protection of frequency assignments.

While there has been little difficulty in the past with regard to recognition of ICAO's responsibility vis-à-vis Annex 10 provisions, frequency allocations have become extremely complex in today's environment, and users are placing different interpretations on the meaning of "responsibility".

Guideline i): *Arrangements must recognize States' responsibility and authority to enforce safety regulations.*

In the complexity of modern satellite systems, particularly in cases of satellite systems sharing resources with other services, the manner in which States' responsibility could be exercised becomes more complex.

Guideline j): *Arrangements must ensure guaranteed priority of aeronautical mobile-satellite safety communications over aeronautical non-safety and non-aeronautical mobile-satellite communications in accordance with ICAO SARPs.*

This guideline is generally acknowledged as a requirement, but the provisions of guaranteed priority for aeronautical safety communications in any satellite system must be demonstrated in practice and under all satellite conditions before acceptance. Relevant details are being studied in the Aeronautical Communications Panel (ACP).

Guideline k): *Arrangements must be in place so that service providers, operating in the same area, cooperate to ensure that space segment resources are made available to handle AMS(R)S service.*

As message traffic increases for both aeronautical safety and non-safety service, situations may arise where one service provider runs out of resources (e.g. satellite power, spectrum, etc.) to support AMS(R)S, however, another service provider(s), providing service in the same area could support AMS(R)S. Under these conditions arrangements should be developed so that resources are made available to handle the AMS(R)S traffic of the first service provider through cooperative use of the resources.

Guideline l): *Arrangements should enable all AMSS functions (ATS, AOC, AAC and APC) to be provided through common avionics equipment in the aircraft.*

This guideline has special significance for the civil aviation industry because of the special problems (technical and economical) involved with multiple airborne satellite installations.

Guideline m): *Arrangements should make all four identified satellite services (ATS, AOC, AAC and APC) available through any given satellite in any region of the world.*

This guideline is in recognition of the difficulties of installing multiple systems aboard aircraft. An aircraft should, as a matter of principle, not be required to access more than one satellite to obtain all four identified AMSS functions (ATS, AOC, AAC and APC).

Guideline n): *Adequate arrangements should be made for recovery in the event of a significant malfunction or catastrophic failure of the satellite system.*

Where a single satellite system provider offers a service in an area, a back-up capability must be available within that system in the event of a significant malfunction or catastrophic failure. In the special case where more than one satellite system provider offers identical, or near identical, and technically compatible services in the same area, cooperative institutional arrangements may facilitate back-up service in the event of a significant malfunction or catastrophic failure in one of the systems.

Guideline o): *Policies governing charges levied on users must not inhibit or compromise the use of satellite-based service for safety messages.*

Because of the importance and the pre-eminence of safety messages in aeronautical mobile communications, their use must be in accordance with regulations and without regard to the cost of individual transmissions. In implementing this guideline, the specific Annex 10 definition of what constitutes a safety message must be conveyed to the service provider of the AMSS system.

Guideline p): *Existing governmental or inter governmental agencies, modified if necessary, should be used to the extent practicable.*

This guideline states the practical fact that new agencies need not be established if existing agencies in present or modified form can do the job satisfactorily.

Guideline q): *Arrangements should allow the introduction of satellite services on an evolutionary growth basis.*

One of the practical difficulties in introducing any new aeronautical service is the implementation of required equipment in aircraft. Therefore, any system which allows for step-by-step and evolutionary implementation and growth is highly desirable.

Guideline r): *Arrangements should provide for the determination of liabilities.*

The determination of liabilities among the various service providers of the AMSS system is a task requiring inputs from work being done by other groups in ICAO. This guideline has been listed here as a reminder that liability issues could have a bearing on institutional arrangements.

Guideline s): *Arrangements must retain ATS authority to coordinate and maintain control, directly or indirectly, over aeronautical mobile satellite communications according to message priorities established in the ITU Radio Regulations.*

This guideline pertains to the requirement for the ATS authority to retain authority and control over aeronautical safety communications and notes the need for a rigid examination and adequate demonstration that this vital function can be retained both in respect of dedicated aeronautical satellite systems and in generic satellite systems.

4.2 AMS(R)S SPECTRUM ISSUES

4.2.1 Under its Constitution and Convention, the International Telecommunication Union (ITU) has recognition and authority as the international body for telecommunications. The Radio Regulations (RR) are the instrument through which this specialization is expressed in internationally agreed terms for radio matters. The ITU Radio Regulations lay down the framework for international spectrum management and contain the Table of Frequency Allocations, which is effectively the worldwide agreement on the deployment and conditions of use of all radio frequencies in the radio frequency spectrum.

4.2.2 Spectrum for the provision of AMS(R)S is made available through agreements reached at World Radiocommunication Conferences of the ITU. These agreements are embodied in the Radio Regulations. Articles 1, 5, 9 and 11 of these regulations address the availability and protection of the spectrum for AMS(R)S. Article 1 defines Safety Service and the Mobile Satellite Service (MSS), which includes the AMS(R)S.

4.2.3 MSS primary allocations are required to be used by satellite systems and networks to provide AMS(R)S (RR Article 5). These allocations generally are used to provide uplinks and downlinks in the range 1.5–1.6 GHz. This frequency range has been divided into a number of MSS allocations which are being used by geostationary and non-geostationary satellite systems. The allocations for these systems include footnotes which are considered part of the allocation and provide an indication that these bands may be used for AMS(R)S. They also specify the requirement for frequency coordination between the MSS systems and with other services operating in the same frequency bands.

4.2.4 Frequency coordination is carried out in accordance with the provisions of Article 9 of the RR. The purpose of this coordination is to ensure that harmful interference is neither caused nor received by the MSS systems concerned. When coordination is successfully completed, the MSS systems are registered with the ITU (RR Article 11) and included in the International Frequency List. When this status is achieved, the systems are entitled to receive protection which also ensures the protection of AMS(R)S.

4.2.5 Additional information is contained in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including Statement of Approved ICAO Policies* (Doc 9718).

4.3 STANDARDS AND RECOMMENDED PRACTICES (SARPS)

4.3.1 During the review of the report of the eighth meeting of the Aeronautical Mobile Communications Panel (AMCP/8), the predecessor of the ACP, the Air Navigation Commission requested the ACP to develop proposals for the reorganization of the AMSS SARPs (Annex 10, Volume III, Part I, Chapter 4) into a section with “core” SARPs, to be

retained in Annex 10, and a set of detailed technical specifications for AMS(R)S, as required. In pursuing this work, the “core” functionality of the AMSS SARPs and the next-generation satellite system (NGSS) draft SARPs, which were developed at the seventh meeting of the AMCP (AMCP/7), were integrated into a single set of AMS(R)S SARPs. These AMS(R)S SARPs have replaced the AMSS and the (draft) NGSS SARPs.

4.3.2 Relevant detailed technical specifications for AMS(R)S have been developed by the ACP and are contained in this manual. In this process, as much as possible, reference has been made to relevant material already available through organizations such as RTCA and EUROCAE.

4.3.3 The AMS(R)S SARPs were incorporated into Annex 10, Amendment 82 and became applicable on 22 November 2007.

4.4 REQUIRED COMMUNICATION PERFORMANCE (RCP)

4.4.1 The emergence of several types of data links for the conduct of air-ground data interchange, as well as for the support of specific navigation, surveillance and other functions, has raised the concern that the air navigation system is becoming too complex. Obviously, it would have been ideal to have a single air-ground communications system capable of handling all communications, navigation and surveillance requirements in all types of airspace and for all phases of flight in a cost-effective manner. However, as no such technological solution has yet been found to meet all operational requirements, the aviation community has to consider all available as well as emerging communications systems, though some may only perform a single function or only serve a limited area.

4.4.2 The availability of several communications systems does provide a degree of flexibility to planning and implementation in different types of airspace; however, the proliferation of subnetworks will add to the complexity of the operation of air-ground communications. One solution to this problem is to do away with the specification of individual systems and, instead, translate all relevant operational requirements in a certain airspace and scenario into a series of communications performance parameters. The term RCP therefore refers to a set of well-quantified communications performance requirements, such as capacity, availability, error rate and transit delay. Once RCP has been specified for an operational scenario in a given airspace, any single communications system, or combination of systems meeting the set parameters, can be considered as operationally acceptable.

4.4.3 Guidance material on RCP is contained in the *Manual on required communication performance (RCP)* (Doc 9869).

4.5 AERONAUTICAL TELECOMMUNICATION NETWORK (ATN)

4.5.1 The concept of an ATN, which was developed through ICAO and other aeronautical organizations, supported the interoperability between the different types of air-ground data links, e.g. Mode S, VDL and AMS(R)S. For packet data service, the AMS(R)S was considered as a subnetwork of the ATN. The ATN concept allowed for connectivity between air-ground data link subnetworks and terrestrial subnetworks, thus integrating all the different aeronautical communication subnetworks, including the aeronautical fixed telecommunication needs.

4.5.2 In the ATN concept, the network aspects of each subnetwork are independent of the application environment, and certain parts of the avionics can be shared between the different air-ground subnetworks. In particular, as data link application services evolve with time, it is important that the subnetwork characteristics remain the same.

4.5.3 To achieve this interoperability between data links, the international aviation community decided to adhere to the open system interconnection (OSI) reference model developed by the International Organization for Standardization (ISO). In February 1993, the Air Navigation Commission established the ATNP to develop SARPs,

guidance material and other relevant documents for the ATN. Work was predicated on the predominant networking technology of that time, the OSI/ISO protocol suite. Since then, significant changes have occurred in the technology arena and in air traffic management. Technologically, the worldwide acceptance of the Internet Protocol Suite (IPS) as internetworking protocol had led industry away from providing OSI-based commercial products. This has led numerous ICAO Member States and aeronautical technical organizations to review their planned implementation of the OSI/ISO protocols; this was also the genesis for the current ICAO activities to include IPS in ATN SARPs.

4.5.4 The ATN and its associated application processes have been specifically designed to provide, in a manner transparent to the end-user, a reliable end-to-end communications service over dissimilar networks in support of air traffic services. ATN can also carry other communications service types, such as AOC communications, AAC and APC. Some other features of the ATN include:

- a) it enhances data security;
- b) it is based on internationally recognized data communications Standards;
- c) it accommodates differing services (e.g. preferred air ground subnetwork);
- d) it allows the integration of public/private networks; and
- e) it makes efficient use of bandwidth, which is a limited resource in air-ground data links.

A diagram of the ATN architecture is given in Figure 4-1.

4.5.5 When a State or organization transitions to an ATN environment, consideration must be given to interfacing with systems of other States and organizations. Furthermore, the ground-to-air interface(s) will be to either an ATN aircraft or a FANS-1/A aircraft. An ATS unit which needs to exchange data with ATN aircraft should implement applications which are the ground-based peers of the aircraft applications. In addition, the ground ATN environment must be connected to the aircraft ATN environment via one or more mobile subnetworks. There are two possible ways to use a mobile subnetwork. The first is a direct connection from the ATS unit to the aircraft router. The second way is to use the air-ground router and mobile subnetwork of another organization. Communication with a FANS-1/A aircraft will be accomplished by an "accommodation software" in an ATS unit. All FANS-1/A accommodation-related work will be done on the ground. Both ATN and FANS-1/A downlink messages will be processed without restriction, and uplink messages will arrive correctly at their intended destination (i.e. FANS-1/A to FANS-1/A aircraft and ATN to ATN aircraft). However, the FANS-1/A-only aircraft are not expected to be able to obtain the same operational services that will be offered to ATN aircraft.

4.5.6 Guidance material can be found in Doc 9880 which contains the detailed technical specifications for the ATN, based on relevant standards and protocols established by the ISO and the Telecommunication Standardization Sector of the ITU for OSI. It contains information on air-ground and ground-ground applications, Internet communication services, including upper layer communications service, directory service, security services, systems management and identifier registration. Additional information may be found in the *Comprehensive Aeronautical Telecommunication Network (ATN) Manual* (Doc 9739). The ATN is currently migrating towards IPS standards.

4.5.7 Enabling early use of current technology by the application of ARINC Specifications 622 (*ATS Data Link Applications Over ACARS Air-Ground Network*) and 623 (*Character-Oriented Air Traffic Service Applications*) over character-based data communication systems such as Aircraft Communications Addressing and Reporting System (ACARS) will provide for significant benefits in ATM. Several States are proceeding with implementation of ATS ground facilities to meet and take early advantage of aircraft CNS packages, both of which are based on the ARINC Specifications 622 and 623. The implementation plans recognize that eventual transition to the ATN is an objective and that ARINC Specifications 622 and 623 are interim steps designed to gain early CNS/ATM benefits from existing technology.

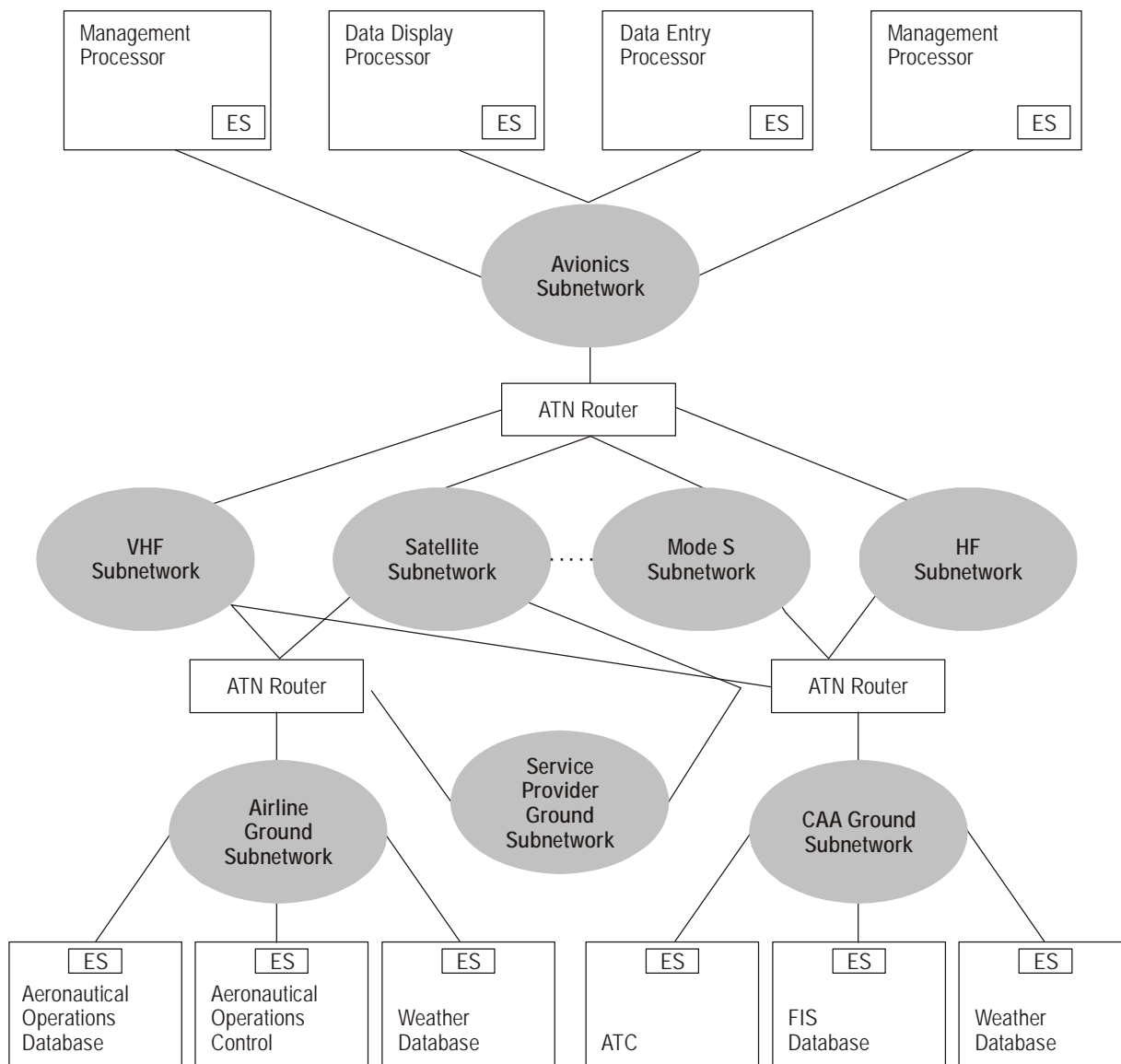


Figure 4-1. Overview of ATN architecture

**MANUAL ON THE
AERONAUTICAL MOBILE
SATELLITE (ROUTE) SERVICE**

Part II

IRIDIUM

Chapter 1

INTRODUCTION

1.1 OBJECTIVE

The objective of this part of the manual is to provide detailed technical specifications and guidance material to ICAO Member States and the international civil aviation community on their consideration of the Iridium Satellite Network, acting as a subnetwork to the ATN, as a platform for offering AMS(R)S communications for the safety and regularity of flight. This manual is to be considered in conjunction with the SARPs contained in Annex 10, Volume III, Part I, Chapter 4.

1.2 SCOPE

This part of the manual contains information about aeronautical mobile satellite communications using the Iridium Satellite system. Information is provided about the Iridium Satellite Network, including system architecture, interoperability and technical characteristics, AMS(R)S system, as well space, ground and airborne equipment. Iridium-specific performance parameters and compliance with AMS(R)S SARPs are also described.

Chapter 1.— “Introduction” provides a background of the ICAO Aeronautical Communications Panel and the AMS(R)S SARPs and an overview of how the Iridium Satellite Network supports AMS(R)S.

Chapter 2.— “Iridium satellite network” provides a detailed description of the Iridium satellite network.

Chapter 3.— “Iridium AMS(R)S system” provides an overview of the integration of the Iridium satellite network into an AMS(R)S system providing end-to-end voice and data communication service.

Chapter 4.— “Iridium AMS(R)S standardization activities” describes efforts within the aviation industry standardization bodies to integrate Iridium AMS(R)S communications services and systems.

Chapter 5.— “Comparison of AMS(R)S SARPs and projected Iridium performance” contains information provided by Iridium Satellite LLC on its compliance with ICAO AMS(R)S SARPs. Appendix A provides information on Iridium-specific performance parameters pertaining to the Minimum Operational Performances Standards for Avionics Supporting Next-Generation Satellite Systems as specified in RTCA DO-262.

Chapter 6.— “Implementation guidance” provides guidance material on the performance of the future Iridium AMS(R)S system, as it is focused primarily on the Iridium subnetwork.

1.3 BACKGROUND

1.3.1 The ICAO ACP has carried forward future air navigation systems planning that designates basic architectural concepts for using satellite communications, initially in oceanic and remote environments and eventually in continental airspace. The progress towards satellite communications for aeronautical safety is realized through the revision of SARPs and guidance material by ICAO for AMS(R)S and through the interactions of ICAO with other international bodies to assure that resources are coordinated and available.

1.3.2 The AMCP, the predecessor of the ACP, concluded at its sixth meeting in March 1999 that the Iridium Satellite Network broadly satisfied the set of acceptability criteria developed for next-generation satellite systems. This was before the more generic performance-oriented AMS(R)S SARPs were adopted by the ICAO Council in 2007.

1.3.3 Part 1 of this manual provides a detailed description of ICAO activities and SARPs related to AMS(R)S. This section, Part 2, provides technical details of the Iridium network and implementation guidance for ICAO Member States.

1.4 TERMS

Throughout this manual the satellite network operations provider may be referred to as Iridium, Iridium Satellite, or ISLLC. Refer to the Abbreviations and Definitions section at the beginning of this manual for a complete list of definitions of the satellite network operation provider, satellite communications services provider and terrestrial network service provider and other terms related to Iridium AMS(R)S.

Chapter 2

IRIDIUM SATELLITE NETWORK

2.1 OVERVIEW

2.1.1 The Iridium Satellite Network, with its constellation of 66 LEO satellites, is a global mobile satellite communication network, with complete coverage of the entire Earth, including polar regions, offering voice and data service to and from remote areas where no other form of communication is available.

2.1.2 As of February 2007, Iridium Satellite LLC had approximately 175 000 subscribers worldwide.

2.1.3 Iridium Satellite launched service in December 2000; Iridium World Data services were launched in June 2001. World Data services include dial-up data with a throughput rate of up to 2.4 kbps, direct Internet data with a throughput rate of up to 10 kbps, and the router-based unrestricted digital interworking connectivity solution (RUDICS). Iridium short burst data (SBD) service was added in June 2003.

2.1.4 Iridium Satellite operates its Satellite Network Operations Centre (SNOC) in Virginia, USA, with gateways in Arizona and Hawaii. Telemetry, tracking, and control (TTAC) facilities are located in Arizona and Alaska, USA; and Yellowknife and Iqaluit, Canada; with an additional TTAC facility planned for Svalbard, Norway, and backup facilities located around the globe.

2.1.5 ISLLC has contracted The Boeing Company to operate, maintain and monitor its satellite constellation. The Iridium constellation, gateway facilities, testing and development laboratories, TTAC facilities, as well as overall network and system health are being permanently monitored.

2.1.6 ISLLC also has contracted Celestica Inc. to manufacture its subscriber equipment, satellite handsets, L-band¹ Transceivers (LBT), and SBD devices. The LBT and SBD devices are installed in the Iridium Satcom Data Units (SDUs).

2.1.7 System improvements in the satellite and user equipment have been introduced, providing improved voice quality and performance. Multiple tests and analyses have demonstrated satellite constellation longevity until at least 2014, yet plans already are underway for the manufacture and launch of the next generation constellation.

2.2 SYSTEM ARCHITECTURE

2.2.1 The Iridium Satellite Network is a satellite-based, wireless personal communications network, based on global system for mobile communications standard (GSM), providing voice and data services to virtually any destination on Earth.

2.2.2 The Iridium communication system comprises three principal components: the satellite network, the ground network and the Iridium subscriber products. The design of the Iridium network allows voice and data to be routed

1. For the purpose of Part II of this manual, the term "L-band" specifically refers to the band 1 616–1 626.5 MHz.

virtually anywhere in the world. Voice and data calls are relayed from one satellite to another until they reach the satellite above the AES, which includes the Iridium SDU, and the signal is relayed back to Earth.

2.2.3 The key elements of the Iridium communication system are illustrated in Figure 2-1.

Space segment

2.2.4 The Iridium space segment utilizes a constellation of 66 operational satellites in LEO, as shown in Figure 2-2. The satellites are located in six distinct planes in near-polar orbit at an altitude of approximately 780 km and circle the Earth approximately once every 100 minutes, travelling at a rate of roughly 27 088 km/h. The eleven mission satellites, which are evenly spaced within each plane, perform as nodes in the communication network. The six co-rotating planes are spaced 31.6 degrees apart in longitude, resulting in a spacing of 22 degrees between Plane 6 and the counter-rotating portion of Plane 1. Satellite positions in adjacent odd and even numbered planes are offset from each other by one-half of the satellite spacing. This constellation ensures that every region on the globe is covered by at least one satellite at all times. There are currently ten additional in-orbit spare satellites ready to replace any unserviceable satellite in case of a failure.

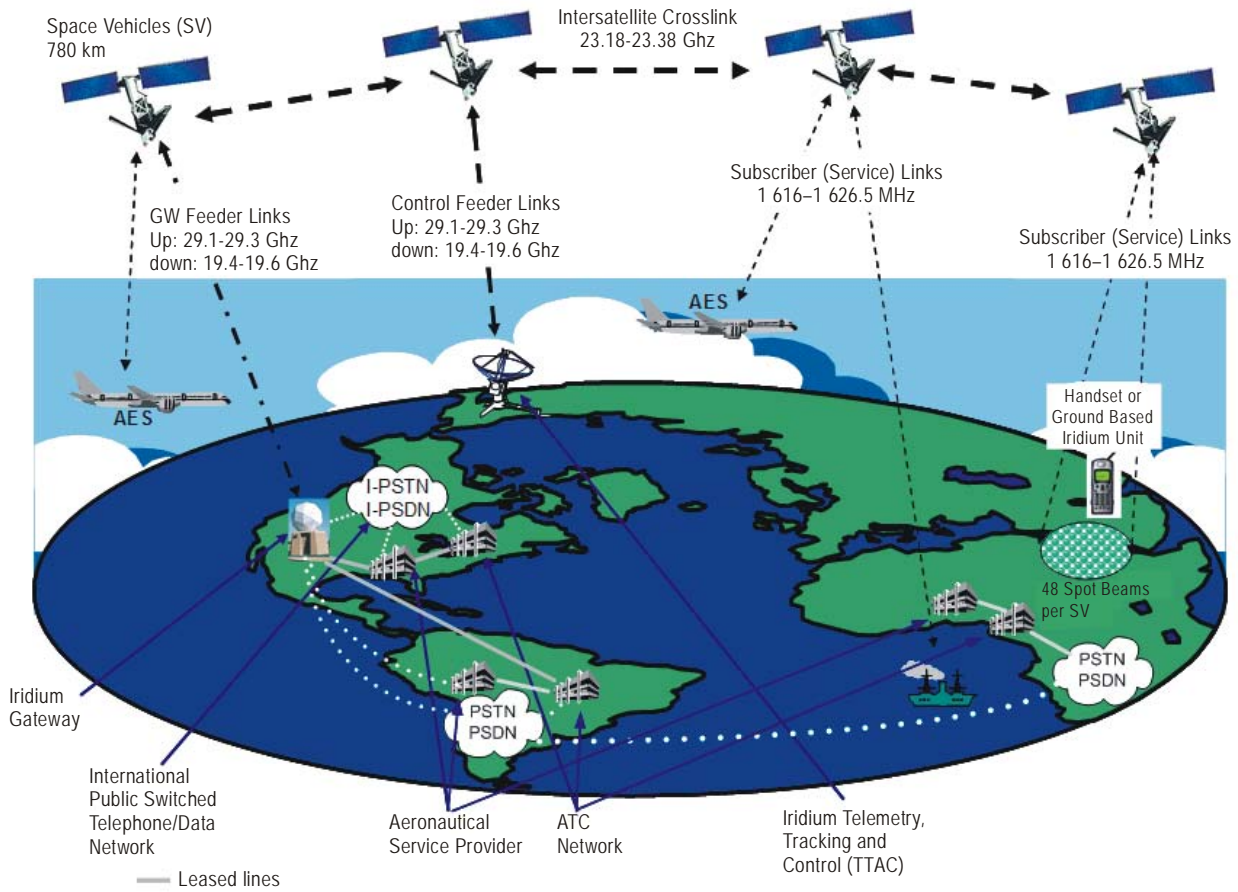


Figure 2-1. Key elements of the Iridium AMS(R)S

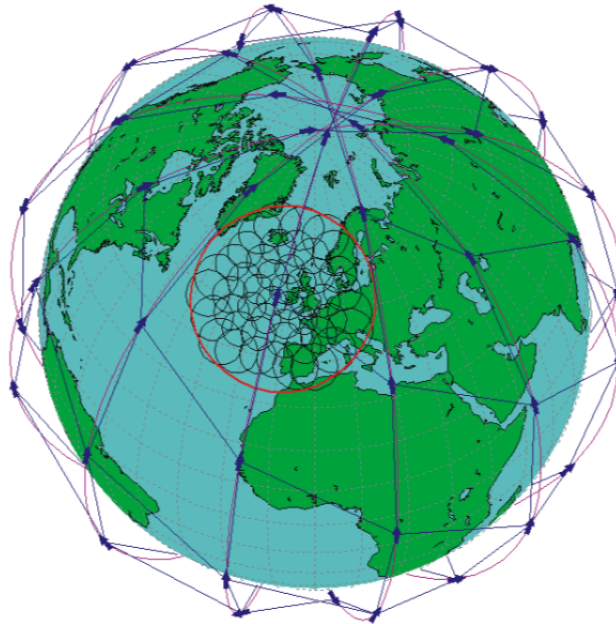


Figure 2-2. Iridium 66-satellite constellation

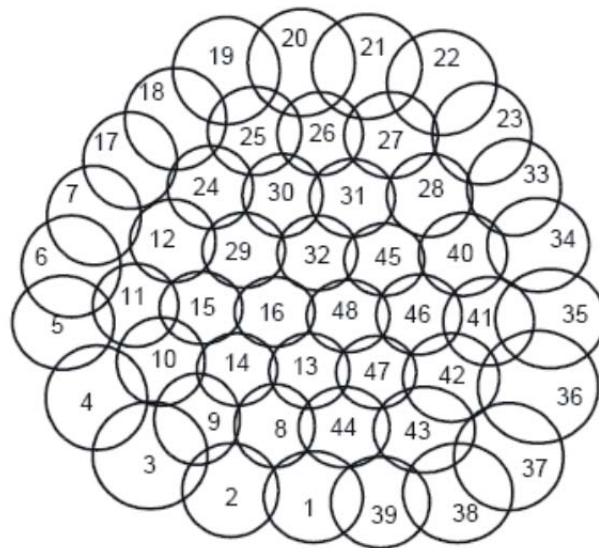


Figure 2-3. Iridium spot-beam configuration

2.2.5 Each satellite communicates with the AES, which includes the SDUs, through tightly focused antenna beams that form a continuous pattern on the Earth's surface. Each satellite uses three phased-array antennas for the user links, each of which contains an array of transmit/receive modules. The phased-array antennas of each satellite create 48 spot beams arranged in the configuration shown in Figure 2-3 covering a circular area with a diameter of approximately 4 700 km. These arrays are designed to provide user-link service by communicating within the 1 616–1 626.5 MHz band.

2.2.6 The near-polar orbits of Iridium satellites (commonly referred to as space vehicles or satellites) cause the satellites to be closer together as the sub-satellite latitude increases, as illustrated in Figure 2-2. This orbital motion, in turn, causes the coverage of neighbouring satellites to overlap increasingly as the satellites approach the poles. A consistent sharing of load among satellites is maintained at high latitudes by selectively deactivating outer-ring spot beams in each satellite. This beam control also results in reduced inter-satellite interference and increased availability in high latitudes due to overlapping coverage.

2.2.7 The Iridium Satellite Network architecture incorporates certain characteristics which allow the space segment communications link with subscriber equipment to be transferred from beam to beam and from satellite to satellite as such satellites move over the area where the subscriber is located. This transfer is transparent to the user, even during real-time communications.

2.2.8 Each satellite has four cross-link antennas to allow it to communicate with and route traffic to the two satellites that are fore and aft of it in the same orbital plane, as well as to neighbouring satellites in the adjacent co-rotating orbital planes. These inter-satellite links operate at approximately 23 GHz. Inter-satellite networking is a significant technical feature of the Iridium Satellite Network that enhances system reliability and capacity and reduces the number of gateways or GESs required to provide global coverage to one with redundant back-up switch, processors and an Earth terminal station which is physically separated from the primary GES.

Terrestrial segment

2.2.9 The terrestrial segment is comprised of the system control segment and Iridium gateways that connect into the terrestrial telephone/data network.

2.2.10 The system control segment is the central management component for the Iridium system. It provides global operational support and control services for the satellite constellation, delivers satellite-tracking data to the Iridium gateways, and performs the termination control function of messaging services.

2.2.11 The system control segment consists of three main components: four TTAC sites, the operational support network and the SNOC. The primary linkage between the system control segment, the satellites, and the gateways is via control feeder links and inter-satellite cross-links throughout the satellite constellation.

2.2.12 The Iridium gateway provides call processing and control activities such as subscriber validation and access control for all calls. The gateway connects the Iridium satellite network to ground communication networks, such as the terrestrial public switched telephone networks (PSTNs) and public switched data networks (PSDNs), and communicates via ground-based antennas with the gateway feederlink antennas on the satellite. The gateway can also serve as a gateway to the ATN for forwarding ATN messages from the aircraft to the required air traffic command or AOC unit or vice versa. The gateway includes a subscriber database used in call processing activities such as subscriber validation; keeps a record of all traffic; and generates call detail records used in billing.

2.3 CHANNEL CLASSIFICATIONS

2.3.1 Each Iridium communications channel consists of a time-slot and a carrier frequency. Channels provided by the system can be divided into two broad categories: system overhead channels and bearer service channels. Bearer service channels include traffic channels and messaging channels, while system overhead channels include ring alert channels, broadcast channels, acquisition and synchronization channels. A specific time-slot-and-frequency combination may be used for several types of channels, depending on what specific activity is appropriate at each instant. Each time-slot-and-frequency combination is only used for one purpose at a time. Figure 2-4 illustrates the hierarchy of Iridium channel types. Iridium aeronautical services utilize only the indicated channel types.

2.3.2 In the discussions that follow, the term “channel” will always refer to a time-slot-and-frequency combination. The terms “frequency” or “frequency access” will denote the specific radio frequency of an individual channel.

Overhead channels

2.3.3 The Iridium Satellite Network has four overhead channels: 1) ring channel; 2) broadcast channel; 3) acquisition channel; and 4) synchronization channel.

2.3.4 The ring channel is a downlink-only channel used to send ring alert messages to individual subscriber units. Its downlink frequency is globally assigned in order to be the same known frequency throughout the world. The ring channel uses a time division format to send ring alert messages to multiple subscriber units in a single frame.

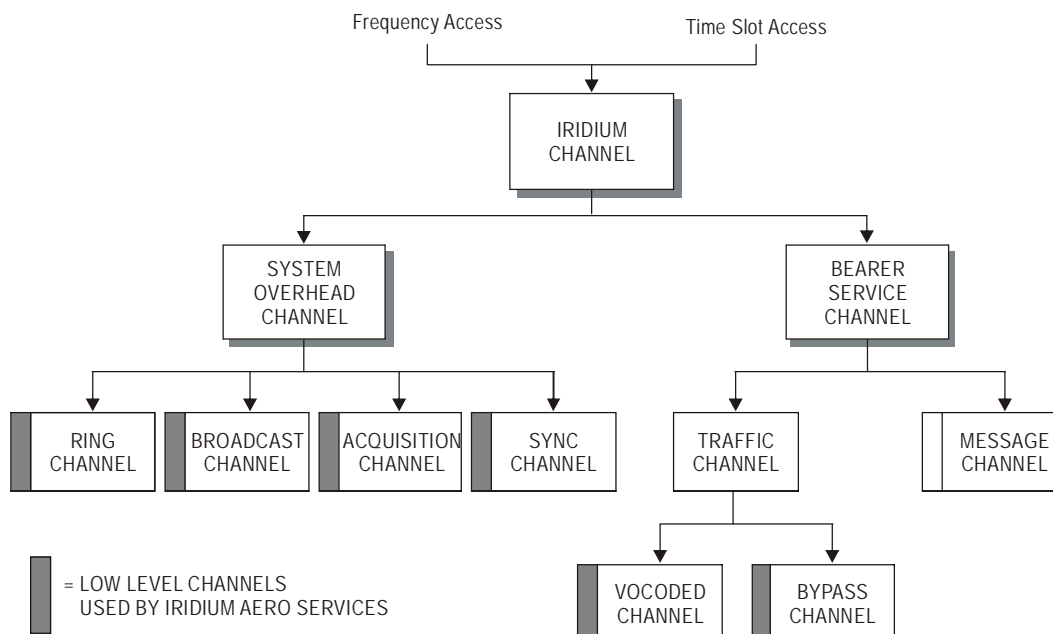


Figure 2-4. Iridium channel structure hierarchy

2.3.5 Broadcast channels are downlink channels used to support the acquisition and handoff processes. These channels provide frequency, timing and system information to SDUs before they attempt to transmit an acquisition request. In addition, broadcast channels provide downlink messages which acknowledge acquisition requests and make channel assignments. Finally, broadcast channels are used to implement selective acquisition blocking to prevent local system overloads.

2.3.6 Acquisition channels are uplink-only channels used by individual subscriber equipment to transmit an acquisition request. These channels use a slotted ALOHA random access process. The time and frequency error tolerances are larger for an acquisition channel to allow for initial frequency and timing uncertainties. SDUs determine which acquisition channels are active by monitoring the broadcast channel.

2.3.7 The synchronization channel is a duplex channel used by the SDU to achieve final synchronization with a satellite before it begins traffic channel operation. The synchronization channel occupies the same physical channel time slots and frequency accesses as the traffic channel that the SDU will occupy when the synch process is complete. During the synch process, the satellite measures the differential time of arrival and differential frequency of arrival of the uplink synch burst and sends correction information to the SDU in the downlink synch burst. A synchronization channel is assigned to an SDU by the satellite. The synchronization procedure is accomplished by the SDU transmitting an uplink burst which the satellite measures for time and frequency error relative to the assigned channel. The satellite sends time and frequency corrections for the latest uplink burst over the downlink channel. This process is repeated until the satellite determines that both the SDU transmit time and frequency are within the tolerance for a traffic channel. When this occurs, the satellite transmits a message to that effect to the SDU and reconfigures the channel for traffic channel operation.

Bearer service channels

2.3.8 The Iridium subscriber link provides two basic types of bearer service channels: traffic channels and messaging channels.

2.3.9 Messaging channels support downlink only simplex messaging service. This service carries numeric and alphanumeric messages to message termination devices such as Iridium pagers. The Iridium aeronautical service does not utilize the simplex messaging services.

2.3.10 Traffic channels support duplex services which include portable mobile telephony and a variety of duplex bearer data services. Each traffic channel consists of an associated uplink and downlink channel. A duplex user has exclusive use of the assigned channels until service terminates or until handed off to a different channel.

2.4 CHANNEL MULTIPLEXING

2.4.1 Channels are implemented in the Iridium Satellite Network using a hybrid time division multiple access/frequency division multiple access (TDMA/FDMA) architecture based on time division duplex using a 90 ms frame. Channels are reused in different geographic locations by implementing acceptable co-channel interference constraints. A channel assignment comprises both a frequency carrier and time slot.

TDMA frame structure

2.4.2 The fundamental unit of the TDMA channel is a time-slot. Time-slots are organized into TDMA frames as illustrated in Figure 2-5. The frame consists of a 20.32 ms downlink simplex time-slot, followed by four 8.28 ms uplink time-slots and four downlink time-slots, which provide the duplex channel capability. The TDMA frame also includes various guard times to allow hardware set up and to provide tolerance for uplink channel operations.

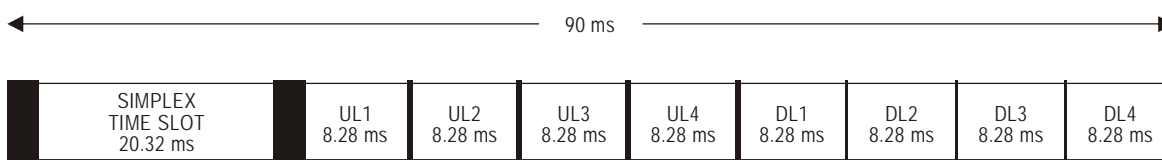


Figure 2-5. Iridium TDMA structure

2.4.3 The simplex time-slot supports the downlink-only, ring and messaging channels. The acquisition, synchronization and traffic channels use the uplink time-slots. The broadcast, synchronization, and traffic channels use the downlink duplex time-slots.

2.4.4 There are 2 250 symbols per TDMA frame at a channel burst modulation rate of 25 ksps. A 2 400 bps traffic channel uses one uplink and one downlink time-slot per frame.

FDMA frequency plan

2.4.5 The fundamental unit of frequency in the FDMA structure is a frequency access that occupies a 41.667 kHz bandwidth. Each channel uses one frequency access. The frequency accesses are divided into the duplex channel band and the simplex channel band. The duplex channel band is further divided into sub-bands.

Duplex channel band

2.4.6 The frequency accesses used for duplex channels are organized into sub-bands, each of which contains eight frequency accesses. Each sub-band, therefore, occupies 333.333 kHz (8 x 41.667 kHz). In duplex operation, the Iridium Satellite Network is capable of operating with up to 30 sub-bands, containing a total of 240 frequency accesses. Table 2-1 shows the band edges for each of the 30 sub-bands. Iridium’s current band usage includes sub-bands 8-30.

2.4.7 The Iridium Satellite Network reuses duplex channels from beam to beam when sufficient spatial isolation exists to avoid interference. Channel assignments are restricted so that interference is limited to acceptable levels. A reuse pair is the minimum group of duplex channels that can be assigned to an antenna beam. A reuse unit pair consists of an uplink reuse unit and a downlink reuse unit. A reuse unit consists of one time-slot and the eight contiguous frequency accesses of a sub-band for a total of eight channels. The frequency accesses are numbered 1 through 8 from lowest to highest frequency.

