Implementation Manual for Iridium Satellite Communications Service

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3. Introduction

3.1 Objective and Scope

The objective of this manual is to provide information and guidance related to the implementation of the Iridium Satellite communication system for air-ground ATS radio-telephony and data communications.

4. Theory of Operations

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

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

- Iridium network
- Iridium based Avionics (SDU)
- Iridium ground based Data Server

The end to end voice service is shown in Figure 4-1, Iridium Aviation Safety Services Air to Ground -Voice, End-to-End Model. This model also applies to ground to air voice service.

FIGURE 4-1

Iridium Aviation Safety Services Air to Ground-Voice End-to-End Model

The end to end voice service is shown in Figure 4-2, Iridium Aviation Safety Services Air to Air -Voice, End-to-End Model.

FIGURE 4-2

Iridium Aviation Safety Services Air to Air-Voice
End-to-End Model

The end to end voice service is shown in Figure 4-3, Iridium Aviation Safety Services Air to Ground -Data, End-to-End Model. This model also applies to ground to air data service.

FIGURE 4-3

Iridium Aviation Safety Services Air to Ground-Data
End-to-End Model

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

FIGURE 4-4

Iridium Aviation Safety Services Air to Air-Data End-to-End Model

4.1 Iridium network

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 Public Switched Telephone Network (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 has a valid handset (or LBT) and SIM card to place or receive calls.

Short Burst Data (SBD/ESS) Service – A packet bearer capability (non-GSM) that provides an non-circuit switched, high-capacity ACK'ed means of transmitting and receiving packets of data (up to 1960 bytes) to/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 WWW by encapsulating the transmitted data in TCP/IP. It provides nothing more than a pipe by which to transmit customer data.

The Iridium network consists of four segments:

1. Space Segment
2. System Control Segment
3. Gateway Segment
4. Subscriber Segment

4.1.1 Space Segment

The space segment consists of a satellite constellation made up of at least 66 Space Vehicles (SVs) orbiting the earth in six low earth orbital planes through the earth's polar axis, as shown in Figure 4-5, Iridium Satellite Constellation. The SVs form a giant packet network which passes

all Iridium based traffic.

Iridium Satellite Constellation

FIGURE 4-5

The SVs are equally distributed among the six orbital planes. In each plane, 11 SVs are Mission SVs. There are also a number of in-orbit spares that can be maneuvered into position should a Mission SV fail or expire. All of the planes are all polar orbits at a height of approximately 420 nautical miles with each plane at a slightly different height to avoid SV collisions at the poles.

Each SV has an orbital period of approximately 100 minutes and an average velocity of 16557 MPH. Orbital plane spacing is 31.6 degrees for the normal planes and 22.1 degrees for the counter rotating seam. In plane spacing between SVs is 32.7 degrees.

The space vehicles (aka satellites or SV) provide the communication links between the aircraft, and between aircraft and gateways during an established call. The SVs also provide communications between gateways during call processing and call maintenance.

Communication links also exist between the SVs and the SCS for managing the constellation.

L-Band (1610 to 1626.5 MHz) radio links provide the physical connections between Iridium Subscriber equipment, or aircraft satcom data unit (SDU) and SVs.

A frequency re-use plan allows radio frequencies to be re-used among beams.

Three Main Mission Antennas (MMA) provide communication links between the aircraft SDU and the SV. Each MMA projects a pattern of 16 beams to the ground, giving a total of 48 beams per SV. These beams create overlapping cells on the ground as shown in Figure 4-6, SV Footprint (Beams), where: MMA1 produces beams 1 to 16, MMA2 beams 17-32, and MMA3 beams 33 – 48.

SV Footprint (Beams)

FIGURE 4-6

4.1.2 System Control Segment

The system control segment (SCS) is the central management function in the Iridium network. It provides global operation, support, and control services for the SV constellation, delivers SV tracking data to gateways, and performs the termination control function of messaging use a Message Termination Center (MTC).

The SCS comprises three main components: Telemetry tracking and control sites (TTAC), Control Facilities (CF), and Operational Support Network (OSN).

4.1.3 Gateway Segment

The Iridium gateway provides a number of roles.

