DEFENCE R&D DÉFENSE

Evaluation of Iridium Paging Services For Military Applications

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Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
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ABSTRACT

Iridium is the first satellite-based personal communications system offering global service via an interconnected constellation of low earth orbit (LEO) satellites communicating directly with handheld terminals. The total constellation of satellites was launched over a 12-month period ending May 1998. Voice service commenced in November 1998 followed by paging services in March 1999. This technical memorandum describes an evaluation of the Iridium paging service carried out by the Military Satellite Communications (MSC) Group at Defence Research Establishment Ottawa (DREO) during the period March to June 1999. Paging tests were performed under two principle scenarios: stationary and inflight paging. Performance parameters observed include delivery time and message error performance.

RÉSUMÉ

Le système Iridium est le premier système de communication personnelle par satellite offrant un service global. Le système consiste en une constellation de satellites interconnectés en basse orbite terrestre et qui fonctionne directement avec les terminaux portatifs. Tous les satellites ont été lancés sur une période de 12 mois se terminant en mai 1998. Le service de voix a commencé en novembre 1998, suivé du service de radio-messagerie en mars 1999. Ce document décrit une évaluation du service de radio-messagerie effectuée par le groupe de Communications par Satellite Militaire au Centre de Recherche pour la Défense à Ottawa (CRDO) qui a eu lieu entre mars et juin 1999. Les tests de radio-messagerie ont été exècutés selon deux scénarios généraux: à poste fixe et mobile. Les caractéristiques de rendement observées ont inclus le delai écoulé et les erreurs d'exècution.

EXECUTIVE SUMMARY

Satellite-based personal communications systems were developed to overcome distance limitations of terrestrial-based systems and offer global connectivity to the user. Iridium is the first system offering global satellite-based personal communications via an interconnected constellation of low earth orbit (LEO) satellites communicating directly with handheld terminals.

The Military Satellite Communications (MSC) Group at Defence Research Establishment Ottawa (DREO) purchased three satellite phones and pagers. Since March 1999, the MSC group has been carrying out tests to evaluate both the phone and messaging services. Service reliability and voice quality are key characteristics of interest. For messaging, efficiency of delivery and error performance were key parameters. This Technical Memorandum focuses on the paging service evaluation.

The Iridium paging service allows up to 120 characters to be transmitted. There are four ways of sending messages to the pager. The first method is by directly dialing the pager number and leaving a numeric (using a touch-tone phone) or voice message. The second method is similar to the first, however, one calls the Iridium message centre to leave a numeric or voice message. The third method is a messaging service available through the Iridium website. The fourth method for sending a message to the pager is via email. The email address for the pager is *<pager_number>*@iridium.com.

In order to receive messages, the location of the pager is specified by the Message Delivery Areas (MDA) set by the user. MDAs are geographical areas defined by Iridium and correspond to local, regional and national boundaries. A maximum of 3 MDAs may be set concurrently for a pager. If a phone and pager are bundled and are located together, a pager MDA may be automatically set by turning the phone on and registering on the Iridium system.

There are two scenarios for which the paging service has been evaluated. The first scenario consists of a paging remaining in one location within one MDA. The second scenario consists of inflight paging tests where the pager is mobile. The stationary paging tests were carried out on an opportunity basis whereas the inflight tests were conducted during seven separate flights.

The procedure for testing the Iridium paging service consists of sending pages to a pager using the different methods described above. Messages sent to the pager include the time at which they are sent. The time reference used for the evaluation is the National Research Council (NRC) clock. The clock on the pager is also synchronized to the NRC clock to provide a simple means of measuring message delivery time or latency. The issues to be considered include the time it takes for the message to be received by the pager, errors in the received message, messages not delivered, effects of transmitting messages greater than 120 characters, effects of pager location on reception of messages, and effects of MDA boundaries.