Table 2-1. Sub-band frequency allocation

Sub-band	Lower edge (MHz)	Upper edge (MHz)
1	1 616.000000	1 616.333333
2	1 616.333333	1 616.666667
3	1 616.666667	1 617.000000
4	1 617.000000	1 617.333333
5	1 617.333333	1 617.666667
6	1 617.666667	1 618.000000

Sub-band	Lower edge (MHz)	Upper edge (MHz)
7	1 618.000000	1 618.333333
8	1 618.333333	1 618.666667
9	1 618.666667	1 619.000000
10	1 619.000000	1 619.333333
11	1 619.333333	1 619.666667
12	1 619.666667	1 620.000000
13	1 620.000000	1 620.333333
14	1 620.333333	1 620.666667
15	1 620.666667	1 621.000000
16	1 621.000000	1 621.333333
17	1 621.333333	1 621.666667
18	1 621.666667	1 622.000000
19	1 622.000000	1 622.333333
20	1 622.333333	1 622.666667
21	1 622.666667	1 623.000000
22	1 623.000000	1 623.333333
23	1 623.333333	1 623.666667
24	1 623.666667	1 624.000000
25	1 624.000000	1 624.333333
26	1 624.333333	1 624.666667
27	1 624.666667	1 625.000000
28	1 625.000000	1 625.333333
29	1 625.333333	1 625.666667
30	1 625.666667	1 626.000000

2.4.8 Table 2-2 lists the lower, upper and centre frequencies for each of the eight frequency accesses within a reuse unit. These frequencies are relative to the lower edge of the sub-band defined in Table 2-1.

2.4.9 Reuse unit pairs can be assigned to a beam, reassigned or activated/deactivated at the beginning of each TDMA frame. Dynamic beam assignment and reclassification are used to provide additional capacity to beams that have heavy traffic loading.

Table 2-2. Reuse unit frequency accesses

Frequency access number	Lower edge frequency (kHz)	Upper edge frequency (kHz)	Centre frequency (kHz)
1	0.000	41.667	20.833
2	41.667	83.333	62.500
3	83.333	125.000	104.167
4	125.000	166.667	145.833
5	166.667	208.333	187.500
6	208.333	250.000	229.167
7	250.000	291.667	270.833
8	291.667	333.333	312.500

Simplex channel band

2.4.10 A 12-frequency access band is reserved for the simplex (ring alert and messaging) channels. These channels are located in a globally allocated 500 kHz band between 1 626.0 MHz and 1 626.5 MHz. These frequency accesses are only used for downlink signals, and they are the only frequencies that may be transmitted during the simplex time-slot. As shown in Table 2-3, four messaging channels and one ring alert channel are available during the simplex time-slot.

Table 2-3. Simplex frequency allocation

Channel number	Center frequency (MHz)	Allocation
1	1 626.020833	Guard channel
2	1 626.062500	Guard channel
3	1 626.104167	Quaternary messaging
4	1 626.145833	Tertiary messaging
5	1 626.187500	Guard channel
6	1 626.229167	Guard channel
7	1 626.270833	Ring alert
8	1 626.312500	Guard channel
9	1 626.354167	Guard channel
10	1 626.395833	Secondary messaging
11	1 626.437500	Primary messaging
12	1 626.479167	Guard channel

2.5 L-BAND (1 616–1 626.5 MHZ) TRANSMISSION CHARACTERISTICS

Signal format

2.5.1 All L-Band uplink and downlink transmissions used in the Iridium Satellite Network employ variations of 25 kilosymbols-per-second (ksps) quadrature phase shift keying (QPSK) modulation and are implemented with 40 per cent square root raised cosine pulse shaping. The variations of QPSK used include differential encoding (DE-QPSK) and binary phase shift keying (BPSK), which is treated as a special case of QPSK. Figure 2-6 illustrates the relevant FDMA frequency characteristics.

2.5.2 The modulation structure used for the uplink and downlink traffic data includes differential encoding to allow demodulators to rapidly reacquire phase and resolve phase ambiguities in case there is a momentary loss of phase-lock due to a link fade.

2.5.3 Downlink traffic, broadcast, synchronization, ring alert, and messaging channels all use DE-QPSK modulation with 40 per cent square root raised cosine pulse shaping. In all cases, the burst transmission rate is 25 ksps and provides a burst data rate of 50 kilobits-per-second (kbps).

2.5.4 Uplink traffic channels use DE-QPSK modulation with 40 per cent square root raised cosine pulse shaping and burst transmission rates of 25 ksps or 50 kbps. Uplink acquisition and synchronization channels both use DE-BPSK with 40 per cent square root raised cosine pulse shaping and burst transmission rates of 25 ksps or 25 kbps. BPSK is used because it provides a 3 dB link advantage, which improves the burst acquisition probability.

2.5.5 Certain signalling, control and traffic applications implement error correction coding to improve the link bit error rate, with characteristics tailored for certain traffic and signalling message applications. The vocoder algorithm provides its own interleaving and forward error correction. Most of the administrative transmissions used in granting access to and exerting control of the link implement their own internal error correction and interleaving.

2.5.6 The link protocol does not provide forward error correction to user-generated data transmitted in the payload. Such data are protected from transmission errors by a 24-bit frame check sequence transmitted in every traffic burst containing a data payload (as opposed to a voice payload). If the frame check sequence does not validate that the payload data were correctly received, the L-Band protocol implements error by retransmission of the Iridium frame.

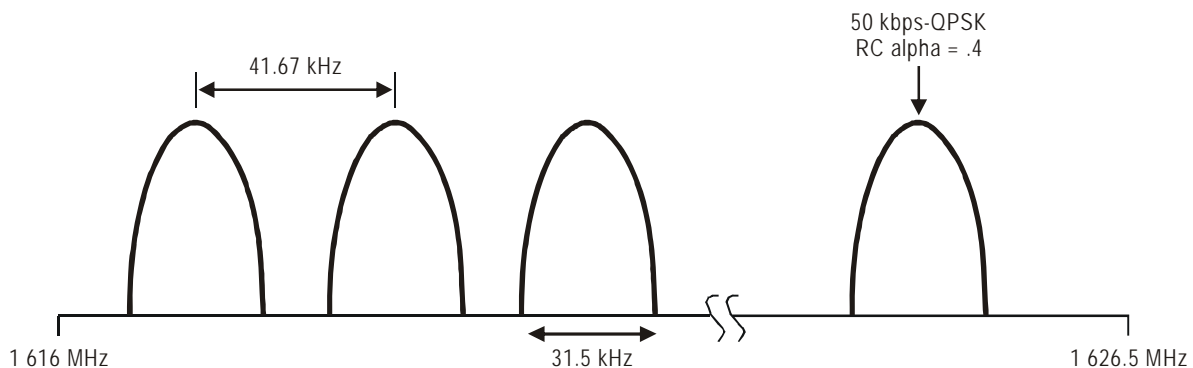


Figure 2-6. FDMA frequency plan

Erroneous information, i.e., payload data that do not satisfy the frame check sequence, is not passed to the end user. Therefore, a decrease in channel quality which causes any increase in channel bit-error-rate results in an increase in the number of retransmissions and a corresponding decrease in the number of user-generated bits provided to the end user. Iridium data service has been designed to provide a minimum throughput of 2400 bps user-generated information.

2.5.7 Traffic channels operate with adaptive power control, as discussed below, which acts to limit power transmissions beyond what is required for appropriate voice and data quality.

Power control

2.5.8 The L-Band link has been designed for a threshold channel bit error of 0.02, which is sufficient to support voice services. This level is achieved at an $E_b/(N_0+I_0)$ of 6.1 dB in clear line of sight conditions. The basic Iridium Satellite Network will operate with an average link margin of 15.5 dB above this level, as required to mitigate fading due to the Rayleigh multipath and shadowing typical of handheld phone operation in urban environments. Under good channel conditions, this level is reduced by adaptive power control. Even under adaptive power control, the link margin is maintained to mitigate fades that are too short in duration to be compensated by the power control loop.

2.5.9 Adaptive power control uses a closed loop algorithm in which the space vehicle and AES receivers measure the received energy per bit per noise power spectral density (E_b/N_0) and command the transmitters to adjust their transmitted power to the minimum value necessary to maintain high link quality. When the entire available link margin is not required to mitigate channel conditions, adaptive power control has the effect of reducing system power consumption. There are slight differences in the power control algorithms used for voice and data operations. For data operations, the algorithm is biased toward higher power levels and does not use adaptive power control, hence ensuring low channel bit error rates and high user throughput.

2.6 CALL PROCESSING

2.6.1 Call processing in the Iridium Satellite Network consists of acquisition, access, registration and auto-registration, telephony and handoff.

Acquisition

2.6.2 Acquisition is the first step in obtaining service from the Iridium Satellite Network. It is the process of establishing a communication link between a satellite and the SDU. Acquisition by an SDU is necessary for registration, call setup, answering call terminations, or to initiate any service on the Iridium Satellite Network.

2.6.3 To enter the Iridium Satellite Network, a subscriber unit must go through an acquisition sequence. The first steps in acquisition are to achieve frame timing alignment, determine the correct downlink time slot, and detect the Doppler shift of the received signal. Then the SDU must pre-correct the transmitted signal so the received signal, at the satellite, arrives during the correct receive time window and has, at most, a small Doppler offset.

2.6.4 To acquire the system, an SDU turns on its receiver and acquires the satellite broadcast channel transmission for the beam in which the SDU is located. The ring channel includes the broadcast time/frequency for each beam, and the SDU can use this to determine which channel to use. The decoded satellite broadcast (broadcast acquisition information message) indicates to the SDU if acquisition is permitted; this is done via the acquisition class control. Acquisition denial might occur as a result of network capacity or some other system constraints. If the network permits acquisition, the SDU extracts the beam ID and selects a random acquisition channel.

2.6.5 The SDU estimates Doppler offset and predicts uplink timing based on beam ID. It pre-corrects its timing and frequency and then transmits a ranging burst (acquisition request message) to the satellite on the acquisition channel. Upon receipt of the acquisition request message from the SDU, the satellite calculates the time and frequency error of the received signal. It then sends a channel assignment message to the SDU along with time and frequency corrections.

2.6.6 After each transmission on the uplink acquisition channel, the SDU decodes the broadcast channel and checks for an acknowledgment of its request (channel assignment message) and makes sure its acquisition class is still allowed on the system. Receiving no acknowledgment after a request, the SDU repeats its request after a random time interval (Slotted Aloha) and on a random acquisition channel. This minimizes the number of collisions between the acquiring SDU and other SDUs attempting to use the acquisition channel.

2.6.7 The SDU, upon receiving the channel assignment message, immediately transitions to the new sync channel and acknowledges the change by sending a sync check message to the satellite. The satellite measures the time and frequency offset error of the received burst and responds with a sync report message. The sync report message contains a sync status information element. The satellite will set sync status to "Sync OK" if the time and frequency errors are within the tolerance for traffic channel operation. If the satellite sends a repeat burst in the sync status information element, the SDU adjusts its timing and frequency and retransmits a sync check message. If the satellite sends "Sync OK" in the sync report message, the SDU acknowledges by sending a sync check message and waits for a sync/traffic switch message from the satellite. Upon receipt of the sync/traffic switch message, the SDU exits the acquisition process and initiates the access process. The satellite then switches the sync channel to a traffic channel.

Acquisition control

2.6.8 Under certain circumstances, it may be necessary to prevent users from making acquisition attempts. Such situations may arise during states of emergency or in the event of a beam overload. During such times, the broadcast channel specifies, according to populations, which SDUs may attempt acquisition. All subscribers are members of one out of ten randomly allocated populations, referred to as Acquisition Class 0 to 9. The subscriber equipment reads the Acquisition Class from the subscriber information module (SIM) card that was programmed when it was initially provisioned. In addition, subscribers may be members of one or more special categories (Acquisition Class 11 to 15), also held in the SDU. The system provides the capability to control a user's acquisition to the system based on the following Acquisition Classes:

15. ISLLC use
14. Aeronautical safety service
13. Reserved
12. Reserved
11. Fire, police, rescue agencies
10. Emergency calls
- 0-9. Regular subscribers (randomly allocated).

2.6.9 The use of acquisition classes allows the network operator to prevent overload of the acquisition or traffic channels. Any number of these classes may be barred from attempting acquisition at any one time. If the subscriber is a member of at least one acquisition class that corresponds to a permitted class, the SDU proceeds with acquisition.

Access

2.6.10 The access process determines the SDUs location with respect to service control areas (SCA) defined in earth fixed coordinates. Based on the SCA within which the SDU is found to be located and on the identity of the SDUs service provider (satellite communications service provider), a decision is made regarding whether or not to allow service, and which gateway should provide that service. The process is initiated immediately following acquisition.

2.6.11 Location information may be reported by the SDU based on an external source such as an aircraft navigation system, or it may be determined by the geolocation function contained within the access function.

Registration and auto-registration

2.6.12 Registration is the process of the SDU communicating its location to the system and requires the prior completion of acquisition and access. The registration process allows the network to maintain an estimate of the location of roaming users as part of mobility management. This location estimate is required to allow the network to notify the subscriber when an incoming call is available (i.e. “ring” an SDU for a mobile terminated call). The SDU must be registered in the gateway serving its location to initiate or terminate a call. An SDU registration occurs for one of five reasons:

1. The SDU presently contains an invalid temporary mobile subscriber identification (TMSI) or location area identity.
2. The TMSI presently assigned to an SDU expires.
3. A call termination or origination is performed and, based on the new location, the SDU is told to re-register by the system.
4. A mobile subscriber initiates a manual SDU registration procedure.
5. The SDU’s present location exceeds the re-registration distance from the point of its last registration.

2.6.13 The procedures used for SDU registration (Location Update) after acquisition and access are GSM procedures.

2.6.14 Auto-registration refers to the capability of an SDU to re-register with the network only on an as-needed basis. The SDU will automatically re-register with the system when it knows its current location exceeds a specified distance from the point it last registered. In order to make this decision, the SDU passively estimates both its location and its positional error, based upon information gathered from the ring channel of the passing satellites.

Telephony

2.6.15 Telephony is the process of establishing a connection between two telephone users and releasing the connection at the end of the call. For mobile terminated calls, telephony also includes the process of alerting an SDU of an incoming call.

2.6.16 Functions supporting telephony are distributed between the SDU, satellite and gateway components. The functions are partitioned to group similar procedures together. The SDU supports a set of protocols used to communicate among the components of the system. In order to reduce the complexity of individual components, the protocols are partitioned to group similar functionalities together. The partition is shown in Figure 2-7.

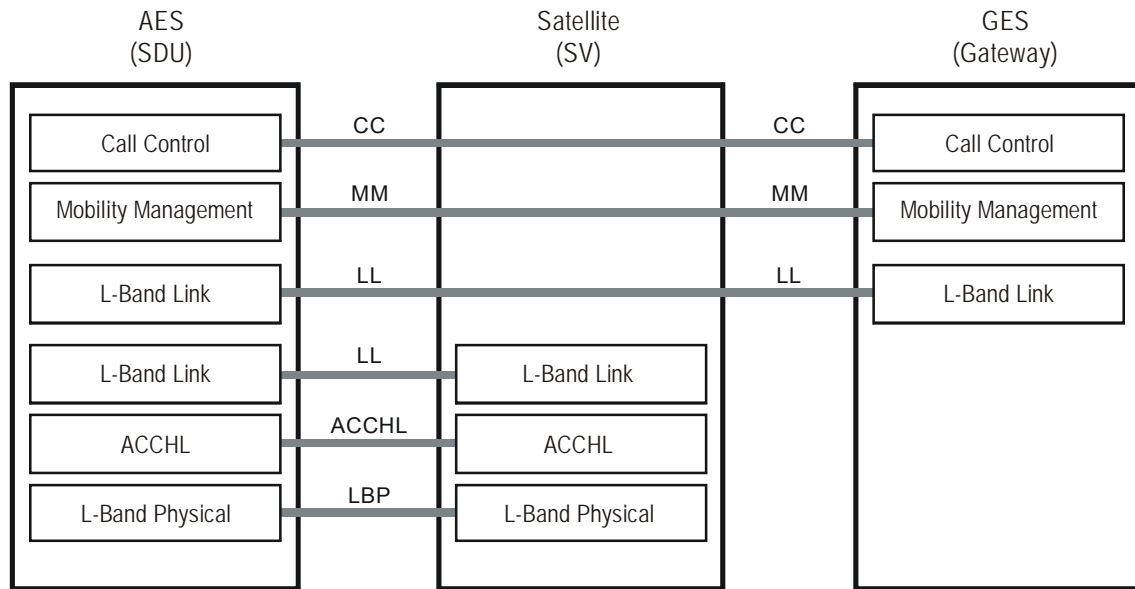


Figure 2-7. Protocol partitions

2.6.17 Five protocol partitions are supported by the SDU:

1. Call Control (CC)
2. Mobility Management (MM)
3. L-Band Link (LL)
4. L-Band Physical (LBP)
5. Associated Control Channel, L-Band (ACCHL).

Call Control. The CC partition is equivalent to call control in the GSM standard. This includes mobile switching centre to mobile subscriber (MSC-MS) signaling in the GSM mobile radio interface CC sub-layer and associated procedures and the general telephony call control capabilities included in a standard GSM switching sub-system.

Mobility Management. The MM partition is equivalent to mobility management in GSM. This includes the MSC-MS signaling in the GSM mobile radio interface MM sub-layer and associated procedures, along with the portions of the mobile application part that support it.

L-Band Link. The LL control provides the functionality to control and monitor the air channels, determine access privileges, update system programmable data, and establish and release connections.

LL is responsible for the call processing-related signaling associated with mobile origination or termination and provides for the signaling procedures associated with the access portion of the Iridium Network. Additionally, LL controls the real-time aspects of radio resource management on the L-band link, such as the allocation and maintenance of L-band resources and handoff procedures.

L-Band Physical. LBP represents the control interface that exists between the satellite and the SDU. The primary distinguishing characteristic of LBP is that unlike ACCHL, the delivery of messages is not guaranteed. Examples of messages carried in this manner are ring alerts, directed messaging, broadcast channel messages, handoff candidates, handoff candidate lists, and Doppler/timing/power control corrections.

Associated Control Channel, L-Band. The ACCHL transmission protocol is used by all entities that need to (reliably) send data via the L-Band traffic channel burst between the satellite and the SDU. The ACCHL protocol permits sharing the traffic channel burst with other protocols. The ACCHL logical channel is bi-directional and uses portions of the uplink and downlink traffic channel, link control word and the payload field between the satellite and the SDU. The traffic channel is described in the next section. The ACCHL protocol will transport variable size messages on the ACCHL logical channel and is used to guarantee the delivery of messages between the satellite and the SDU. It relies on LBP only in that LBP arbitrates the access to the physical layer when there is contention for the physical layer resources.

Handoff

2.6.18 The Iridium satellites, in low Earth polar orbit, have highly directional antennas providing Iridium system access to SDUs. These antennas are configured to project multiple beams onto the surface of the Earth. The beams move rapidly with respect to SDUs and with respect to other satellites. Handoff, the process of automatically transferring a call in progress from one beam to another (or sometimes within a beam) to avoid adverse effects of either user or satellite movement in this highly mobile environment, is required in three situations. First, an SDU must be handed off between satellites as they move relative to the SDU (Inter-satellite). Second, an SDU must be handed off between beams on a satellite as beam patterns move relative to the SDU (Intra-satellite). Last, an SDU must be handed off to another channel within a beam for frequency management and to reduce interference (Intra-beam). Although the Iridium system may force a handoff, handoff processing is primarily SDU initiated.

2.6.19 As a satellite moves away (for example, moves over the horizon) and a new satellite approaches (for example, comes into view over the horizon), an SDU must transfer from the current satellite (the losing satellite) to the new satellite (the gaining satellite). This inter-satellite handoff, on the average, occurs approximately every five minutes during a telephone call. It may be initiated as frequently as five seconds or as long as ten minutes, depending on link geometry.

2.6.20 As satellites move from the equator to a pole, the actual distance between adjacent satellites decreases to a few kilometres and then increases to several thousand kilometres as the satellites again approach the equator. To avoid radio interference, beams near the edges of a satellite's coverage field are turned off as the satellite approaches a pole and then turned on again as it approaches the equator. Additionally, the same radio channels are never available in adjacent beams on a satellite or between nearby satellites. Thus, as the satellite and its beams pass by, an SDU must frequently transition to a new beam. This Intra-satellite handoff occurs approximately every 50 seconds during a call.

2.6.21 As the inter-satellite geometry changes, radio channels must be reallocated among the beams to avoid interference. This process can cause an SDU to be handed off to a different channel in the same beam. This is called intra-beam handoff. An SDU can also request an intra-beam handoff to reduce interference. If the Iridium system detects an allocation change coming up where it will not have enough channels to support the number of current users, the satellite will ask for volunteers to handoff into other beams so calls will not have to be dropped when the resource change takes place. Handoffs made under these conditions are called volunteer handoffs. Volunteer handoffs may result in one of two situations requiring handoff, namely inter-satellite or intra-satellite, but are initiated by the SDU (at the request of the Iridium system) rather than by the Iridium system itself.

2.7 VOICE AND DATA TRAFFIC CHANNEL

2.7.1 Traffic channels provide two-way connections between space vehicles and subscriber equipment that support Iridium services. These channels transport the system voice and data services along with the signaling data necessary to maintain the connection and control the services.

2.7.2 The uplink and downlink traffic channels use identical burst structures. Each burst is 8.28 ms long and contains 414 channel bits. The bursts are divided into four major data fields: preamble, unique word, link control word and payload field. The preamble and unique word are used in the receiving demodulator for burst acquisition. The preamble and unique word patterns are different for the uplink and downlink. The link control word provides a very low data rate signaling channel that is used to support link maintenance, the associated control channel and handoff. The payload field furnishes the primary traffic channel that carries the mission data and signaling messages.

2.7.3 The link control word field provides a low rate signaling channel used for control of the subscriber link. The uplink and downlink traffic channels use the same link control word format. The link control word is used to support link maintenance, handoff and the ACK/NAK of the associated control channel transmission protocol. The link control word field is protected by forward error correction (FEC) code.

2.7.4 The traffic channel payload field provides the primary traffic channel. This field carries the mission data and mission control data. This field supports a channel bit rate of 3466.67 bps. Typically error correction coding and other overhead functions provide a nominal information throughput on this channel of 2400 bps.

2.7.5 Mission data may be either vocoded voice data or data services. For voice service, the proprietary Iridium vocoder uses FEC to ensure good (based on mean opinion score for a basic telephony voice call, where 1 is bad and 5 is excellent, good is roughly a 4), or adequate, quality vocoded voice performance tailored for the Iridium communication channels. For data service, the L-band transport employs a frame check sequence to provide essentially error-free data transport service.

2.7.6 The basic interface to the SDU and the circuit switched channel setup/teardown are provided at a modem application level using the Iridium AT command set². Some Iridium data services also provide additional service specific interfaces to facilitate user access. In summary, the Iridium communication channel appears to the end users as an efficient and reliable data transport.

2.8 IRIDIUM DATA SERVICES — RUDICS AND SBD

Iridium RUDICS service

2.8.1 The Iridium RUDICS service is an enhanced gateway termination and origination capability for circuit switched data calls across the Iridium satellite network. RUDICS offers an optimized data connection service for various end-to-end data applications or solutions.

2.8.2 There are four key benefits of using RUDICS as part of a data solution over conventional PSTN circuit switched data connectivity or mobile-to-mobile data solutions:

1. Elimination of analog modem training time, hence faster connection establishment time;

2. The Hayes command set, a specific programming language originally developed for the modems operated on telephone lines, is also called the AT commands, AT is short for attention.

2. Increased call connection quality, reliability and maximized throughput;
3. Protocol independence;
4. Both Mobile Originated (MO) and Mobile Terminated (MT) calls are rated at the same rate.

2.8.3 Remote applications use AT commands to control a circuit switched data capable SDU. Figure 2-8 illustrates the call set up process of a MO data call. Iridium pre-assigns RUDICS server number(s) to satellite communications service providers who assign and provision these numbers to customers. The remote application dials the customer's assigned RUDICS server number which connects the call through a telephony switch to the RUDICS server. Each SDU is authenticated using calling line identification for the RUDICS server number that it dialed. Once authenticated, the call is routed over the terrestrial connection to a customer-specified Internet protocol (IP) address and port. The RUDICS service supports the following service transport types: transport control protocol/Internet protocol (TCP/IP) encapsulation, point-to-point protocol (PPP), and multi-link PPP (MLPPP).

2.8.4 The host application can make an MT call by opening a Telnet session to the RUDICS server. Once authenticated, a series of AT commands are used to connect to the remote SDU and establish a circuit switched data call. MT access must specifically be requested at the time of the initial configuration and set up. Connectivity between the Iridium gateway and the end user host server can be via a number of options, including:

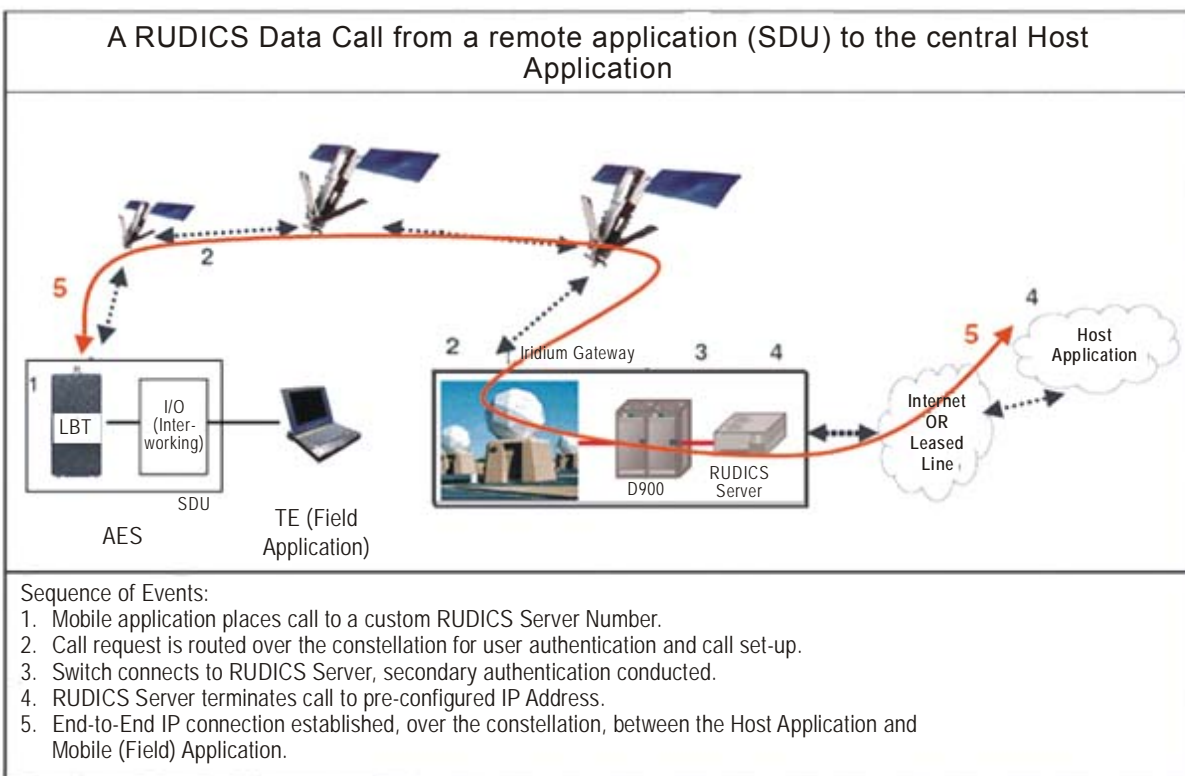


Figure 2-8. Iridium RUDICS mobile originated data call set-up

- Internet
- Internet with virtual private network
- Private leased line such as:
 - Frame relay
 - T1/E1 leased line.

2.8.5 Additionally, the RUDICS capability offers the capability for MLPPP. This is where multiple SDUs can be used to send data simultaneously and the data can be delivered in an $N \times 2400$ bps PPP connection.

Iridium SBD service

2.8.6 The Iridium short burst data service is a satellite network transport capability to transmit short data messages between (data) terminal equipment (TE) and a centralized host computing system. An MO SBD message can be up to 1 960 bytes. An MT SBD message can be up to 1 890 bytes.

2.8.7 Figure 2-9 shows the system architecture of the Iridium SBD service while Figure 2-10 depicts the MO call set up process. The original SBD service delivers SBD messages to email addresses provisioned on the SBD sub-system. The newer SBD service added direct IP capability allowing SBD messages to be delivered directly to IP sockets provisioned on the SBD Subsystem. For an MT application, an SBD message is sent to the SBD sub-system by the host via the Internet or leased line. A ring alert is then sent by the SBD Subsystem to the addressed SDU to notify it of the arrival of a new message. The SDU then initiates an MO call to the SBD Subsystem to pull down the message.

2.8.8 Since the SBD message utilizes the Iridium signaling transport during the access phase of a circuit-switched voice call set-up process, it has the benefits of additional FEC protection as well as on-the-air, off-the-air, packet delivery service.

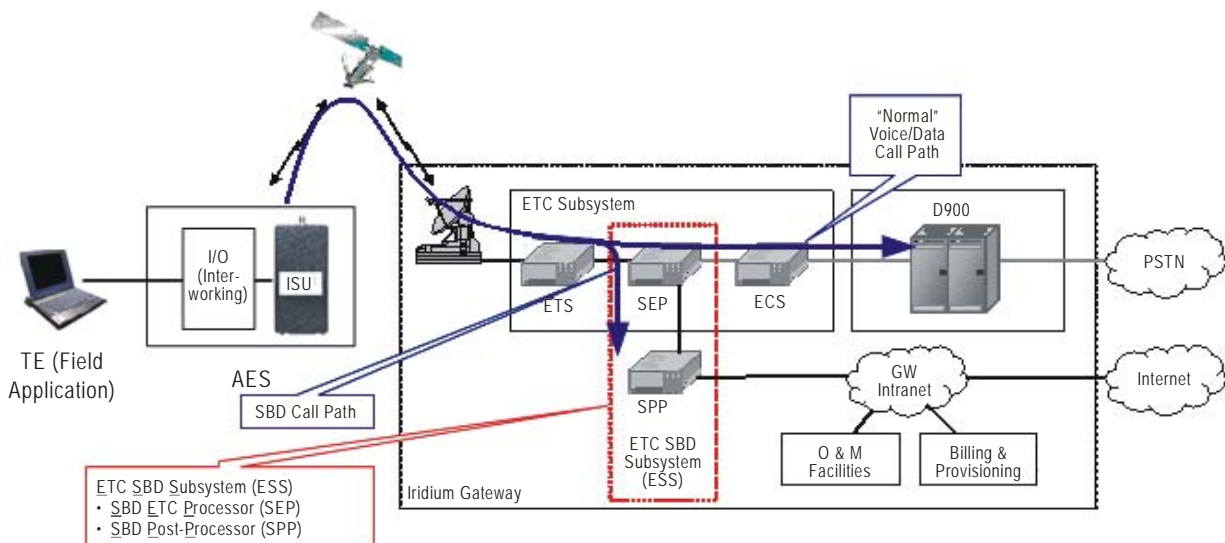
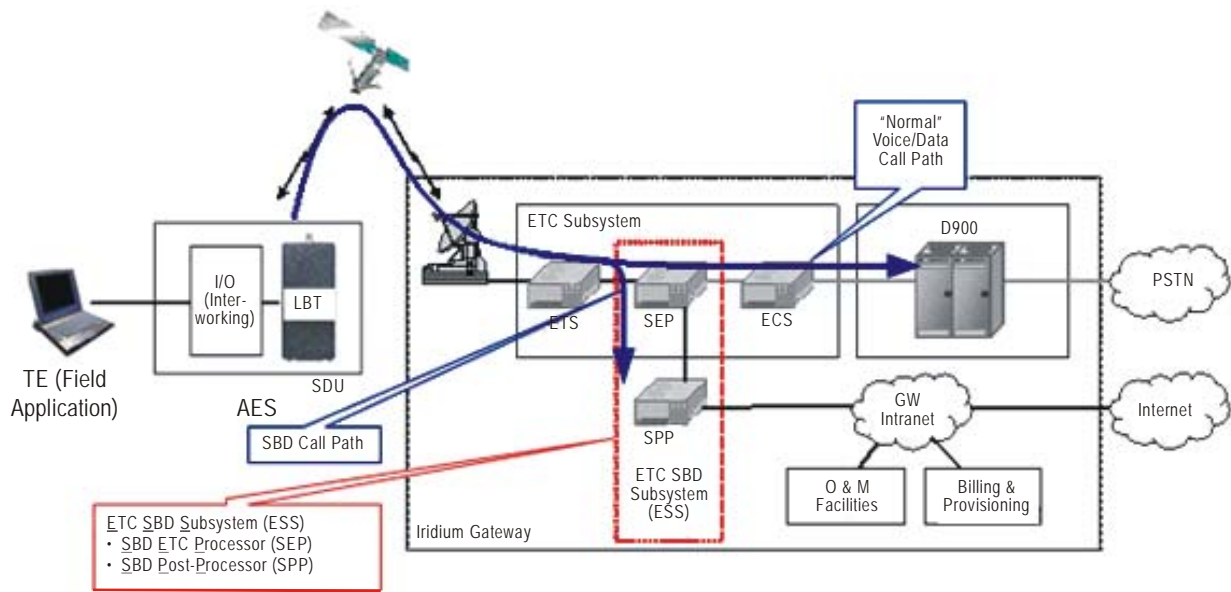
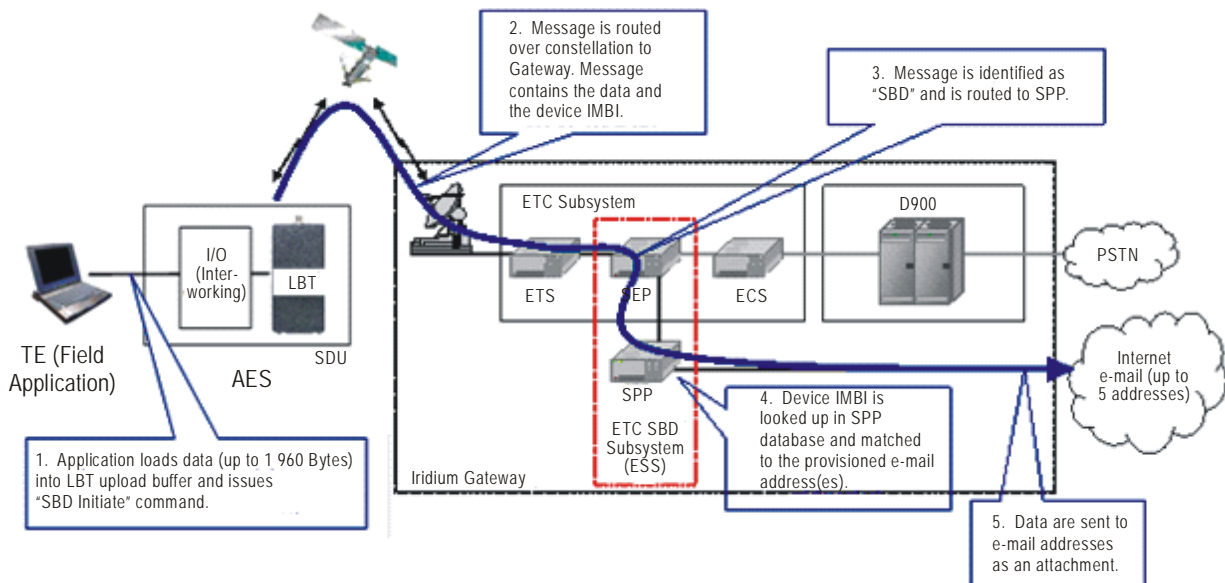


Figure 2-9. System architecture of Iridium SBD service



(a)



(b)

Figure 2-10. Setting up an MO SBD call (a) registration; (b) message delivery

Chapter 3

IRIDIUM AMS(R)S SYSTEM

3.1.1 End-to-end AMS(R)S data communications are provided by several subnetworks. Subnetworks may be classified as ground-ground (fixed), air-ground (mobile) or airborne subnetworks. More information on the ATN, including mobile subnetworks, is contained in the *Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)* (Doc 9705) and the *Comprehensive Aeronautical Telecommunication Network (ATN) Manual* (Doc 9739).

3.1.2 Iridium AMS(R)S will comprise safety and non-safety communications. Safety communications refer to communications for ATS and AOC to the flight deck. Non-safety communications to the cabin crew and passengers are known as AAC and APC, respectively.

System overview

3.1.3 The major elements of an Iridium AMS(R)S system are the AES, Iridium space segment, GES or gateway, and the network control stations. In addition, for data communication services, a ground-based server is required for connectivity between the Iridium satellite network and the aviation centric data communication network. The aviation network provides connectivity to the end user, e.g. ATS units, airline operations, flight departments and aviation support application services, such as meteorological information.

3.1.4 Use of the Iridium network for ATS, particularly in remote areas where connectivity between the Iridium gateway and responsible ATS units is difficult to achieve, could be facilitated by the deployment of ground-based Iridium units. This set-up can support voice service but is not recommended for data communication services.

Aircraft Earth station (AES)

3.1.5 An AES includes all avionics on board an aircraft necessary for implementing satellite communications. This includes modulators and demodulators, RF power amplifier, transmitter and receiver, and the antenna. An Iridium AES includes the SDU, consisting of one, or multiple, Iridium LBTs, which serve as radio transceivers and provide the actual modem and signal processing functions, Iridium satellite subnetwork protocol management including circuit-switched voice/data management, and data and voice interfaces with other aircraft systems.

Space segment

3.1.6 Information on the Iridium satellite constellation is given in Chapter 5.

Ground Earth station (GES)

3.1.7 The GES, also referred to as a gateway, provides appropriate interface between the space segment and the fixed voice and data networks, public switched telephone, and private networks (e.g. ARINC, SITA).

Chapter 4

IRIDIUM AMS(R)S STANDARDIZATION ACTIVITIES

4.1 IRIDIUM AIR INTERFACE SPECIFICATIONS

The Iridium air interface specifications define technical aspects of the Iridium aeronautical system (including the functional requirements of ground and aircraft Earth stations). This document was developed and is maintained by Iridium LLC. In addition to these Iridium-developed specifications and the definition of SARPs by ICAO (*refer to Chapter 1, section 1.3*), this chapter describes standardization activities being undertaken by other bodies.

4.2 AEEC AND ARINC STANDARDS

The Airline Electronic Engineering Committee, an international body of airline industry representatives, leads the development of technical standards for airborne electronic equipment including avionics. These standards are published through ARINC and located on the ARINC web site (www.arinc.com). Signal characteristics and procedures are defined in detail in ARINC Characteristic 761, *Second Generation Aviation Satellite Communications System, Aircraft Installation Provisions*, Part I (form, installation and wiring) and Part II (operational capability of the equipment and interchangeability). Additional relevant ARINC Specifications and Characteristics 429 (*Digital Information Transfer System (DITS)*), 618 (*Air-Ground Character-Oriented Protocol Specifications*), 619 (*ACARS Protocols for Avionic End Systems*), 620 (*Datalink Ground Systems Standard and Interface Specification (DGSS/IS)*), 622 (*ATS Datalink Applications Over ACARS Air-Ground Network*) and 637 (*ATN Implementation Provisions, Part I, Protocols and Services*) will be reviewed and revised as needed.

4.3 AVIONICS AND CERTIFICATION

4.3.1 Iridium has developed an LBT for use by avionics manufacturers. Iridium has established processes to control design and manufacturing, test procedures for all transceiver design and manufacturing elements, and change control processes for software development and releases. All LBTs undergo Iridium-specified standardized factory test procedures before being released for shipment. All LBT software revisions are tested prior to release.

4.3.2 The LBTs are provided to Iridium-approved avionics manufacturers who design their avionics units, SDUs, to contain the LBT(s) and provide the aircraft system interfaces. Avionics manufacturers are responsible for adherence to all applicable civil aviation regulatory agency requirements. Avionics manufacturers are responsible for all parts manufacturing authority and for aircraft installation certification, which includes airworthiness and environmental testing. All new Iridium aviation products are tested per Iridium and manufacturer test procedures within the Iridium technical support centre (TSC) prior to acceptance by Iridium for use with the Iridium system.

4.3.3 RTCA has developed DO-262 "Minimum Operational Performance Standards (MOPS) for Next Generation Satellite Systems". Compliance of aircraft Earth stations, which include the SDU and antenna, with this standard should ensure that the system can be installed and properly operated on board aircraft. In addition, ITU Recommendation,

ITU-R M.1343 “Essential Technical Requirements of Mobile Earth Stations for Global Non-Geostationary Mobile-Satellite Service Systems in the bands 1-3 GHz,” is applicable to this aircraft system.

4.3.4 RTCA also has developed DO-270 “Minimum Aviation System Performance Standards (MASPS) for AMS(R)S as used in Aeronautical Data Links.”

4.4 SATELLITE SYSTEM ACCESS APPROVAL

4.4.1 Iridium subscribers may be distinguished by several identifiers. Each user is assigned an international mobile network subscriber identifier (IMSI) which is a permanent number stored on the user’s SIM card. To maintain subscriber confidentiality, the IMSI is only transmitted over the air when a valid temporary mobile subscriber identifier (TMSI) is unavailable. A TMSI is a temporary identifier assigned to a mobile subscriber and stored on the user’s SIM card and at the gateway. The TMSI is periodically changed based on system parameters and is used to identify the user over the air. The mobile subscriber integrated services digital network number (MSISDN) is the Iridium subscriber’s phone number. Subscriber telephone numbers are assigned to the service provider who controls and allocates telephone numbers based upon business rules. The international mobile equipment identifier (IMEI) is a permanent identifier assigned to each SDU, not to the Iridium subscriber (SIM card).