1) Setup and maintain basic telephony services. The gateway provides the interface for communication between Iridium subscribers and between Iridium subscribers and PSTN/leased line users world-wide.
2) Provide messaging and data services (including Direct Internet, RUDICS, dial-up data and Short Burst Data (SBD).
3) Interface to the PSTN, or leased lines
4) Interface to the Constellation
5) Gateway functions.
6) Messaging processing and services
7) Management and billing functions.

The gateway is split into two functional areas:

1) The gateway management System (GMS)
2) The gateway operational elements

The gateway is comprised of the following network elements:

1) GSM switch (SSS)
2) Earth Terminals (ET)
3) ETC Transmission Subsystem (ETS)
4) ETC Communications Subsystem (ECS)
5) Message Origination Center (MOC)
6) Notification Center (NC)
7) Web and Email messaging server (WEMS)
8) RUDICS
9) ETC Short Burst Data Subsystem (ESS)

Figure 4-7, Iridium gateway Diagram, shows the gateway elements and their connectivity.

Iridium Gateway Diagram

FIGURE 4-7

4.1.4 Subscriber Segment (Avionics)

Iridium has developed an ISU, L-band transceiver (LBT), for use by avionics manufacturers. Iridium has established processes to control design and manufacturing, established test procedures for all transceiver design and manufacturing elements, and established change control processes for software development and releases. All ISU's go through this standardized factory test procedures before being released for shipment. All ISU software revisions are tested prior to release.

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

RTCA has developed minimum operations performance standards, RTCA DO-262, for aircraft avionics systems supporting next generation satellite systems. Compliance of aircraft earth station, which includes the SDU and antenna, with this standard should insure 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.

4.1.4.1 Iridium Identifiers

Iridium subscribers may be distinguished by several identifiers. Each user is assigned an Iridium network subscriber identifier (INSI) which is a permanent number stored on the user's SIM card and in the HLR. To maintain subscriber confidentiality, the INSI 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 ISDN Number (MSISDN) is the Iridium subscriber's phone number. The International Mobile Equipment Identifier (IMEI) is a permanent identifier assigned to each ISU, not to the Iridium subscriber (SIM card).

4.2 Iridium based Avionics (SDU)

The avionics required to support the Iridium network consist of a satcom data unit (SDU) and antenna(s). The SDU consist of the Iridium LBT and the I/O processing to properly interface with the existing aircraft voice and/or data communications systems.

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

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 (ICD), developed jointly between the avionics manufacturer and the ground based data server host/developer.

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

4.3 Iridium Ground Based Data Server

The ground based data server serves as the conduit and traffic controller for the data communications between the aircraft SDU and the aviation centric networks (e.g., ARINC and SITA networks), and/or leased lines to air traffic service 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 data services SBD and RUDICS support both character and bit oriented communications protocols which are used by ACARS which currently utilizes character oriented protocols with plans to migrate to bit oriented protocol. ATN utilizes bit oriented protocols only which can be supported by Iridium data services.

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

5. Services Supported

The Iridium network carries voice and data traffic to and from Iridium subscriber equipped aircraft across the world or to a public switched telephone network (or directly through leased lines). Only validated aircraft SDU's are allowed to use the system.

5.1 Voice Service

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).

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.

An 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

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)

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

Key elements of call handling, shown in Figure 5-1, are identical for all calls. These elements are:

1) Acquiring a traffic channel on a SV (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:

3) Geolocation - Call processing location determination

4) Aircraft SDU Parameter Download

5) Registration/Location update

6) Authentication of SDU's SIM including TMSI assignment (Authentication)

7) Call Establishment is the processes of setting up a call which include:

- 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)

8) Call Maintenance is the process of maintaining a connection which include Handoff, Reconfiguration (cut through/intercept/grounding).

9) Call Release

Call Handling Elements

FIGURE 5-1

5.1.1.1 Acquisition

Acquisition is the process of the SDU obtaining a bidirectional communications channel, called a Traffic Channel, between the SDU and a Space Vehicle (SV). 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

or MCDU responding to a Ring Alert that ultimately notifies the cockpit of an incoming call.

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

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). This feature is not currently in operation. It requires a software upload to the SV's to implement.