A total of 111 stationary pages were transmitted. In general, delivery times ranged from less than a minute to 35 minutes, with an average of 5-7 minutes. The delivery times observed were irrespective of transmit method. A total of 74 pages were transmitted during inflight tests. Of those, 30 were transmitted while the pager was onboard the aircraft and "in flight". In this case, an average delivery time of 3 minutes was observed. A number of pages were either not received or were receive in error. Those received in error consisted of one or two characters missing or incorrect and did not impact on intelligibility of the message greatly.

Other observations noted during the trials include notification of missed messages occurring 30 minutes after an out-of-sequence message is received. The location of the pager was observed to affect the ability to receive messages on the pager. For the inflight tests, the pager had to be situated close to the window to consistently receive messages on the pager. The results of the inflight paging tests are consistent with those obtained by the service provider, Infosat Telecommunications Inc., who conducted paging tests in various locations in a building to examine the performance of the pager.

With the relatively short delivery times and successful reception of messages observed during the trials, the Iridium paging service would be suitable for military application. As the pager is a receive-only device, short messages would still be delivered without worrying about security concerns over emissions which may compromise the recipient's position. However, one disadvantage for military use may be the 120-character limit on message length.

Future work on evaluating the paging service includes testing the "Follow-me" paging capability in terms of selecting whether text messages are delivered to the phone, pager, or both. Other work may include further investigation of the MDA boundaries and their effects on the ability to receive messages.

Tom, C., Wagner, L.C., Evaluation of Iridium Paging Services for Military Applications, Defence Research Establishment Ottawa, DREO TM 1999-087. August 1999.

SOMMAIRE

Les systèmes de communications personnelles par satellite ont été conçus pour dépasser les limites de portée des systèmes de Terre et pour offrir une connectivité universelle aux utilisateurs. Iridium est le premier système qui permet d'établir des communications personnelles par satellite partout dans le monde grâce à une constellation de satellites sur orbite terrestre basse interconnectés qui communiquent directement avec des terminaux à main.

Le Groupe des télécommunications militaires par satellite (MSC) du Centre de recherches pour la Défense Ottawa (CRDO) a acheté trois téléphones et trois récepteurs de téléappel pour le service par satellite. Depuis mars 1999, le Groupe MSC effectue des essais pour évaluer le service téléphonique et le service de messagerie. La fiabilité du service et la qualité des communications vocales sont les principaux éléments à l'étude. En ce qui a trait à la messagerie, l'efficacité de la remise des messages et les erreurs étaient les paramètres clés. La présente note technique porte principalement sur l'évaluation du service de téléappel.

Le service de téléappel d'Iridium permet la transmission d'un maximum de 120 caractères. Quatre méthodes peuvent être utilisées pour envoyer des messages au récepteur de téléappel. La première méthode consiste à composer directement le numéro du récepteur de téléappel et à laisser un message en format numérique (à l'aide d'un téléphone à clavier) ou un message vocal. La deuxième méthode est semblable à la première, sauf que l'utilisateur appelle le centre de messagerie d'Iridium pour laisser un message en format numérique ou un message vocal. La troisième méthode consiste à passer par le service de messagerie offert sur le site Web d'Iridium. La quatrième méthode consiste à transmettre le message par courrier électronique. L'adresse électronique du récepteur de téléappel est *<numéro du récepteur>*@iridium.com.

Pour que le récepteur de téléappel puisse recevoir des messages, son emplacement doit être spécifié par les paramètres de zone de remise de message (MDA), qui sont réglés par l'utilisateur. Ces zones sont des régions géographiques définies par Iridium, qui correspondent aux frontières locales, régionales et nationales. Un maximum de 3 zones peuvent être définies concurremment pour un récepteur. Si un téléphone et un récepteur de téléappel sont regroupés et sont situés au même emplacement, la zone de remise de message du récepteur de téléappel peut être automatiquement réglée en mettant le téléphone sous tension et en l'enregistrant auprès du système Iridium.