4.4.2 All new avionics are required to successfully complete ISLLC testing to ensure the avionics properly interoperate within the Iridium network. In addition, all avionics providing ACARS service are required to successfully complete testing with their associate satellite communications service providers (SPs) to ensure the avionics interoperates properly with the ground-based server and the SP’s ACARS network. Avionics failing to successfully complete the ISLLC and ACARS qualification testing are not allowed access to the Iridium network until the avionics are re-designed and re-tested to ensure compliance. Access to the Iridium network and to safety services is granted via controlled Iridium safety services subscriber SIM cards and look-up tables.

Airworthiness certification

4.4.3 All avionics are subject to the airworthiness regulations that apply to the aircraft in which the avionics are to be installed. Adherence to these civil aviation regulations for aircraft equipment and system installation(s) is provided by the avionics manufacturer and the installation entity providing the engineering and certification.

4.4.4 Several relevant documents should be consulted for the Iridium network and the LBT, with reference to the appendix of specifications.

Satellite communications service providers

4.4.5 Iridium has maintained an open position relative to exclusive offerings by a single satellite communications service provider, in compliance with ICAO policy which provides for competition among service providers. Iridium has maintained dialogue with a variety of service providers. Aviation safety services SPs must demonstrate the ability to properly support safety services, on an end-to-end basis and in a manner consistent with the published MASPS for AMS(R)S.

4.4.6 Iridium aviation satellite communications SPs shall provide the ground connectivity between the Iridium network and the aviation centric network, which connects with ATS providers, air transport operations and flight departments. In addition to connectivity to these networks, each SP approves certain avionics based on their documented communications protocol. These avionics may not be interchangeable amongst the SPs.

4.4.7 Aviation satellite communications SPs shall provide, at a minimum:

- Technical support
 - Customer care
 - Product support.
-

Chapter 5

COMPARISON OF AMS(R)S SARPS AND PROJECTED IRIDIUM PERFORMANCE

This chapter contains information provided by Iridium Satellite LLC regarding the Iridium satellite network's conformity with the AMS(R)S SARPs, specific to the subnetwork. Table 5-1 (located at the end of this Chapter) tabulates the AMS(R)S SARPs requirements and the associated Iridium-specific performance parameters.

Further validation activities have been undertaken by Iridium and provide supplementary information to Chapter 5 of this manual. Actual ICAO verification of the Iridium AMS(R)S system's compliance with the AMS(R)S SARPs is beyond the scope of this manual.

Compliance with RTCA DO-262 and DO-270 is one means of assuring that Iridium AMS(R)S will perform its intended functions satisfactorily under all aircraft conditions. Any regulatory application of RTCA DO-262 and DO-270 is the sole responsibility of appropriate national authorities.

5.1 GENERAL

The AMS(R)S SARPs require that an AMS(R)S system shall support packet data service, or voice service, or both. Iridium currently provides both voice and data services in the aviation sector. Iridium data are format neutral and can support both character- and bit-oriented data traffic. Voice service is in use today on fixed and rotary wing aircraft.

5.2 RF CHARACTERISTICS

Frequency bands

5.2.1 Iridium subscriber links operate in the 1 616–1 626.5 MHz band, which is allocated to the MSS in the Earth-to-space direction on a primary basis and in the space-to-Earth direction on a secondary basis.

5.2.2 This band is also allocated on a primary basis to the AMS(R)S both in the Earth-to-space and the space-to-Earth directions, subject to agreement obtained under No. 9.21 (ITU Radio Regulations No. 5.367).

5.2.3 The spectrum used for the Iridium satellite service is regulated according to Nos. 5.359, 5.364, 5.365, 5.366, and 5.367 of the Radio Regulations. No. 5.364 specifies sharing conditions and coordination requirements for MSS (Iridium) Earth stations in the Earth-to-space direction. No. 5.365 requires coordination for the space-to-Earth transmissions. The required coordinations have been carried out, and the Iridium system service link spectrum was notified to the ITU-BR in 1998. An indication of this may be found in the ITU-BR International Frequency List (IFL), and thereby the frequency assignments in the notification are entitled to protection.

5.2.4 The system was brought into use in the mid 1990s. Coordination under No. 5.366 and 5.367 regarding use of satellite facilities on airplanes and use of the AMS(R)S on a primary allocation basis, respectively, has been carried out under the provisions of these regulations (No. 9.21).

5.2.5 Finally, coordination with fixed services in the countries indicated in 5.359 has also been carried out. This regulation encourages the indicated countries not to authorize additional fixed stations in the band.

5.2.6 The Iridium Satellite Network also uses inter-satellite service links in the 23.18-23.38 GHz band. The Iridium feeder link utilizes a 19.4-19.6 GHz downlink band and a 29.1-29.3 GHz uplink band for communications between the Iridium satellite and the Iridium gateway/TTAC. Given the critical functions of these high-capacity links, they are designed to provide high reliability and integrity.

Emissions

5.2.7 The AMS(R)S SARPs require that 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 that are installed on the same or other aircraft. The Iridium AMS(R)S AES are designed to meet the emission requirements of RTCA DO-262. This, together with a predefined AMS(R)S antenna-to-GNSS antenna isolation, should ensure that AMS(R)S equipment can be operated simultaneously and independently from other communication and navigation equipment installed on the same or other aircraft.

5.2.8 Over 5 000 aircraft are in service with installed Iridium systems. Prior to certification of aircraft installations, ground and flight tests are conducted to ensure safety of flight and to validate that the system maintains electromagnetic compatibility with other systems on board the aircraft.

5.2.9 The Iridium SDU is designed to meet the emission limits set out in ITU-R Recommendation M.1343, "Essential technical requirements of mobile earth stations for global non-geostationary mobile-satellite service systems in the bands 1-3 GHz", as well as national/regional type-approval specifications such as FCC Part 2 and Part 25 and ETSI EN301 441 specifications. U.S. Federal Communications Commission and the European Telecommunications Standards Institute measurements of a standard Iridium SDU have shown that the Iridium SDU meets the specified emission limits.

5.2.10 Iridium AES equipment emissions are compliant with existing protection requirements for all existing onboard radio transceivers. Protection criteria requirements are currently driven by output from RTCA. Iridium continues to track these requirements as new aviation CNS equipment becomes available.

Susceptibility

5.2.11 The Iridium AMS(R)S AES equipment shall operate properly in an interference environment causing a cumulative relative change in its receiver noise temperature ($\Delta T/T$) of 25 per cent.

5.2.12 A 25 per cent increase in receiver noise temperature is equivalent to a 1.0 dB link margin degradation. This additional degradation due to interference is accounted for in the Iridium link budget. Service links are designed to provide a 15 dB margin.

5.3 PRIORITY AND PRE-EMPTIVE ACCESS

5.3.1 The basis for Iridium AMS(R)S priority, precedence, and pre-emption (PPP) is the set of mechanisms designed for, and already implemented in, the Iridium Satellite Network for signaling and system management purposes. The Iridium Satellite Network utilizes two resource management functions, acquisition class control and priority class control, to assure access to communication channels for priority users.

5.3.2 The acquisition process is one of several protocols completed between an SDU and the satellite constellation for each call set up regardless if the call is mobile originated (from aircraft) or mobile terminated (to aircraft). For a mobile originated call, the SDU will start the acquisition process once the call is placed. For a mobile terminated call, the SDU will start the acquisition process upon the reception of a RING, indicating an incoming call from the GES.

5.3.3 Each satellite beam broadcasts which acquisition classes are allowed to acquire satellite resources on that beam. Only SDUs with the proper acquisition class (AC) are allowed to start the acquisition process. AC ranges from 0-15. Default non-safety Iridium terminals use an AC in the range of 0–9. AMS(R)S safety traffic will be assigned AC-14.

5.3.4 Acquisition class is mainly used for satellite load shedding. In a satellite beam with heavy traffic load, certain acquisition classes (e.g. AC 0–9) will be shut down to prohibit further traffic load on the satellite. To ensure AMS(R)S safety traffic will get through, Iridium will not shut down AC-14 for satellite load shedding.

5.3.5 The AC affects how calls initially gain access to the satellite constellation while priority class provides continued access for safety-related calls.

5.3.6 The Iridium Satellite Network allows for four levels of priority. Each satellite has priority queuing for both channel assignment of new calls and handoff order of in-progress calls. High priority calls take precedence and are queued before low priority calls.

5.3.7 The four Iridium priority levels are mapped to the four-level AMS(R)S priority structure as specified by Table 2-7 of RTCA DO-262:

Iridium Priority 3 (AMS(R)S #4, Distress, Urgency, highest priority);
Iridium Priority 2 (AMS(R)S #3, Direction finding, Flight Safety);
Iridium Priority 1 (AMS(R)S #2, Other Safety and Regularity of Flight);
Iridium Priority 0 (AMS(R)S #1, AMSS Non-Safety, lowest priority).

5.3.8 In case of extreme system resource shortage, ongoing low priority calls will be pre-empted by the system to allow access for higher priority calls.

5.3.9 While the Iridium acquisition class control and priority class control provide internal system controls for internal priority, precedence and pre-emption management, the Iridium AMS(R)S AES manufacturers and satellite communications service providers will need to provide the input/output queuing for call/message priority function at the Iridium network interfaces. These capabilities are intrinsic to the protocol machines that interface Iridium AMS(R)S with its external users and reside in the AMS(R)S AES and GES.

5.3.10 Currently both the acquisition class and priority class are encoded on a SIM card; hence the acquisition class and priority class are associated with a SIM card and an SDU that uses that SIM card. For AMS(R)S, the acquisition class and priority class will need to be associated with each AMS(R)S call (type) and will be controlled by the protocol software that sets up the call.

5.3.11 Iridium AMS(R)S AES and GES will support priority, precedence and pre-emption 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.

5.3.12 All AMS(R)S data packets and all AMS(R)S voice calls will be identified as to their associated priority.

5.3.13 Within the same message category, the Iridium AMS(R)S service will provide voice communications priority over data communications.

5.4 SIGNAL ACQUISITION AND TRACKING

5.4.1 The AMS(R)S SARPs require that Iridium AES, GES and satellites properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 1 500 km/h along any heading and when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 0.6 g.

5.4.2 The Iridium Satellite Network consists of fast moving LEO satellites and is designed to handle large Doppler frequency shift and Doppler rate of change. Signal acquisition and tracking functions are handled internally within the Iridium Satellite Network by the SDU and the satellites and are transparent to Iridium users.

5.4.3 Link synchronization is achieved by pre-correcting the SDU transmit timing and frequency so that uplink bursts arrive at the satellite in the correct time slot and on the correct frequency access for the assigned channel. This pre-correction is accomplished by adjusting the SDU timing and frequency in accordance with error feedback which is sent in the downlink maintenance messages by the satellite. The SDU will compensate for a maximum uplink carrier frequency Doppler shift of up to +/-37.5 KHz to achieve the specified uplink frequency of arrival requirements. The SDU receiver will accommodate a carrier frequency Doppler shift of up to +/-37.5 KHz.

5.4.4 Since the Iridium Satellite Network became operational, the Iridium SDUs have been demonstrated to maintain link connectivity in numerous test flights on board jets and research rockets. A test involving the NASA Sounding Rocket was conducted in April 2004. An Iridium flight modem, consisting of an Iridium SDU and other electronics, sent data successfully and continuously from lift-off through two rocket stage burns, reaching a peak velocity of up to 1.5 km/sec (5 400 km/h) and only cut out when the rocket tumbled at apogee (120 km). The flight modem reacquired after the first parachute deployed, and data were sent until the rocket hit the ground with a reported force of 50 g's. The Iridium link was maintained on impact, and the flight modem continued to transmit for another 25 minutes. This and other demonstrations show that Iridium communication links are robust for high-speed flights with large Doppler offset and Doppler rate of change.

5.5 PERFORMANCE REQUIREMENTS

Designated operational coverage

5.5.1 Iridium Satellite Network provides mobile communication with operational pole-to-pole coverage of the entire Earth.

Failure notification

5.5.2 The AMS(R)S SARPs require that in the event of a service failure, the Iridium AMS(R)S system shall provide timely predictions of the time, location and duration of any resultant outages until full service is restored. The system shall annunciate a loss of communications capability within 30 seconds of the time when it detects such a loss.

5.5.3 As an operational network serving subscribers all over the globe, the Iridium Satellite Network is being permanently monitored by its Network Operation and Maintenance Contractor. There are methods and processes in place for network outage detection, prediction, reporting, warning and remediation. The current processes ensure that the Iridium AMS(R)S system will annunciate a loss of communications capability within 30 seconds.

AES requirements

5.5.4 The Iridium AMS(R)S AES should meet the relevant voice and data performance requirements of the AMS(R)S SARPs for aircraft in straight and level flight throughout the designated operational coverage of the Iridium satellite system.

5.5.5 The Iridium AMS(R)S AES should meet the relevant voice and data performance requirements of the AMS(R)S SARPs for aircraft attitudes of +20/-5 degrees of pitch and +/-25 degrees of roll throughout the designated operational coverage of the Iridium satellite system.

5.5.6 Further validation of the ability of AES equipment to meet sections 4.6.4 and 4.6.5 of the SARPs shall be demonstrated during acceptance testing.

5.5.7 There are four levels of acceptance testing required for the AES equipment:

- Avionics manufacturer system testing (lab, ground and flight test)
- Iridium satellite testing
- Satellite communications SP testing
- Aeronautical terrestrial network SP (e.g. ARINC and SITA) (data only).

5.5.8 During the installation of the Iridium system aboard aircraft, it is usual practice to conduct both ground safety of flight testing and flight testing where the Iridium system is tested during higher than normal flight attitudes to ensure the system functions properly while maintaining safety of flight.

Packet data service performance

5.5.9 The AMS(R)S SARPs require that an AMS(R)S system providing a packet-data service shall be capable of operating as a constituent mobile subnetwork of the ATN. The role of the ATN is to define an environment within which reliable end-to-end data transfer may take place, spanning the airborne, air-ground and ground-based data subnetworks while providing interoperability among those networks. The Iridium Satellite Network supports the transparent transfer of data between adjacent inter-network entities. This includes the transparent transfer of global ATN addresses and quality-of-service information, as well as user data. The AMS(R)S subnetwork interface to an ATN router occurs within the ATN network layer, thus control information for the data link and physical layers is not passed from subnetwork to subnetwork. Hence, the subnetwork may utilize non-ATN conforming protocols within these layers while maintaining ATN protocol architecture conformance within the network layer. Whilst it is not strictly required to adopt a common standard subnetwork interface protocol for all air-ground subnetworks, it greatly simplifies the implementation and validation of the inter-network process since only a single communication software package is required to service the interface with the different air-ground subnetworks. The ISO 8208 packet level protocol has been adopted as the standard for this interface. A subnetwork interface protocol for an Iridium AMS(R)S has not yet been specified by ICAO. Thus, compliance of the Iridium Satellite Network with AMS(R)S SARPs requires the specification and development of an appropriate subnetwork interface protocol.

5.5.10 The Iridium RUDICS and SBD data services are advantageous for different AMS(R)S applications. RUDICS offers the shortest call establishment time among all standard Iridium circuit-switch data services. SBD, though also based on circuit switch channels, offers a data transport service which has a number of characteristics very similar to a packet data call. The following performance parameters are based on statistics accumulated over many years of Iridium Satellite Network operation.

5.5.11 The Iridium data service RUDICS is based on circuit-switch mode. A data circuit is established, and the channel stays up until the connection is torn down. The connection establishment time for a RUDICS call ranges from

10–14 seconds. Once the circuit is established, the channel provides a reliable transport service of 2.4 kbps, at a minimum, with a more typical throughput of around 2.6 kbps.

5.5.12 Since the Iridium SBD service utilizes only the access phase of the normal Iridium call establishment, it does not traverse the full path of the Iridium Gateway to the switch and, thus, has a shorter call establishment delay. A SBD call can send data immediately upon completion of the acquisition process, which, on average, is about 1.5 sec. Therefore, the average call establishment time is about 1.5 sec for mobile-originated SBD and 3.6 sec for mobile-terminated SBD, assuming an average RING alert duration of 2.1 sec in a typical operating environment. Since SBD utilizes the signaling channel payload (with FEC protection) rather than the normal traffic channel payload, its average throughput is around 1.2 kbps, which is less than that of standard Iridium data services such as RUDICS.

5.5.13 Since the Iridium Satellite Network provides AMS(R)S packet data service it shall meet the delay and integrity requirements as stated below.

Delay parameters

5.5.14 Based on accumulated Iridium satellite network performance statistics, the connection establishment delay of a RUDICS-based packet data call is expected to be less than 30 s and the connection establishment delay of an SBD-based packet data call less than 9 s.

5.5.15 With a subnetwork service data unit (SNSDU) length of 128 octets, the Iridium satellite subnetwork supports the following data transit delay values:

5.5.16 For RUDICS-based packet data service, the expected data transit delay (average transfer delay) of a 128-byte payload will be around $128 \times 8/2400 = 0.43$ s. For SBD-based packet data service, the expected data transit delay of a 128-byte message will be around $128 \times 8/1200 = 0.86$ s. Hence, the data transit delay of the highest priority packet should be less than 5 s regardless of whether it is from AES or GES.

5.5.17 Based on earlier discussion and the average data transfer delay value, the 95th percentile transfer delay should be less than 15 s for the highest priority data service whether to or from aircraft.

5.5.18 Based on operational experience and performance statistics, most calls are released within 2 s. Hence, connection release delay for all calls should be less than 5 s.

Integrity

5.5.19 The AMS(R)S SARPs specify packet data service integrity by residual error rate. They further define residual error rate as the combination of the probabilities of undetected error, undetected loss of an SNSDU, and an undetected duplicate SNSDU.

5.5.20 Regarding probabilities of undetected loss and undetected duplicate, both the Iridium circuit switch data transport and the Iridium SBD protocol employ message sequence number and automatic repeat request (ARQ) retransmission at the Iridium protocol data unit (PDU) level. For SBD, a message sequence number is also applied at the SNSDU level. These mechanisms will ensure that the required probabilities for undetected loss and undetected duplicate of an SNSDU can be met.

5.5.21 Probability of undetected error is the packet error rate.

5.5.22 RUDICS employs a 24-bit frame check sequence, and the user payload field in an Iridium PDU is 248 bits. To transport a 128-byte data packet would take five Iridium PDUs. Analysis indicates the probability of a 128-byte data packet transmitting in error is about 3×10^{-7} . The packet error rate can be further reduced if an additional protocol layer

with additional error detection capability is employed. It is assumed that a packet error rate of 3×10^{-7} can be achieved with no further enhancement by other protocol layers.

5.5.23 The SBD service uses the Iridium signaling channel for data transport and is a guaranteed delivery service with multiple layers of error protection. It employs forward error control in the form of BCH³ coding in addition to selective ARQ. By design, the SBD data transport has a better packet error rate performance than circuit switch data transport.

5.5.24 It is expected that Iridium AMS(R)S packet data can provide a residual error rate no greater than 10^{-6} per SNSDU, whether to or from aircraft.

5.5.25 For the Iridium AMS(R)S, a probability of a subnetwork connection (SNC) provider-invoked release is expected to be less than 10^{-4} over any one-hour interval; a probability of an SNC provider-invoked reset is expected to be less than 10^{-1} over any one-hour interval.

Voice service performance

5.5.26 The AMS(R)S SARPs require that Iridium AMS(R)S voice service shall meet the requirements outlined in the following subsections. Note that ICAO is currently considering these provisions in light of the introduction of new technologies.

Call processing delay

5.5.27 Based on Iridium satellite network operational experience and performance statistics, most mobile-originated and mobile-terminated voice calls take 12 s and 14 s to set up, respectively.

5.5.28 For Iridium AMS(R)S, the 95th percentile of time delay for a GES to present a call origination event to the terrestrial network inter-working interface after a call origination event has arrived at the AES interface is not expected to be greater than 20 s.

5.5.29 For Iridium AMS(R)S, the 95th percentile of 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 inter-working interface is not expected to be greater than 20 s.

Voice quality

5.5.30 The Iridium SDU incorporates a 2.4 kbps advanced multi-band excitation vocoder developed by Digital Voice System Inc. This vocoder is tailored to the Iridium communication channel and provides good quality audio performance with a nominal mean opinion score (MOS) of 3.5 under typical non-aeronautical operating and channel conditions.

5.5.31 Iridium terminals have been installed and successfully operated on various types of aircraft including helicopters. Additional qualitative testing will be completed to measure and validate Iridium AMS(R)S voice quality.

5.5.32 An Iridium voice call delay analysis estimated a total one-way voice transfer delay over the Iridium satellite network of about 374 ms. That delay value compares well with measurements undertaken by Iridium LLC. Additional data regarding Iridium voice call delay will be gathered and documented as part of Iridium AMS(R)S verification efforts.

3. Bose, Ray-Chaudhuri, Hocquenghem (a type of error control code)

5.5.33 For the Iridium AMS(R)S voice service, a total voice call transfer delay within the AMS(R)S subnetwork is expected to be no greater than 0.375 s.

Voice capacity

5.5.34 Iridium AMS(R)S will 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} .

5.5.35 Based on the Communications Operating Concept and Requirements (COCR Study) for the Future Radio System, version 1.0, commissioned by the FAA and EuroControl, it is expected that Iridium AMS(R)S will have sufficient available voice traffic channel resources for oceanic and remote operations for both Phases 1 and 2 (projected past the year 2025) 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} .

Security

5.5.36 The Iridium Satellite Network, being an operational satellite service, employs various security measures against external attack and tampering.

Iridium channel security

5.5.37 The complexity of the Iridium network air interfaces makes message interception or tampering very difficult.

5.5.38 To successfully monitor an L-band channel, an eavesdropper must be located within the transmit range of the SDU being monitored, approximately 10 to 30 km from the transmitting SDU in a ground use scenario and approximately 250 to 350 km from an AES in flight. SDU downlink L-Band transmissions could be received over a much wider area. A single satellite beam covers an area of about 400 km in diameter.

Air interface

5.5.39 The complexity of the Iridium air interface would make the development of an Iridium L-Band monitoring device very challenging. Among the complications are:

- Iridium's air interface is proprietary;
- Large, continually changing Doppler shifts;
- Frequent inter-beam and inter-satellite handoffs;
- Time-division multiplexed burst mode channels;
- Complicated modulation, interleaving and coding.

Feederlink interface

5.5.40 A sophisticated monitoring device would be needed in the general proximity of an Iridium gateway to receive the feederlink channel. The complexity of the feederlink interface poses a formidable technical challenge for prospective eavesdroppers. Among the technical complications are:

- Large, continually changing Doppler shifts;
- High capacity, ~3 Mbps channels;
- High-gain tracking antenna required;
- Must reacquire new satellite every ten minutes.

Fraud protection

5.5.41 Fraud protection is provided during the access process. During this process, the gateway determines if the requesting SDU is providing its own geographical location. If true, the system requests a check of the geographical location provided by the requesting SDU with the beam ID the SDU is using. If the beam coverage location associated with the beam ID does not match with the SDU-provided location, the system sets a fraud flag. The system then sends the SDU the "Access Decision Notification" message with the indicator set to "access denied" and service is denied, with the exception of emergency calls.

5.5.42 The Iridium authentication process is adapted without change directly from GSM specifications.

Note.— There is nothing to prevent encryption at the field application level.

5.5.43 It is expected that the Iridium system will provide protection against external attacks on service due to security measures in place at its gateways and facilities, as well as built-in protections in its air interface and authentication process.

Note.— Additional security measures are provided through the aviation centric networks (e.g. ARINC and SITA) which are outside the scope of this manual.

Physical security

5.5.44 The Iridium gateway(s), its master control facility, and its telemetry, tracking and control stations are all secured facilities providing protection against unauthorized entry.

5.5.45 These security aspects of the Iridium Satellite Network provide the same level of protection against certain types of denial of service, such as intentional flooding of traffic, as currently implemented in the GSM.

5.5.46 It is expected that the Iridium satellite network will provide very high degrees of protection at the physical and network levels.

5.5.47 In order to safeguard the Iridium Satellite network, command and control of access to the Iridium constellation is limited to the Iridium SNOC and the Iridium TSC, which access and load the constellation control software.

5.5.48 Secure access is provided at the SNOC and TSC including 7 x 24 guards (SNOC only) with multiple-door badge access restrictions and password-protected Mission LAN access; firewalled connections also are in place to protect against unauthorized access.

5.5.49 Outside of these sites, malicious corrupt software loading would require Iridium-specific TTAC and Mission LAN hardware and software, which are not readily available. This equipment and software are rare and would be extremely difficult to obtain and properly configure to access the constellation.

5.5.50 Additionally, the probability of unauthorized personnel being able to cause permanent damage to a satellite by uploading malicious software is mitigated due to the following factors:

1. Unauthorized personnel would need access to detailed information about software product upload directories, command and verification formats, etc., that are specified in detailed procedures and checklists. Without this information, malicious software would not be accepted by the satellite.
2. The satellite commanding requirements are so esoteric that extensive training and practice are required before an upload can be successfully performed.

3. The satellite itself has multiple computers, so that any malicious software would have to be loaded to multiple satellite computers successfully in order to do any permanent damage.

5.6 SYSTEM INTERFACES

5.6.1 AMS(R)S SARPs require that an AMS(R)S system providing packet-data service shall be capable of operating as a constituent mobile subnetwork of the ATN. The Iridium Satellite Network supports the transparent transfer of data between adjacent inter-network entities. This includes the transparent transfer of global ATN addresses (e.g. 24-bit aircraft addresses) and quality-of-service information, as well as user data. A subnetwork interface protocol for Iridium AMS(R)S has not yet been specified by ICAO. Thus, compliance of the Iridium Satellite Network with AMS(R)S SARPs requires the specification and development of an appropriate subnetwork interface protocol.

5.6.2 Iridium will work with its AMS(R)S service providers and AES manufacturers to ensure that the Iridium AMS(R)S system will allow subnetwork users to address AMS(R)S communications to specific aircraft by means of the ICAO 24-bit aircraft address and will provide an interface to the ATN as well as a connectivity notification (CN) function.

5.6.3 Aircraft avionics shall be tested in accordance with the satellite communications SP test plan for avionics prior to approval and certification as a qualified safety services system for packet data services.

Table 5-1. Iridium AMS(R)S system parameters per ICAO AMS(R)S SARPs

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value ⁴	Additional comments on performance
4.2	General	N/A	Placeholder
4.2.1	AMS(R)S shall conform to ICAO Chapter 4	Yes	—
4.2.1.1	Support packet data, voice, or both	Yes; Both	By design.
4.2.2	Mandatory equipage	N/A for service provider	—
4.2.3	Two years' notice	N/A for service provider	—
4.2.4	Recommendation to consider worldwide implementation	N/A for service provider	—
4.3	RF Characteristics	N/A	Placeholder
4.3.1	Frequency Bands	N/A	Placeholder
4.3.1.1	Only in frequency bands allocated to AMS(R)S and protected by ITU RR	Yes; 1 616–1 626.5 MHz	—
4.3.2	Emissions	N/A	Placeholder

4. Iridium supplied values.

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value ⁴	Additional comments on performance
4.3.2.1	Limit emissions to control harmful interference on same aircraft	Yes	Analysis, unit testing, and aircraft installation testing Reference DO-294A
4.3.2.2	Shall not cause harmful interference to AMS(R)S on other aircraft	N/A	Placeholder
4.3.2.2.1	Emissions shall not cause harmful interference to an AES providing AMS(R)S on a different aircraft	Yes	Analysis, unit testing, and aircraft installation testing Reference DO-262 and DO-294A
4.3.3	Susceptibility	N/A	Placeholder
4.3.3.1	Shall operate properly in cumulative $\Delta T/T$ of 25%	Yes	Analysis and LBT design
4.4	Priority and pre-emptive access	N/A	Placeholder
4.4.1	Priority and pre-emptive access	Yes	Avionics compliance with RTCA DO-262 and Iridium network support of priority, precedence and pre-emption
4.4.2	All AMS(R)S packets and voice calls shall be identified by priority	Yes	Avionics compliance with RTCA DO-262 and Iridium network support of priority, precedence and pre-emption
4.4.3	Within the same message category, voice has priority over data	Yes	Avionics compliance with RTCA DO-262 and Iridium network support of priority, precedence and pre-emption
4.5	Signal acquisition and tracking	N/A	Placeholder
4.5.1	Properly track signal for aircraft at 800 knots along any heading	Yes	Verified by operational experience.
4.5.1.1	Recommendation for 1 500 knots	Yes	Verified by flight test.
4.5.2	Properly track with 0.6 g acceleration in plane of orbit	Yes	Verified by flight test.
4.5.2.1	Recommendation 1.2 g	Yes	Verified by flight test.
4.6	Performance requirements	N/A	Placeholder
4.6.1	Designated operational coverage	N/A	Placeholder
4.6.1.1	Provide AMS(R)S throughout designated operational coverage	Yes	Verified by operational experience
4.6.2	Failure notification	N/A	Placeholder
4.6.2.1	Provide timely predictions of service failure-induced outages	Yes	Currently provides
4.6.2.2	System failure annunciation within 30 seconds	Yes	Verified by sub-system testing
4.6.3	AES requirements		Placeholder

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value ⁴	Additional comments on performance
4.6.3.1	Meet performance in straight and level flight	Yes	Supports flight envelope throughout DOC. Compliance of 4.6.4 and 4.6.5 are provided in their respective sub-sections
4.6.3.1.1	Recommendation for +20/-5 pitch and +/-25 roll	Yes	Supports flight envelope throughout DOC. Compliance of 4.6.4 and 4.6.5 are provided in their respective sub-sections
4.6.4	Packet data service performance	N/A	Placeholder
4.6.4.1	Requirements on AMS(R)S packet data	Yes	See sub-sections
4.6.4.1.1	Capable of mobile subnetwork in ATN	Yes	Subnetwork supports character and bit oriented protocols in support of end-to-end system
4.6.4.1.2	Delay parameters	N/A	Placeholder
4.6.4.1.2.1	Connection establishment delay <70 seconds	Yes <30s RUDICS <9s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork CDF 95th percentile values charted in support of validation process
4.6.4.1.2.1.1	Recommendation Connection establishment delay <50 seconds	Yes <15s RUDICS <9s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork CDF 95th percentile values charted in support of validation process
4.6.4.1.2.2	Transit delay based on SNSDU of 128 octets and defined as average values	Yes <1s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process
4.6.4.1.2.3	From aircraft highest priority <40 seconds	Yes <1s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process
4.6.4.1.2.3.1	Recommendation from aircraft highest priority <23 seconds	Yes <1s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process
4.6.4.1.2.3.2	Recommendation from aircraft lowest priority <28 seconds	Yes <1s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process
4.6.4.1.2.4	To aircraft high priority <12 seconds	Yes <2s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value ⁴	Additional comments on performance
4.6.4.1.2.4.1	Recommendation to aircraft lowest priority <28 seconds	Yes <2s RUDICS <3s SBD	Iridium subnetwork performance verified by Auto-dialer data. Subnetwork averaged values in support of validation process
4.6.4.1.2.5	From aircraft data transfer delay 95th percentile highest priority <80 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.5.1	Recommendation from aircraft data transfer delay 95th percentile highest priority <40 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.5.2	Recommendation from aircraft data transfer delay 95th percentile lowest priority <60 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.6	To aircraft data transfer delay 95th percentile high priority <15 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.6.1	Recommendation to aircraft data transfer delay 95th percentile low priority <30 seconds	Yes <2s RUDICS <1s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.7	Connection release time 95th percentile <30 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.2.7.1	Recommendation connection release time 95th percentile <25 seconds	Yes <2s RUDICS <6s SBD	Iridium subnetwork performance verified by current performance data. Subnetwork CDF 95th percentile values charted using auto-dialer data collected in support of validation process
4.6.4.1.3	Integrity	N/A	Placeholder
4.6.4.1.3.1	Residual error rate from aircraft <10 ⁻⁴ /SNSDU	<10 ⁻⁶	Verified by current performance data. (M)

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value ⁴	Additional comments on performance
4.6.4.1.3.1.1	Recommend RER from aircraft <math><10^{-6}</math>/SNSDU	<math><10^{-6}</math>	Verified by current performance data. (M)
4.6.4.1.3.2	RER to aircraft <math><10^{-6}</math>/SNSDU	<math><10^{-6}</math>	Verified by current performance data.
4.6.4.1.3.3	Pr{SNC provider invoked release} <math><10^{-4}</math>/hr	SBD-N/A RUDICS <math><10^{-4}</math>/hr	SBD is connectionless protocol for FANS1/A datalink and does not apply
4.6.4.1.3.4	Pr{SNC provider invoked reset} <math><10^{-1}</math>/hr	NA	Not applicable to Iridium Network
4.6.5	Voice service performance	N/A	Placeholder
4.6.5.1	Requirements for AMS(R)S voice service	Yes	See sub-paragraphs for compliance
4.6.5.1.1	Call delay processing	N/A	Placeholder
4.6.5.1.1.1	AES call origination delay 95th percentile <math><20</math> seconds	≤ 16 s	Iridium subnetwork performance verified by current performance data. CDF statistics provided for 95th percentile value verification.
4.6.5.1.1.2	GES call origination delay 95th percentile <math><20</math> seconds	≤ 19 s	Iridium subnetwork performance verified by current performance data. CDF statistics provided for 95th percentile value verification.
4.6.5.1.2	Voice quality	N/A	Placeholder
4.6.5.1.2.1	Voice intelligibility suitable for intended operational and ambient noise environment	Yes	To be verified by AES manufacturer.
4.6.5.1.2.2	Total allowable transfer delay within AMS(R)S subnetwork <math><0.485</math> second	<math><0.375</math> s	Verified by current performance data.
4.6.5.1.2.3	Recommendation to consider effects of tandem vocoders	—	Recommendation to take into account effects of tandem vocoders and other analog/digital conversions must be taken on an “as encountered” basis. Testing and analysis cannot take into account all permutations
4.6.5.1.3	Voice capacity	N/A	Placeholder
4.6.5.1.3.1	Sufficient voice traffic channel resources for Pr{blockage <math><0.01</math>} for AES or GES originated calls	<math><0.01</math>	Analysis provided for all regions based on FAA/EuroControl COCR study, Ver 1.0
4.6.6	Security	N/A	Placeholder
4.6.6.1	Protect messages from tampering	Yes	—
4.6.6.2	Protect against denial of service, degradation, or reduction of capacity due to external attacks	Yes	—

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Iridium Subnetwork value⁴	Additional comments on performance
4.6.6.3	Protect against unauthorized entry	Yes	—
4.7	System Interfaces	N/A	Placeholder
4.7.1	Address AMS(R)S by means of 24 bit ICAO address	Yes	By design
4.7.2	Packet data service interfaces	N/A	Placeholder
4.7.2.1	If the system provides packet data service, it shall provide an interface to the ATN	Yes	By design
4.7.2.2	If the system provides packet data service, it shall provide a CN function	Yes	By design

Chapter 6

IMPLEMENTATION GUIDANCE

6.1 THEORY OF OPERATION

6.1.1 The Iridium aviation satellite communications system can provide voice and data services for aviation safety services. In support of this service, a new type of avionics, an SDU, will be deployed and will interoperate with the Iridium global satellite communications system and existing aircraft voice and data communication systems. In addition, a ground-based server will be deployed by Iridium-approved satellite communications service provider(s) for data service. This server will provide connectivity with existing aviation data networks, such as ARINC and SITA, in support of AAC, AOC and ATC data communications.

6.1.2 The three main components of the aviation safety service are as follows:

- Iridium network;
- Iridium-based Avionics (SDU);
- Iridium ground-based data server.

6.1.3 There is a fourth pre-existing component of the aviation safety service, the aviation data network. This network(s) has been in existence for a number of years, evolving to meet the changing needs of the aviation industry. This network will not be described in detail but may have been referenced throughout this manual. SITA or ARINC should be contacted directly for further details about the aviation network.

6.1.4 The end-to-end voice service is shown in Figure 6-1, Iridium Aviation Safety Services Air-to Ground Voice, End-to-End Model. This model also applies to ground-to-air voice service.

6.1.5 The end-to-end voice service is shown in Figure 6-2, Iridium Aviation Safety Services Air-to-Air Voice, End-to-End Model.

6.1.6 The end-to-end voice service is shown in Figure 6-3, Iridium Aviation Safety Services Air-to- Ground Data, End-to-End Model. This model also applies to ground-to-air data service.

6.1.7 The end-to-end voice service is shown in Figure 6-4, Iridium Aviation Safety Services Air-to- Air Data, End-to-End Model.

6.2 IRIDIUM NETWORK

6.2.1 The Iridium network is a global satellite communications system. The system supports voice, data, fax and messaging traffic to and from subscriber equipment across the world or to a PSTN through the Iridium gateway. The services supporting safety services are basic voice calling (telephony), short burst data, and RUDICS.

Basic telephony — Allows an Iridium subscriber, when properly provisioned in the GSM switch and using a valid handset (or LBT) and SIM card, to place or receive calls.