The subscriber equipment reads the Acquisition Class from the SIM card that was programmed when it is initially provisioned. The system provides the capability to control a user's acquisition to the system based o 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)

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 satcom data unit proceeds with Acquisition.

Acquisition

Figure 5-2

Acquisition consists of establishing a link between the SDU and the SV and acquisition control, as shown in Figure 5-2, above.

5.1.1.2 Access

The Access process determines the SDU's location with respect to Service Control Areas defined in Earth Fixed Coordinates. Based on the Service Control Area 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 5-3 below, is initiated immediately following Acquisition.

ACCESS

FIGURE 5-3

Location information may be reported by the SDU based on an external source such as Global Positioning System (GPS) 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 (CPLD) to provide an estimate of the user's location. The systems accuracy in determining location depends upon the relative geometry of the aircraft and SV constellation, accuracy of measurements made by the aircraft, accuracy of measurements made by the SV, and algorithm calculations.

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.

After the location is determined, the Access approval-denial process starts when the SDU sends the" Access Request" through the SV and to the gateway. Based on the calculated geographic location of the user, the gateway checks the user's current Service Control Area (SCA) against the user's service provider I.D. 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 SV path information to the SDU.

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

5.1.1.3 Call Establishment

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 it's 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.

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 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.

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

After a speech path has been created via the SV, 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

Upon the called party answering the call, the gateway informs the SDU that the called party has answered the call and the ring tone is disabled.

5.1.1.4 Call Maintenance

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 SVs orbit overhead, the network passes the traffic channel from SV to SV, a process referred to

as handoff.

The Iridium network SVs have highly directional antennas providing Iridium network access to aircraft SDU's. 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 SV 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 SVs as they move relative to the aircraft (Inter-SV).
2) An aircraft SDU must be handed off between beams on an SV as beam patterns move relative to the aircraft (Intra-SV).
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).

5.1.1.5 Call Release

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.

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

5.1.2 Data Link

The Iridium network supports two type of data service for aviation safety service, short burst data (SBD) and router UDI connectivity service (RUDICS). The 9522A LBT fully supports the use of both of these services. The 9601 LBT (modem) supports SBD only, with a few minor differences. Use of either type of data exchanges shall be seamless to the end-user.

5.1.2.1 SBD

Iridium's Short Burst Data Service (SBD) 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 (MO), which can be referred to as aircraft originated, SBD message can be between 1 and 1960 bytes (205 bytes maximum for a 9601 LBT). A Mobile Terminated (MT), which can be referred to as aircraft bound, SBD message can be between 1 and 1890 bytes (135 bytes maximum for a 9601 LBT).

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 ISU using the +SBDWB or +SBDWT AT Commands
- A message transfer session between the ISU and the gateway is initiated using the AT

Command +SBDI

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

- The ISU 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 ISU by the Field Application using the +SBDRB or +SBDRT AT Commands.

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.

The primary elements of the end to end SBD architecture are shown in Figure 5-9, below. Specifically, the elements consist of the satellite data unit (SDU) Field Application (FA), the Iridium network, and the Vendor Application (VA).

SBD Architecture

FIGURE 5-9

The Field Application represents the hardware and software that is defined by the avionics manufacturer which in 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 L-Band Transceiver (LBT) with the SBD feature available in firmware, aircraft communication interfaces, and memory and processor logic.

The interface between the Vendor Application and the Iridium network gateway uses standard Internet protocols to send and receive messages.

5.1.2.2 RUDICS

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.

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 application or customer's request. The customer must be properly provisioned in both the SSS and the RUDICS ACS (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).

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)

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.

The primary elements of the end to end RUDICS architecture are shown in the Figure 5-10, below. 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.

RUDICS Architecture

FIGURE 5-10

The standard sequence of events for a mobile originated call:

1. Mobile application places 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.

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.

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 be by a variety of methods, including Internet, Virtual Private Network and Leased Line. Aviation safety services may only utilize approved VPN connectivity and leased lines, in a redundant fashion.

6. Operations

6.1 Connectivity

The 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.

6.2 Calling Characteristics

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 msec. This number may vary due to end-user PBX's and end-user's telecommunication company connection/configurations

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

6.3 Security

All physical properties within Iridium Satellite are maintained in a secure fashion with extra secure measures, locked passages with access on an as-needed" basis, deployed at the gateway, Satellite network operations center and technical support center.