Deux scénarios d'utilisation du récepteur de téléappel ont été évalués. Le premier consiste à transmettre des messages à un récepteur de téléappel situé dans un emplacement fixe à l'intérieur d'une zone de remise de messages. Le second consiste à effectuer des essais en vol, pendant que le récepteur de téléappel se déplace. Les essais de téléappel avec un récepteur fixe ont été réalisés lorsque l'occasion se présentait tandis que les essais en vol ont été réalisés durant sept vols distincts.

La procédure de mise à l'essai du service de téléappel d'Iridium consiste à envoyer des messages à un récepteur de téléappel en utilisant les différentes méthodes décrites ci-dessus. Les messages envoyés au récepteur contiennent l'heure à laquelle ils sont envoyés. L'heure de

l'horloge du Centre national de recherches du Canada (CNRC) a été utilisée comme référence temporelle pour l'évaluation. L'horloge du récepteur de téléappel a également été synchronisée à cette heure afin de fournir un moyen simple de mesurer le délai de remise des messages ou le temps d'attente. Les facteurs à prendre en considération comprennent le délai de réception du message, les erreurs contenues dans le message reçu, la non-livraison des messages, les effets de la transmission de messages dépassant 120 caractères, les effets de l'emplacement du récepteur et les effets des frontières des zones de remise de messages.

Au total, 111 messages ont été transmis au récepteur fixe. En général, le délai de remise du message se situait entre moins d'une minute et 35 minutes; la moyenne étant entre 5 et 7 minutes. Aucune corrélation n'a été observée entre les délais de remise et la méthode de transmission utilisée. Au total, 74 messages ont été envoyés durant les essais en vol. Trente de ces messages ont été envoyés pendant que le récepteur était à bord de l'aéronef et en vol. Dans ce dernier cas, le délai moyen de remise des messages observé était de 3 minutes. Un certain nombre de messages n'ont pas été reçus ou contenaient des erreurs. Ces derniers comportaient un ou deux caractères manquants ou erronés; ce qui n'a pas nuit grandement à l'intelligibilité des messages.

Parmi les autres observations notées au cours des essais, on a constaté que la notification de non-remise des messages se produisait 30 minutes après la réception d'un message hors séquence. On a remarqué que l'emplacement du récepteur de téléappel avait une incidence sur sa capacité de réception des messages. Pour les essais en vol, le récepteur devait être placé près de la fenêtre pour que tous les messages soient reçus. Les résultats des essais de réception des messages en vol sont conformes à ceux obtenus par le fournisseur de services, Infosat Telecommunications Inc., qui a réalisé des essais de téléappel à divers endroits dans un immeuble pour évaluer la performance du récepteur de téléappel.

Compte tenu des délais de remise des messages relativement courts et du succès dans la réception des messages au cours des essais, le service de téléappel d'Iridium conviendrait à des applications militaires. Étant donné que cet appareil sert à la réception seulement, des messages courts pourraient être livrés sans qu'on ait à se préoccuper des problèmes de sécurité relatifs aux émissions, qui peuvent compromettre la position du destinataire. Toutefois, la limite de 120 caractères pour les messages constitue un désavantage pour son utilisation à des fins militaires.

Les futurs travaux d'évaluation du service de téléappel comprendront l'essai de la fonctionnalité « Suis-moi », plus particulièrement la sélection de la destination pour la remise des messages texte, soit le téléphone, soit le récepteur de téléappel ou les deux. D'autres travaux pourraient comprendre une étude plus poussée des frontières des zones de remise des messages et de leurs effets sur la capacité de réception des messages.