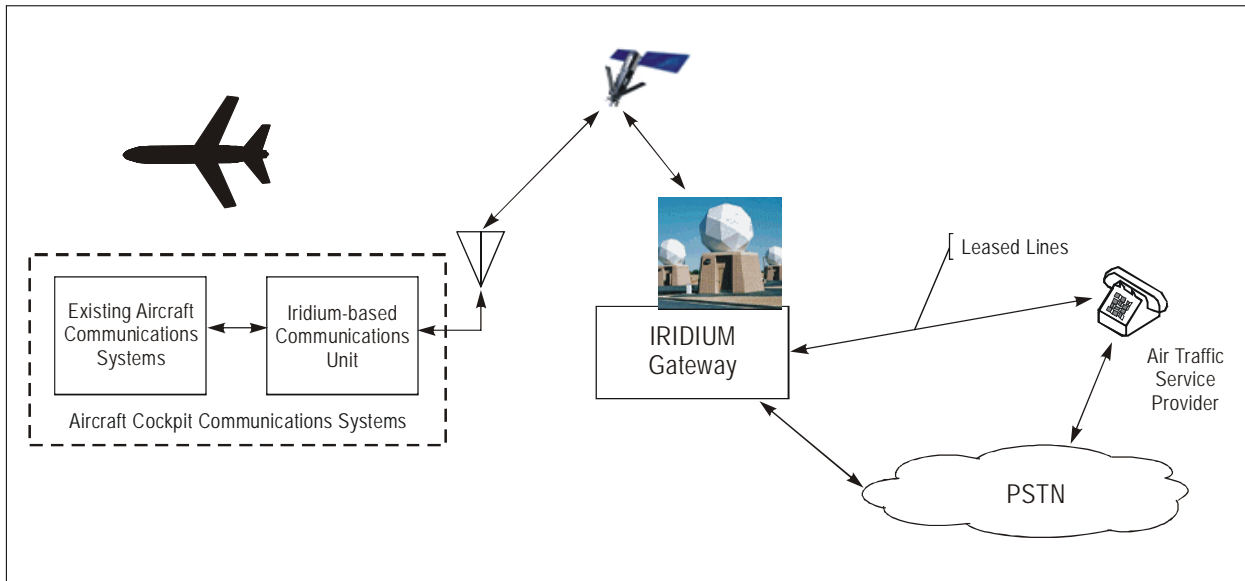


Figure 6-1. Iridium aviation safety services air-to-ground voice (End-to-end model)

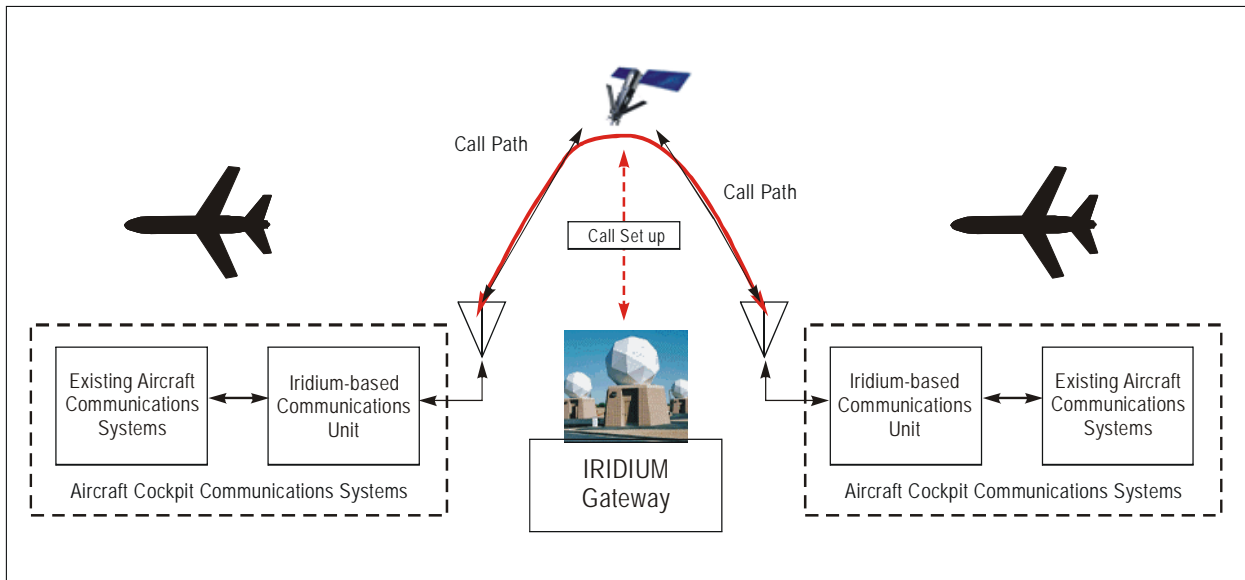


Figure 6-2. Iridium aviation safety services air-to-air voice end-to-end model

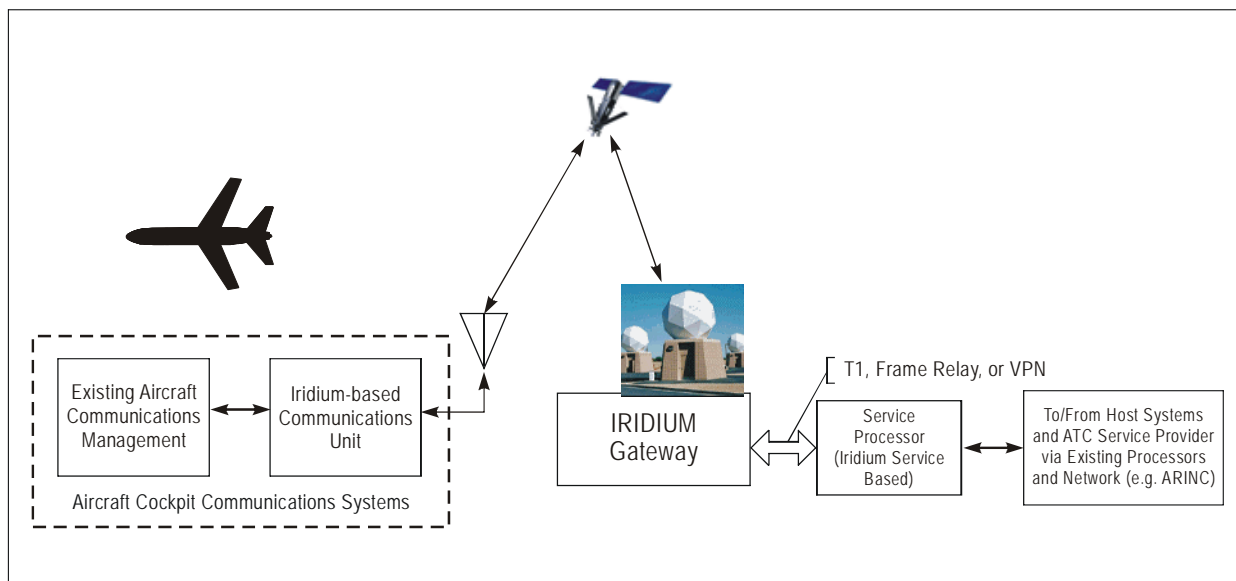


Figure 6-3. Iridium aviation safety services air-to-ground data end-to-end model

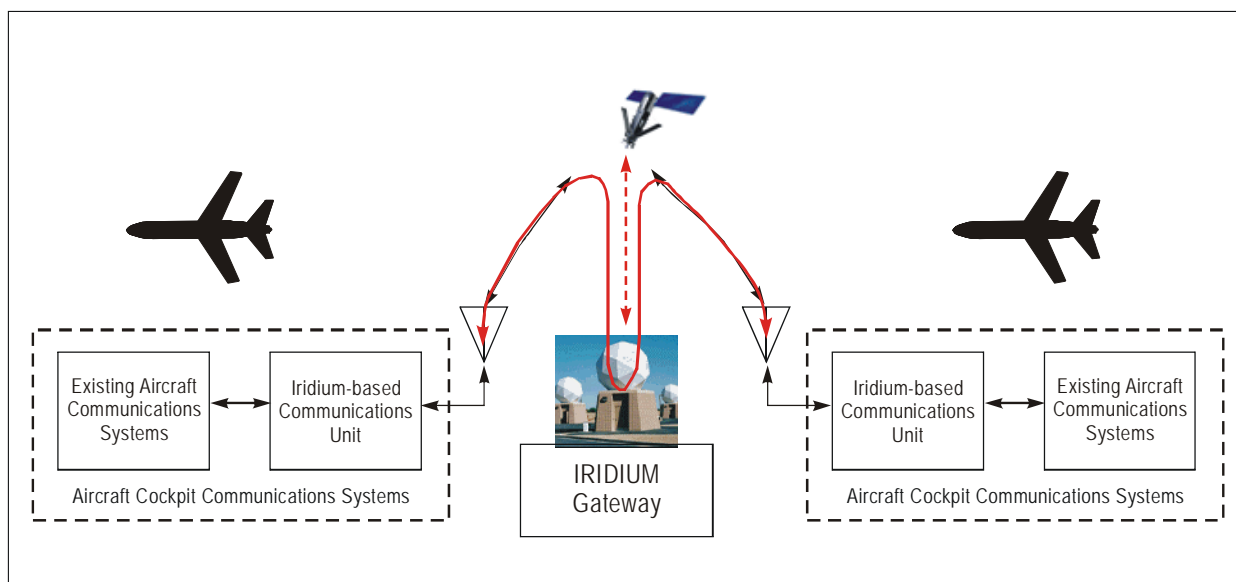


Figure 6-4. Iridium aviation safety services air-to-air data end-to-end model

Short Burst Data (SBD/ESS) Service — A packet bearer capability (non-GSM) that provides a non-circuit switched, high-capacity ACK'ed means of transmitting and receiving packets of data (up to 1960 bytes) to and from compatible SBD subscriber devices across the Iridium network to a specified IP address.

RUDICS — Allows custom devices in the field to connect to servers on the Internet by encapsulating the transmitted data in TCP/IP. It provides nothing more than a pipe through which to transmit customer data.

6.3 SUBSCRIBER SEGMENT (AVIONICS)

6.3.1 The avionics required to support the Iridium network consist of an SDU and antenna(s). The SDU consists of the Iridium LBT and the I/O processing to properly interface with the existing aircraft voice and/or data communications systems. Further details can be found in Section 6.8 of this manual.

6.3.2 These aircraft systems include the cockpit audio control and recording systems, the aircraft communication addressing and reporting system (ACARS) (as applicable for data service), multi-purpose control and display units (e.g., CDU and MCDU) and a communication management system (e.g., MU and CMU).

6.3.3 Iridium has developed a derivative of the Iridium telephone handset, referred to as an L-band transceiver (LBT), for use by avionics manufacturers. Iridium has established processes to control design and manufacturing, test procedures for all transceiver (LBT) design and manufacturing elements, and change control processes for software development and releases. All LBTs go through these standardized factory test procedures before being released for shipment. All LBT software revisions are tested prior to release.

6.3.4 LBTs are provided to Iridium-approved avionics manufacturers who design their avionics units, or SDUs, to contain the LBT and provide the aircraft system interfaces. Avionics manufacturers are responsible for adherence to all applicable civil aviation regulatory agency requirements. Avionics manufacturers are responsible for all parts manufacturing authority and aircraft installation certification, which includes airworthiness and environmental testing.

6.3.5 RTCA has developed minimum operations performance standards, RTCA DO-262, for aircraft avionics systems supporting next generation satellite systems. Compliance of an aircraft earth station, which includes the SDU and antenna, with this standard should ensure that the system can be installed and properly operated on board aircraft. In addition, ITU Recommendation ITU-R M.1343 "Essential Technical Requirements of Mobile Earth Stations for Global Non-Geostationary Mobile-Satellite Service Systems in the bands 1-3 GHz" is applicable to this aircraft system.

6.3.6 The SDU and the ground-based data server, provided by the aviation safety service SP, shall be harmonized to properly support data exchanges, via a published interface control document, developed jointly between the avionics manufacturer and the ground-based data server host/developer.

6.3.7 The SDU will be capable of recognizing prioritized call selection by the cockpit crew and issuing the appropriate commands to initiate priority calling.

6.3.8 In addition, the SDU shall obtain and transmit the aircraft's 24-bit ICAO address. A typical scenario for supporting the 24-bit ICAO address would be that the SDU would be externally wired (strapped) with the aircraft's unique 24-bit address. Upon initiation, the SDU would transmit the aircraft information, which includes the ICAO address, through the Iridium network to provide identification to the ATN.

Iridium Identifiers

6.3.9 Iridium subscribers may be distinguished by several identifiers. Each user is assigned an IMSI which is a permanent number stored on the user's SIM card. To maintain subscriber confidentiality, the IMSI is only transmitted

over the air when a valid TMSI is unavailable. A TMSI is a temporary identifier assigned to a mobile subscriber and stored on the user's SIM card and at the gateway. The TMSI is periodically changed based on system parameters and is used to identify the user over the air. The MSISDN is the Iridium subscriber's phone number. The IMEI is a permanent identifier assigned to each SDU, not to the Iridium subscriber (SIM card).

6.4 IRIDIUM GROUND-BASED DATA SERVER

6.4.1 The ground-based data server serves as the conduit and traffic controller for data communications between the aircraft SDU and the aviation centric networks (e.g., ARINC and SITA networks), and/or leased lines to ATS providers in support of AAC, AOC and ATC messaging. This messaging is currently supported by the ACARS data service with plans to evolve to support ATN. The Iridium SBD and RUDICS data services support both character and bit-oriented communications protocols used by ACARS, which currently utilizes character-oriented protocols with plans to migrate to bit-oriented protocols. ATN utilizes bit-oriented protocols which only can be supported by Iridium data services.

6.4.2 The server will support 24-bit ICAO addressing. The entire system shall provide for message delivery assurance protocols, via message delivery acknowledgement and retransmissions.

6.5 SERVICES SUPPORTED

The Iridium network carries voice and data traffic to and from Iridium subscriber-equipped aircraft across the world or to a PSTN (or directly through leased lines). Only validated aircraft SDUs are allowed to use the system, except for emergency communications, in which all SDUs are allowed to place distress calls.

6.6 VOICE SERVICE

6.6.1 Every voice call must involve an ISU (resident inside the SDU), whether the call is Iridium subscriber (aircraft) to subscriber (aircraft), subscriber (aircraft) to PSTN number (ground-based user), or PSTN number (ground-based user) to subscriber (aircraft).

6.6.2 The Iridium SDU sets up a circuit-switched voice or data call by dialing a voice or data call number using the Iridium AT command: `ATDnx.x` where `n` is a Dial Modifier and `x` is a number.

One example of how to make and disconnect a voice call is given below:

- `ATD1234567890`; (dial remote phone)
- OK (call connected; phone stays in command mode)
- `< ... conversation ... >`
- `ATH` (hangup call)
- OK

One example of how to make a data call is given below:

- `AT+CBST=6,0,1` (asynchronous modem 4800 bps and IRLP)
- OK
- `AT+CR=1` (enable reporting)

- OK
- ATD1234567890 (dial remote modem)
- +CR: REL ASYNC
- CONNECT 9600 (call connected at DTE rate of 9600)

The Iridium SDU is capable of accepting mobile terminated data calls. The following is a sequence of commands that can be used to establish the connection:

- RING (indicates arrival of call request)
- ATA (manually answer the call)
- CONNECT 9600 (call connected at DTE rate of 9600)
- To automatically answer a call, register 0 should be set to a non-zero value.
- ATS0=2
- RING
- CONNECT 9600 (call connected at DTE rate of 9600)

The Iridium SDU AT Command Reference provides descriptions of all the Iridium AT commands for proper interfacing to the SDU.

Key elements of call handling, shown in Figure 6-5, are identical for all calls. These elements are:

- 1) acquiring a traffic channel on a satellite (Acquisition) by the subscriber unit (such as the aircraft SDU);
- 2) accessing the gateway (Access) is the process of obtaining the SDU's access to the Iridium network which can include:
 - geolocation — call processing location determination;
 - aircraft SDU parameter download;
 - registration/location update;
 - authentication of SDU's SIM including TMSI assignment (authentication);
- 3) setting up a call through the process of call establishment which includes:
 - originating a call from an SDU (MOC) or PSTN via the gateway (MTC);
 - terminating a call at an SDU (MTC) or PSTN number via the gateway (MOC);
- 4) maintaining a connection through call maintenance which includes handoff, reconfiguration (cut through/intercept/grounding).
- 5) call release.

Acquisition

6.6.3 Acquisition is the process of the SDU obtaining a bi-directional communications channel, called a Traffic Channel, between the SDU and a satellite. The process is initiated either by the SDU user taking action to request a service that requires a channel, or by the SDU via CDU, MCDU or cockpit handset ring tone responding to a Ring Alert that ultimately notifies the cockpit of an incoming call.

6.6.4 Acquisition is the first step in obtaining service from the Iridium network. It is the process of establishing a communication link between a satellite and an SDU. Acquisition by an SDU is necessary for registration, call setup, answering call terminations, or to initiate any service on the Iridium network.

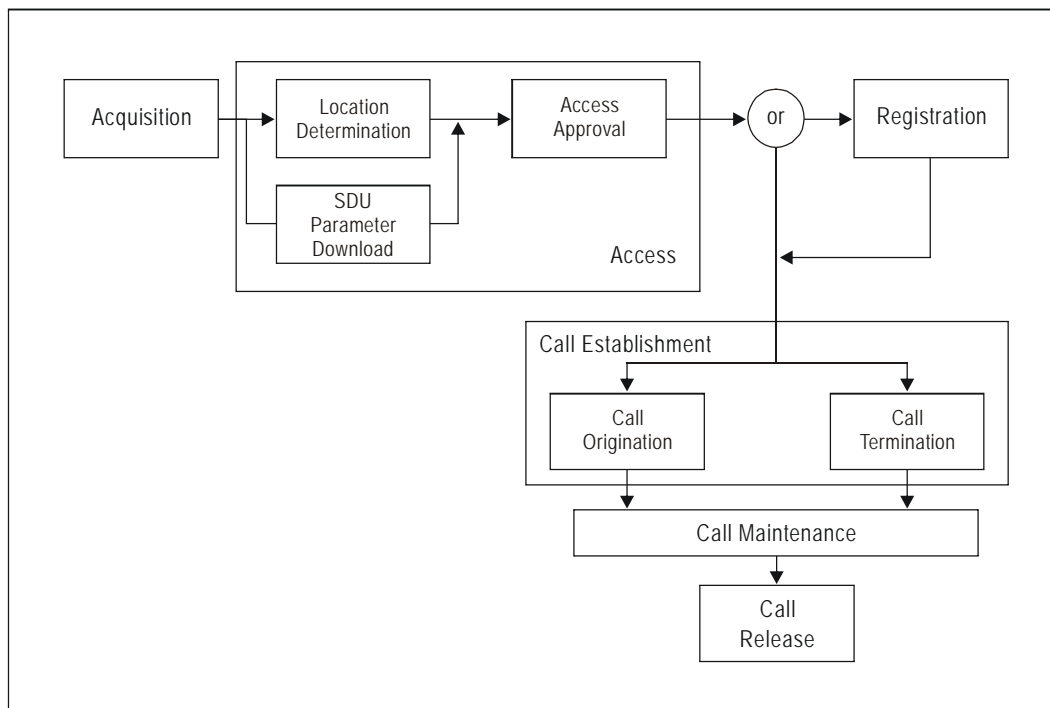


Figure 6-5. Call handling elements

6.6.5 Under certain circumstances, it is necessary to prevent users from making acquisition attempts. Such situations may arise during states of emergency or in the event of a beam overload. During such times, the broadcast channel specifies, according to populations, which Iridium subscribers may attempt acquisition (based on acquisition class).

6.6.6 The subscriber equipment reads the acquisition class from the SIM card that was programmed when initially provisioned. The system provides the capability to control a user's acquisition to the system based on the following acquisition classes:

15. Iridium LLC Use
14. Aeronautical Safety Services
13. Reserved
12. Reserved
11. Fire, Police, Rescue Agencies
10. Emergency Calls
- 0-9. Regular Subscribers (Randomly allocated)

6.6.7 The use of acquisition classes allows the network operator to prevent overload of the acquisition or traffic channels. Any number of these classes may be barred from attempting acquisition at any one time. If the subscriber is a member of at least one acquisition class that corresponds to a permitted class, the SDU proceeds with acquisition.

6.6.8 Acquisition consists of establishing a link between the SDU and the satellite and acquisition control, as shown in Figure 6-6.

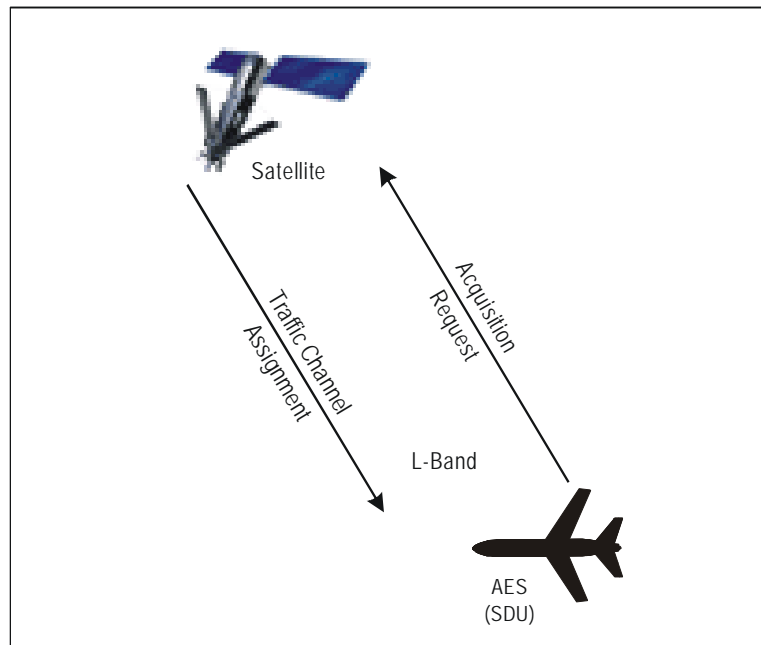


Figure 6-6. Acquisition

Access

6.6.9 The access process determines the SDU's location with respect to service control areas (SCA) defined in Earth fixed coordinates. Based on the SCA within which the SDU is found to be located and on the identity of the SDU's service provider, a decision is made regarding whether or not to allow service. The process, shown in Figure 6-7, is initiated immediately following acquisition.

6.6.10 Location information may be reported by the SDU based on an external source such as the global positioning system or the aircraft's navigation system, or it may be determined by the geolocation function contained within the access function. The geolocation function uses call processing location determination to provide an estimate of the user's location. The system's accuracy in determining location depends upon the relative geometry of the aircraft and satellite constellation, accuracy of measurements made by the aircraft, accuracy of measurements made by the satellite, and algorithm calculations.

6.6.11 Iridium supports a method for a sovereign country to deny services to classes of subscribers roaming into its territory. Services will be denied if the Iridium network determines that the aircraft is in an unauthorized area.

6.6.12 After location is determined, the access approval-denial process starts when the SDU sends the "Access Request" through the satellite and to the gateway. Based on the calculated geographic location of the user, the gateway checks the user's current SCA against the user's satellite communications service provider ID access information for that SCA. The gateway downloads the SDU configuration parameters to update any changes that may have been made, and the gateway determines the registration parameters as specified for the SDU's location area code (LAC) to determine if the aircraft needs to re-register. If there are no access restrictions for the aircraft (SDU), an Access Decision Notification is sent and the gateway indicates to the SDU if access has been denied or approved. If approved, the gateway provides satellite path information to the SDU.

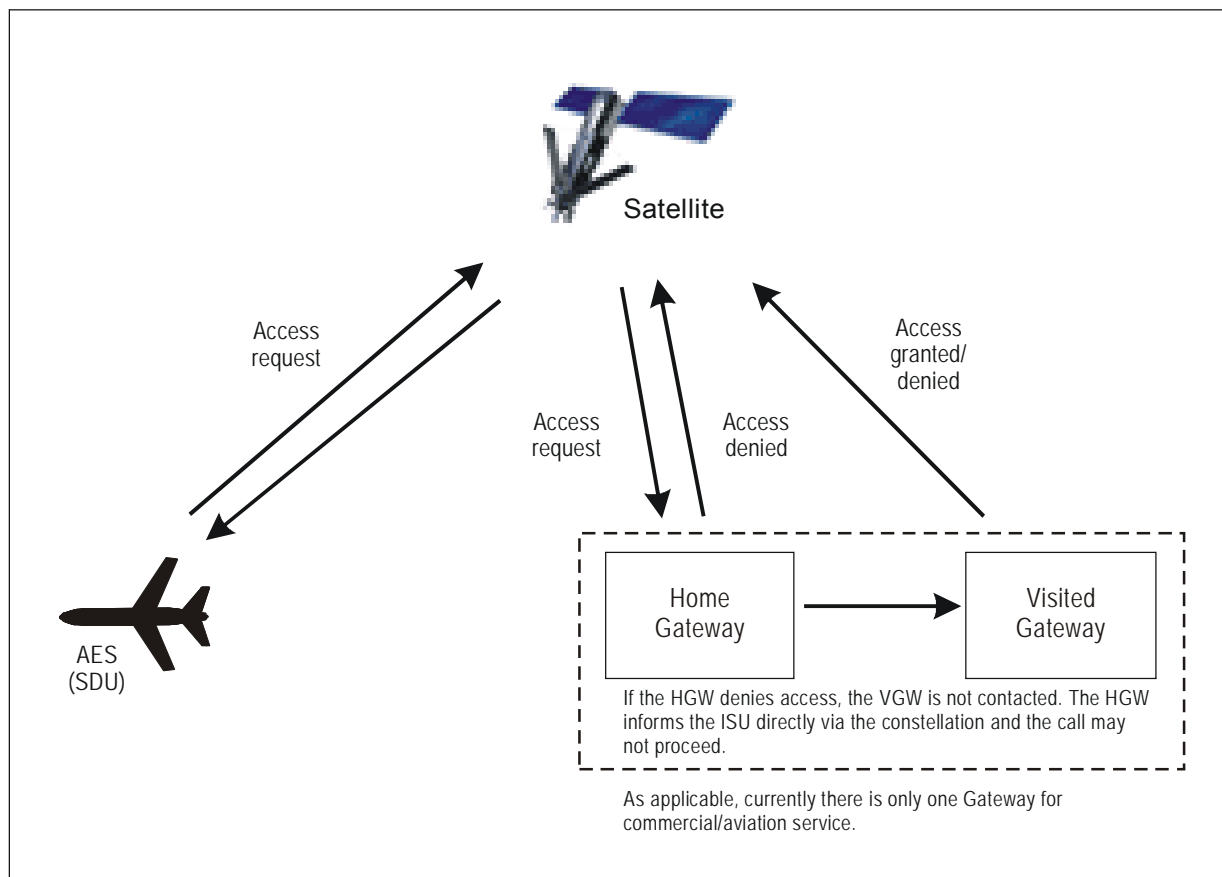


Figure 6-7. Access

6.6.13 If access is denied, one of the following denial cause values will be provided via the access decision notification from the gateway:

- Unknown
- Restricted area
- Indeterminable area
- Subscriber parameter unknown
- Insufficient resources
- Protocol error
- Access guard timer expiration
- NIL LAC
- Access Denied
- None

Call establishment

6.6.14 Subsequent to gaining access to a gateway, the SDU must register with the gateway, if it has not already done so. There are three reasons for a re-registration, which is determined by the gateway:

- 1) the aircraft has moved from one gateway to another;
- 2) the aircraft has moved from one LAC to another;
- 3) the aircraft has moved away from its old position by more than the re-registration distance as specified by the LAC. That is, the relocation distance calculated by the gateway is greater than the re-registration distance for the LAC.

6.6.15 Call control. If the aircraft originates the call, it will then send the dialed number to the visiting gateway (as applicable) and the gateway will process the dialed number. The gateway verifies the aircraft SDU's SIM card to authenticate that the business rules for the aircraft are valid. If the SDU's SIM card is authorized to place the call, then the gateway will allocate the resources to support the call, such as the circuits, transcoders and trunks.

6.6.16 The gateway then alerts the SDU that the called party is ringing (provides a ring tone to the user's ear piece).

6.6.17 After a speech path has been created via the satellite, the visiting gateway is removed from the speech path, which is referred to as "cut-through". Cut-through is not done for data calls, supplemental and fax services. Cut-through reduces voice path time delay and conserves K-band resources.

6.6.18 When the called party answers the call, the gateway informs the SDU that the called party has answered the call and the ring tone is disabled.

Call maintenance

6.6.19 Once the call has been established, the Iridium network nodes involved with the call enter a maintenance state. In this state, the network maintains the connection between the nodes. As the satellites orbit overhead, the network passes the traffic channel from satellite to satellite, a process referred to as "handoff".

6.6.20 The Iridium network satellites have highly directional antennas providing Iridium network access to aircraft SDUs. These antennas are configured to project multiple beams onto the surface of the earth. Handoff is the process of an aircraft (SDU) moving from its current traffic channel to a different traffic channel, usually because satellite motion has resulted in the current traffic channel no longer being suitable for continuing service. The handoff process is required in three situations:

- 1) An aircraft SDU must be handed off between satellites as they move relative to the aircraft (Inter-satellite).
- 2) An aircraft SDU must be handed off between beams on a satellite as beam patterns move relative to the aircraft (Intra-satellite).
- 3) As the inter-satellite geometry changes, radio channels are reallocated among the beams to manage interference. This process can cause an aircraft SDU to be handed off to a different channel in the same beam (Intra-beam).

Call release

6.6.21 Call release occurs when one of the connected parties goes on-hook or the network detects a call-terminating fault. In either case, the originator of the release generates a release message which transverses through all nodes involved in the call. A release acknowledgement is sent back through the network, each node drops the call, and all resources being used for the call are released.

6.6.22 The gateway generates billing records of the call and stores this information within the gateway. Billing records are later sent to the appropriate billing centres.

Data link

6.6.23 The Iridium network supports two types of data service for aviation safety service, SBD and RUDICS. Some LBTs fully support the use of both of these services, whereas other LBT models support SBD only. Use of either type of data exchanges shall be seamless to the end-user.

SBD

6.6.24 Iridium's SBD Service is a simple and efficient satellite network transport capability to transmit short data messages between the aircraft data management unit (e.g. MU and CMU) and the ground-based data server. A mobile originated, or aircraft originated, SBD message can be between 1 and 1 960 bytes (for example, there is a 340-bytes maximum for a 9601 LBT). A mobile terminated, or aircraft bound, SBD message can be between 1 and 1 890 bytes (for example, there is a 270-bytes maximum for a 9601 LBT).

6.6.25 The interface between the Field Application and the ISU (both contained within the SDU) is a serial connection with extended proprietary AT commands.

For a Mobile Originated SBD Message (MO-SBD):

- The message is loaded into the MO buffer in the SDU using the +SBDWB or +SBDWT AT Commands.
- A message transfer session between the SDU and the gateway is initiated using the AT Command +SBDI.

For a Mobile Terminated SBD Message (MT-SBD):

- The SDU initiates a Mailbox Check using the AT Command +SBDI and when the message is received from the gateway.
- To retrieve from the MT buffer in the SDU by the Field Application, the +SBDRB or +SBDRT AT Commands are used.

6.6.26 All safety services aircraft originated (MO) and aircraft terminated (MT) messages between the vendor application (ground-based service processor) and the Iridium network gateway utilize a Virtual Private Network (VPN) and leased line routing of messages to provide additional security, capacity and/or redundancy. Additionally, Iridium subscriber (aircraft or ground-based subscriber) to Iridium subscriber (aircraft or ground-based subscriber) messages remain entirely within the Iridium network infrastructure, which provides a high level of security.

6.6.27 The primary elements of the end-to-end SBD architecture are shown in Figure 6-8. Specifically, the elements consist of the SDU field application, the Iridium network, and the vendor application.

6.6.28 The field application represents the hardware and software that is defined by the avionics manufacturer which is synchronized with the vendor application, or ground-based service processor, to perform data exchanges such as ACARS, or collecting and transmitting aircraft location information. The SDU includes the Iridium LBT with the SBD feature available in firmware, aircraft communication interfaces, and memory and processor logic.

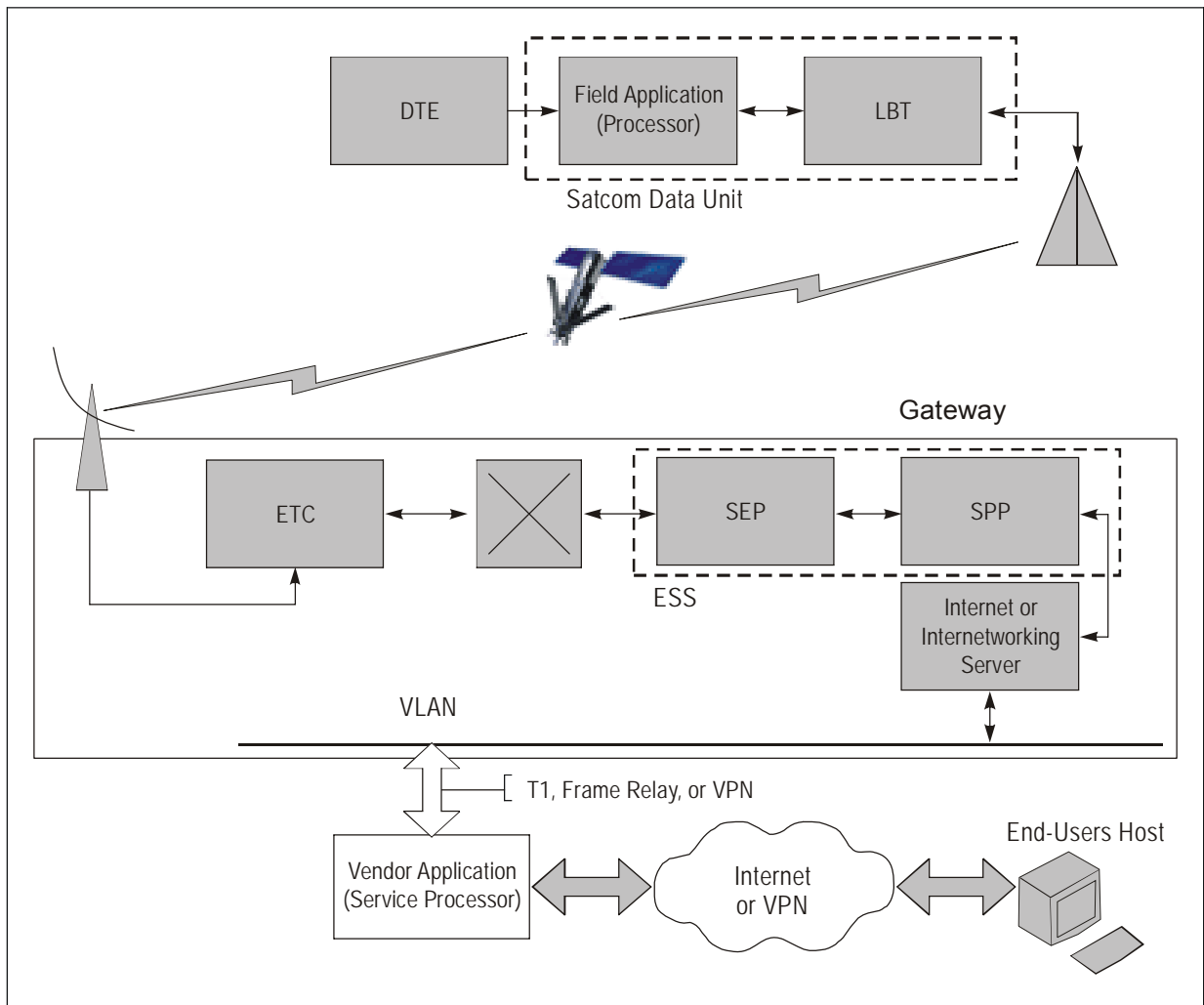


Figure 6-8. SBD architecture

6.6.29 The interface between the vendor application and the Iridium network gateway uses standard Internet protocols to send and receive messages.

RUDICS

6.6.30 Iridium’s RUDICS is a circuit-switched data service designed to be incorporated into an integrated data solution. Integrated data solutions are applications such as remote asset monitoring, control, and data file transfer. Often these applications are designed to support hundreds or thousands of remote units. RUDICS is designed to take advantage of the global nature of the Iridium communications system and combine that with a modern digital connection between the Iridium gateway and the ground-based service processor, or host application.

6.6.31 RUDICS provides a circuit-switched data service, a data pipe, by which to transmit and receive customer data. The service can be configured on a customer basis for PPP or MLPP depending on the application or customer’s request. The customer must be properly provisioned in both the switching subsystem and the RUDICS access control server in order to use this service. Access is provided from the Iridium network to the Internet or dedicated circuits (or visa versa).

6.6.32 An example of how to make a data call is given below:

- AT + CBST=6,0,1 (asynchronous modem 4800 bps and IRLP)
- OK
- AT + CR=1 (enable reporting)
- OK
- ATD1234567890 (dial remote modem)
- + CR: REL ASYNC
- CONNECT 9600 (call connected at DTE rate of 9600)

6.6.33 Service can be configured to limit access to user group functionality whereby only those configured for a particular destination will be able to reach that destination.

6.6.34 The primary elements of the end-to-end RUDICS architecture are shown in Figure 6-9. Specifically, the elements consist of the Field Application, the Iridium Subscriber Unit, the Iridium satellite constellation, the standard telephony units and the RUDICS server located at the Iridium gateway, the VPN, and the Vendor Application, or ground-based service processor.

6.6.35 The standard sequence of events for a mobile originated call:

- 1) Mobile application places a call to a custom RUDICS server number.
- 2) Call request is routed over the constellation for user authentication and call set-up.
- 3) Switch connects to RUDICS server, secondary authentication conducted.
- 4) RUDICS server terminates call to pre-configured IP Address.
- 5) End-to-end IP connection established, over the constellation, between the host application and mobile application.

6.6.36 The standard sequence of events for a mobile terminated call:

- 1) Host application places telnet call to RUDICS server.
- 2) RUDICS server authenticates host.
- 3) Call request is routed to the switch for call set-up.
- 4) Call request is routed over the constellation for user authentication and call set-up.
- 5) Mobile application answers call. End-to-end IP connection established, over the constellation, between the host application and mobile application.

6.6.37 RUDICS uses routers to allow termination and origination of circuit switched data calls to and from a specific IP address via a Telnet protocol. The capability is designed to support applications that have many field devices and one central host application. The service allows field devices to directly call the host application, and the host application is able to directly call the field devices. Connectivity between the Iridium gateway and the host application can take place through a variety of methods, including Internet, VPN and leased line. Aviation safety services may only utilize approved VPN connectivity and leased lines, in a redundant fashion.

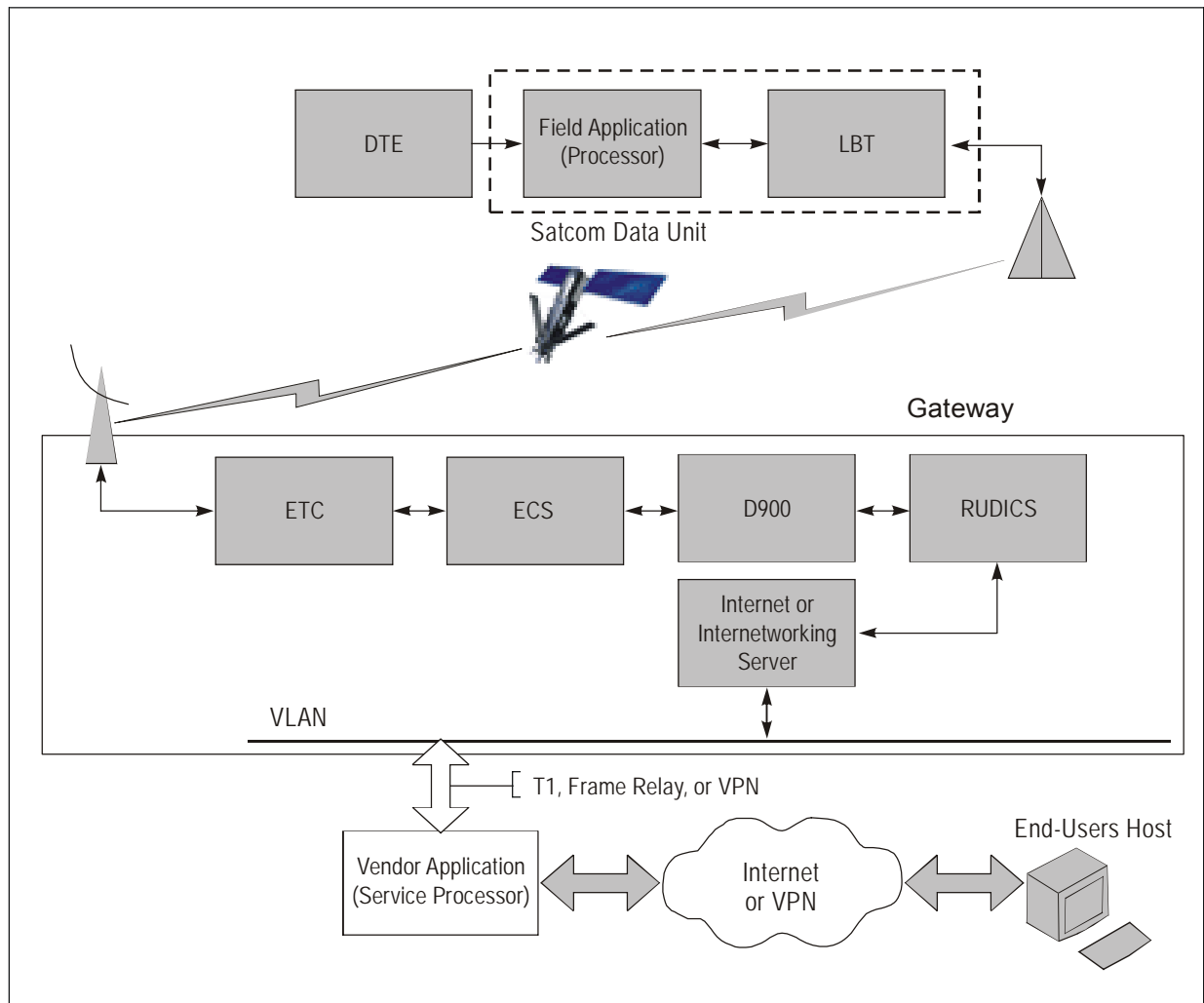


Figure 6-9. RUDICS Architecture

6.7 OPERATION

Connectivity

6.7.1 End-to-end voice services should take into account the quality of service provided by the PSTN and/or use of leased telecommunications lines to achieve compliance with the AMS(R)S SARPs.

Calling characteristics

6.7.2 The Iridium network was modeled after the telecommunications industry standard GSM telephone system. The Iridium network system architecture provides a short voice delay, with worst-case estimates (one-way voice transfer delay) calculated to be less than 375 ms. This number may vary due to end-user PBXs and the end-user's telecommunication company connection/configurations.

6.7.3 Call set-up time, call establishment rates, and dropped call rates are monitored and reported on a periodic basis.

Security

6.7.4 All physical properties within Iridium satellite are maintained in a secure fashion with extra secure measures, including locked passages with access on an “as-needed” basis, deployed at the gateway, satellite network operations centre and technical support centre.

6.7.5 In addition, the following security measures have been taken to assure secure network services:

- Handling of misdirected calls and protection of GTA communications consists of validation of authorized calling telephone number and validation of authorized personal identification number (PIN) for calls placed to the aircraft cockpit. This feature is based on the ability of the avionics, which is an option on some models, to block out calls from telephone numbers not listed in a pre-loaded authorized telephone number list. One number on the authorized calling list shall be an Iridium-provided number which requires PIN entry. The caller, calling into the Iridium-provided telephone number must then enter the prescribed PIN. The user is allowed three attempts to enter the proper PIN. After the third attempt, the call process is halted and the caller must re-dial the aircraft telephone number and re-enter the PIN sequence.
- Fraud protection is provided during the access process. During this process, the gateway determines if the requesting SDU is providing its own geographical location. If true, the system requests a check of the geographical location provided by the requesting SDU with the beam ID the SDU is using. If the beam coverage location associated with the beam ID does not match the SDU-provided location, the system sets a fraud flag. The system then sends the SDU the “Access Decision Notification” message with the indicator set to “access denied,” and service is denied, with the exception of emergency calls.
- Denial of service due to unauthorized usage is supported during the access, registration and authentication processes. These rules can be made available to the proper authorities on an “as needed” basis.

Quality of service measurement

6.7.6 Service quality is measured by a number of devices, which are referred to as auto-dialers. These auto-dialers are deployed around the world and are configured to automatically place calls through the Iridium network. As each call is dialed, the system starts a timer. As the call process proceeds and the call is established, the connection time is stopped and the total time to connect is recorded. If the call is dropped prematurely, the premature call is recorded, as is the recording of properly terminated calls.