In addition, the following security measured have been taken to assure secure network services

- Handling of Miss-directed Calls and Protection of GTA Communications
  Consist 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 a 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 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.
- Denial of Service due to other business rules is supported during the Access, Registration and Authentication processes. These rules can be made available to the proper authorities, on an "as needed" basis.

6.4 Quality of Service Measurement

Service quality is measured through the use of 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 well the recording of properly terminated calls.

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 to place calls through the system and records the results. Each day, each Auto-dialer attempts over 1440 calls, 365 days a year, which has continued since 1998 which equates to 525,600 calls per auto-dialer per year, or well over 10 millions calls attempted each year using the 25 auto-dialers.

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

6.5 System Outages and Maintenance

Iridium has in place processes and procedures set up to minimize the impact of an outage and to minimize the impact of a 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.

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

The aviation safety services SP is the initial contact point for service issues. Iridium has processes in place to handle service issues when the SP's cannot resolve the issue.

6.5.1 Planned Outages

Iridium has established a permanently scheduled maintenance window [Window] for the facilities at the gateway in Tempe, AZ every Wednesday between 15:00 and 19:00 MST. [22:00 GMT Wednesday to 02:00 GMT Thursday.]

If Iridium intends to utilize the Window, Iridium will endeavor to send an email notification to Iridium SPs by close of business MST on the Tuesday immediately prior to the Window. A corresponding email notification will be sent once the maintenance has been completed.

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 safety service SPs are required to coordinate maintenance activities to coincide with Iridium's maintenance window and to provide notification to end-users.

6.5.2 Unplanned Outages

In the event of an unplanned outage affecting service, Iridium will issue an email notification to SPs within 30 seconds of 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

6.5.3 Notifications

Notifications will be provided to the SPs. Iridium does not currently supply notifications to third parties.

Figure 6-2, Planned Maintenance Notification, is an example of a planned maintenance notification.

From: tier 2 support
Sent: Wednesday, January 18, 2006 11:07 AM
To: tier 2 support
Cc: Global Alliance Manager; Iridium Support Center; BD Channel Lead Mgmt; Data Support
Subject: System Advisory - Maintenance

Importance: High

Service Impact: SPNet and Prepaid Platform Activations/Modifications

Begin Date: January 19th, 2006
Begin Time: 00:00 (GMT)

End Date: January 19th, 2006
End Time: 04:00 (GMT)

Comments: We will be performing a system maintenance during the above timeframe. SP's will not have the ability to access SPNet during this maintenance period. Due to SPNet being unavailable, provisioning new accounts in the Prepaid Platform will not be possible.

There will be no advisory update sent when the maintenance is completed.

We apologize for any inconvenience this may cause. Should you have any questions, please contact us at 1.480.752.5100.

Thank you,

Tier 2 Support
Iridium Satellite, LLC.
8440 South River Parkway
Tempe, AZ 85284
(480) 752-5100

Planned Maintenance Notification

Figure 6-1

Figure 6-2, Service Outage and Restoration Notification**,** is an example of a service disruption message. These types of messages provide the start and end times of the outage and type of service affected.

From: Data Support
Sent: Tuesday, December 20, 2005 3:28 PM
To: Data Support
Cc: Global Alliance Manager; Iridium Support Center; BD_Channel_Lead Mgmt;

Subject: SBD Advisory

Importance: High

Service Impact: Short Burst Data

Begin Date: December 20, 2005
Begin Time: 20:46 (GMT)

End Date: December 20, 2005
End Time: 21:28 (GMT)

Comments: SBD was down during the above timeframe. Service has now been restored.

We apologize for any inconvenience this may have caused. Should you have any questions, please contact us at 1.480.752.5100.

Thank you,

Data Support
Iridium Satellite, LLC.
8440 South River Parkway
Tempe, AZ 85284
(480) 752-5100

Service Outage and Restoration Notification

Figure 6-2

Figure 6-3, Unplanned Outage Notification**,** is an example of an unplanned outage notification.