Tom, C., Wagner, L.C., Évaluation du service de messagerie Iridium pour l'utilisation possible par les Forces canadiennes , Le Centre de recherches pour la défense Ottawa, DREO TM 1999-087. août 1999. (en anglais)

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LIST OF SYMBOLS AND ABBREVIATIONS

C3I	Command, Control, Communications and Information
DREO	Defence Research Establishment Ottawa
FDMA	Frequency Division Multiple Access
GMPCS	Global Mobile Personal Communications Systems
GSM	Global System for Mobile communications
LEO	Low Earth Orbit
MDA	Message Delivery Area
MSC	Military Satellite Communications
NRC	National Research Council
QPSK	Quadrature Phase Shift Keying
TDMA	Time Division Multiple Access
TP	Technical Panel
TTCP	The Technical Cooperation Program
UK	United Kingdom
US	United States

1 INTRODUCTION

1.1 General

Over the past decade there has been a phenomenal growth in the demand for terrestrial-based cellular personal communications services. The current estimate is that by the year 2000, there will be between 300 to 350 million subscribers worldwide. Personal communications services is centred around populated areas in developed countries, but expansion of the service to less populated areas and Third World countries is progressing rapidly. Terrestrial-based cellular is a line-of-sight technology in that a subscriber must have a line-of-sight to the base transceiver stations. Distances covered by the base transceiver stations range from a few kilometres in high density areas to a few tens of kilometres in less dense areas. Therefore, to extend the reach of this technology base transceiver stations must be constructed with linkages back to central hubs. Satellite-based personal communications systems were designed to overcome the distance limitations of terrestrial-based systems and provide a truly global capability.

The advantage of satellite-based cellular services is that the functional equivalent of the base stations is provided by a constellation of orbiting satellites. Each satellite projects a number of beams, or cells, on the surface of the earth. Typically, each beam or cell measures a few hundred kilometres in diameter. The design of the satellite and satellite constellation is such that at least one satellite is always in view of the handset. Because the satellite is moving at a much higher speed relative to the user, the user is effectively stationary and the satellite base stations move. This is the opposite of terrestrial-based systems where the user is mobile and the transceiver base stations are stationary. A disadvantage of the satellite-based service is the greater line-of-sight distance between the user and the base station, and consequently the need for much higher link margins. This need must be balanced with the need for a small handheld terminal that is comparable in size to that available for a terrestrial-based system. As a result, service inside buildings and in areas obstructed by terrain or foliage is degraded in a satellite-based system.

1.2 The Iridium System

The Iridium system is designed to provide global personal communications via an interconnected constellation of low earth orbit (LEO) satellites communicating directly with handheld terminals. The system provides communications to all parts of the globe, including the polar regions. The Iridium constellation consists of 66 satellites in 6 near polar orbits of 11 satellites at an altitude of 780 km as shown in Figure 1.1. Each satellite projects 48 beams of approximately 70 km diameter each on the surface of the earth, with a total footprint of approximately 4,700 km diameter. The constellation was selected to provide overlapping footprints at the equator to support continuous coverage and transparent hand-off between satellites. As a consequence, the overlap increases as the satellites approach the poles.

The Iridium satellite is a processing satellite based upon Global System for Mobile communications (GSM) technology. This allows the handset to directly communicate to the satellite and to pass data independent of terrestrial gateways. Iridium is the only system that provides communications between two satellite handsets without being downlinked through a terrestrial gateway. The Iridium system uses 1616 MHz to 1626.5 MHz to provide communications between the handset and satellite for telephone and messaging services. The links use frequency division multiple access (FDMA) and time division multiple access (TDMA) to separate users and uplink and downlink communications. The waveform employs quadrature phase shift keying (QPSK). Each satellite is linked to four other satellites (one behind, one ahead, and one in each adjacent orbit) by four separate inter-satellite links. This allows users to be handed off between satellites as they pass overhead and allow communication traffic to be routed to the closest satellite before being downlinked. The picture in Figure 1.2 is an artist's rendition of the Iridium satellite. The second picture, shown in Figure 1.3, is an actual photograph of seven Iridium spacecraft attached to a Russian Proton launcher.