6.7.7 Iridium has set up approximately 25 auto-dialers around the world, in both the northern and southern hemispheres. Each auto-dialer is connected to a computer that runs a script placing calls through the system and records the results. Since 1998, 365 days per year, each auto-dialer attempts over 1 440 calls per day, which equates to 525 600 calls per auto-dialer per year, or well over 10 million calls attempted each year using the 25 auto-dialers.

6.7.8 The following key performance indicators are monitored closely:

- Call set-up
- Call establishment rates

- Drop rates
- Drop rate vs. call duration
- Data throughput
- Data error rate.

System outages and maintenance

6.7.9 Iridium has processes and procedures in place to minimize the impact of an outage or planned outage due to system maintenance. In addition to the spare satellites in orbit in each plane, Iridium has redundant gateway processors in place to negate processor hardware failures, as well as redundant telecommunication lines.

6.7.10 Iridium's satellite communications SPs are required to have similar equipment and telecom line redundancy, as well as processes and procedures in place to handle outages. These SPs are also required to synchronize their maintenance outage windows and trouble ticket systems with Iridium to minimize the impact of outages on the end-users.

6.7.11 The aviation satellite communications SP is the initial contact point for service issues. Iridium has processes in place to handle service issues when the SPs cannot resolve an issue.

6.7.12 Any significant service outage (including loss of a space vehicle) results in issuance of a network advisory notification. The notification specifies the satellite ID number involved. A number of commercial, off-the-shelf (COTS) computer software tools are available to allow users to track the identified satellite. A screen shot of one available tracking tool is shown in Figure 6-10.

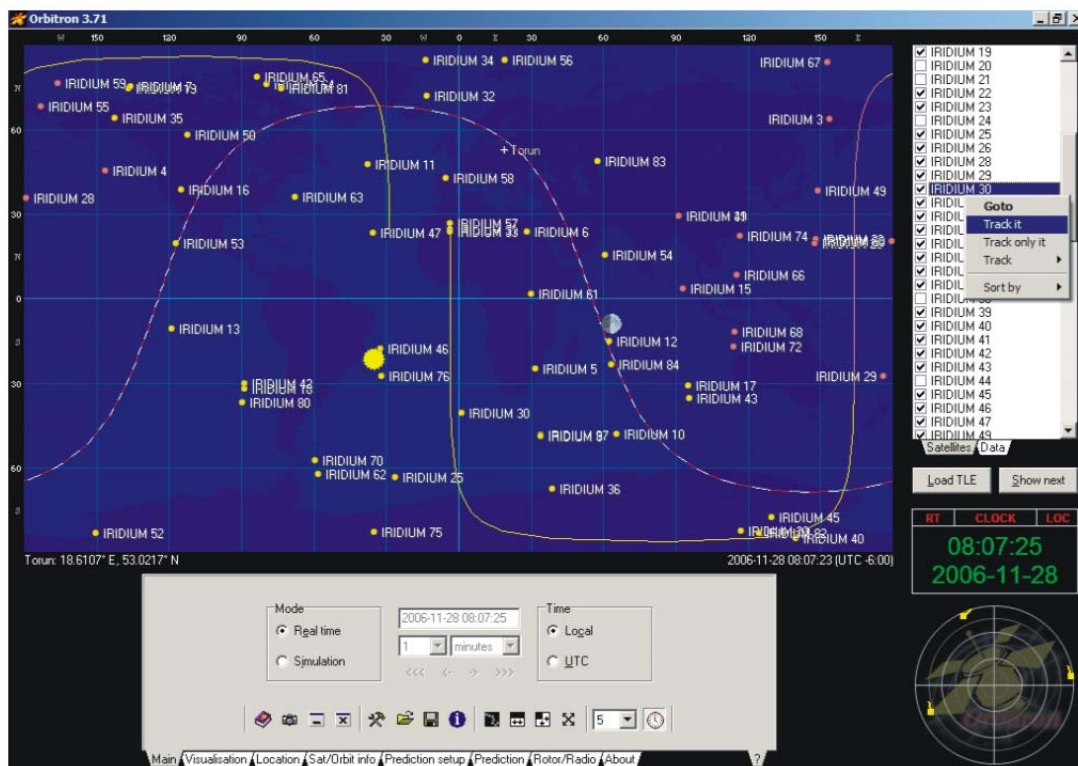


Figure 6-10. COTS satellite tracking application screenshot

6.7.13 Should it be determined that the outage will persist for a lengthy period of time (e.g., loss of a satellite in a plane that has no spares readily available), ISLLC attempts to fill in as much as possible of the missing L-band footprint by developing and uploading new beam laydown tables to the constellation.

6.7.14 If a spare satellite is available in the same plane, it can usually be manoeuvred into the vacant slot in a few days time, but that also requires generation and upload of new beam laydown tables because of the change in satellite node ID.

6.7.15 Iridium satellite can provide recommendations on suitable COTS satellite tracking software.

Planned outages

6.7.16 Iridium has established a scheduled maintenance window [Window] for GES facilities. It should be noted that scheduled maintenance windows are not utilized each week, the entire maintenance window may not be utilized, and the maintenance activity may not impact the entire network or services. Iridium will endeavor to sustain service during the maintenance activity to minimize impact on end-user operations.

6.7.17 If Iridium intends to utilize the Window, Iridium will endeavor to send an email notification to Iridium SPs by close of business Mountain Standard Time on the Tuesday immediately prior to the Window. The email notification shall indicate the type of potential service impact (e.g. voice, billing). A corresponding email notification will be sent once the maintenance has been completed.

6.7.18 If Iridium does not intend to utilize the Window, no notification will be sent. Iridium will always attempt to minimize the duration of the actual outage. Depending on the nature of the maintenance, service may be completely unavailable for the entire maintenance window or for varying periods of time within the Window. Depending on the nature of the maintenance, mobile originated messages may be stored in the gateway resulting in increased latency during this period. Iridium aviation satellite communications SPs are required to coordinate maintenance activities to coincide with Iridium's maintenance window and to provide notification to end-users.

Unplanned outages

6.7.19 In the event of an unplanned outage affecting service, Iridium will issue an email notification to SPs upon detecting such a loss of service. Depending on the nature of the outage, the initial notification email may contain the following:

- Approximate start time of the outage;
- End time of the outage.

Notifications

6.7.20 Notifications will be provided to the SPs and end-users, as required for planned maintenance, service outage and service restoration.

6.8 AVIONICS

6.8.1 Iridium avionics are based on the Iridium-supplied LBT, with one voice/data channel for each LBT, as shown in Figure 6-11, Two channel avionics block diagram. The LBT provides, at minimum, the following:

- Seamless, low latency link with the Iridium network;
- Vocoder, to ensure a consistent quality;
- Data linkage with the SBD and RUDICS processors at the gateway to ease integration and ensure seamless service;
- SIM card, to assure that safety-related aeronautical services obtain timely access to the resources needed within the Iridium AMS(R)S, which includes provision for priority, precedence and pre-emption of system resources and support of Acquisition Class 14;
- Sub-miniature D connector for interfacing with the avionics interworkings;
- AT command structure to control the LBT;
- Transmission of the 24-bit ICAO aircraft address.

6.8.2 All avionics shall be tested and approved by the aviation satellite communications SP to assure proper interaction through the Iridium network and adherence to published communications protocols. Only those avionics tested and approved by both Iridium and the satellite communications SP are provided with the safety services SIM card.

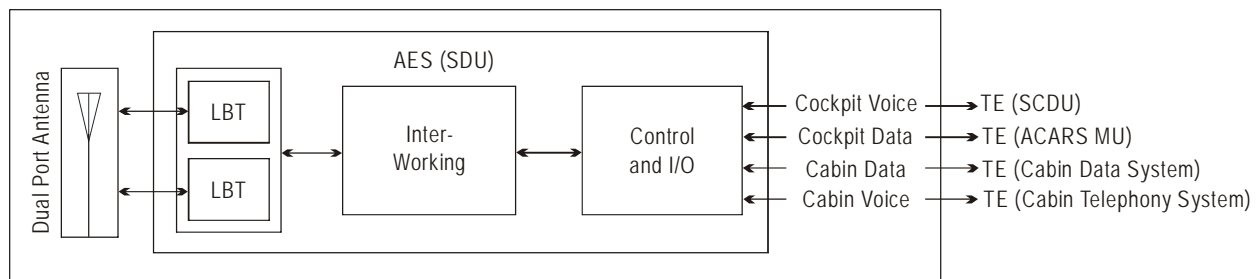


Figure 6-11. Two channel avionics block diagram

6.9 REQUIREMENTS DEFINITION

6.9.1 All avionics are subject to the airworthiness regulations that apply to the aircraft in which the avionics are to be installed, as directed by applicable civil aviation authorities. Adherence to these civil aviation regulations for aircraft system installation(s) is provided by the avionics manufacturer and the installation entity providing the engineering and certification of the installation engineering and certification package required for a type certificate, a new aircraft, or a supplemental type certificate for modification of an aircraft.

6.9.2 The appendix of specifications of several relevant Iridium network and LBT documents should be consulted for additional information.

6.10 AIRCRAFT INSTALLATION

6.10.1 RTCA DO-160, *Environmental Conditions and Test Procedures for Airborne Equipment* provides guidelines on aircraft radio installation location, or qualified equivalent. In the event that an Iridium system and other MSS system are co-located on the same aircraft, simultaneous operation may require additional interference mitigation techniques. For example, in the case of Inmarsat/MTSAT, significant isolation is required between the Inmarsat/MTSAT transmitter and Iridium receiver. This could be achieved by the installation of a Type-D or Type-E or equivalent diplexer, as specified in ARINC 741 or 781.

Aircraft antenna mounting

6.10.2 The Iridium antenna(s) shall be installed on top of the aircraft, as close to the aircraft centreline as possible, with sufficient physical separation between the Iridium antenna and all other CNS system antennas. The Iridium antenna shall be mounted such that the installation provides the clearest line-of-sight path to the satellites with the highest amount of unobstructed view to the horizon and maximum allowable separation from any other installed MSS system antenna(s). It is recommended that a site survey of the aircraft be conducted prior to installation to ensure that the Iridium equipment will operate properly in coexistence with other MSS systems. As per the requirements of obtaining an aircraft supplemental type certificate or type certificate for a new aircraft, ground and flight testing of the Iridium network shall be conducted to ensure interoperability with all other CNS systems and to ensure the Iridium network installation provides adequate electromagnetic compatibility for safety of flight (EMC/SOF).

6.11 IRIDUM GROUND-BASED SERVICES

6.11.1 Iridium has a number of ground-based communications systems manufactured by various equipment manufacturers which are available for ATS providers. These systems can be equipped with a special aviation safety services SIM card to enable these aviation systems to have the highest acquisition class in the event of load shedding.

6.11.2 Where leased telecommunications lines are not available, the Iridium ground-based system may provide the primary circuit mode channel(s), as shown in Figure 6-12.

Note.— Data can be supported, however ACARS/ATN protocols require specialized data terminal equipment, and aircraft messaging should be routed through the aeronautical terrestrial service to ensure proper message routing and tracking.

6.12 PROCESS FOR IMPLEMENTING FUTURE SERVICES

6.12.1 Iridium and Iridium SPs will coordinate the need for new services and features. The Iridium SPs shall work with the end-users, civil aviation authorities and ATS providers to gain an understanding of the aviation community's needs and priorities.

6.12.2 Iridium will publish annually a list of services and features planned for the upcoming year, based on estimated quarterly system upgrades. This list will be made available on the Iridium website and will be made available to Iridium's value added manufacturers, resellers, service providers and end-users, including ATS providers.

6.12.3 Iridium will take into consideration backward compatibility with in-service transceivers and avionics when developing new features.

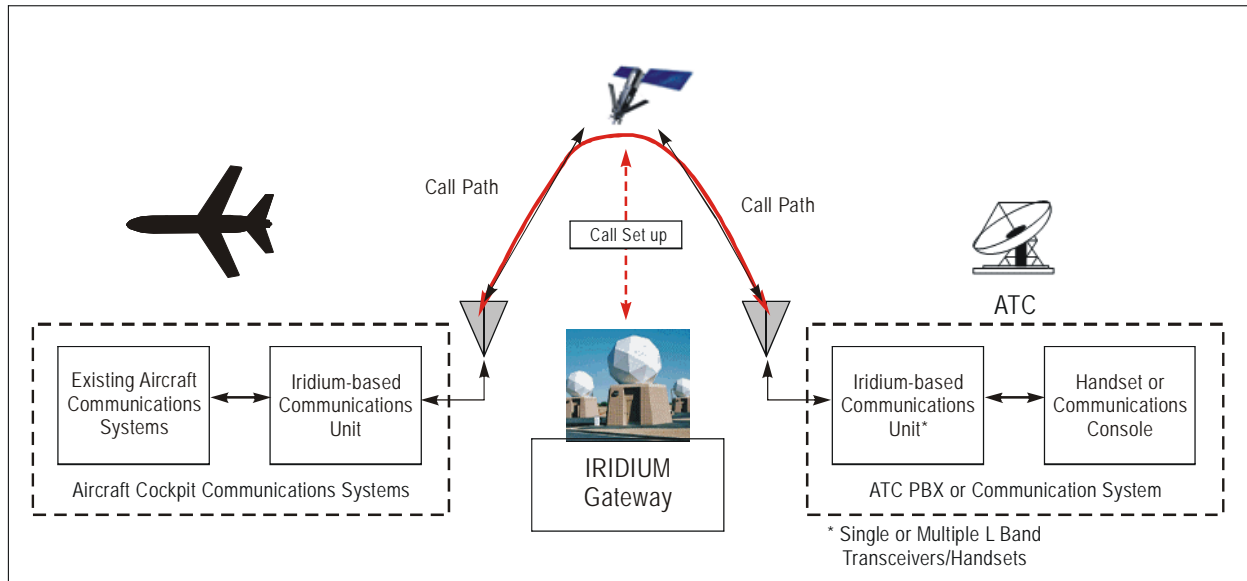


Figure 6-12. IRIDIUM aviation safety services — voice aircraft to air traffic service provider service model

Appendix A

AIRCRAFT EARTH STATION RF CHARACTERISTICS

In the United States, the FAA's Technical Standard Order, TSO-C159, states that "Avionics Supporting Next Generation Satellite Systems (NGSS)" identified and manufactured on or after the effective date (20 September 2004) of the TSO must meet the MOPS specified in RTCA DO-262.

RTCA DO-262 is a normative specification dealing mainly with RF characteristics and performance of AES supporting NGSS. Each NGSS is to provide system-specific performance specification so that RF performance of AES built for that particular satellite system could be tested and verified.

Table A-1 tabulates some of the system-specific performance parameters for the Iridium communication satellite system per RTCA DO-262. Iridium will work with its AES manufacturers in understanding the MOPS and the Iridium-specific system parameters.

Table A-1. Iridium AMS(R)S system parameters per RTCA DO-262

Symbol	Characteristics	System specific value	Paragraph reference
A_{RSV}	System-specific axial ratio for space vehicle. This parameter is used only to compute the gain necessary to overcome losses due to mismatch of the axial ratios.	3.5 dB	DO-262 2.2.3.1.1.2
f_{RMX}	Maximum operating frequency for space vehicle transmissions (AES reception)	1626.5 MHz	DO-262 2.2.3.1.1.4
f_{RMN}	Minimum operating frequency for space vehicle transmissions (AES reception)	1616.0 MHz	DO-262 2.2.3.1.1.4
f_{TMX}	Maximum operating frequency for AES transmissions	1626.5 MHz	DO-262 2.2.3.1.1.4
f_{TMN}	Minimum operating frequency for AES transmissions	1616.0 MHz	DO-262 2.2.3.1.1.4
f_M	Channel modulation rate	50 kbps	DO-262
P	Nominal polarization of AES antenna	RHCP	DO-262 2.2.3.1.1.1.2
P_{NC}	Maximum output power allowed during intervals when no transceiver channel is transmitting	-77 dBW / 100 kHz	DO-262 2.2.3.1.2.1.7
S_D	Minimum data channel carrier level for sensitivity test	-114 dBm	DO-262 2.2.3.1.2.2.1.1
S_{HSNT}	Maximum level of harmonics, spurious and noise allowed within the designated transmit band	-35 dBW / 100 kHz	DO-262 2.2.3.1.2.1.5
S_{HSNR}	Maximum level of harmonics, spurious and noise within the designated receive band	-35 dBW / 100 kHz	DO-262 2.2.3.1.2.1.5

Symbol	Characteristics	System specific value	Paragraph reference
S_{IMT}	Maximum level of 2-tone intermodulation products allowed within the designated transmit band	N/A, no multi-carrier IM expected	DO-262 2.2.3.1.2.1.4
S_{IMR}	Maximum level of 2-tone intermodulation products allowed within the designated receive band	N/A, no multi-carrier IM expected	DO-262 2.2.3.1.2.1.4
S_{UW}	Maximum level of undesired wideband noise from interfering sources external to the NGSS system that can be accepted within the designated receive band, expressed as a power spectral density	-174 dBm/Hz	DO-262 2.2.3.1.2.2.6
S_{UN}	Maximum level of undesired narrowband interference from interfering sources external to the NGSS system that can be accepted within the designated receive band, expressed as an absolute power level.	-128 dBm	DO-262 2.2.3.1.2.2.6
S_V	Minimum voice channel carrier level for sensitivity test	-114 dBm	DO-262 2.2.3.1.2.2.1.2
θ_{SA}	Minimum separation angle between the line of sight to two satellites within the NGSS constellation	N/A ⁽¹⁾	DO-262 2.2.3.1.1.8
A_{RA}	Maximum axial ratio for AES antenna	4 dB at 8 deg. elevation; 3 dB at zenith	DO-262 2.2.3.1.1.2
D/U	Minimum pattern discrimination between two potential satellite positions above the minimum elevation angle, θ_{MIN}	N/A	DO-262 2.2.3.1.1.8
ϕ_{Δ}	Maximum phase discontinuity permitted between beam positions of a steered AES antenna.	N/A	DO-262 2.2.3.1.1.9.1
G_{MAX}	Maximum gain of the aeronautical antenna pattern in the upper hemisphere above the minimum elevation angle, θ_{MIN}	3 dBic	DO-262 2.2.3.1.1.1.3
G_{MIN}	Minimum gain of the aeronautical antenna pattern in the upper hemisphere above minimum elevation angle, θ_{MIN}	-3.5 dBic	DO-262 2.2.3.1.1.1.3
L_{MAX}	Maximum cable loss between AES antenna port and the AES transceiver input port	3 dB	DO-262 2.2.3.1.2.2
L_{MSG}	Maximum length in octets of user data sequence using Data 2 transmissions	TBD	DO-262 2.2.3.6.2
L_{SNDP}	Maximum length in octets of user data contained in a maximum length subnetwork dependent protocol data block	TBD	DO-262 2.2.3.3.1
N_D	Maximum number of simultaneous data carriers	2 ⁽²⁾	DO-262 2.2.3.1.2.1.1
N_V	Maximum number of simultaneous voice carriers	2 ⁽²⁾	DO-262 2.2.3.1.2.1.1
P_D	Maximum single carrier power for each of N_D data carriers in a multi-carrier capable AES	5.5 W	DO-262 2.2.3.1.2.1.1
P_{RNG}	Range over which the AES transmit power must be controlled	+0 to -8 dB relative to P_D , Iridium internal controlled	DO-262 2.2.3.1.2.1.8

Symbol	Characteristics	System specific value	Paragraph reference
P_{SC-SC}	Maximum burst output power of single carrier AES	8.5 dBW	DO-262 2.2.3.1.2.1.2
P_{STEP}	Maximum acceptable step size for controlling AES transmit power	1 dB step, Iridium internal controlled	DO-262 2.2.3.1.2.1.8
P_V	Maximum single carrier power for each of N_V voice carriers in a multi-carrier capable AES	5.5 dBW	DO-262 2.2.3.1.2.1.1
R_{SC-UD}	Minimum average single channel user data rate sustainable at a residual packet error rate of 10^{-6}	2.4 kbps	DO-262 2.2.3.1.2.2.1.1
θ_{MIN}	Minimum elevation angle for satellite coverage	8.2 deg.	DO-262 2.2.3.1.1.1.1
τ_{SW}	Maximum switching time between electronically steered antenna patterns.	N/A	DO-262 2.2.3.1.1.9.2
ρ_{RA}	Minimum exclusion zone radius necessary for protection of Radio Astronomy	N/A	DO-262 2.2.3.1.2.1.6.2
C/M	Carrier-to-multipath discrimination ratio measured at the minimum elevation angle	6 dB	DO-262 2.2.3.1.1.7
V_{SWR}	Maximum Voltage Standing Wave Ratio measured at a single input port of the AES antenna	1.8:1	DO-262 2.2.3.1.1.5

Notes.—

1. Line of sight separation angle depends on latitude and specific location of the terminal.
2. In general, this is left to the AES manufacturer as long as other RF performance parameters are within specifications. Assuming a dual-carrier antenna unit, $N_D + N_V$ shall be less than or equal to two.

**MANUAL ON THE
AERONAUTICAL MOBILE
SATELLITE (ROUTE) SERVICE**

Part III

INMARSAT AND MTSAT CLASSIC AERO

Chapter 1

INTRODUCTION

1.1 OBJECTIVE AND SCOPE

1.1.1 The objective of this part of the manual is to provide detailed technical specifications and guidance material to ICAO Member States and the international civil aviation community on the “Classic Aero” aviation satellite system which provides AMS(R)S communications for the safety and regularity of flight. The Classic Aero aviation satellite system is operated globally by Inmarsat and regionally by the Japanese Civil Aviation Bureau (JCAB). This manual is to be considered in conjunction with the SARPs contained in Annex 10, Volume III, Part I, Chapter 4.

1.1.2 This part of the manual consists of the following sections:

1. Introduction
 2. Classic Aero system overview
 3. Air interface
 4. AES characteristics
 5. GES characteristics
 6. Telecommunication services and their operation
- Appendix. Compliance matrix to Annex 10, Volume III, Part I, Chapter 4 SARPs.

1.2 BACKGROUND

The ICAO ACP has carried forward future air navigation systems planning that designates basic architectural concepts for using satellite communications, initially in oceanic and remote environments and eventually in continental airspace. The progress towards satellite communications for aeronautical safety is realized through the revision of SARPs and guidance material by ICAO for the AMS(R)S and through the interactions of ICAO with other international bodies to assure that resources are coordinated and available.

1.3 HISTORY OF CLASSIC AERO

1.3.1 Inmarsat was the world’s first global mobile satellite operator, created at the beginning of the 1980s to serve the shipping community. In the late 1980s Inmarsat offered the aeronautical community the possibility of using its satellite infrastructure for aeronautical communications. The system design was to allow all aeronautical uses ranging from passenger communications to safety-related ATS communications, and special provisions were included to ensure safety uses had priority over other uses.

1.3.2 The Inmarsat system became the basis of the initial AMSS, and the original AMSS SARPs drew heavily on the Inmarsat System Definition Manual (SDM) for AMSS including provisions for priority and pre-emption capability.

1.3.3 The Inmarsat aeronautical system brought the benefits of reliable, high-quality voice and data communications to aircraft far beyond the effective reach of conventional radio systems. This system has, over time,

become known as the Classic Aero satellite system. The year 2006 saw the completion of interoperability tests and operational integration of the JCAB regional AMSS service within the Inmarsat global system. The JCAB system is known as the Multifunctional Transport Satellite System (MTSAT) because, in addition to Classic Aero, the MTSAT satellites host payloads for meteorological and satellite-based augmentation systems.

1.3.4 The Classic Aero services are used to support ATS data link applications such as ADS/CPDLC utilizing both the industry standard ACARS and the FANS 1/A protocols defined in AEEC 622. The FANS 1/A system is typically fitted to long-haul aircraft and used in remote and oceanic environments. The Classic Aero services are also used to support ATS data link applications such as D-ATIS and OCD defined in AEEC 623. ANSPs access the satellite service via communications service providers who in turn have arrangements with the Inmarsat Land Earth Stations (LES) and Inmarsat for use of the space segment. Note that ACARS and FANS are not standardized by ICAO.

1.3.5 Additionally helicopters operating from Norway servicing the North Sea oil rig platforms utilize AMSS low gain packet data services in a system which utilizes a near complete ATN-compliant communications stack.

1.3.6 The SDM defines the design requirements for the components of the Classic Aero system. All avionics and ground Earth station manufacturers and operators planning to develop equipment for use within the system must adhere to these requirements. The SDM is available from Inmarsat under non-disclosure agreement or licence.

1.3.7 Inmarsat has also evolved higher data rate services, which can operate simultaneously with the Classic Aero system, offered by the fourth generation Inmarsat satellites.

1.4 REFERENCES

1. RTCA document DO-210D, Minimum Operational Performance Standards for Geosynchronous Orbit Aeronautical Mobile Satellite Services (AMSS) Avionics. This document defines requirements for AES that operate with the Inmarsat and MTSAT Classic Aero system and is consistent with the Inmarsat aeronautical SDM.
 2. Inmarsat Aeronautical System Definition Manual. This document is proprietary to Inmarsat but is made available to interested parties (e.g. AES and GES manufacturers, GES operators, and ATSPs) subject to confidentiality or license agreements. It is the definitive document describing the air interface and technical requirements for the AES and GES for the Inmarsat and MTSAT Classic Aero system.
 3. AEEC (Airlines Electronics Engineering Committee) 622. This document defines FANS protocol over ACARS with the Inmarsat and MTSAT Classic Aero system.
 4. AEEC 623. This document defines character-oriented ATS data link application over ACARS with the Inmarsat and MTSAT Classic Aero system.
 5. ICAO-ACP-WG-M-12 Report on Agenda Item 4.
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Chapter 2

CLASSIC AERO SYSTEM OVERVIEW

2.1 GENERAL

2.1.1 The Classic Aero system consists of a space segment of geostationary satellites⁵ that connect 1) to the GES via feeder links and 2) to aircraft via user links, a ground segment of GESs and an airborne segment known as an AES. An illustration of the system is presented in Figure 2-1, and the aeronautical services provided by the system appear in Table 2-1. The system is capable of operating user links in the 1.5/1.6 GHz bands using 1 530 to 1 559 MHz in the forward direction (to aircraft) and 1 626.5 to 1 660.5 MHz in the return direction (from aircraft). The ITU Radio Regulations provide protection to AMS(R)S only in the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz. (Refer to Annex 10, Volume III, Part I, Chapter 4, 4.3.1.1.)

2.1.2 An AES can use satellites and GES from a number of satellite operators through use of a common System Table that defines satellite locations, bulletin board frequencies and log-on frequencies. Hence interoperability has been and can be achieved between a number of operators.

2.1.3 Four aeronautical services are defined which operate using a common family of channel types and protocols and depend on the gain of the aircraft antenna.

2.1.4 The telecommunication services offered include voice, packet data, facsimile and PC data. This section describes the:

- space segment
- aircraft Earth station
- ground segment
- interoperability between satellite operators
- aeronautical services; and
- telecommunication services.

2.2 SPACE SEGMENT

2.2.1 The space segment consists of geostationary satellites with maximum inclination of within 3 degrees.

Classic Aero “7+1” constellation

2.2.2 Prior to 2009 Inmarsat delivered Classic Aero services via a constellation of four satellites. These included three I-3 satellites and one I-4 satellite. On completion of interoperability tests and operational integration of the JCAB regional AMSS service within the Inmarsat global system, an additional “MTSAT” satellite was added to the global Classic Aero constellation in July 2006, making a total of five satellites.

5. The satellites are slightly inclined (typically a few degrees) due to gravitational and other effects.

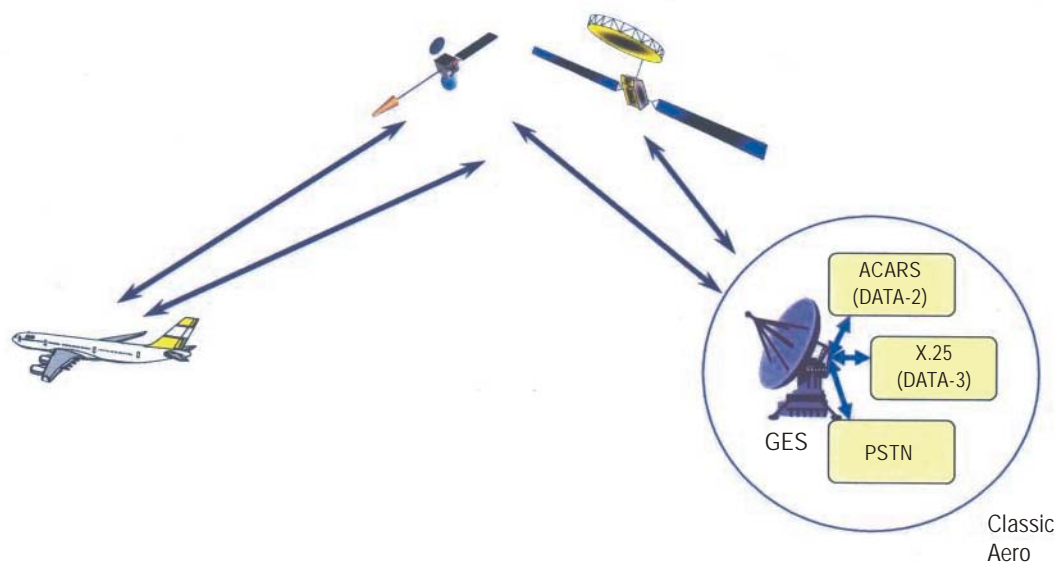


Figure 2-1. Key elements of the Classic Aero AMS(R)S

Table 2-1. Classic Aero services

Service	Antenna Type	Global Beam Operation	Spot Beam Operation	Data ⁶ Channel Rates	Circuit ² Switched Channel Rates
Aero-L	Low Gain (nominally 0dBic)	Y	N	600, 1 200	
Aero-I	Intermediate Gain (nominally 6dBic)	N ⁷	Y	600, 1 200	8 400
Aero-H	High Gain (nominally 12dBic)	Y	Y	600, 1 200, 10 500	21 000
Aero-H+	High Gain (nominally 0dBic)	Y	Y	600, 1 200, 10 500	8 400, 21 000

2.2.3 After the successful deployment of its second and third I-4 satellites, in mid-2009 Inmarsat made Classic Aero services available across all three of its I-4 satellites and over four I-3 satellites making a total of seven Inmarsat satellites and one MTSAT satellite for provision of Classic Aero services globally.

6. These are the channel rates of the air interface.

7. Operation of Aero-I in the global beam for distress and urgency voice calls is possible having implemented a specific Inmarsat SDM change notice.

Inmarsat satellites

2.2.4 Illustrations of Inmarsat satellites appear in Figure 2-2. Inmarsat satellites include:

- Four I-2 satellites launched between 1990 and 1992. As of 1 January 2007, one of these satellites had been decommissioned having come to the end of its useful life. Although capable of AMS(R)S global beam operations, these satellites are used for lease services and offer back-up to the I-3s in contingency operations.
- Five I-3 satellites launched between 1996 and 1998.
- Three I-4 satellites launched between 2005 and 2008.

2.2.5 All Inmarsat satellites support a global beam. The I-3 satellites support five spot beams, while the I-4 satellites support 19 spot beams.

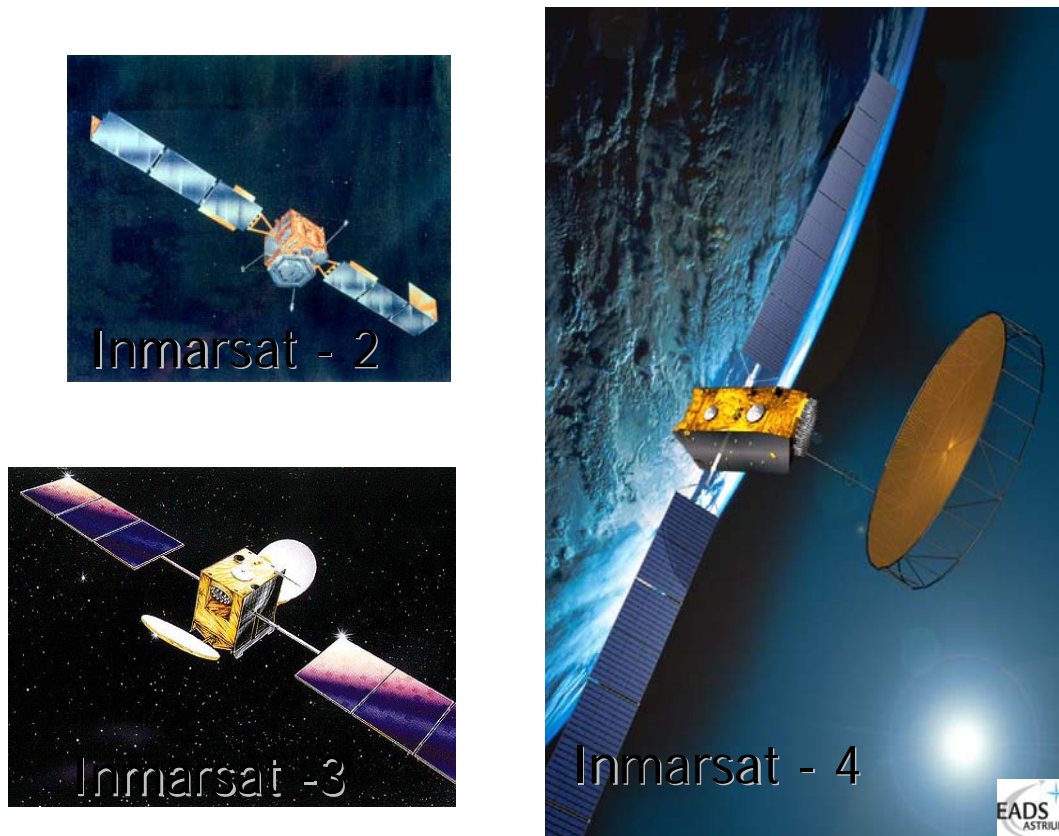


Figure 2-2. Inmarsat satellites

2.2.6 The orbital slots and satellites of the seven Inmarsat satellites constellation, after the introduction of the three I-4 satellites in mid-2009, are shown in Table 2-2.

Table 2-2. Inmarsat orbit slots (from Spring 2009)

<i>Region</i>	<i>Longitude</i>	<i>Generation and satellite number</i>
IOR	64.5E	3F1
AOR-E	15.5W	3F2
POR	178E	3F3
AOR-W	54W	3F4
AsiaPac	143.5E	I-4F1
EMEA	25E	I-4F2
Americas	98W	I-4F3

The combined coverage of the satellites is shown in Figure 2-3.

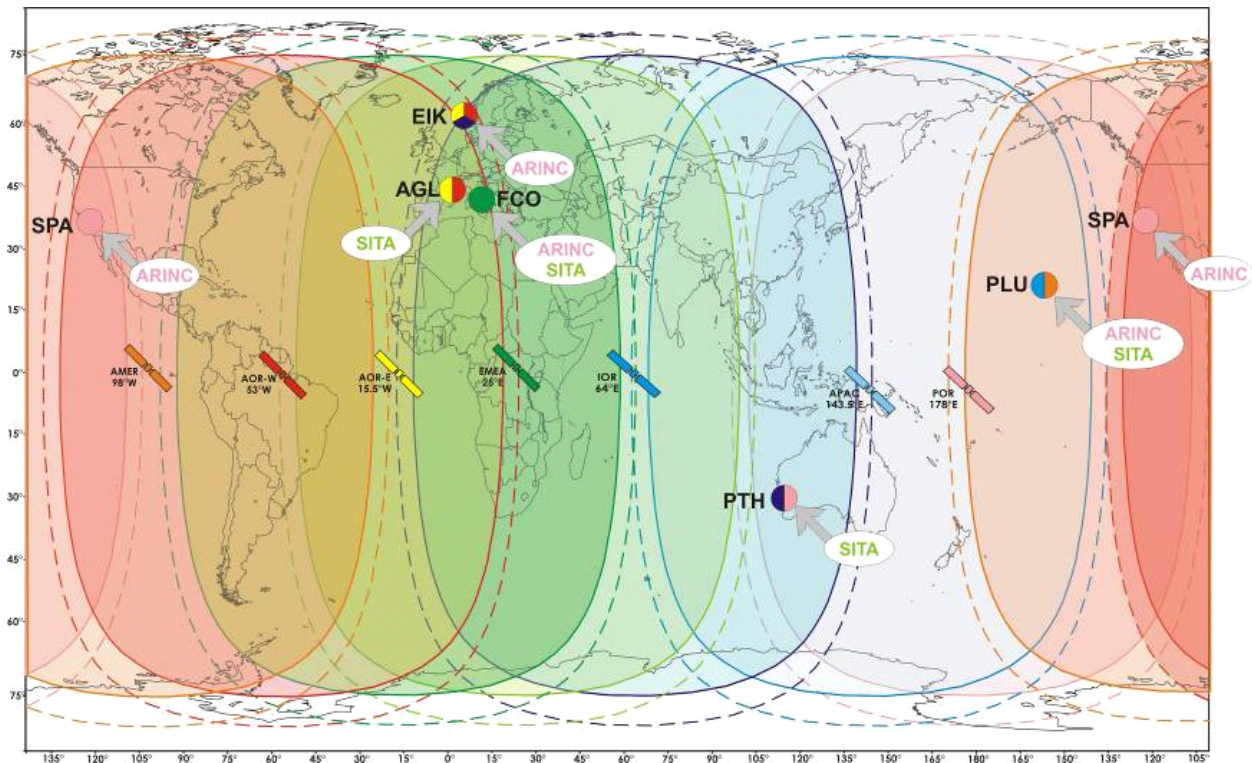


Figure 2-3. Inmarsat global and spot beam (shaded areas) coverage for Classic Aero post mid 2009

Changes to the Inmarsat Classic Aero constellation

2.2.7 Inmarsat repositioned its I-4 satellites in order to optimize its network during January and February 2009. The repositioning process was completed by late February 2009. The positions of the I-4F1 and I-4F2 satellites prior to repositioning were 53W (I-4 F2) and 64E (I-4 F1). After repositioning, the respective positions of each I-4 satellite are, 98W (I-4 Americas), 25E (I-4 EMEA) and 143.5E (I-4 Asia-Pacific).

2.2.8 Prior to 2009 in the Atlantic Ocean Region-West (AOR-W), all aeronautical services were delivered via the I-4 F2 satellite. After the successful in-orbit testing and positioning of the I-4F3 satellite, classic services traffic in AOR-W was transferred back to an I-3 satellite (I-3F4) in January 2009.

2.2.9 After the repositioning of the I-4 satellites was complete, Aero H+ (voice and data) Aero H and I (data) were made available over the repositioned I-4 constellation. The provision of these services over the combined I-4 and I-3 constellations resulted in the creation of seven Inmarsat satellite regions providing Aero safety services around the world.

To reflect the geographic locations covered by the satellites, Inmarsat refers to its three I-4 satellite regions as:

- I-4 Americas
- I-4 EMEA (Europe, Middle East, Africa)
- I-4 Asia-Pacific

Note.— From January 2009, spot beam coverage from the I-3 in AOR-W was extended as far South as possible to provide Aero_I service improvement.

MTSAT satellites

2.2.10 MTSAT-1R launched in 2005 and MTSAT-2 in 2006. JCAB initially began to provide MTSAT Classic Aero service with one satellite in July 2006 and then commenced the service with a two-satellite constellation in July 2007. Although the two satellites are located at 140E and 145E, the JCAB operates them as one satellite by broadcasting a system table announcing that one MTSAT satellite is located at 142.5E. Samples of MTSAT satellites are illustrated in Figure 2-4.

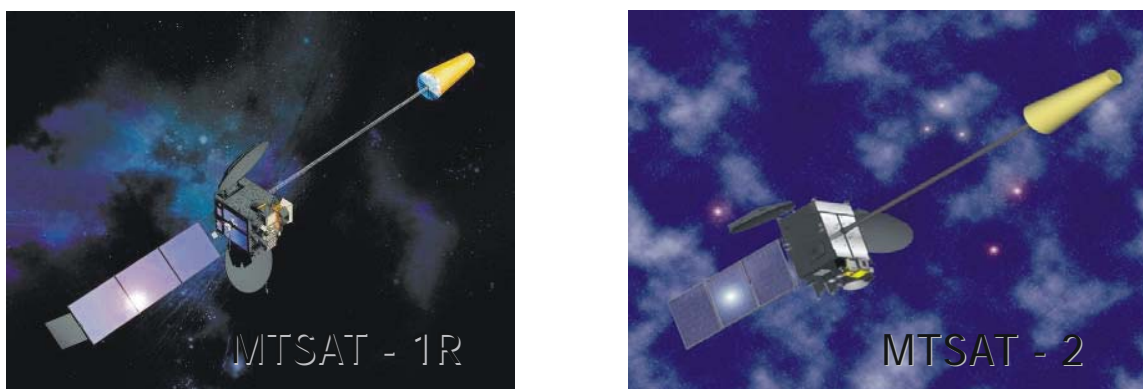


Figure 2-4. MTSAT satellites

2.2.11 Since the MTSAT AMS(R)S system has adopted the hot stand-by architecture, two-satellite and four-GES, which is based on no interruption switching concept, the system features a dynamic frequency management method between MTSAT-1R and MTSAT-2, flexible system/network architecture, and a redundant structure to build a robust and highly reliable system.