From: Data Support
Sent: Tuesday, December 20, 2005 4:42 PM
To: Data Support
Cc: Global Alliance Manager; Iridium Support Center; BD_Channel_Lead Mgmt;

Subject: SBD Advisory

Importance: High

Service Impact: Short Burst Data (Mobile Originated and Terminated)

Begin Date: December 20 2005
Begin Time: 22:26 (GMT)

End Date: December 20 2005
End Time: TBD (GMT)

Comments: SBD is currently unavailable. We will advise you once the service is restored.

We apologize for any inconvenience this may cause. Should you have any questions, please contact us at 1.480.752.5100.

Thank you,

Data Support
Iridium Satellite, LLC.
8440 South River Parkway
Tempe, AZ 85284
(480) 752-5100

Unplanned Outage Notification

Figure 6-3

Figure 6-4, Service Restoration Notification**,** is an example of a service restoration notification.

From: Data Support
Sent: Tuesday, December 20, 2005 6:11 PM
To: Data Support
Cc: Global Alliance Manager; Iridium Support Center; BD_Channel_Lead Mgmt;

Subject: SBD Advisory

Importance: High

Service Impact: Short Burst Data

Begin Date: December 20, 2005
Begin Time: 20:46 (GMT)

End Date: December 20, 2005
End Time: 23:55 (GMT)

Comments: SBD Mobile Originated and Mobile Terminated has been restored. Any Messages that have not been delivered or received as of the restore time will need to be resent.

We apologize for any inconvenience this may cause. Should you have any questions, please contact us at 1.480.752.5100.

Thank you,

Data Support
Iridium Satellite, LLC.
8440 South River Parkway
Tempe, AZ 85284
(480) 752-5100

Service Restoration Notification

Figure 6-4

7. Avionics

The Iridium based avionics are based on the Iridium supplied LBT, one voice/data channel for each LBT, as shown in Figure 7-1, Two Channel Avionics Block Diagram. The LBT provides, as a minimum, the following:

- Seamless, low latency link with the Iridium network
- Vocoder, to insure a consistent quality
- Data linkage with the SBD and RUDICS processors at the gateway to ease integration and insure 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 Preemption (PPP) 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

Two Channel Avionics Block Diagram

FIGURE 7-1

All avionics shall be tested and approved by the aviation safety services 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 safety services SP are provided with the safety services SIM card.

7.1 Requirements Definition

All avionics are subject to the airworthiness regulations that apply to the aircraft to which the avionics are to be installed. Adherence to these civil aviation regulations for aircraft system installation(s) are 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 (TC), for a new aircraft, or a Supplemental Type Certificate (STC) for modification of an aircraft.

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

7.2 Aircraft Installation

RTCA DO-160, Environmental Conditions and Test Procedures for Airborne Equipment provides guidelines on aircraft radio rack, or equivalent rack, for qualified installation.

7.2.1 Aircraft Antenna Mounting

The Iridium antenna(s) shall be installed on top of the aircraft, as close to aircraft centerline, as possible, with sufficient physical separation between the Iridium antenna and all communication, navigation and surveillance systems 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 installed Inmarsat system antenna(s). It is recommended that a site survey of the aircraft should be conducted prior to installation to insure that the Iridium equipment will operate properly in coexistence with the Inmarsat system. 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 insure interoperability with all other communication, navigation and surveillance systems to insure the Iridium network installation provides adequate electromagnetic compatibility for safety of flight (EMC/SOF).

8. Aviation Safety Services SP

Iridium aviation safety services SP shall provide the ground connectivity between the Iridium network and the aviation centric network, which connects with air traffic service providers, air transport operations and flight departments. In addition to connectivity to these networks, the SP a number of service providers and value-added resellers to provide the services that extend beyond the Iridium network. Each SP approves certain avionics based on their documented communications protocol. These avionics may not be interchangeable amongst the SP's.

The aviation safety services SP's shall provide, as a minimum:

- Technical support
- Customer Care
- Product Support

9. Operational Concepts

This section describes the AOC and ATS communications services that are expected to be made available by the use of Iridium communications in oceanic, remote and polar regions and as a supplemental communications link in continental airspace. It is not envisioned that Iridium will replace current VHF radios as the main voice and data communications system on the aircraft, but provide coverage in areas that do not have adequate aeronautical communications. Integrated with ACARS and other avionics system, Iridium can provide data services that are currently used in other covered regions with little or no flight crew action required. There are a number of different methods for implementing some of the technical aspects of the Iridium system, and this description is provided only as a means to explain some of the high level aspects of the use of Iridium communications.