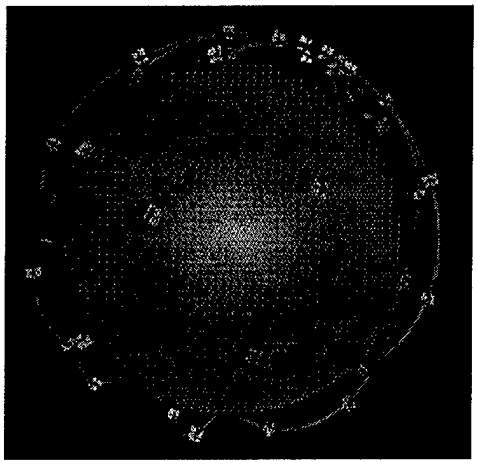

Figure 1.1 The Iridium Constellation (www.iridium.com)

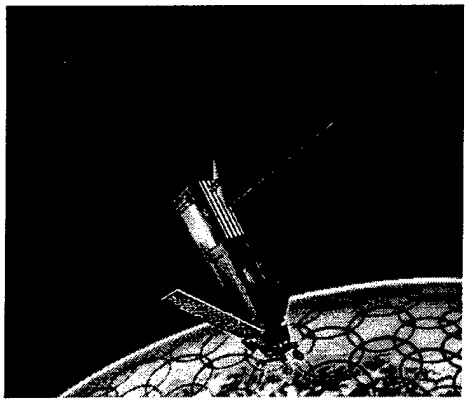

Figure 1.2 Artist's Rendition of an Iridium Satellite (www.flatoday.com)

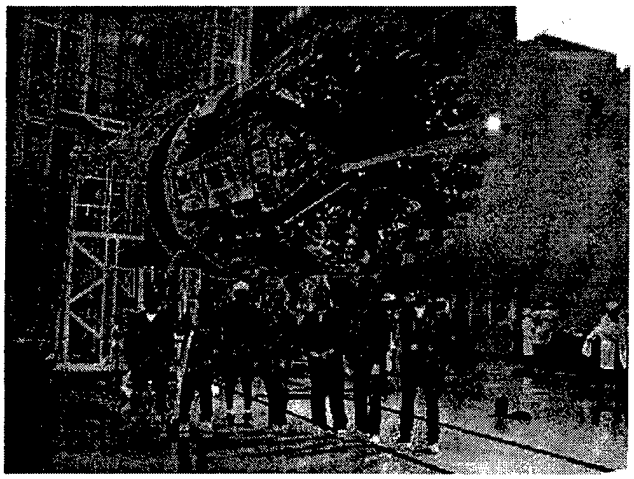

Figure 1.3 Seven Iridium Satellites on a Proton Launcher (www.flatoday.com)

The first four satellites were launched into orbit in May 1997, with the total constellation of 66 satellites plus spares being completed in May 1998. A total of 72 satellites were put into orbit with 15 launches over a 12-month period. Initial voice service commenced in November 1998, followed by paging service in March 1999. Data service at 2400 b/s is planned for the fall of 1999.

Pictures of the Motorola and Kyocera Iridium phones are shown in Figure 1.4. The Motorola phone is shown on the left with a cellular cassette and antenna mounted. The Kyocera phone is shown with the satellite phone antenna installed. They are comparable in size and weight to existing medium sized cellular phones. The current price is around $2,500 Cdn with usage fees from $2.50 Cdn per minute for domestic calls to $4.50 Cdn per minute for international calls. Calls made to non-Iridium phones may also have "tail" circuit costs. Depending on the batteries used, the phones can communicate continuously from 2 to 6 hours or operate on standby from 16 to 60 hours.

In addition to the phones, pagers are also available to be used on the Iridium system. A Motorola pager is shown in Figure 1.5. The pager can be purchased separately and currently costs approximately $750 Cdn. In addition, a monthly network access fee is charged for the pager with the price depending on whether the pager is operated as a standalone device or is linked with the Iridium satellite phone using the "Follow-me" paging service.