2.2.12 The MTSAT satellites support both global and spot beams MTSAT coverage as shown in Figures 2-5 and 2-6.

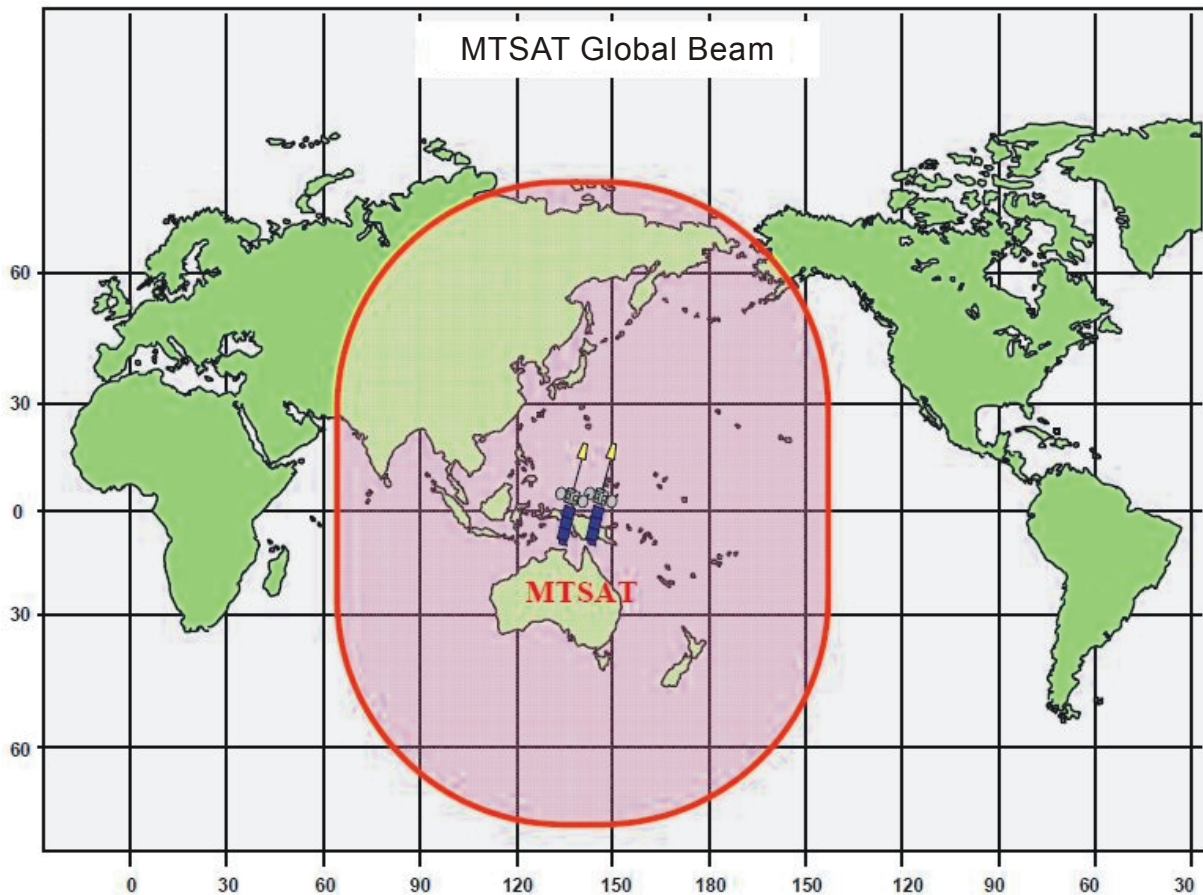


Figure 2-5. MTSAT satellite global beam coverage

2.3 AIRCRAFT EARTH STATION

2.3.1 The AES consists of two major components being the antenna subsystem and the avionics. The antenna subsystem consists of the antenna radiating elements, the antenna pointing mechanism (either mechanical or phased array of high gain antenna), and the Diplexer/low noise amplifier. The avionic subsystem consists of the high-power amplifier, RF circuitry, modems and protocol stack. The avionics interfaces to other aircraft systems to deliver the communications service.

2.3.2 The antenna and avionics in terms of form, fit, wiring and functionality comply with AEEC 741, AEEC 761 and AEEC 781. Other form factors may be used.

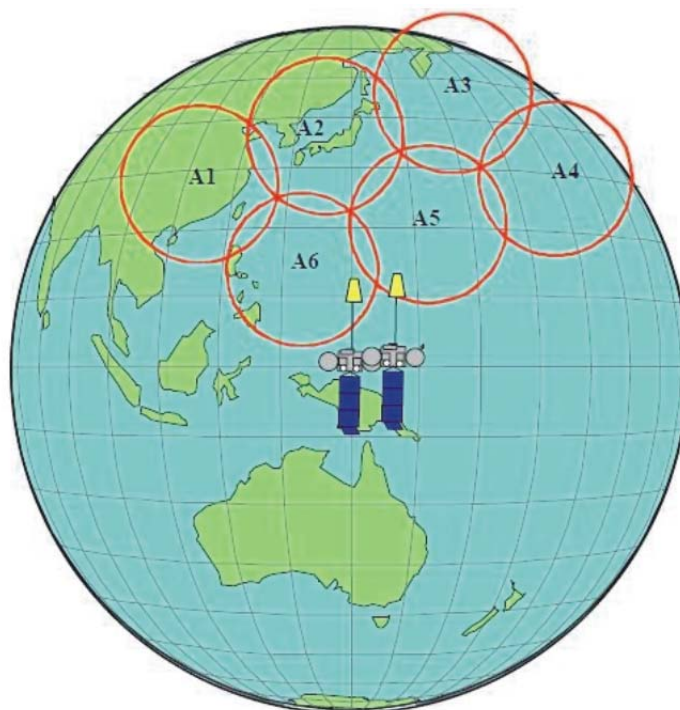


Figure 2-6. MTSAT satellite spot beam coverage

2.4 GROUND SEGMENT

2.4.1 The ground segment consists of a network of ground Earth stations. These interface to the satellites by feeder links (C band (6/4 GHz) for Inmarsat; Ku band (14/12 GHz) and Ka band (30/20 GHz) for MTSAT) and to terrestrial circuit switched and packet switched networks. The GESs control the system in terms of broadcasting a bulletin board and allocating channels.

2.4.2 For provision of CNS/ATM for data, the GESs are connected to communication service providers (e.g. Arinc or SITA) networks and thence to ATSP equipment.

2.4.3 MTSAT GESs have direct connections to the CNS/ATM system in JCAB's Air Traffic Management Centre (ATMC) to provide air traffic controllers and pilots with direct and secure data and voice ATS communications. JCAB also offers voice and data service from/to other end users than ATMC through the SITA network.

2.5 CLASSIC AERO INTEROPERABILITY

2.5.1 Interoperability of the Classic Aero system consists of:

- technical interoperability; and
- appropriate management controls.

Technical interoperability

2.5.2 Technical interoperability allows any Classic Aero AES to operate with either MTSAT or Inmarsat satellites and ground infrastructure and to switch seamlessly between the two systems during a flight. A common signal in space specification is used, and a common system table is broadcast by both Inmarsat and MTSAT satellites. The system table includes both Inmarsat and MTSAT satellite identities, satellite location and Psid. It is maintained in all GESs and AESs. The table contains the information necessary for an AES to establish initial communication with a GES and carry out the log-on procedure.

Management controls

2.5.3 Management controls are designed to ensure that the Inmarsat and MTSAT AMS(R)S systems have common functionality, operate in synergy and have compatible forward development plans.

2.5.4 Any other operators wishing to offer Classic Aero service on an interoperable basis will need to implement such management controls with existing operators.

2.6 AERONAUTICAL SERVICES

The aeronautical services are shown in Table 2-1.

2.7 TELECOMMUNICATION SERVICES

The following telecommunication services are provided depending on GES and AES implementation:

Circuit switched

- Voice coded at 9 600 and 4 800 bps.
- Fax coded at 2 400 and 4 800 bps.
- PC data coded at 2 400 bps.

Packet switched

- Data 2 service (compatible with ACARS/FANS).
 - Data 3 service (compatible with ATN/OSI).
-

Chapter 3

TECHNICAL CHARACTERISTICS

3.1 FREQUENCY

The system is capable of operating in the L-band using 1 525 to 1 559 MHz in the forward direction (to aircraft) and 1 626.5 to 1 660.5 MHz in the return direction (from aircraft). The actual frequency bands used depend on spectrum allocations from the ITU and other entities. AMS(R)S usage is accommodated, and has priority over other services, in the bands 1 545–1 555 and 1 646.5–1 656.5 MHz.

3.2 POLARIZATION

Right-hand circular polarization is used as defined in ITU-R Recommendation 573.

3.3 CHANNEL TYPES

The channels used for communications services and signalling between AESs and GESs are as follows:

P-channel: Packet mode time division multiplex (TDM) channel, used in the forward direction (ground-to-air) to carry signalling and user data. The transmission is continuous from each GES in the satellite network. A P-channel being used for system management functions is designated Psmc, while a P-channel being used for other functions is designated Pd. The functional designations Psmc and Pd do not necessarily apply to separate physical channels.

R-channel: Random access (slotted Aloha) channel, used in the return direction (aircraft-to-ground) to carry some signalling and user data, specifically the initial signals of a transaction, typically request signals. An R-channel being used for system management functions is designated Rsmc, while an R-channel being used for other functions is designated Rd. The functional designations Rsmc and Rd do not necessarily apply to separate physical channels.

T-channel: Reservation Time Division Multiple Access (TDMA) channel, used in the return direction only. The receiving GES reserves time slots for transmissions requested by AESs, according to message length. The sending AES transmits the messages in the reserved time slots according to priority.

C-channel: Circuit-mode single channel per carrier (SCPC) voice channel, used in both forward and return directions. The use of the channel is controlled by assignment and release signalling at the start and end of each call.

3.4 CHANNEL CHARACTERISTICS

General

3.4.1 The Classic Aero system uses digital modulation on all channels in order to utilize satellite power and bandwidth efficiently, with FEC to improve performance. Individual channel configurations are described in this section.

3.4.2 The basic transmission characteristics of the channels are given in Table 3-1, which shows the modulation method and the channel spacing achievable for a wide range of bit rates. The bit rates were selected to facilitate their implementation with a single programmable channel unit and to provide future flexibility. Raise root cosine filtering is used on all channels to maximize spectral efficiency and the rolloff factor (α) is shown below.

Table 3-1. Channel transmission characteristics

Reference: RTCA DO210D 2.2.4.2.1 Channel rates and tolerances in relation to channel spacing

Channel rate (bit/s)	Channel Type	Channel spacing ⁽¹⁾ (kHz)	Modulation	Modulation symbol duration (ms)	Raise Root Cosine Filter Rolloff (α)
21 000	C	17.5	A-QPSK ⁽²⁾	95.24	1.0
10 500	P, R, T	10/7.5	A-QPSK	190.48	1.0
8 400	C	5.0	A-QPSK	238.09	0.6
1 200	P, R, T	5.0/2.5 ⁽³⁾	A-BPSK ⁽⁴⁾	833.33	0.4
600	P, R, T	5.0/2.5	A-BPSK	1666.67	0.4

Notes.—

1. These channel spacings are for reference only. Operational spacings may differ.
2. A-QPSK is aviation quadrature-phase shift keying, a form of Offset QPSK.
3. 5.0 applies to P-channel, 2.5 to R- and T-channels.
4. A-BPSK (aviation binary-phase shift keying) is a form of differentially encoded BPSK in which alternate modulation symbols are transmitted in notional in-phase and quadrature channels.

P-channel configuration

3.4.3 The P-channel bit rates and other characteristics are listed in Tables 3-1 and 3-2.

Table 3-2. P-channel frame parameters

Reference: DO-210D 2.2.4.1.11 P-channel configuration and receiver requirements,
 Reference Document A (Inmarsat SDM Module 1 version 1.42) section 3.1, 3.3.1, and 3.4

			Bits in frame					
			After coding				Before coding	
FEC rate	Channel rate (bit/s)	Frame duration (ms)	Channel	Overhead bits	Info bits	Interleaver	Total	Signal units (n)
0.50	10 500	500	5 250	258	4 992	4,992	2 496	26
0.50	1 200	1 000	1 200	48	1 152	576	576	6
0.50	600	2 000	1 200	48	1 152	384	576	6

R-channel configuration

3.4.4 The R-channel bit rates and other characteristics are listed in Tables 3-1 and 3-3.

Table 3-3. R-channel frame parameters

Reference: RTCA DO-210D 2.2.4.2.17 R-and T-channel configuration and transmitter requirements,
 Reference Document A (Inmarsat SDM Module 1 version 1.42) section 3.1, 3.3.2,3.4 and Appendix 6,
 Reference Document B (Inmarsat SDM Module 2 version 1.16) section 4.2.3

Channel rate (bit/s)	FEC rate	Number of bits			Signal units	Duration (ms)		
		Overhead	Info	Total		Burst	Slot	Guard
10 500	0.5	584	304	888	1	84.6	125	40.4
4 800	0.5	305	304	609	1	126.9	167	40.1
1 200	0.5	248	304	552	1	460.0	500	40.0
600	0.5	272	304	576	1	960.0	1 000	40.0

T-channel configuration

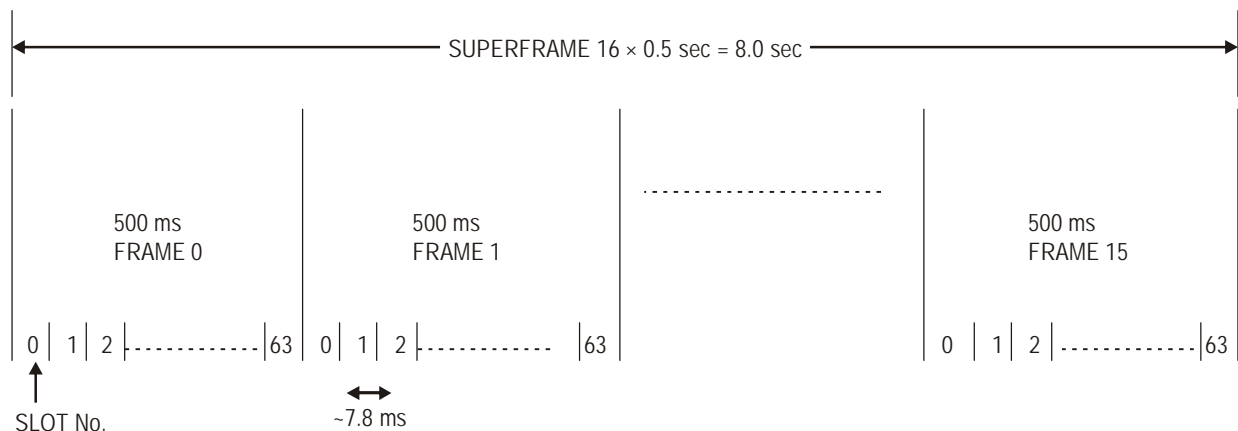
3.4.5 The T-channel bit rates and other characteristics are listed in Tables 3-1 and 3-4.

Table 3-4. T-channel frame parameters

Reference: RTCA DO-210D 2.2.4.2.17 R-and T-channel configuration and transmitter requirements, Reference Document A (Inmarsat SDM Module 1 version 1.42) section 3.1, 3.3.2,3.4 and Appendix 6, Reference Document B (Inmarsat SDM Module 2 version 1.16) section 4.2.3

Channel rate (bits/s)	FEC rate						Signal units	Burst duration (ms)
		Preamble	UW	Info	Flush	Total		
10 500	0.5	504	64	6 048	32	6 648	31	633.6
1 200	0.5	200	32	3 360	32	3 624	17	3 020.0
600	0.5	224	32	3 552	32	3 840	18	6 400.0

3.4.6 A T-Ch superframe has a duration of 8 s and is synchronized to the P-Ch frame and consists of 16 frames each having a duration of 0.5 s as shown in Figure 3-1. Each frame is divided into 64 slots each having a duration of approximately 7.8 ms. When an AES is issued a T-Ch assignment by a GES, the AES is given a frequency (channel number), a frame number and a slot number for the start of the T-Ch burst.

**Figure 3-1. T-Channel frame structure**

C-channel configuration

3.4.7 The C-channel bit rates and other characteristics are listed in Tables 3-1 and 3-5.

3.4.8 The Classic Aero system supports two different C-channel formats. The higher-rate (21 000 bit/s) format has been offered since the inception of the system. The lower-rate (8 400 bit/s) format entered service with the introduction of intermediate-gain AES equipment in 1998.

Table 3-5. C-channel frame parameters

Reference: RTCA DO-210D 2.2.4.1.12 C-channel configuration and receiver requirements, Reference Document A (Inmarsat SDM Module 1 version 1.42) section 3.1, 3.2 and 3.4.

FEC rate	Channel rate (bit/s)	Frame duration (ms)	Primary Rate (bit/s)
0.50	21 000	500	9 600
0.67	8 400	500	4 800

3.4.9 The C-channel is divided into the primary field and the sub-band data field. The former carries voice-codec data, the latter is used for channel management, carrying power-control or call-progress information. The primary field can also carry fax and PC modem data. The standard bit error rate (BER) for the C-channel is 1×10^{-3} . An enhanced GES circuit-mode data service supports BERs of 1×10^{-5} .

3.4.10 All C-channels use aviation quadrature-phase shift-keying (A-QPSK) modulation. Frame duration at all bit rates is 500 ms. Carrier activation (burst mode) is used in the forward (ground-to-air) channel to conserve spacecraft power by taking advantage of the short pauses that occur in normal speech. At each activation, a preamble and a unique word are transmitted to start the burst, and thereafter further unique words occur every 500 ms. The unique words help the demodulator to achieve and maintain C-channel frame synchronization.

3.4.11 In the return direction, the carrier is transmitted continuously during the call. The start of the transmission is the same as for the forward direction, with a preamble and unique word transmitted at the beginning, followed by further unique words at 500 ms intervals.

3.5 RF CHARACTERISTICS

3.5.1 In order to comply with provisions 4.3.1.1 and 4.3.2.2 of the AMS(R)S SARPs (Refer to: Annex 10, Volume III, Part I, Chapter 4), systems which provide Classic Aero service should only use the frequency band 1 646.5–1 656.5 MHz.

3.5.2 The requirements for spurious, noise, phase noise, intermodulation products, frequency stability, EIRP levels and transmit spectrum to which the system complies are in the RTCA DO-210D MOPS.

3.6 LINK LAYER CHARACTERISTICS

General

3.6.1 The Classic Aero system processes user communications — voice, fax or packet-mode data — through three system specific layers on their way from point of origin to destination. The layers are designated:

- Physical
- Link
- Network.

3.6.2 Each layer performs its distinct functions transparently to the adjoining layer(s). The user, which can be either a person making a phone call or a computer transmitting data, interfaces with the Classic Aero system at the network layer.

Physical layer

3.6.3 The physical layer carries the data making up the communication from the AES to the GES via the satellite (and vice versa). It consists of the AES and GES hardware, the software that performs the channel-unit function in the GES and AES, and the satellite. The transmit channel units receive data from the link layer. Then they scramble the data to facilitate subsequent error correction, encode it for forward error correction, interleave and modulate it, and send it to be upconverted in frequency for transmission to the satellite via the high-power amplifier and antenna of the AES. The reverse takes place at the receive channel units. The structure of the physical layer is illustrated in Figure 3-2.

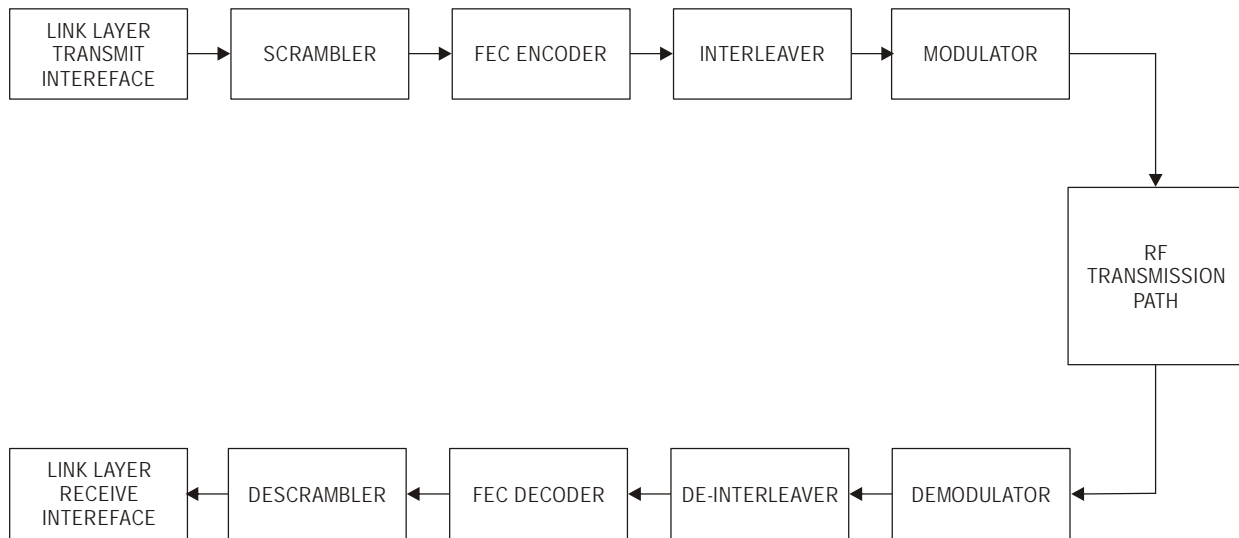


Figure 3-2. Physical layer functional blocks

Link layer

3.6.4 The link layer is responsible for interfacing the link-service users — a telephone caller, for example, or a computer sending data — with the channel units (or the physical layer) and exists at the AES and GES. The link layer divides the data passed to it from the link service user into smaller packets to be passed on to the physical layer for transmission. When receiving, the link layer reassembles the data it gets from the physical layer. It also adds and removes the information needed to ensure that the data packets are correctly sent and received error-free and at the appropriate priority level, and retransmits any data lost over the satellite link.

Network layer

3.6.5 The network layer is the interface between the user networks and the satellite system. User networks supported are X.25⁸ and ACARS for data, and standard terrestrial PSTNs for voice. The network layer formats, manages and passes data to and from the link layer, ensuring that they pass transparently to and from the user networks.

3.6.6 The network layer transmits satellite sub-network protocol data units (SSNPDU) to the user networks and receives them in return. It passes the SSNPDU to and from the link layer in the form of link interface data units (LIDU). These data units are broken down into fixed units — called signal units (SU) — to fit into the specific structure of the satellite link channels. LIDUs comprise “real” data (link service data units) and control information (link interface control units).

Signal units

3.6.7 Signaling and user data messages on the P- and T-channels and the sub-band of the C-channel are formatted into SUs with a standard length of 96 bits (12 octets). This size allows for the most common transactions to be carried out within a single SU, with a minimum of spare capacity left unused. More complex messages (including user data) can be carried by a sequence of several SUs, up to a maximum of 64. Longer messages generated in a user application are broken into fragments in the network layer before being presented for transmission via the link layer.

3.6.8 R-channel signaling and user data messages are formatted into SUs with a length of 152 bits (19 octets).

3.6.9 The format of an individual SU is dictated by the function it is performing: functions include circuit-mode access requests, log-on requests, and user packet-data forwarding. A typical SU is shown in Figure 3-3.

Basic signal unit concepts

3.6.10 A message that can be accommodated in a single SU is formatted into a lone signal unit (LSU). Longer messages are formatted into more than one SU. The first of these is an initial signal unit (ISU), and it is followed by one or more subsequent signal units (SSUs).

3.6.11 Each SU includes 16 check bits (the last two octets) for error detection. The check bits are calculated from the first ten octets of a standard-length SU or from the first 17 octets of an extended-length (R-channel) SU. The check bits are calculated on reception of the SU. If there is a mismatch the SU is discarded.

3.6.12 The ISU and SSUs comprising a message are ordered by the sequence number in the standard-length signal unit and by the sequence indicator in the extended-length signal unit.

3.6.13 To allow high-priority messages to pre-empt those of lower priority, each message is given a Q number to indicate its precedence in the range 0 (low) to 15 (high). Most SUs incorporate a four-bit Q-number field.

3.6.14 The link reference number logically associates all SUs belonging to a particular multi-unit message. The Q number and link reference number are assigned by the link layer.

8. For some GESs this is implemented via XOT (X25 over TCP/IP).

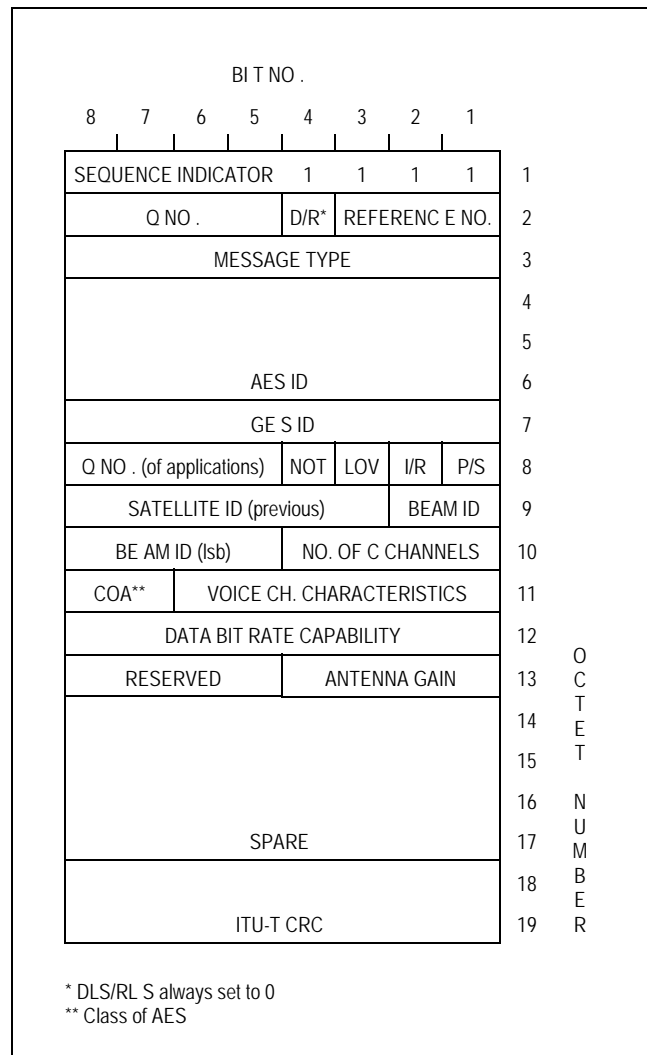


Figure 3-3. Typical signal unit format

3.6.15 The telephony and log control functions are regarded as signalling applications by the link-layer logic. They may operate at separate user-defined priority levels (i.e., with their own Q numbers) and perform their own allocations of link reference numbers.

Link layer services

3.6.16 The system provides for two types of service at the link layer:

- The simpler is the direct link service, in which the data are transmitted directly on the appropriate channel and delivered without any request for retransmission of lost SUs. The direct link service is generally used for ground-to-air broadcasts and for signalling. In the latter case, any lost SUs are handled within the signalling logic procedures.

- Reliable link service, in which any SUs lost in transmission are repeated until they have been received error free.

3.6.17 Direct link service via the P- and R-channels is mandatory for all AESs and GESS. Reliable link service is mandatory only for packet-mode data services.

Link layer functional description

3.6.18 The link layer comprises:

- a channel interface sub-layer, which passes SUs to and from the channel units;
- a priority and routing sub-layer, which transmits SUs in priority order and re-associates SUs correctly on receipt;
- a link service data unit (LSDU) segmentation and reassembly sub-layer, which converts among lone SUs, sets of SUs and LSDUs;
- when packet-mode data service is supported, a reliability sub-layer to assure correct reception of SU sets transmitted under reliable link service.

3.6.19 In addition, there are transmission resource management and channel unit control functions.

3.6.20 The structure of the link layer functional blocks for the data channels (P, R and T) is shown in Figure 3-4.

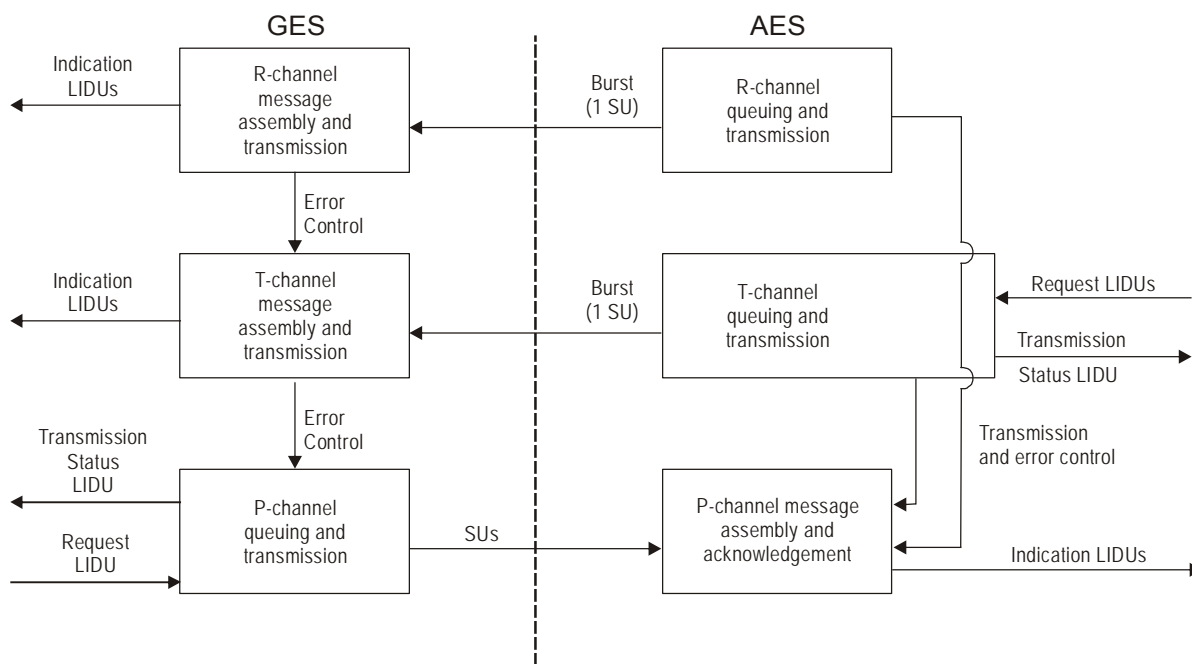


Figure 3-4. P-, R- and T-channel data transmission functions

3.6.21 The link-layer functional blocks for the sub-band of the C-channel are shown in Figure 3-5.

3.6.22 The basic routing paths within the link layer are illustrated in Figure 3-6. The functions required by the priority and routing sub-layer are defined by the transmit and message assembler processes. The functions required by the reliability sub-layer are defined by the queuing unit and acknowledge processes.

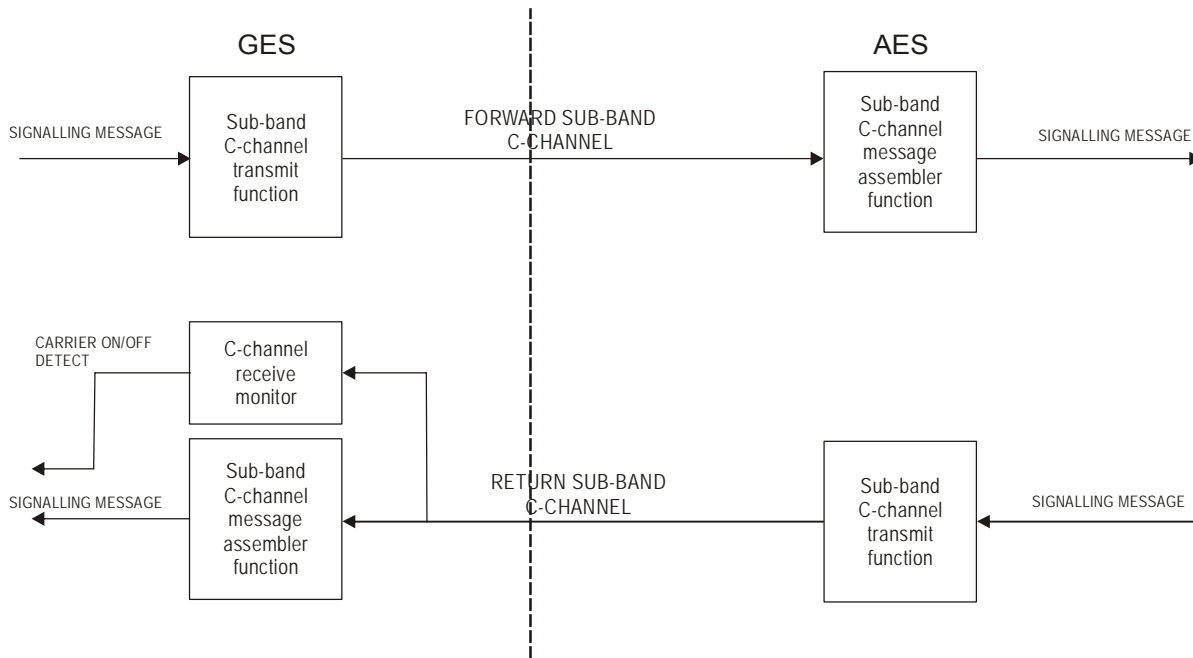


Figure 3-5. C-channel sub-band transmission functions

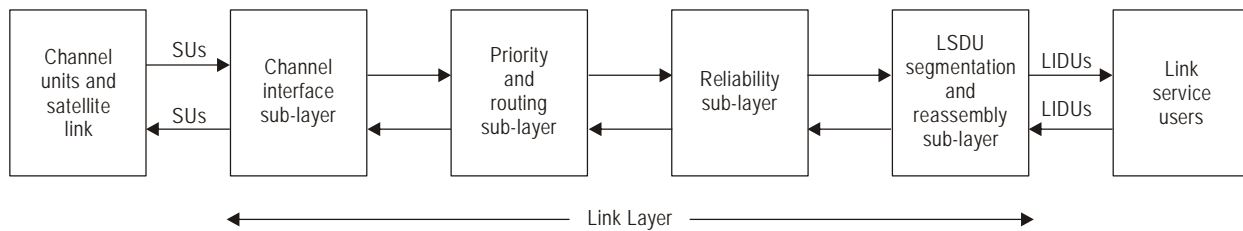


Figure 3-6. Link-layer basic routing paths

Transmission sequence

3.6.23 Each channel has a similar sequence of processes. LSDUs for transmission are converted to a set of SUs consisting of either one LSU or a set of one ISU and one or more SSUs. The processing includes addition of link protocol control information and assignment of a link reference number. The transmission sequence begins with acceptance of an LSDU into the queuing unit.

3.6.24 Each SU set (ISU plus one or more SSUs) from the queuing unit is passed to the transmit process in a standard form and as a single entity. The SU sets are queued according to their Q numbers. The SU sets are then transmitted one by one in the order dictated by their Q numbers. In all channels, transmission of an SU set may be interrupted to make way for a set with higher precedence. In the P-channel, if no traffic SU is ready when the channel becomes available, an AES system table broadcast SU or a fill-in SU is sent. In the R-channel each SU is formatted into its own burst.

3.6.25 At the receiving end the incoming SUs enter the message assembler, where they are assembled into complete SU sets (with possible missing SUs) before passing to the acknowledge process.

3.6.26 If reliable link service is in use, the acknowledge process requests and inserts any missing SUs.

3.6.27 If the direct link service is to be used, the LSDU is formatted into an SU set and transmitted. Each SU set is passed to its destination without any patching of missing data: any reliability checks required must be done at network or a higher level.

R-channel retransmission randomization

3.6.28 To support reliable link service on the R-channel, the link layer provides repeat-attempt control, needed because of the potential for collision among messages. If the first transmission attempt times out, an R-channel is selected at random and a repeat transmission attempted automatically. The time slot for the repeat burst is chosen at random by the AES. Repeat bursts are transmitted up to a maximum of four times, after which the attempt is deemed to have failed. The error is then reported to the higher layer by an LSDU.

3.6.29 At AES turn-on, or after receiving a new set of R-channel frequencies at log-on, the frequency to be used for the first R-channel burst is chosen at random. In the event of a successful transmission, the same frequency is used for the next. If a first transmission attempt times out, however, another frequency is selected at random for the re-attempt.

Link reference number

3.6.30 In converting an LSDU into a set of SUs, the link layer either assigns a link reference number to the SU set or, for circuit-mode services, uses the application reference number assigned by the higher layer to perform the same task. Separate allocations are made for LSDUs sent via the R-, T- and P-channels.

3.6.31 The link reference number and the Q number assigned at the same time are used to reassemble messages at the receiving end and to guard against confusion in subsequent acknowledgements, retransmissions and requests for acknowledgement.

3.6.32 Series of link reference numbers for each type of channel are maintained in the AES for air-to-ground transfers. In the GES, link reference numbers are assigned to each channel for ground-to-air transfers. There is no correspondence between the two sets of numbers.

3.6.33 If there is temporarily no link reference number available for allocation, the LSDU is buffered until a number has been released.

3.6.34 On the P- and R-channels a link reference number is released as soon as

- the LSDU is passed for transmission (direct link service); or
- the receipt of the LSDU has been acknowledged as correct (reliable link service).

3.6.35 On the T-channel, an application reference number is released when both the transmission and the reservation protocols for the LSDU have been satisfied.

Link interface data unit

3.6.36 The LIDU is the total information unit transferred across the interface between a link service user and the link layer in a single interaction. Each LIDU contains link interface control information (LICI) and may also contain an LSDU.

3.6.37 The LICI provides the interaction between the link layer and a link service user (which includes the satellite subnetwork layer for packet-mode services, the AES/GES management functions and the circuit-mode services).

3.6.38 The LSDU is the part of the LIDU whose identity is preserved when two link service users communicate.

3.6.39 The LIDU may comprise:

- LSDUs (accompanied by any necessary housekeeping information such as length and destination) or LSDU identity;
 - Q number;
 - link service requirement (RLS or DLS; transmit only);
 - transmission quality achieved (error/no error; receive only);
 - reference number assigned by the link service user (when applicable);
 - AES or GES ID;
 - transmission acknowledgement (fail/success/DLS transmitted);
 - flow-control parameter (as required).
-

Chapter 4

AES CHARACTERISTICS

4.1 INTRODUCTION

4.1.1 An AES has two primary tasks: to secure access to the Classic Aero system by logging on to a GES, and then to support a range of communications services between the air and the ground.

4.1.2 RTCA document DO-210D [1], Minimum Operational Performance Standards for Geosynchronous Orbit Aeronautical Mobile Satellite Services (AMSS) Avionics, defines requirements for AES that operate with the Inmarsat and MTSAT Classic Aero system.

4.1.3 This chapter provides an overview of the AES characteristics and requirements.

4.2 AES ARCHITECTURE

4.2.1 The architecture of an AES is not prescribed in this document. However the text below describes a typical AES architecture as defined in Arinc 741. All AES will require the functions described.

4.2.2 An AES is made up of a number of sub-units. A basic system comprises an SDU, a radiofrequency unit (RFU), a high-power amplifier (HPA), a low-noise amplifier combined with a diplexer (LNA/diplexer), and an airframe-mounted antenna subsystem.

4.2.3 The SDU is the “brain” of the AES. It contains the interface electronics for all the other equipment aboard the aircraft that makes use of the satellite link, as well as the network, link-layer, channel coding and modulation functions.

4.2.4 The RFU upconverts the frequencies from the SDU, and the HPA amplifies the signal before passing it through the antenna to the satellite.

4.2.5 On the forward link, signals from the GES are received by the AES through the antenna. These very-low-power signals are amplified in the LNA/diplexer.

4.2.6 The diplexer ensures that the high-power transmitted signals do not interfere with the low-power received signals.

4.2.7 The RFU receives the signals after amplification by the LNA/diplexer and downconverts them in frequency for processing in the SDU.