9.1 AOC OPERATIONAL CONCEPT

Iridium communications provides the medium for the exchange of safety information for AOC and ATC information in the oceanic, remote and polar regions (ORP). Routine long-range AOC communication involves elements of international travel and increasing use of twin-engine aircraft in an extended twin-engine operations (ETOPS) environment. Iridium communications provides AOC voice and data communications that the operator needs to deal with routine, urgency and emergency situations efficiently.

9.1.1 Flight crew need for Iridium for AOC communications

The need for long-range data exchange varies widely by air operator. Iridium extends to remote and polar regions the flight crew's timely access to the air operator's flight-following personnel for flight position, schedule tracking and fuel burn projections. In addition to voice communications, Iridium extends the ability of the flight crew to request automatic terminal information service (D-ATIS, or D-OTIS) and weather information (D-SIGMET) and NOTAMs for alternate and destination airports from the airline host computer and an increasing number of airports while in regions where data was once not available or significant gaps existed. ACARS via Iridium allows the exchange of fixed-format messages or free-text messages between flight crew, dispatchers, and maintenance personnel. An integrated system design provides a transparent selection of media, including Iridium, with minimal flight crew actions.

9.1.2 Other operator needs for Iridium communications

The deployment of Iridium extends aircraft information for other operational users other than flight crew use. Air operators will now be able to send automatic position reports, weather reports, and real-time aircraft and engine performance data while operating in remote regions. These messages are rather long (over 100 characters) and are sent frequently during the en-route phase of the flight. Infrequent but important reports are needed during en-route flight phases, such as when an engine or APU exceeds a normal operation or is shut down. Ground maintenance personnel may use this service to poll certain engine functions on demand.

9.2 ATS OPERATIONAL CONCEPT

In order to be considered a fully operational data link medium for support of a particular ATS service, the system will have to demonstrate it can meet the qualification criteria.

As Iridium is new to the aviation community and certain aspects of the above criteria will require some time for qualification, an incremental approach to the utilization of Iridium communications for

ATS is considered to be the most effective. It is foreseen that trials of several ATS applications will be conducted, using ATS applications with corresponding incremental progression of benefits to the users. Eventually the performance, availability and integrity parameters of which Iridium communications is capable will be determined through analysis, simulation and testing, and Iridium communications will be deemed an acceptable communications medium, either solely or in conjunction with other communications media, of ATS data link communications operation.

9.3 Supplemental communications for remote ground locations or Air Traffic Services SP's

There are some terrestrial based communications services that have been extended to remote locations via the use of leased telecommunications lines. In some these solutions, redundant lines are either not available, or would be routed to the location along the same path. In order to mitigate the lack of a back up leased line, or routing of the line along the same path, an Iridium land based communication system could be used to provide back up communications service.

Iridium has a number of ground based communications system manufactured by various equipment manufacturers which can be provided for remote service, either as a temporary solution or a more permanent basis. These systems can be equipped with the special aviation safety services SIM card to provide the higher aviation safety services priority, pre-emption and precedence capabilities.

Where leased telecommunications lines are not available, the Iridium ground based system could provide the primary circuit mode channel(s).

10. Process for Implementing Future Services

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

Iridium will annually publish 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-user, including air traffic service providers.

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

11. Avionics-Ground Based Processor Harmonization Document (Integration Control Documents)

The Iridium aviation safety services SP shall be responsible for defining and documenting the harmonization between the avionics (SDU) with the ground based server. The SP shall publish a harmonization document (also referred to as an interface control document) which establishes the interworking of the SDU to insure the SDU will be able to properly communicate with the ground based server.

The ground based server provides the link between the Iridium network (gateway) and the aviation networks (e.g., ARINC and SITA). The aviation networks provide connectivity to the end-user system (e.g., air transport system), air traffic service SP's, civil aviation applications, and other value added application servers. Figure 11-1, Datalink over Iridium illustrates the interconnectivity of the ground based server.

Figure 11-1

Datalink over Iridium