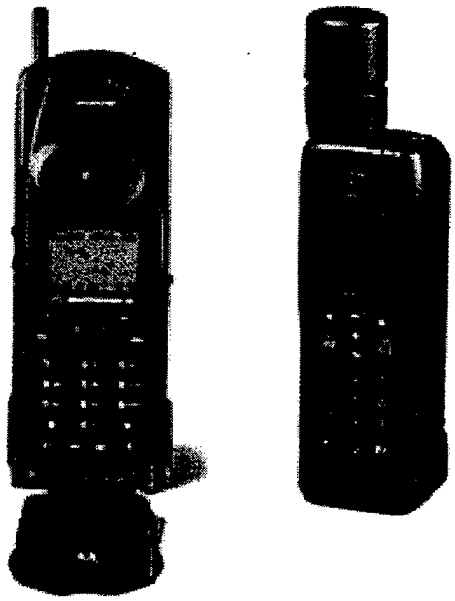

Figure 1.4 Motorola and Kyocera Iridium Phones (www.infosat.com)

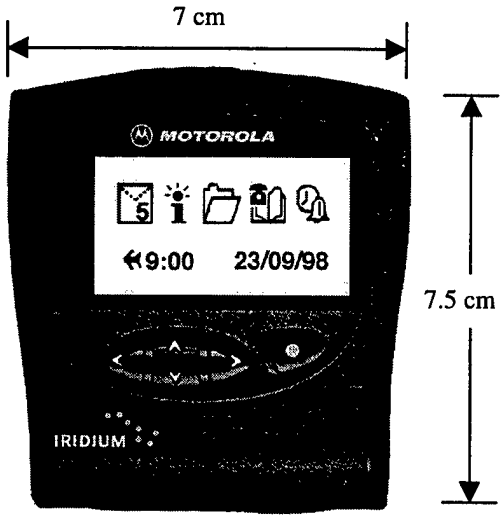

Figure 1.5 Motorola Iridium pager.

1.3 Background

The Military Satellite Communications (MSC) Group of the Defence Research Establishment Ottawa (DREO) purchased three (3) Iridium Satellite Series 9500 phones and Satellite Series 9501 pagers in March 1999. Since March 1999, the MSC group has carried out several tests of both the voice and paging service. The purpose of the tests is to assess the Iridium system's potential for use by military. Of particular interest is the aspect of being able to communicate anywhere in the world with a small handheld device. Reliability and quality of the voice service is a key characteristic being examined. As well, messaging services to the satellite phones and pagers are evaluated for efficiency of delivery and error performance. The 2,400 b/s data service was not yet available at the time of writing this Technical Memorandum and thus, is not considered here. Evaluation of Iridium's voice service is documented in a separate DREO Technical Memorandum [3].

The MSC Group is also participating in The Technical Cooperation Program (TTCP) Command, Control, Communications and Information (C3I) Group, Technical Panel (TP) 6 Workshop on Global Mobile Personal Communications Systems (GMPCS) to examine the Iridium system for military applications. Members from four of the five TTCP nations (Australia, Canada, United Kingdom, United States) are participating in the workshop. The TTCP forum allows an opportunity for the MSC group to share technical knowledge as well as coordinate national efforts for evaluating the Iridium service. The work presented in this Technical Memorandum has been briefed to the TTCP workshop. In general, the results obtained in the DREO evaluation agree with the results from the other nations.

1.4 Outline of Technical Memorandum

This Technical Memorandum focuses on the DREO evaluation of the Iridium paging service. An overview of the general features and operation of the pager is given in Section 2.0. Section 3.0 describes the test procedure for the evaluation and identifies the scenarios tested. The results of the tests carried out are presented in Section 4.0 as well as any observations noted about the paging service. The issues that were unresolved during this test period are identified. Where applicable, any further testing to resolve these issues is outlined. In addition, a preliminary assessment of the utility of the Iridium paging for the military is made in Section 4.0. General conclusions are given in Section 5.0.

2 PAGER FEATURES AND OPERATION

DREO purchased three Motorola Satellite Series 9501 Pagers along with the Motorola Satellite Series 9500 Portable Phones. The pagers are a one-way personal messaging device and have a 4-line alphanumeric display, showing up to 80 characters. Memory is available in the pager to hold up to ninety-nine (99) in-coming personal messages with an additional ninety-nine (99) storage locations in a separate message folder. A phone directory is also included in the pager where the user can download phone records to the pager via an infrared interface. Additional settings for the pager include the ringer selection, and dual time zone display. A detailed list of the features of the pager and its operation can be found at the Iridium website under owner tools [www.iridium.com].