4.2.8 The relationship between the AES sub-units is shown in Figure 4-1.

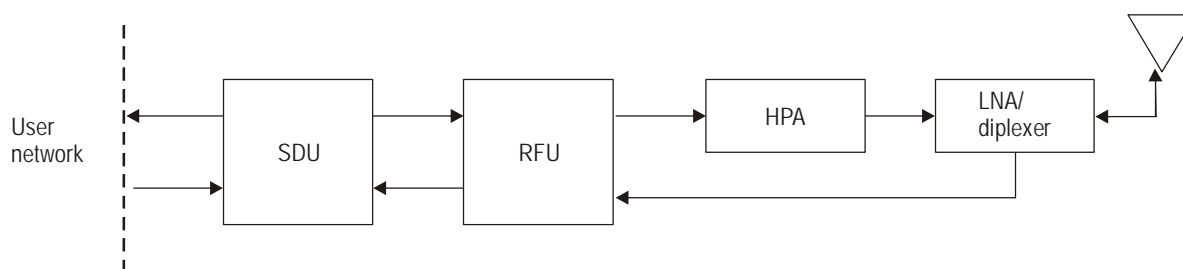


Figure 4-1. AES Components (Arinc 741)

4.2.9 Antenna subsystems are classified as low, intermediate or high-gain. Each antenna subsystem design must meet a range of performance requirements, depending on its classification. The requirements — including gain-to-noise-temperature ratio (G/T), equivalent isotropically radiated power (EIRP) and axial ratio — must be met simultaneously over defined minimum fractions of the hemisphere of sky around and above the aircraft. These are defined in RTCA document DO-210D.

4.3 AES CLASSES

4.3.1 AESs are classified according to their equipment configuration and capabilities, as follows:

- Class 1: Low gain antenna only, packet-mode data services only;
- Class 2: High gain or intermediate gain antenna, circuit-mode services only;
- Class 3: High gain or intermediate gain antenna, circuit-mode and packet-mode data services;
- Class 4: High gain or intermediate gain antenna, packet-mode data services only.

The vast majority of installed AESs are Class 3.

4.3.2 The nominal gain values for the three AES antenna types referenced above are:

- Low gain: 0 dBi;
- Intermediate gain: 6 dBi;
- High gain: 12 dBi.

4.4 AES FUNCTIONS

4.4.1 AESs are designed to interwork through the Classic Aero space segment and GESs, correctly and without endangering the integrity of the satellite network. An AES performs two principal functions: access control and communications.

Access control

4.4.2 To carry out its access control tasks an AES must be able to:

- continuously receive a P-channel (Psmc-channel before log-on, Pd-channel after log-on). Class 2 installations need not receive a P-channel while engaged in a voice call;

- automatically recognize and respond to applicable messages and commands contained in the received P-channel, and to sub-band messages and commands in a received C-channel;
- request spot-beam service if it is available when logging on to a GES;
- follow handover procedures, including spot-beam handover, as needed to maintain a workable service whenever operation is required and possible;
- follow the access control and signalling procedures applicable to the communications services provided by the AES.

Communications functions

4.4.3 Depending on its classification, an AES can support some or all of these services:

- circuit-mode services, including duplex telephony and, optionally, circuit-mode data and fax;
- packet-mode services (connection-oriented data services);
- optionally, polled and contracted periodic data-reporting.

4.5 SERVICE AND MINIMUM COVERAGE REQUIREMENTS

4.5.1 All AES installations must be able to see the hemisphere above the aircraft through 360 degrees in azimuth and between 5 degrees and 90 degrees in elevation. This is known as the service coverage requirement.

4.5.2 With the aircraft in horizontal flight, the AES installation must simultaneously meet the performance requirements described below over a minimum fraction of the hemisphere (less the first 5 degrees in elevation). The fraction varies with antenna type:

- Low-gain 85 per cent
- Intermediate-gain 85 per cent
- High-gain 75 per cent.

This is the minimum coverage requirement.

Antenna performance requirements

4.5.3 Table 4-1 shows the principal performance requirements for low, intermediate and high-gain antennas.

Table 4-1. Principal antenna performance requirements

Reference: RTCA DO-210D 2.2.2.1 AES Effective Isotropic Radiated Power (EIRP) and Figure-of-Merit, and 2.2.3 Antenna Subsystem Requirements

	Minimum G/T ⁹ (dB/K)	EIRP range (dBW)	Polarization	Axial ratio ¹⁰
Low-gain	-26	-1.5 to 13.5 ¹¹	Right-hand circular (receive and transmit)	<6dB within 45° of zenith; <20dB from 45° to 85° ¹²
Intermediate-gain	-19	-0.5 to 12.5 ¹³ 2.0 to 12.0 ¹⁴ 6.5 to 13.5 ¹⁵	As low-gain	<6dB ¹⁶
High-gain	-13	to 23.5 ¹⁷ 10.5 to 21.5 ¹⁸ to 21.5 ¹⁹ 10.5 to 19.5 ²⁰ to 13.5 ²¹ 10.5 to 18.5 ²² to 22.5 ²³	As low-gain	As intermediate-gain

4.6 AES MANAGEMENT

Summary

4.6.1 To begin communicating through the Inmarsat system an AES must log on to one of the GESs offering service in the region in which the aircraft is operating. Working either automatically or under user control, the AES selects a satellite and the most suitable GES serving that satellite region.

-
9. Minimum gain-to-noise-temperature ratio (G/T) to be achieved over the operating bandwidth by the complete AES receive system. Antenna gain performance must be such as to make this figure attainable.
 10. Over declared coverage volume.
 11. Minimum range must be at least 15 dBW, with a maximum value of at least 13.5 dBW. EIRP for R and T-channels must be adjustable under GES command over a range of at least 15 dBW in steps of 1 dB.
 12. Polarization losses caused by an axial ratio exceeding 20dB can be offset by excess antenna gain.
 13. Minimum for safety voice service.
 14. Minimum for non-safety voice service.
 15. Minimum for packet-mode data service.
 16. Polarization losses caused by an axial ratio exceeding 6dB can be offset by excess antenna gain.
 17. Minimum for 21 000 bit/s safety voice service.
 18. Minimum for 8 400 bit/s safety voice service.
 19. Minimum for 21 000 bit/s non-safety voice service.
 20. Minimum for 8 400 bit/s non-safety voice service.
 21. Minimum for 600/1 200 bit/s packet-mode data service.
 22. Minimum for 4 800 bit/s packet-mode data service.
 23. Minimum for 10 500 bit/s packet-mode data service.

4.6.2 To log on the AES sends a log-on request to the GES, supplying its own identity, that of the spot beam in which it is currently located, and details of its communications capabilities. If the GES can support the requested services, it confirms the request by transmitting a log-on confirm. The AES and GES then exchange log-on acknowledgements and the AES is ready for the placing of voice and data calls, as described in Section 2.

4.6.3 The AES can make initial contact with a GES because it holds in memory a system table containing information such as satellite and GES identities and frequencies, along with another showing the coverage areas of the spot beams in the region. The table is regularly updated by means of data broadcasts by the GESs. All Inmarsat GESs maintain a table of all the AESs currently logged on. Inmarsat uses this information in combination with inter-station links to facilitate handover of an AES from one Inmarsat GES to another.

4.6.4 The AES may also terminate communications by logging off from the GES. The AES sends a formatted SU to the GES. The GES then deregisters the AES from its tables and informs the other GESs in the ocean region that the AES has been deregistered.

General

4.6.5 An AES must log on to a GES to enter the aeronautical system and log off to terminate its operations with the system or before handing over to another GES, satellite or spot beam. When an AES needs to change its log-on GES, satellite or spot beam, the AES and GES follow the handover procedure described here. Log off is by user command, as part of normal operational procedures; the AES does not log off if handover is initiated as a result of P-channel loss or degradation.

AES status table (held in the Inmarsat GESs)

4.6.6 Each Inmarsat GES maintains an up-to-date status table of the AESs logged on to it. Inmarsat uses inter-GES signaling facility to allow the Inmarsat GESs to set up calls to and from any AES operating to a common satellite and to manage the handover process.

AES operation modes

4.6.7 An AES can operate in two modes: automatic and user-commanded. In the former, the operation of the AES is fully automatic, with satellite system log-on and handover procedures conducted without external control. In user-commanded mode the crew or flight control system can select the satellite and GES for log-on and handover and initiate handovers at any time. Automatic is the normal mode of operation.

AES system table

4.6.8 Each AES holds an AES system table in non-volatile memory. The system table contains data needed by the AES to establish initial communications and to carry out the log-on procedure. The currency of the data in the table is maintained by checking its version number and updating the table if there is a new current version. The update is carried out automatically by the AES, which does not log on if its system table is not current. Each satellite region maintains its own system table and revision number.

4.6.9 The table contains the following information:

For each satellite

- satellite identity
- satellite location, orbit inclination and right-ascension epoch
- satellite identifying P-channel frequency (1)
- satellite identifying P-channel frequency (2).

For each satellite region

- system table revision number
- satellite identity for system table segment
- R and T-channel EIRP levels.

For each GES in the satellite region

- GES identity
- Psmc- and Rsmc-channel frequencies
- table indicating which spot beams are supported by the GES.

4.6.10 When the AES leaves one region and enters another, the system table data for the first region are retained along with the data for other previously visited regions. The AES's stored system table is scanned to determine if the data for the new region are already present. If present, they are used. If not, the data are added to the table from the GES broadcast system table.

4.6.11 The AES also holds the additional information needed for automatic log-on and handover, and for user override of the automatic procedures, in the owner/operator requirements table. Finally, each AES operating in a spot beam maintains a table — the spot-beam map — containing information on spot-beam service areas.

System log-on/log-off

4.6.12 The requirement for AESs to log on and log off allows the GES to manage the number of AESs receiving one forward P-channel (Pd) and transmitting on each R-channel (Rd), and thus to control queuing delays and burst-collision probabilities.

GES selection

4.6.13 If the log-on policy is set to automatic mode at switch-on, the AES selects the most suitable GES serving the satellite region in which it is located; the GES and satellite are then selected for log-on. If the log-on policy is set to user-commanded mode, the AES waits while the user either selects a GES and a satellite selection or opts to revert to automatic mode.

Satellite acquisition

4.6.14 Having selected a satellite, the AES tries to acquire one of the satellite-identifying P-channel frequencies in its initial search table. A satellite-identifying P-channel is either a dedicated global-beam P-channel or the Psmc-channel of a designated GES. Typically there are two frequencies per satellite (or group of satellites, if several satellites provide service to essentially one region).

4.6.15 On acquiring a P-channel, the AES receives it until one of the system-table broadcast SUs is received, allowing the AES to check the validity of the revision number of the system table it is using. If the revision number is out of date, an updating procedure is followed. AESs with spot-beam capability perform a similar check on the spot-beam map. If the revision number is out of date, an updating procedure is carried out. If the system table and spot-beam map revision numbers are correct, the AES is ready to log on.

Log-on procedure

4.6.16 Log-on is initiated by tuning to the global-beam Psmc-channel of the selected GES and sending a log-on request SU on one of the corresponding Rsmc-channels. If the request cannot be accepted — reasons include GES overload, invalid message and unauthorized access — the GES responds with a log-on reject SU indicating the reason for the rejection (which can be either temporary or permanent). If an AES receives a log-on reject with permanent unavailability then the AES does not attempt to log on to that GES for the duration of the current flight unless specifically selected by the pilot.

4.6.17 The GES may, optionally, offer log-on in a different AES class than that specified in the log-on request. It would do so by returning a different value in the log-on confirm SU to the AES. In such cases, the AES may either accept by continuing the log-on signaling procedure relevant to the class offered or reject by discontinuing the log-on signaling procedure with the GES.

Log-on request and confirm signals

4.6.18 In the log-on request the AES supplies its own identity (in the form of the ICAO 24-bit aircraft identification code) plus the identity of the spot beam in which it is currently located. The AES identifies the beam by checking its current position against the spot-beam map and entering it in the spot-beam ID field of the log-on request message.

4.6.19 The AES also informs the GES of the number of C-channels it supports, its antenna gain, the voice-channel bit rates and coding algorithms, and the data bit rates of the P-, R- and T-channels. If the GES can support all the services that the AES requests, it confirms the log-on request by transmitting a log-on confirm SU. To ensure that both the AES and the GES are now aware of each other's capabilities (that is, both the request and confirm have been correctly received), they exchange log-on acknowledgements.

4.6.20 To log off, the AES sends a log-off SU containing its own identity and that of the GES. The GES responds with a log-off information SU, which acknowledges receipt of the log-off request. In the Inmarsat system that GES informs the other GESs in the ocean region that the AES is no longer logged on.

AES handover procedures

4.6.21 If an AES does not receive a Pch transmission for ten seconds or more, that AES will handover to another satellite in order to log on to another GES.

AES system table broadcast

4.6.22 The AES system table is updated whenever a change is made to either the initial search data or the regional data and broadcast by the GES to logged-on AESs.

4.6.23 System table data are broadcast in two forms:

- the most recent update (partial sequence);
- full initial search and regional data (complete sequence).

4.6.24 The data are delivered by means of one or more broadcast SUs containing this information:

- the broadcast index;
- GES P/R-channels;
- satellite;
- spot-beam;
- data EIRP table.

4.6.25 The partial sequence comprises four series of broadcast SUs, each containing a sequence number starting from an initial value and ending in zero.

4.6.26 The complete sequence comprises five series of broadcast SUs: two GES P/R-channel series, a satellite identification series, a spot-beam support series and a data EIRP table series. As in the partial sequence, each series comprises broadcast SUs with a sequence number starting from an initial value and ending in zero.

4.6.27 Both sequences are broadcast on the satellite-identifying P-channels. On all other P-channels, only the partial sequence is broadcast.

4.6.28 The GES monitors the time required for complete transmission of each sequence and issues an alert to reduce P-channel loading if the time required exceeds a pre-set limit for three consecutive transmission cycles.

Spot-beam map broadcast

4.6.29 Within each satellite region, every GES and AES maintains a copy of the spot-beam map. The map contains information on the nominal coverage areas for all the spot beams covering the region and is controlled by means of a revision number.

4.6.30 For each spot beam, the map contains a list of latitude/longitude points on the Earth's surface. The area enclosed by the spherical polygon delimited by the great-circle arcs joining these points indicates the nominal coverage of the spot beam. When logging on, the AES specifies the identity of a spot beam in whose coverage area it is located. After logging on, the AES periodically checks its position against the map and performs a handover if it detects that it is no longer located in the polygon associated with the assigned beam.

4.6.31 Spot-beam map information is updated in much the same way as the AES system table. The data are broadcast in partial and complete sequences on the satellite identifying P-channels. On all other P-channels, only the partial sequence is broadcast. The spot-beam map broadcast SUs are inserted in the same cyclic queue as those of the AES system table and are interleaved one-to-one. If both the partial and the complete sequences are transmitted, they are queued so that the partial sequence is transmitted twice as often as the complete sequence. The GES monitors transmission time as it does for the AES system table.

4.6.32 Updates and subsequent monitoring of version numbers are carried out as for the AES system table.

4.7 PRIORITY AND PRE-EMPTION

4.7.1 A priority and pre-emption mechanism is implemented within the AES so that higher priority circuit switched calls have priority and pre-emption over lower priority calls when there are insufficient AES resources (e.g. channel units and/or HPA power) to support all calls. Priority levels are defined in Table 4-2.

Table 4-2. Circuit mode priority

Reference: RTCA DO-210D 2.2.8.1 Priority, Precedence and Pre-emption

Priority	Service	Link layer Q no.	C channel Q no.	Description
1 ²⁴	AMS(R)S	15	15	Distress and urgency
2	AMS(R)S	12	12	Flight safety
3	AMS(R)S	10	10	Regularity and meteorological
4	AMSS	9	4	Public correspondence

4.7.2 Priority and pre-emption is also implemented for the data-3 service but is not implemented for data-2 since the ACARS system is not able to provide priority information to the satellite sub-network.

24. 1 is highest priority, and 4 is lowest priority.

Chapter 5

GES CHARACTERISTICS

5.1 SUMMARY

5.1.1 There are a number²⁵ of ground Earth stations in the Classic Aero system. They act as the interface between the satellite system and the terrestrial public phone and data networks on the ground. Located to support all satellites, the GESs make it possible for aircraft flying almost anywhere in the world — over oceans, deserts and wilderness as well as populated areas — to communicate with phone, data and fax users on the ground.

5.1.2 As well as supporting communications services, GESs carry out a range of system functions, including access control and signalling, network management and station supervision.

5.1.3 Inmarsat's GESs for the three I-4 satellites and for the I-3 satellites were developed by two different contractors. For the Classic Aero I-4 satellites, Inmarsat owns and operates its own GESs, while the I-3 GESs are owned by the Classic Aero's distribution partners. The two GESs developed for the I-4 satellites were operational post-April 2009.

5.1.4 The two I-4 Classic Aero GESs are:

- Hawaii Dual Ocean Region (98W, 143.5E)
- Fucino (25E).

5.1.5 The I-4 GESs included the FANS improvements later in 2009. The platform is sustainable for many years providing a flexible architecture for expansion. The design features of the I-4 GESs enable the GES to provide high availability and provides hardware reliability models for each subsystem with availability predictions. The degree of redundancy designed into each subsystem provides high system-level availability throughout the life of the GES.

5.1.6 The GES design is very robust, allowing continued operation even if individual components fail. The design can tolerate all single-point failures of components and most two-point failure modes.

5.2 COMMUNICATIONS SERVICES

5.2.1 GESs support these communications services:

- voice services for passengers and for airline and crew operations, making use as necessary of the PSTN and leased circuits;
- packet data on dedicated data channels, making use as necessary of public and private data networks.

25. As at 1 March 2007, there were five GESs in the Inmarsat system (Eik [Norway], Aussaguel [France], Southbury [USA], Santa Paula [USA] and Perth [Australia], and two GESs in the MTSAT system (Kobe [Japan], and Hitachi-Ota [Japan]).

5.2.2 Each GES has a minimum core capability comprising a 600 bit/s R-channel (receive) and 600 bit/s P-channel (transmit) to support its communications functions. In practice, additional capability is needed, and a typical GES offers 600 bit/s, 1 200 bit/s and 10 500 bit/s P- and R-channels.

5.2.3 GESs must ensure that the level of performance offered to users is sufficient to meet their needs while posing no threat to the integrity of the Classic Aero system.

5.3 SYSTEM FUNCTIONS

Access control and signalling

5.3.1 GESs are responsible for:

- AES management for log-on/log-off and handover;
- reception and processing of aircraft-originated call requests and signalling messages carried on R-channel;
- processing of ground-originated call requests and transmission of signalling messages on P-channel;
- demand assignment of voice communications channels from within the fixed block of frequencies allocated temporarily to each GES, including pre-emption if necessary of satellite and GES channels for high-priority calls. See Table 4-2;
- transmission and reception of signalling messages through the sub-band channels on SCPC voice;
- assignment of time slots within one or more T-channel time plans for air-to-ground data services;
- maintenance of the AES status table;
- interworking with AESs and fixed networks in the course of call set-up and clear-down.

5.3.2 Within the Inmarsat system signalling messages transmitted on Psmc-channels are received and relayed by other Inmarsat GESs, there is also transmission of signalling messages to other Inmarsat GESs.

Network management (Inmarsat system only)

5.3.3 GES network management responsibilities are:

- control of space-segment power and bandwidth resources from within the fixed block of carrier frequencies that Inmarsat temporarily pre-assigns to each;
- provision of facilities for communications with other GESs;
- periodic monitoring at C-band return direction of the power and frequency of AES transmit channels to identify malfunctioning AESs and sources of interference within the channels temporarily assigned to the GES;
- self-test.

Station supervision

5.3.4 A GES must be able to monitor at least the following aspects of its own functioning:

- operating status of P-channels transmitted;
- status of phase lock with the automatic frequency compensation (AFC) pilot;
- data-channel loading (P/R/T-channels);
- status of assigned voice channels (C-channels);
- existence and progress of distress, urgent or safety calls.

5.4 GES FEEDER LINK REQUIREMENTS

Pass-band frequencies

5.4.1 Because AES and GES transmit and receive performance varies with frequency, it is necessary to define the range of frequencies within which performance specifications are met. This range is called the pass-band.

Table 5-1. Inmarsat C-band pass-band frequencies

Transmit			Receive		
Second-generation satellites	Third-generation satellites	Fourth-generation satellites	Second-generation satellites	Third-generation satellites	Fourth-generation satellites
Minimum requirement: 6 425.0–6 443.0 MHz Recommended: at least 6 425.0–6 454.0 MHz	6 417.5– 6 454.0 MHz	6 425.0– 6 575.0 MHz	Minimum requirement: 3 600.0–3 623.0 MHz Recommended: at least 3 600.0–3 629.0 MHz	3 599.0– 3 629.0 MHz, 4 192.5– 4 200.0 MHz	3 550.0– 3 700.0 MHz

5.4.2 Table 5-1 shows the transmit and receive pass-band frequencies (to 0.5 dB points) for Inmarsat GES communications and signalling operations with Inmarsat second-, third- and fourth-generation satellites.

5.4.3 The MTSAT system operates a transit band at either 14 GHz (Ku band) or 30 GHz (Ka band) and a receive band at 12 GHz (Ku band) or 20 GHz (Ka band).

Receive G/T requirements

5.4.4 The G/T of the Inmarsat GES C-band receive system must be at least +30.7 dB/K in the direction of the satellite over the entire receive pass-band under both clear-sky and average wind conditions.

5.4.5 The G/T of the MTSAT GES Ku and Ka-band receive system must be at least +39.9 dB/K and +41.40 dB/K, respectively, in the direction of the satellite over the entire receive pass-band under both clear-sky and average wind conditions.

5.4.6 In both cases, the requirement must be met with the transmitter operating at normal output power and including losses caused by pointing errors and antenna polarization misalignment.

5.4.7 GESs must meet these requirements at elevation angles of 5° or more in the direction of geostationary orbit (c. 36 000 km altitude in the plane of the equator).

Antenna system

Transmit gain

5.4.8 For Inmarsat, the transmit antenna gain measured at the transmit feed must be at least 54.0 dBi at any frequency within the required transmit pass-band. For MTSAT, the transmit antenna gain measured at the transmit feed must be at least 63.6 dBi for Ku band and 69.0 dBi for Ka band at any frequency within the required transmit pass-band. The half-power beamwidth for any cross-section of the main beam must be less than or equal to 0.33°.

Receive gain

5.4.9 For operation with both second- and third-generation Inmarsat satellites, the receive antenna gain measured at the low-noise amplifier input must be at least 49.2 dBi at any frequency within the required receive pass-band.

5.4.10 For operation with MTSAT satellites, the receive antenna gain measured at the low-noise amplifier input must be at least 61.9 dBi for Ku band and 65.6 dBi for Ka band at any frequency within the required receive pass-band. The half-power beamwidth for any cross-section of the main beam must be less than or equal to 0.57°.

Polarization

5.4.11 The transmit feed of the Inmarsat antenna must be right-hand circular (RHC) polarized, the receive feed left-hand circular (LHC) polarized.

5.4.12 The MTSAT antenna can either be horizontal or vertically polarized. The antenna feed must be able to transmit and receive RHC and LHC-polarized waves simultaneously.

5.5 GES L-BAND REQUIREMENTS

5.5.1 Each GES must have at least these L-band transmit and receive capabilities:

- continuous transmission of the L-to-C (Inmarsat)/Ku,Ka (MTSAT)-band AFC pilot;
- continuous reception of the C (Inmarsat)/Ku,Ka(MTSAT)-to-L-band AFC pilot;
- reception and monitoring of the GES's own C/Ku-Ka-band transmit carriers, as required for GES testing purposes;

- for Inmarsat, reception and monitoring of the GES's own Psmc-channel and those of every other GES operating to the Inmarsat network.

5.5.2 In addition, it is recommended that for testing purposes the GES be able to transmit and receive standard L-band voice and data carriers in the same manner as an AES.

5.6 GENERAL AFC REQUIREMENTS

5.6.1 The GES carries out automatic frequency compensation (AFC) on the ground-to-air (C/Ku,Ka-to-L-band) and air-to-ground (L-to-C/Ku,Ka-band) signals to minimize the frequency errors seen by the AES and GES demodulators.

5.6.2 AFC is applied to all communications signals, using error-correction signals obtained from uncorrected pilot signals.

5.7 ACCESS CONTROL

Overall requirements

5.7.1 The GES analyses incoming signalling messages from airborne and ground users, processes them and responds appropriately.

5.7.2 It assigns and supports carrier frequencies for transmit and receive from within fixed blocks. The frequencies within the blocks are determined by the satellite operator and may be reviewed and changed, either periodically (for satellite operational reasons, for example) or at short notice in the event of a problem such as interference on a particular frequency.

Signalling channels

5.7.3 The GES receives the SUs carried on the R-channels from aircraft and responds on the P-channel to messages addressed to it. Signalling on the R- and P-channels is used to establish and, when necessary, forcibly clear down all communications channels.

5.7.4 The GES can transmit and receive signalling messages over the sub-band signalling channel provided in voice SCPC C-channels. If the terrestrial telephone network provides a code to generate audible tones, the GES can translate and transmit it over the sub-band signalling channel so that the AES can regenerate the tones.

C-channel assignments

5.7.5 The frequencies assigned by the GES for a telephone call or other service requiring a C-channel are selected from a list (provided by the satellite operator) by means of a pseudo-random sequence. The utilization of C-channel units is distributed evenly among all available units to rule out inadvertent overuse of any that may be suffering from performance degradations.

GES tables

5.7.6 The GES maintains tables recording:

- AES authorization and log-on status;
- satellite resources: EIRP, frequencies and numbers for the channels temporarily pre-assigned to the GES.

GES update of AES system table

5.7.7 The GES transmits AES system table broadcast SUs on the Psmc-channel.

5.7.8 The necessary information is created by Inmarsat and JCAB by sharing their configuration data. Inmarsat then supplies it to all its GESs and similarly JCAB supplies it to the MTSAT GESs. For routine updates, Inmarsat and JCAB agree well in advance to the time at which the updated system table will be transmitted. In contingency operations, the Network Operations Centres of the two organizations coordinate this activity in real time.

5.7.9 Classic Aero GESs can announce future Psid (P channel satellite ID) changes so that AESs can be informed of upcoming Psid changes well in advance of the system table change. This will ensure that the Non Volatile RAM (NVRAM) entries in the AES are amended to include the new Psids, reducing the probability of an AES becoming permanently unable to monitor any Psid and log on to the system.

Satellite services and capabilities

5.7.10 The GES provides a function allowing the mobile users to obtain information about which services are available from each satellite. This enables more rigorous satellite selection based not only on Classic Aero support but also new generation services and any other service that is satellite-generation dependent.

Priority calls and pre-emption

5.7.11 Air-originated distress calls have the highest priority and are assigned immediately to an available channel or channel pair, depending on the service type. If no channel frequency or channel unit is available, the GES pre-empts an existing lower-priority call (from the same or another aircraft) to free the necessary satellite channels and GES channel units. If there are multiple calls with the lowest priority, the oldest call with that priority is pre-empted. Priority levels are defined in Table 4-2.

5.8 SIGNALLING CHANNEL REQUIREMENTS

General

5.8.1 The GES receives the SUs carried on R-channels from aircraft logged on to it and transmits SUs to them on one or more P-channels. A sub-band signalling channel is provided on all C-channels.

5.8.2 P- and R-channels are used for signalling to establish and, when necessary, forcibly clear down C-channels.

5.8.3 Signalling on P-channels in the forward direction and on R- and T-channels, as appropriate, in the return direction is used to establish and, when necessary, terminate T-channel assignments.

5.8.4 There is no dynamic power control for data channels. The power requirements for the R- and T-channels are determined by the AES from the system table.

P-, R- and T-channel management

5.8.5 When a GES has more than one P-channel, more than eight R-channels or more than one T-channel, it uses a channel load distribution mechanism.

5.8.6 One P-channel is designated for Psmc functions, with the others confined to Pd functions. The GES assigns an appropriate P-channel to each AES when it logs on. It does so in a way that ensures uniform and acceptable queuing for access to all P-channels, especially for signalling traffic.

5.8.7 Similarly, one set of R-channels is designated for Rsmc functions, with the others performing Rd functions only. The GES assigns an appropriate R-channel set to each AES when it logs on, doing so in a way that ensures uniform and acceptable collision probabilities.

5.8.8 One or more appropriate T-channels is assigned to each AES at log-on, the selection depending on the functional specializations of the T-channels and their respective loadings.

5.9 TELEPHONY SERVICE REQUIREMENTS

Voice activation of forward-link telephony carrier

5.9.1 The GES provides voice activation on each forward-link telephony (C-channel) carrier. The voice detector is specified as part of the voice codec equipment specification.

5.9.2 A forward-link telephony carrier is transmitted only after a channel has been assigned to an AES and when the transmission of voice signals or sub-band signalling messages is required.

Forward-link power control

5.9.3 The GES applies forward-link power control to C/Ku,Ka-to-L-band carriers for voice to adjust the C/Ku-band EIRP in accordance with link-quality measurements performed during the call. The maximum rate of change of EIRP is controlled.

Return-link power control

5.9.4 The GES applies AES return-link power control to L-to-C/Ku,Ka-band voice carriers.

Telephony audible tones

5.9.5 Audible tones from the GES to the terrestrial telephone network must meet ITU-T Recommendation Q.35, where applicable. Audible tones from the terrestrial telephone network are transmitted transparently through the GES to AESs.

5.10 NETWORK MANAGEMENT REQUIREMENTS (INMARSAT SYSTEM ONLY)

Inter-GES and GES/NCS signalling

5.10.1 The Inmarsat GES receives the Psmc-channel from every other GES operating to the Inmarsat network in an ocean region but relays only those assignments that are addressed to aircraft logged on to itself. Similarly, the GES's own Psmc-channel contains signalling information destined for the other GESs in the Inmarsat network. The I-4 GESs do not require inter-GES signalling as each I-4 ocean region is served by an individual GES.

AES monitoring

5.10.2 The GES periodically monitors in C-band the L-to-C/Ku,Ka-band carriers corresponding to the frequencies temporarily assigned to it. At a minimum, the carrier power and frequency of R-, C- and T-channels are monitored to identify any malfunctioning AESs and sources of L-band interference.

Chapter 6

TELECOMMUNICATION SERVICES AND THEIR OPERATION

6.1 TELEPHONY (VOICE) SERVICES

Quality-of-service targets

6.1.1 These quality-of-service targets have been set for the Classic Aero system telephony service:

Voice quality: The satellite link and its voice codecs are to introduce no more than 5QDU of degradation into the connection (see ITU-T Red Book, Vol III.1, Recommendation G.113).

Blocking: The probability of end-to-end call blocking over the AMS(R)S as a voice communication performance should be less than 1 per cent average during the busiest hour for ATS communication traffic. When a call clears without confirmation that the receive channel is clear, the GES will set the status of the C-channel as blocked. In order to minimize blocking for ATC communication, pre-emption mechanisms are implemented in both INMARSAT and MTSAT voice communication services.

Ground-to-air calls

6.1.2 All calls in the ground-to-air direction may go to a single answering point on the aircraft or may be addressed to specific terminals. The routing of ground-to-air calls to specific aircraft may be barred at the request of the aircraft operator. This restriction is imposed in the GES or elsewhere, at the discretion of the GES or AES operator.

Air-to-ground calls

6.1.3 Air-to-ground calls may be made by crew or passengers with several types of service provided. Service capabilities include:

- crew general telephony;
- crew ATS voice.

Crew voice operation

6.1.4 Airline crew may have access to special telephony services and networks. Minimum capabilities include:

- crew access to the full public telephone network connected directly from the GES operator to the aircraft operator;

- crew ATS voice²⁶
(*Note.*— As of March 2008 NAVCANADA now provides satcom telephony services for routine ATS in the North Edmonton airspace employing the call priority scheme defined in Table 4-2, enhanced access security for ground initiated calls via the service providers' networks, and the ability to display priority of the incoming call to the crew.);
- access to specialized telephony services via private networks;
- ability to pre-empt an existing passenger call in order to make AES voice equipment, a satellite channel or GES voice equipment, available for use in case of emergency;
- ability to seize the next available AES voice circuit, without clearing any calls in progress.

Passenger telephony service

6.1.5 It should be noted that both the Inmarsat and MTSAT systems support passenger telephony service in addition to cockpit and cabin staff telephony services. The system and service options available are defined in the Inmarsat SDM.

Number of simultaneous calls

6.1.6 The maximum number of simultaneous calls that can be set up to or from an AES is limited by the number of available channel units in the AES and GES and application reference numbers. There must be at least eight (optionally 24) of the latter in the air-to-ground direction and eight in the ground-to-air direction.

Air-to-ground call set-up

User perspective

6.1.7 To make an air-to-ground call the user dials an international number on a handset or terminal (e.g. MCDU) in the aircraft. The dialled number is passed on the sub-band of the C-channel via satellite to a GES for interconnection to the PSTN.

6.1.8 It is possible to place calls with predefined abbreviated dialling codes. The GES converts each abbreviated number to a PSTN number. A typical use of this feature is access to an ATC centre from the flight deck of an aircraft. This process ensures that the ATC number is not transmitted over the air, which would risk compromising its security.

26. As of summer 2007 the North Atlantic (NAT) ATSPs/radio operators conducted trials of enhanced operational and service provider (SP) technical provisions for Classic Aero telephony's (satcom voice) use for routine ATS communications. This document will be updated should these provisions be accepted by regulators and widespread approval for satcom voice for routine ATS communications be granted.

Technical perspective

Channel and power availability check

6.1.9 The AES starts the process to request a channel from the GES on receiving the called number. It then reserves a channel unit and checks that HPA power is available for the call. The caller is notified if either is unavailable, the form of the notification varying according to the call's priority status.

6.1.10 If a call request initiated by an AES with both C-channel types (8 400 bit/s and 21 000 bit/s) is rejected by a GES because the requested channel type is unavailable, the AES retransmits, requesting a different channel type.

Call request

6.1.11 The initial call request is sent on the Rd-channel to the GES to which the AES is logged on. In response, a channel assignment is received on the corresponding Pd-channel. The communications channel is then set up and tested with signals carried on the sub-band of the C-channel.

6.1.12 The call-information SUs — containing the called-party address plus, if applicable, the credit card number — are sent by the AES to test the channel. The SUs are sent consecutively and continuously until a call-result message is received from the GES or the attempt times out.

6.1.13 On receiving the SUs, the GES starts to send test SUs, transmitting them continuously and consecutively until it receives a call-progress signal.

Call set-up to "other" GES (Inmarsat system only)

6.1.14 If the call is to an Inmarsat GES to which the AES is logged on, all access-request and channel-assignment transactions are carried on the Rd- and Pd-channels. If the call is to an Inmarsat GES other than the log-on Inmarsat GES, the latter forwards the access request from the AES to the called GES on the inter-station link.

Ground-to-air call set-up

User perspective

6.1.15 A call placed by a terrestrial user is passed through the PSTN to a GES. The choice of GES is determined by the caller's terrestrial service provider. If the called AES is logged on to the GES to which the call is passed, a normal call set-up is established through that GES. If the AES is not logged on to the GES to which the call is passed, a transit call is established. The numbering plan used to access AESs from the ground is detailed below.

Technical perspective

Channel and power availability checks

6.1.16 The GES sends the call-announcement and channel-assignment information to the AES over the Pd-channel. The AES allocates a channel unit and checks that HPA power is available for the call. If either power or a channel unit are unavailable, the AES returns a call-result signal on the Rd-channel, including the appropriate cause code. If both a channel unit and power are available, the continuity check for proper channel set-up and the channel-release functions over the satellite link are carried out using signals on the sub-band of the C-channel.

Power control

6.1.17 Power control for the forward and return directions is mandatory in the AES and GES. It is needed to conserve satellite L-band power in the forward direction and to enable an AES to provide multiple channels when link conditions are favourable, while permitting service with a smaller number of channels when link conditions are unfavourable.

Power control management

6.1.18 The GES derives the initial C-channel power setting, expressed as EIRP measured in dBW, for the worst-case link condition and conveys it to the AES in the C-channel assignment signal transmitted on the Pd-channel. The initial EIRP value is set at the safety-service level for all C-channel assignments. If there is insufficient power to attain that level, the AES initiates the C-channel with the maximum available EIRP, which normally varies depending on whether it is intended to operate through a satellite spot beam or a global beam.

6.1.19 When an AES under favourable operational conditions is establishing a C-channel in addition to one or more existing channels, it is still assigned an initial EIRP corresponding to the worst-case link budget. If the maximum EIRP available in the AES is less than the initial setting, the AES initiates the additional C-channel being with the maximum available EIRP, which must be equal to or higher than the EIRP of any C-channels already in operation.

Power control operation (forward link)

6.1.20 After every power-control signalling sequence the GES adjusts its own EIRP according to the BER value received from the AES. If no BER value is received from the AES before the next power-control signalling sequence, it is recommended that the GES increase its EIRP by 1 dB. If an invalid BER value is received from the AES, it is recommended that the GES keep its EIRP unchanged. However each GES has its maximum power setting, and alarms are raised if the maximum power control setting is reached at any time.

Power control operation (return link)

6.1.21 Before every power-control signalling sequence the GES assesses the need for the AES to adjust its transmitted power, based on the BER value measured at the GES. The GES sends to the AES a channel status report signal containing an EIRP adjustment value, and the AES alters its EIRP accordingly.

6.2 DATA SERVICES

General

6.2.1 The elements of the data system are defined in accordance with OSI system architecture. Each layer of the system performs a subset of the functions needed to communicate with another data system. The lower layers — the physical, data link and network layers — comprise the network-dependent portion of the OSI architecture. As such, they are provided by the satellite communications system. Together they make up the satellite sub-network (SSN).

Data system architecture

6.2.2 The overall function of the SSN is to act as a communications system providing reliable transfer of sub-network service data units (SNSDUs) between AES and GES. It therefore performs:

- physical link functions (Layer 1);
- data link functions and protocols (Layer 2); and
- sub-network functions and protocols (Layer 3).

6.2.3 Data services are carried in the forward direction on a P-channel and in the return direction on an R- or T-channel.

6.2.4 The reference model for data communications in the Classic Aero system is shown in Figure 6-1.

Satellite sub-network layer structure

6.2.5 A higher-level entity (HLE) — the satellite system user — may connect directly to the SSN or via an interface using an access protocol. An SSN-dependent sub-layer is provided within Layer 3 of the SSN to support access by HLEs, either through direct connection or by connection via an interworking protocol.

Sub-network service

6.2.6 The sub-network service (SNS) provides for transparent transfer of data between an airborne user and a terrestrial user. Each user accesses the SNS by means of a sub-network connection (SNC). In particular, the SNS provides for:

- independence of underlying satellite link transmission media;
- end-to-end transfer across the SSN;
- transparency of transferred information;
- quality-of-service (QOS) selection;
- user addressing;
- transfer of the globally significant network service access point (NSAP) addresses used for internetwork routing purposes.

6.2.7 The SSN offers connection-oriented services. It makes invisible to the users the way in which supporting communications resources are used to achieve the transfer of data from the AES to the GES and vice versa.

Link-layer protocol description

P-channel protocol

6.2.8 The sequence for transfer of LSDUs in the ground-to-air direction is shown in Figure 6-2.

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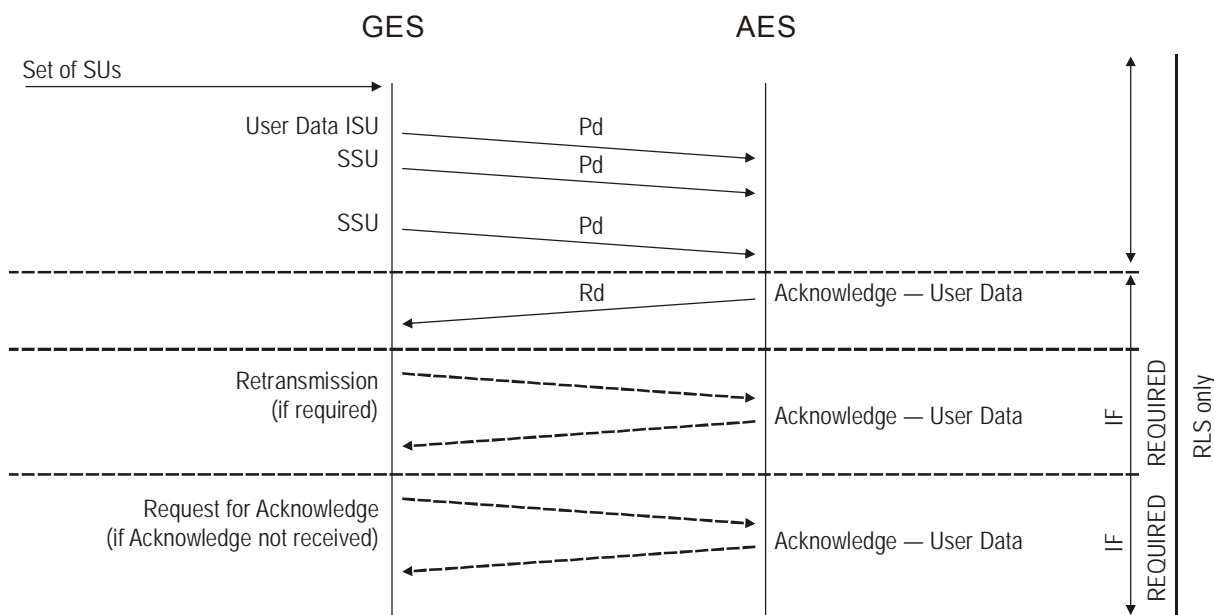


Figure 6-2. LSDU transfer on the P-channel

6.2.9 The SU set is sent on the P-channel at the appropriate priority level. When the complete SU set has been received at the AES, and following correction or replacement of any lost SUs, the LSDU is reassembled and acknowledged as correct. A LIDU consisting of the received LSDU and associated LICI is forwarded to the link service user in the AES.