The Iridium paging service allows text and numeric messages of up to 120 characters to be transmitted to the pager. The paging service also provides notification of pending voicemail messages. There are four ways to send a message to the pager. The first method for sending messages to the pager is directly dialing the pager number. In this case, the caller is connected to the Iridium messaging centre where a numeric message or a voice message can be left. The second method, which provides the same service as the first, involves dialing the Iridium Satellite messaging centre directly at 1-888-588-2456. In this case, the caller is asked to enter the pager number to be reached. Subsequently a numeric message or voice message can be left. The third method is available via the messaging system on the Iridium website under owner tools [http://corpweb2.iridium.com/use/ownertools/message/]. Users specify the pager number they wish to reach and can enter a text message of up to 120 characters. The fourth method for sending messages to the pager is via email. The email address for the pager is *<pager_number>*@iridium.com. The Iridium System supports email messages of up to 120 characters. Messages sent to the pager are also registered at the Iridium message centre in the personal mailbox. As a result, any missed messages can be re-sent from the mailbox.

The location of the pager is specified by the Message Delivery Areas (MDAs). MDAs are geographical areas defined by Iridium and correspond to local, regional, and national boundaries. A map showing the MDAs around the world can be found in [http://www.iridium.com/use/ownertools/covermaps/] . The MDAs must be set by the user to register the pager on the Iridium System to receive messages in that MDA. A maximum of three (3) MDAs can be programmed simultaneously. There are currently two ways of changing the MDAs of the pager. The first method consists of calling the Iridium messaging centre to manually change the MDAs. The second method is available for pagers that are bought as a package with the Iridium Satellite Series 9500 Phones. In this configuration, the user can update the pager MDA by simply turning the associated portable phone on to register on the Iridium System. When the phone is registered on Iridium, the pager is automatically updated with the appropriate MDA. This capability is called "Follow-me" paging which can be activated and de-activated by the user. A possible third method for changing MDAs may be available from the Iridium website in the future.

3 TEST PROCEDURE

3.1 Objective

The objective of the tests documented in this memorandum is to become familiar with the features of the Iridium paging service and to evaluate the paging service capabilities. Subsequently, a preliminary assessment of its utility for military applications is made.

3.2 Test Method

The procedure for testing the Iridium paging service consists of sending pages to a pager using the different methods described in Section 2.0. Messages sent to the pager include the time at which they are sent. The time reference used for the evaluation is the National Research Council (NRC) clock. The clock on the pager is also synchronized to the NRC clock to provide a simple means of measuring message delivery time or latency. The issues to be considered include the time it takes for the message to be received by the pager, errors in the received message, messages not delivered, effects of transmitting messages greater than 120 characters, effects of pager location on reception of messages, and effects of MDA boundaries.

3.3 Test Scenarios

There are two scenarios for which the paging service is evaluated. The first scenario considered is stationary paging. In this scenario, it is assumed that the pager remains in one location and within one MDA. The second scenario consists of inflight paging tests where the pager is mobile. The tests carried out in each of these scenarios are described further in the following subsections.

3.3.1 Stationary

For the stationary paging test, a series of messages are sent to the pager using the methods described in Section 2.0. For the purposes of the evaluation and of this Technical Memorandum, the first and second methods of sending a numeric or voice message are considered to be the same. As such, the second method is actually used for the evaluation. The date/time stamp feature is activated on the pager. Messages sent to the pager include the time sent in order to measure the delivery time of the page. Log sheets were created and used to record parameters of interest. A sample log sheet is included in Appendix A.

MDAs for the pager were set for 122 and 123 corresponding to coverage over the provinces of Quebec and Ontario respectively.

Stationary paging tests were carried out between March and June 1999 on an opportunity basis.