6.2.10 The complete procedure is protected against loss of SUs in arbitrary positions. The most serious loss is that of the ISU, which requires the complete retransmission of the SU set. In other cases, generally, only lost SUs are retransmitted.

R-channel protocol

6.2.11 The sequence for transfer of LSDUs in the air-to-ground direction via the R-channel is shown in Figure 6-3. This protocol applies only to short LSDUs, which are sent entirely on the R-channel as a series of independent bursts, up to a limit of three bursts.

6.2.12 An air-to-ground LSDU is formatted into one user data ISU followed by 0, 1 or 2 SSUs and sent on the R-channel. The sequence of events is then identical to that for the P-channel.

T-channel protocol

6.2.13 The sequence for transfer of LSDUs via the T-channel is shown in Figure 6-4. This protocol applies to LSDUs in the air-to-ground direction which are too long (more than 33 octets) to be sent entirely on the R-channel. There are two protocols, one for the request of T-channel capacity, the other for the transmission of the SU set.

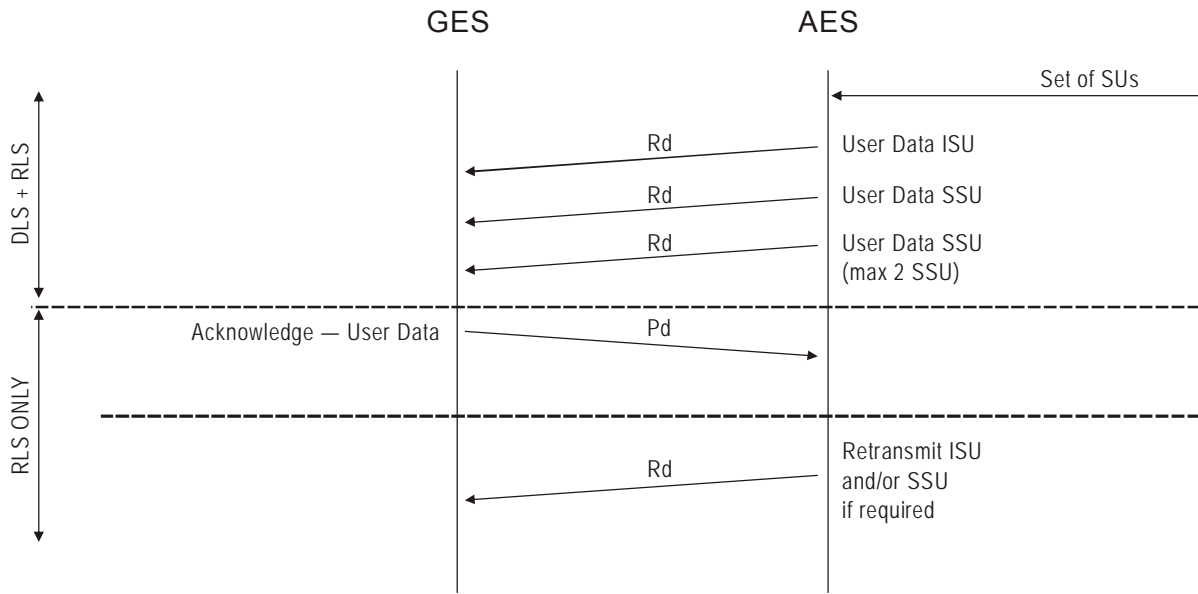


Figure 6-3. LSDU transfer on the R-channel

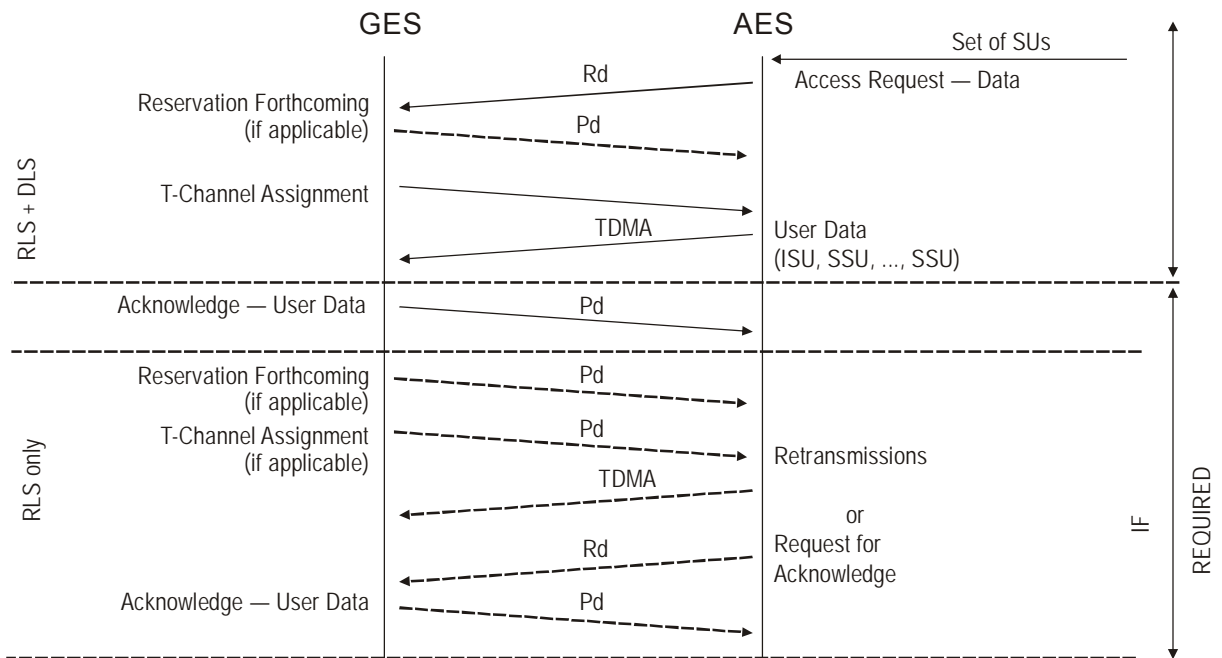


Figure 6-4. LSDU transfer on the T-channel

6.2.14 If an SU set is waiting for transmission in an allocated time slot and a higher-priority SU set is submitted to the T-channel for transmission, the new set displaces SUs from the lower-priority set. This capability means that it is possible for TDMA bursts to carry data from LSDUs other than the one that initiated the original burst request.

6.2.15 The transmission sequence of events is identical to that for the P and R-channels.

6.3 NUMBERING PLAN

AES identification scheme

6.3.1 The Classic Aero system utilizes the 24-bit ICAO technical address of the aircraft for addressing purposes. Inmarsat and MTSAT operations refer to this as the AES identifier (“AES id”), and Inmarsat assigns the unique address to every AES commissioned for operation in the Classic Aero system. The telephone number of each aircraft is derived by converting the 24-bit address to octal.

Network numbering plans

Inmarsat public network numbering plan

6.3.2 Inmarsat employs the ITU definition of the format of the international public numbers for AESs as follows:

International telephone number: 0870 + 5 + Inmarsat (Aeronautical) Mobile Number.

International data number: 111S + 5 + Inmarsat (Aeronautical) Mobile Number + D.

D = optional digit identifying the data terminal equipment on the aircraft.

Inmarsat (Aeronautical) Mobile Number = 8-digit number, uniquely identifying an AES.

6.3.3 The Single Network Access Code (SNAC) numbering change (January 2009) saw the removal of the S digit for calling into the Inmarsat network. Service providers use one common number (0870...) to route calls into the Inmarsat network.

6.3.4 Inmarsat service providers offer a two-stage secure access dialling method for ground-to-air calls of AMSS. The callers dial an assigned phone number or 0870 access number and the following facilities are offered by the service provider;

- caller line identification (CLI);
- personal identification number (PIN) entry;
- assignment of priority unique to ATS and AOC calls.

6.3.5 Cockpit multifunction control and display units (MCDU) also have the ability to display a priority indicator for received ground-to-air Classic Aero telephony.

MTSAT public network numbering plan

6.3.6 MTSAT provides the interface of direct connection and pre-emption function between the aircraft and JCAB's ATS unit for ground-to-air calls of AMS(R)S.

6.3.7 MTSAT employs a two-stage dialling method for ground-to-air calls of AMSS. The callers dial an assigned phone number and then dial the following numbers in accordance with voice guidance;

- the security ID (assigned to a caller);
- the priority number;
- the aircraft's AES ID;
- the terminal ID, if used.

If a caller's phone number is registered within the MTSAT system, the security ID is omitted.

Classic Aero system mobile numbering scheme

6.3.8 The Classic Aero mobile number can commonly take an 8-digit primary number, assigned to all aircraft.

6.3.9 Inmarsat can also issue and provide routing to and from a 6-digit alternate number (not supported by MTSAT) and 2 or 3 direct dial-in digits (only for circuit-mode services) for selected aircraft. Inmarsat uses the first digit of the (Aeronautical) mobile number to discriminate among these various forms.

ATS short codes

6.3.10 The Inmarsat/MTSAT have implemented a common ATS short code system that allows AES to be programmed with ATS-unit-specific short codes for PSTN dialling. Air-to-ground calls are set up by signalling these codes to the GES which in turn creates the PSTN dialling string. The advantage of this is that changes to the PSTN numbering are managed at the GES without having to modify AES tables.

Appendix A

COMPLIANCE MATRIX TO ANNEX 10, VOLUME III, PART I, CHAPTER 4 (SARPS)

**Table A-1. Classic Aero AMS(R)S system parameters per ICAO AMS(R)S SARPs
Annex 10, Volume III, Part I, Chapter 4**

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Classic Aero Subnetwork value	Additional comments on performance
4.2	General	N/A	Placeholder
4.2.1	AMS(R)S shall conform to ICAO Chapter 4	Yes	—
4.2.1.1	Support packet data, voice, or both	Yes; both	By design.
4.2.2	Mandatory equipage	N/A for service provider	—
4.2.3	Two years' notice	N/A for service provider	—
4.2.4	Recommendation to consider worldwide implementation	Yes	—
4.3	RF Characteristics	N/A	Placeholder
4.3.1	Frequency bands	N/A	Placeholder
4.3.1.1	Only in frequency bands allocated to AMS(R)S and protected by ITU RR	Yes; 1 545–1 555 and 1 646.5–1 656.5 MHz	—
4.3.2	Emissions	N/A	Placeholder
4.3.2.1	Limit emissions to control harmful interference on same aircraft	Yes	
4.3.2.2	Shall not cause harmful interference to AMS(R)S on other aircraft	N/A	Placeholder
4.3.2.2.1	Emissions shall not cause harmful interference to an AES providing AMS(R)S on a different aircraft	Yes	See ICAO-ACP-WG-M-12 Report on Agenda Item 4
4.3.3	Susceptibility	N/A	Placeholder

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Classic Aero Subnetwork value	Additional comments on performance
4.3.3.1	Shall operate properly in cumulative $\Delta T/T$ of 25%	Yes	
4.4	Priority and pre-emptive access	N/A	Placeholder
4.4.1	Priority and pre-emptive access	Yes	
4.4.2	All AMS(R)S packets and voice calls shall be identified by priority	Yes	
4.4.3	Within the same message category, voice has priority over data	Yes	
4.5	Signal acquisition and tracking	N/A	Placeholder
4.5.1	Properly track signal for aircraft at 800 knots along any heading	Yes	
4.5.1.1	Recommendation for 1 500 knots	No	Changes would need to be made to AES to meet this recommendation.
4.5.2	Properly track with 0.6 g acceleration in plane of orbit	Yes	
4.5.2.1	Recommendation 1.2 g	Yes	It is known that the majority of AES meet this requirement
4.6	Performance requirements	N/A	Placeholder
4.6.1	Designated operational coverage	N/A	Placeholder
4.6.1.1	Provide AMS(R)S throughout designated operational coverage	Yes	
4.6.2	Failure notification	N/A	Placeholder
4.6.2.1	Provide timely predictions of service failure-induced outages	Yes	For data-2 operations this function is provided by the Communications Service Provider. ATN (Data-3 X.25 protocol) can achieve this.
4.6.2.2	System failure annunciation within 30 seconds	Yes	
4.6.3	AES requirements		Placeholder
4.6.3.1	Meet performance in straight and level flight	Yes	

AMS(R)S SARP reference	AMS(R)S SARP contents	Classic Aero Subnetwork value	Additional comments on performance
4.6.3.1.1	Recommendation for +20/-5 pitch and +/-25 roll	No	To meet this requirement would require significantly different antenna system on aircraft
4.6.4	Packet data service performance	N/A	Placeholder
4.6.4.1	Requirements on AMS(R)S packet data	Yes	See subsections.
4.6.4.1.1	Capable of mobile subnetwork in ATN	Yes; ISO-8028	
4.6.4.1.2	Delay parameters	N/A	Placeholder
4.6.4.1.2.1	Connection establishment delay <70 seconds	Yes <70s	
4.6.4.1.2.1.1	Recommendation Connection establishment delay <50 seconds	Yes <50s	
4.6.4.1.2.2	Transit delay based on SNSDU of 128 octets and defined as average values	Yes	
4.6.4.1.2.3	From aircraft highest priority <40 seconds	Yes <40 s	
4.6.4.1.2.3.1	Recommendation from aircraft highest priority <23 seconds	Yes <23 s	
4.6.4.1.2.3.2	Recommendation from aircraft lowest priority <28 seconds	Yes <28 s	
4.6.4.1.2.4	To aircraft high priority <12 seconds	Yes <12 s	
4.6.4.1.2.4.1	Recommendation to aircraft lowest priority <28 seconds	Yes <28 s	
4.6.4.1.2.5	From aircraft data transfer delay 95th percentile highest priority <80 seconds	Yes <40 s	
4.6.4.1.2.5.1	Recommendation from aircraft data transfer delay 95th percentile highest priority <40 seconds	Yes <40 s	
4.6.4.1.2.5.2	Recommendation from aircraft data transfer delay 95th percentile lowest priority <60 seconds	Yes <60 s	
4.6.4.1.2.6	To aircraft data transfer delay 95th percentile high priority <15 seconds	Yes <15 s	

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Classic Aero Subnetwork value	Additional comments on performance
4.6.4.1.2.6.1	Recommendation to aircraft data transfer delay 95th percentile low priority <30 seconds	Yes <30 s	
4.6.4.1.2.7	Connection release time 95th percentile <30 seconds	Yes <30 s	
4.6.4.1.2.7.1	Recommendation connection release time 95th percentile <25 seconds	Yes < 25 s	
4.6.4.1.3	Integrity	N/A	Placeholder
4.6.4.1.3.1	Residual error rate from aircraft 10^{-4}/SNSDU	Yes 10^{-4}	
4.6.4.1.3.1.1	Recommend RER from aircraft 10^{-6}/SNSDU	*	The definition on RER in the SARPs is unclear. It is believed that 'lost SNSDUs' will exceed these requirements. However, the AES/GES will detect with probability better than 10^{-6} , lost or corrupted or duplicate SNSDUs
4.6.4.1.3.2	RER to aircraft 10^{-6} /SNSDU	No	As above
4.6.4.1.3.3	Pr{SNC provider invoked release}10^{-4}/hr	N/A	
4.6.4.1.3.4	Pr{SNC provider invoked reset}10^{-1}/hr	Yes < 10-1/hr	
4.6.5	Voice service performance	N/A	Placeholder
4.6.5.1	Requirements for AMS(R)S voice service	Yes	-
4.6.5.1.1	Call delay processing	N/A	Placeholder
4.6.5.1.1.1	AES call origination delay 95th percentile <20 seconds	Yes <20 s	
4.6.5.1.1.2	GES call origination delay 95th percentile <20 seconds	Yes <20 s	
4.6.5.1.2	Voice quality	N/A	Placeholder
4.6.5.1.2.1	Voice intelligibility suitable for intended operational and ambient noise environment	Yes	

AMS(R)S SARPs reference	AMS(R)S SARPs contents	Classic Aero Subnetwork value	Additional comments on performance
4.6.5.1.2.2	Total allowable transfer delay within AMS(R)S subnetwork <0.485 second	Yes <0.485 s	
4.6.5.1.2.3	Recommendation to consider effects of tandem vocoders	Yes	
4.6.5.1.3	Voice capacity	N/A	Placeholder
4.6.5.1.3.1	Sufficient voice traffic channel resources for Pr{blockage <0.01} for AES or GES originated calls	Yes <0.01	
4.6.6	Security	N/A	Placeholder
4.6.6.1	Protect messages from tampering	Yes	
4.6.6.2	Protect against denial of service, degradation, or reduction of capacity due to external attacks	Yes	
4.6.6.3	Protect against unauthorized entry	Yes	-
4.7	System Interfaces	N/A	Placeholder
4.7.1	Address AMS(R)S by means of 24 bit ICAO address	Yes	
4.7.2	Packet data service interfaces	N/A	Placeholder
4.7.2.1	If the system provides packet data service, it shall provide an interface to the ATN	Yes	
4.7.2.2	If the system provides packet data service, it shall provide an CN function	Yes	By design.

**MANUAL ON THE
AERONAUTICAL MOBILE
SATELLITE (ROUTE) SERVICE**

Part IV

INMARSAT SWIFTBROADBAND

Chapter 1

INTRODUCTION

1.1 OBJECTIVE AND SCOPE

1.1.1 The objective of Part IV of this manual is to provide technical specifications and guidance material to ICAO Member States and the international civil aviation community on the SwiftBroadband (SBB) aviation satellite system, which provides AMS(R)S communications for the safety and regularity of flight. The SBB aviation satellite system is operated globally by Inmarsat. This manual is to be considered in conjunction with the AMS(R)S Standards and Recommended Practices (SARPs) contained in Annex 10, Volume III, Part I — *Digital Data Communication Systems*, Chapter 4 [see 1.2, ref. 1].

1.1.2 This part of the manual consists of the following chapters:

- Chapter 1: Introduction
- Chapter 2: Overview of SwiftBroadband
- Chapter 3: Compliance Matrix to Annex 10, Volume III, Part I, Chapter 4 (SARPS) [see 1.2, ref. 1]
- Chapter 4: Guidance for ANSPs and Aircraft Operators

1.1.3 This part of the manual was developed in advance of any system and air traffic management (ATM) validation activities. It references the RTCA SBB minimum aviation system performance standards (MASPS) [see 1.2, ref. 2], Attachment 1, Inmarsat SwiftBroadband Specific Material, for the full technical description of the SwiftBroadband system, in order to avoid duplication of technical material. The RTCA SBB MASPS [see 1.2, ref. 2] also contains a list of system requirements. Detailed requirements on the aircraft terminal are provided in the RTCA SBB MOPS [see 1.2, ref. 3].

1.2 REFERENCES

1. "Annex 10 to the Convention on International Civil Aviation, *Aeronautical Communications*, Volume III *Communication Systems*, (Part I — *Digital Data Communication Systems*)," International Civil Aviation Organization (ICAO), Montréal, July, 2007.
2. "Minimum Aviation System Performance Standard for AMS(R)S Data and Voice Communications Supporting Required Communications Performance (RCP) and Required Surveillance Performance (RSP) in Procedural Airspace", RTCA, Inc., DO-343, 21 August 2013.
3. "Minimum Operational Performance Standards for Avionics Supporting Next Generation Satellite Systems (NGSS)," RTCA, Inc., Washington, DC, DO-262B (July 2014).
4. "*Performance-based Communication and Surveillance (PBCS) Manual* (Doc 9869)", International Civil Aviation Organization (ICAO), Montréal.
5. "*Global Operational Datalink (GOLD) Manual* (Doc 10037)", International Civil Aviation Organization (ICAO), Montréal.
6. "*Satellite Voice Operations Manual (SVOM)* (Doc 10038)", International Civil Aviation Organization (ICAO), Montréal.

Chapter 2

OVERVIEW OF SWIFTBROADBAND

2.1 GENERAL

2.1.1 This section provides a general introduction to the SwiftBroadband System (SBB). For a detailed system description of SBB, please refer to the RTCA SBB MASPS [see 1.2, ref. 2], Attachment 1, Section 3.

2.1.2 The Inmarsat SBB system has been in service since November 2007, initially for non-safety users. SBB is based on third-generation (3G) universal mobile telecommunications system (UMTS), operates over geostationary satellites, and provides both circuit-switched services (for voice) and Internet Protocol (IP)-based packet-switched services (for data and voice) with a data rate of up to 432 kbit/s per channel. In Standard IP mode, the service is shared with other concurrent users of the system, ensuring best use of the available spectrum.

2.1.3 SBB is delivered over the Inmarsat-4 (I-4) (three satellites launched between 2005 and 2008) and Alphasat (launched July 2013) satellites using user links in the L-band and feeder links in the C-band. The satellites are geosynchronous, with inclination typically less than 3 degrees, and provide worldwide coverage with the exception of the polar regions. Key aspects of the I-4 satellites are a single 9 metre aperture antenna and a transparent, bent-pipe, digital signal processor (DSP) that performs the channelization and beam forming functions. Each I-4 satellite provides a global beam, 19 regional beams, and typically 192 narrow spot beams.

2.1.4 SBB shares the same satellite and ground infrastructure used to deliver similar services to other market segments (enterprise (also known as land portable), land mobile and maritime). The enterprise service is known as BGAN (broadband global area network) and this term is often used to describe the totality of the system across all market segments. The maritime service is known as FleetBroadband.

2.1.5 The SwiftBroadband system is composed of four segments:

- a) the airborne (or user) segment known as an aircraft Earth station (AES);
- b) the Inmarsat satellites;
- c) the Inmarsat ground infrastructure; and
- d) the communication network provider's (CNP's) ground infrastructure.

2.1.6 Inmarsat owns and operates the satellite ground infrastructure and delivers traffic at meet-me-points (MMPs) to the CNPs (such as, for example, Aeronautical Radio Inc. (ARINC) and Société Internationale de Télécommunication Aéronautiques (SITA)). The CNPs provide key elements of the end-to-end aircraft communications addressing and reporting system (ACARS) and voice service and deliver traffic to air navigation services providers (ANSPs) and airlines. A key service that the CNPs offer is a secure two-stage dialling capability for access to prioritize ground-to-air voice communication.

2.1.7 The SBB data and voice communication services described in this document form part of the AMS(R)S (aeronautical mobile satellite (route) service) system and are delivered between the AES avionics interface and the CNPs' interfaces to the ANSP/airline as shown in Figure IV-1-1 below.

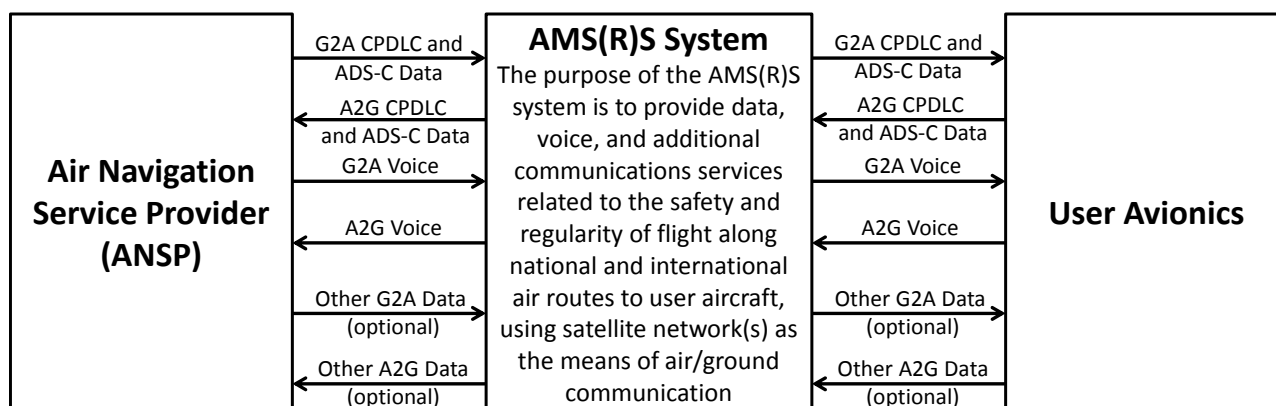


Figure IV-1-1. AMS(R)S system boundary diagram (illustrates main data flows)

2.2 SWIFTBROADBAND SERVICES

2.2.1 To support cockpit safety services at the performance level defined in the RTCA SBB Minimum Aviation System Performance Specifications (MASPS) [see 1.2, ref. 2], the Inmarsat SBB system includes gateway functions that utilize the 3G bearer services to provide the ACARS service and the voice over Internet Protocol (VoIP) component of the voice service. The ACARS gateway, at the Inmarsat satellite access stations (SAS) sites, transports ACARS data in both air-ground and ground-air directions over the SBB IP link, enabling the future air navigation systems (FANS) operation for automatic dependent surveillance — contract (ADS-C) and controller-pilot data link communication (CPDLC), with priority and pre-emption to protect FANS ACARS traffic over the link from network congestion. Thus, SBB provides the following services:

- a) ACARS data service supporting FANS and airline operational control (AOC) applications;
- b) two channels of cockpit voice, with the required call priority levels;
- c) prioritized IP service (standard service and streaming service) to the cockpit for support of new ATS and AOC applications; and
- d) position reporting service.

2.2.2 SBB provides AMS(R)S communications for the safety and regularity of flight, in addition to the non-safety communications services. The system may be used on its own to provide aircraft cockpit communications functions (and non-safety services), and also for accessing avionics data, e.g. ADS-C, or may be combined with Classic Aero.

2.2.3 The SBB system provides data and voice communication services that will enable widespread implementation of the 30/30 NM separation standards for oceanic and remote airspace operations along international air routes. Data communication (using ACARS) complies with the RCP240, RSP180 and operational requirements in the *Performance-based Communication and Surveillance (PBCS) Manual* (Doc 9869) [see 1.2, ref. 4], while voice communications comply with the RSP400/V and operational requirements in Doc 9869.

2.2.4 The position reporting service is implemented within the ACARS infrastructure and provides position reports containing latitude, longitude, altitude, true heading and ground speed, at an interval that is configurable from the ground (this position reporting service can be requested as part of the terminal activation and provisioning process). For aircraft using the SBB system, Inmarsat will also be able to make the aircraft position data available (via the Inmarsat Distribution Partner) for search and rescue (SAR) following an emergency. Position reports are appended to each ACARS aircraft gateway (AAGW) message from the aircraft, including system level logon, logoff, downlinks, uplink acknowledgements, and keep-alives, and the position information is decoded and logged at the ACARS ground gateway (AGGW) at the Inmarsat SAS sites, thus offering the potential for a high rate of aircraft location and track information.

2.2.5 Four classes of AES are defined as follows:

- a) Class 4 uses an enhanced low gain antenna (ELGA);
- b) Class 7 uses an intermediate gain antenna (IGA);
- c) Class 6 uses a high gain antenna (HGA); and
- d) Class 6 with Classic Aero reversion capability, which uses an HGA.

2.2.6 AESs that incorporate Classic Aero reversion capability are designed for tight interoperability with the Classic Aero service operating on the I-3 and I-4 satellites, and may seamlessly switch between the three networks.

2.3 REQUIREMENTS

2.3.1 For the requirements on the SBB system, refer to the RTCA SBB MASPS [see 1.2, ref. 2], Section 2. For SBB compliance to these requirements, refer to RTCA SBB MASPS [see 1.2, ref. 2], Attachment 1, Section 2.

2.3.2 For the requirements on AESs supporting the SBB system, refer to the RTCA SBB MOPS [see 1.2, ref. 3].

2.3.3 The MASPS requirements were sourced from the following documents:

- a) the *Global Operational Datalink (GOLD) Manual* (Doc 10037) [see 1.2, ref. 5]. The required communications performance (RCP) and required surveillance performance (RSP) requirements are now contained in Doc 9869 [see 1.2, ref. 4]; and
- b) the *Satellite Voice Operations Manual (SVOM)* (Doc 10038) [see 1.2, ref. 6], previously published as *Satellite Voice Guidance Material (SVGGM)*.

Chapter 3

COMPLIANCE MATRIX TO ANNEX 10, VOLUME III, PART I, CHAPTER 4 (SARPs)

Table IV-3-1. SwiftBroadband aeronautical mobile satellite (route) service (AMS(R)S) system parameters per ICAO AMS(R)S Standards and Recommended Practices (SARPs) Annex 10, Volume III, Part I, Chapter 4

AMS(R)S SARPs reference	AMS(R)S SARPs contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.2	General.	N/A	
4.2.1	AMS(R)S shall conform to Chapter 4.	Yes	
4.2.1.1	Support packet data, voice, or both.	Yes; both	By design
4.2.2	Mandatory equipage.	N/A for service provider	
4.2.3	Two years' notice.	N/A for service provider	
4.2.4	Recommendation to consider worldwide implementation.	Yes	
4.3	RF Characteristics.	N/A	
4.3.1	Frequency bands.	N/A	
4.3.1.1	Only in frequency bands allocated to AMS(R)S and protected by ITU RR.	Yes	<p>The 28th Meeting of the Aeronautical Communications Panel Working Group – Frequency (ACP-WG-F) (see ICAO-ACP-WG-F-28 Report, Section 8.4) concluded that:</p> <p>a) the proposed spectrum use is in accordance with the ITU RR;</p>

AMS(R)S SARPs reference	AMS(R)S SARPs contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
			<p>b) no changes are required to Annex, Volume III, 4.3.1.1 (frequency bands) of the AMS(R)S SARPs;</p> <p>c) the system would receive priority toward fulfilling its spectrum requirements within the bands covered by No. 5.357A; and</p> <p>d) AMS(R)S operations in the extended L-band (1 518-1 525 MHz and 1 668-1 675 MHz) would require additional study.</p>
4.3.2	Emissions.	N/A	
4.3.2.1	Limit emissions to control harmful interference on same aircraft.	Yes	
4.3.2.2	Interference to other AMS(R)S equipment.	N/A	
4.3.2.2.1	Emissions shall not cause harmful interference to an aircraft Earth station (AES) providing AMS(R)S on a different aircraft.	Yes	See the ICAO-ACP-WG-M-12 Report on Agenda Item 4
4.3.3	Susceptibility.	N/A	
4.3.3.1	Shall operate properly causing a cumulative $\Delta T/T$ of 25%.	Yes	
4.4	Priority and pre-emptive access.	N/A	
4.4.1	Priority and pre-emptive access.	Yes	
4.4.2	All AMS(R)S packets and voice calls shall be identified by priority.	Yes	The SBB 3G components in the AES, radio access network (RAN), and core network provide a transport mechanism with priority/pre-emption capability (see RTCA MASPS [see 1.2, ref. 2]).
4.4.3	Within the same message category, voice has priority over data.	Yes	

AMS(R)S SARP reference	AMS(R)S SARP contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.5	Signal acquisition and tracking.	N/A	
4.5.1	Properly track signal for aircraft at 1 500 km/h (800 knots) along any heading.	Yes	
4.5.1.1	Recommendation for 2 800 km/h (1 500 knots).	No	This recommendation is based on support for supersonic aircraft, but there is no demand on such aircraft for this service.
4.5.2	Properly track with 0.6 g acceleration in plane of orbit.	Yes	
4.5.2.1	Recommendation 1.2 g.	Yes	
4.6	Performance requirements.	N/A	
4.6.1	Designated operational coverage.	N/A	
4.6.1.1	Provide AMS(R)S throughout designated operational coverage.	Yes	
4.6.2	Failure notification.	N/A	
4.6.2.1	Provide timely predictions of service failure-induced outages.	Yes	
4.6.2.2	System failure annunciation within 30 seconds.	Yes	
4.6.3	AES requirements.	N/A	
4.6.3.1	Meet performance in straight and level flight.	Yes	
4.6.3.1.1	Recommendation for +20/-5 pitch and +/-25 roll.	No	Meeting this requirement would require significantly different antenna systems to be installed on aircraft.
4.6.4	Packet data service performance.	N/A	
4.6.4.1	Requirements on AMS(R)S packet data.	Yes	See subsections.
4.6.4.1.1	Capable of mobile subnetwork in the aeronautical telecommunication network (ATN).	Yes	Part of planned future extension. The terminal supports both background and prioritized Internet Protocol (IP) communication.

AMS(R)S SARPs reference	AMS(R)S SARPs contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.6.4.1.2	Delay parameters.	N/A	
4.6.4.1.2.1	Connection establishment delay <70 seconds.	Yes <70 s	
4.6.4.1.2.1.1	Recommendation. Connection establishment delay <50 seconds.	Yes <50 s	
4.6.4.1.2.2	Transit delay based on subnetwork service data unit (SNSDU) of 128 octets and defined as average values.	Yes	
4.6.4.1.2.3	From aircraft highest priority <40 seconds.	Yes <40 s	
4.6.4.1.2.3.1	Recommendation from aircraft highest priority <23 seconds.	Yes <23 s	
4.6.4.1.2.3.2	Recommendation from aircraft lowest priority <28 seconds.	Yes <28 s	
4.6.4.1.2.4	To aircraft high priority <12 seconds.	Yes <12 s	
4.6.4.1.2.4.1	Recommendation to aircraft lowest priority <28 seconds.	Yes <28 s	
4.6.4.1.2.5	From aircraft data transfer delay 95th percentile highest priority <80 seconds.	Yes <80 s	
4.6.4.1.2.5.1	Recommendation from aircraft data transfer delay 95th percentile highest priority <40 seconds.	Yes <40 s	
4.6.4.1.2.5.2	Recommendation from aircraft data transfer delay 95th percentile lowest priority <60 seconds.	Yes <60 s	
4.6.4.1.2.6	To aircraft data transfer delay 95th percentile high priority <15 seconds.	Yes <15 s	
4.6.4.1.2.6.1	Recommendation to aircraft data transfer delay 95th percentile low priority <30 seconds.	Yes <30 s	
4.6.4.1.2.7	Connection release time 95th percentile <30 seconds.	Yes <30 s	

AMS(R)S SARPs reference	AMS(R)S SARPs contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.6.4.1.2.7.1	Recommendation connection release time 95th percentile <25 seconds.	Yes < 25 s	
4.6.4.1.3	Integrity.	N/A	
4.6.4.1.3.1	Residual error rate (RER) from aircraft 10^{-4}/ subnetwork service data unit (SNSDU).	Yes 10^{-4}	
4.6.4.1.3.1.1	Recommend RER from aircraft 10^{-6}/SNSDU.		The definition of RER in the SARPs is unclear. It is believed that "lost SNSDUs" will exceed these requirements. However, the AES/satellite access stations (SAS) will detect with a probability better than $1 \cdot 10^{-6}$, lost, corrupted or duplicate SNSDUs.
4.6.4.1.3.2	RER to aircraft 10^{-6}/SNSDU.	No	As above.
4.6.4.1.3.3	Probability of sub-network connection (SNC) provider invoked release 10^{-4}/hr.	N/A	
4.6.4.1.3.4	Probability of SNC provider invoked reset 10^{-1}/hr.	Yes 10^{-1}/hr	
4.6.5	Voice service performance.	N/A	
4.6.5.1	Requirements for AMS(R)S voice service.	Yes	
4.6.5.1.1	Call processing delay.	N/A	
4.6.5.1.1.1	AES call origination delay 95th percentile <20 seconds.	Yes <20 s	
4.6.5.1.1.2	Ground Earth station (GES) call origination delay 95th percentile <20 seconds.	Yes <20 s	
4.6.5.1.2	Voice quality.	N/A	

AMS(R)S SARP reference	AMS(R)S SARP contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.6.5.1.2.1	Voice intelligibility suitable for intended operational and ambient noise environment.	Yes	
4.6.5.1.2.2	Total allowable transfer delay within AMS(R)S subnetwork <0.485 second.	No ²⁷ 0.585 second 1 st call 0.750 second 2 nd call	
4.6.5.1.2.3	Recommendation to consider effects of tandem vocoders.	Yes	
4.6.5.1.3	Voice capacity.	N/A	
4.6.5.1.3.1	Sufficient voice traffic channel resources for probability of blockage <0.01 for AES- or GES-originated calls.	Yes <0.01	
4.6.6	Security.	N/A	
4.6.6.1	Protect messages from tampering.	Yes	The service access capabilities include authentication, authorization and security. Standard 3G security mechanisms are employed including ciphering of the air interface. Further, security provisions are set-out in RTCA MASPS DO-343, MOPS DO-262B section 2.2.3.10 and ARINC 781-6 Attachment 8.
4.6.6.2	Protect against denial of service, degradation, or reduction of capacity due to external attacks.	Yes	See comment against 4.6.6.1.
4.6.6.3	Protect against unauthorized entry.	Yes	See comment against 4.6.6.1.
4.7	System Interfaces.	N/A	
4.7.1	Address AMS(R)S by means of ICAO 24-bit address.	Yes	
4.7.2	Packet data service interfaces.	N/A	

²⁷ Although the system is non-compliant to the ICAO SARP requirement, it is believed the system is fit for purpose. It is further noted that Classic Aero has been measured as achieving 0.59 s for the 4.8 kbps codec. The ICAO SARP requirement is for the "subnetwork" while this specification includes the ground network, although the latter is not expected to add a significant delay.

AMS(R)S SARPs reference	AMS(R)S SARPs contents	SwiftBroadband (SBB) Subnetwork value	Additional comments on performance
4.7.2.1	If the system provides packet data service, it shall provide an interface to the ATN.	Yes	Part of planned future extension.
4.7.2.2	If the system provides packet data service, it shall provide a core network function.	Yes	By design.

Chapter 4

GUIDANCE FOR ANSPs AND AIRCRAFT OPERATORS

4.1 GENERAL

4.1.1 This section provides guidance to air navigation services providers (ANSPs) and aircraft operators for the use of SwiftBroadband (SBB).

4.2 GUIDANCE FOR ANSPs

4.2.1 In order to ensure communications with SBB-capable aircraft for air traffic control (ATC) purposes, ANSPs should:

- a) secure a contract with one or more communications network providers (CNPs) to enable voice and data communication with aircrew via SBB, considering whether, to achieve operational aims, service level agreements (SLAs) are required with each CNP (potential SLA metrics may be found in the annexes of Doc 9869 [see 1.2, ref. 4]) (for further details of internetworking for ANSP connection to one or more CNP(s), see RTCA SBB MASPS [see 1.2, ref. 2], Attachment 1 Inmarsat SwiftBroadband Specific Material, Section 1.3);
- b) determine if they intend to conduct ground-to-air dialling to aircrew in SBB-capable aircraft and ensure access to a suitable secure dialling system via SBB service providers, considering whether they need a tail number to an ICAO address mapping system;
- c) review operational ATC procedures for communicating with aircrew via SBB satcom — if the ANSP already has contract(s) in place with CNP(s) to support ATC communication with aircrew via Classic Aero satcom, these procedures are likely to remain unchanged;
- d) consider the long term aim of using the aircraft address field in the flight plan (FPL) which is hexadecimal, and convert this address into the octal number required to dial the aircraft via the two-stage secure dialler or equivalent;
- e) require operators to file the aircraft address under Item 18 of the FPL following “CODE/”;
- f) monitor the initial usage of the service with a view to approving its use by aircraft in its airspace based on satisfactory performance according to the minimum communications and surveillance performance parameters set out in the annexes of Doc 9869 [see 1.2, ref. 4]; and
- g) carry out post-implementation monitoring to continue the measurement of SBB communications and surveillance performance as per Doc 9869 [see 1.2, ref. 4].

4.3 GUIDANCE FOR AIRCRAFT OPERATORS

- 4.3.1 In order to use SBB to provide cockpit data and voice safety services, aircraft operators should:
- a) ensure that the designated operational coverage area provided by the SBB service is appropriate for the flight routes used by the airline, and that SBB is approved for use in the flight information regions (FIRs) traversed on such routes;
 - b) purchase SBB aircraft terminal(s) that are certified to support the ACARS, cockpit voice and prioritized IP services on the specified airframe or purchase upgrades to existing terminals for which upgrade kits are available from the terminal manufacturer;
 - c) ensure that SBB aircraft terminal(s) are appropriately configured by checking with the SBB terminal manufacturer;
 - d) contract with a service provider who is able to provide the SBB cockpit safety services on a commercial basis to airlines;
 - e) ensure that SBB aircraft terminal(s) are appropriately activated with Inmarsat for the services that the aircraft operator wishes to use on the terminal;
 - f) ensure that they file the aircraft address under Item 18 of the FPL following "CODE/";
 - g) inform Inmarsat of a point of contact within the organization who can receive regular updates to Inmarsat air-ground short codes for voice dialling of ATS centres; and
 - h) report any service performance issues to the problem-reporting agencies, such as the North Atlantic Data Link Monitoring Agency (DLMA) and the Informal South Pacific ATC Coordinating Group (ISPACG), Central Reporting Agency (CRA) (see Doc 9869 [see 1.2, ref. 4] for further details). Also participate in problem investigations (e.g. authorize the release of data, etc.) and correct any problems when a solution is found that affects their operation (e.g. an upgrade to the flight management system (FMS) or reconfiguring an owner requirements table (ORT).

— END —

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