3.3.2 Inflight

For the inflight paging test, messages are sent to the pager at regular intervals (between 20 and 60 minutes) during the estimated travel period. During the period March to June 1999, seven (7) flights were available to carry out the test. Table 3.1 lists the travel times during which paging tests were carried out.

Two methods of transmitting messages to the pager were used. For shorter duration flights, numeric messages were transmitted to the pager using the Iridium messaging centre (1-888-588-2456). The numeric message consisted of the time the page was sent. For longer flights, an email script for a Macintosh computer was created and used to automatically send an email to the pager at pre-determined times. A copy of the email script file is included in Appendix B. The same log sheet is used to record the inflight pages as for the stationary pages.

For the seven flights during which paging tests were carried out, the pager was situated in different locations to examine the effect on the reception of messages. The different locations included inside a briefcase below the seat, clipped on back of seat in aisle, clipped on back of seat beside window, and clipped on back of seat in middle of the plane.

Table 3.1 Inflight Paging Trials List

Date	Origin/Destination	Test Period
06 April 1999	Ottawa, Canada to Toronto, Canada	0530 – 0800 (EDT)
06 April 1999	Ottawa, Canada to SanDiego, United States (US)	1300 – 1600 (EDT)
09 April 1999	SanDiego, US to Ottawa, Canada	1100 – 2300 (EDT)
20 April 1999	Ottawa, Canada, to Washington, US	1130 – 1400 (EDT)
23 April 1999	Washington, US to Ottawa, Canada	1300 – 1640 (EDT)
22 May 1999	Ottawa, Canada, to London, United Kingdom (UK)	1540 – 0341+ (EDT)
29 May 1999	London, UK to Ottawa, Canada	0730 – 1900 (EDT)

The MDAs were set up for each of the tests as shown in Table 3.2.

Table 3.2 MDA Settings for Inflight Paging Trials

Date	Origin/Destination	MDA(s)
06 April 1999	Ottawa, Canada to Toronto, Canada	122, 123
06 April 1999	Ottawa, Canada to SanDiego, United States (US)	123, 2021, 17
09 April 1999	SanDiego, US to Ottawa, Canada	(14,16,17) (14,16,11) (14,10,11) (10,11,123)*
20 April 1999	Ottawa, Canada, to Washington, US	122, 123, 10
23 April 1999	Washington, US to Ottawa, Canada	122, 123, 10
22 May 1999	Ottawa, Canada, to London, United Kingdom (UK)	122, 2022, 44
29 May 1999	London, UK to Ottawa, Canada	122, 2022, 44

*MDAs were modified over the course of the flight.

4 RESULTS AND OBSERVATIONS

4.1 General

The following section presents the results of the paging tests carried out over the period of March to June 1999. Observations and comments on the Iridium service are also included. Issues that were unresolved during the trial period for the paging service are identified and proposals for future testing are outlined. Finally, a preliminary assessment of the paging service for military applications is provided.

4.2 Paging Statistics

A summary of the stationary paging results is given in Table 4.1. A total of 111 stationary pages were transmitted using three of the four methods described in Section 2.0. In general, delivery times ranged from less than a minute to 35 minutes with an average of 5 to 7 minutes. The advertised delivery time is within 15 minutes, while most should arrive within 7 minutes, according to information posted on the Iridium website.

Table 4.1 Stationary Paging Results during March-June 1999 Trial Period

Parameter	Method of Sending Pages		
	Email	Website	1-888-588-2456
Total number of pages	33	46	32
Minimum Delivery Time (minutes)	<1	1	1
Maximum Delivery Time (minutes)	35	116 (35)	47
Average Delivery Time (minutes)	5.7	6.7	7.0
Number of missed pages / % pages missed	2 / 6.1%	4 / 8.7%	3 / 9.4%
Number of pages received with error / % received with error	2 / 6.5%	8 / 19%	0 / 0%

Table 4.2 contains the statistics for the inflight paging tests carried out. Thirty (30) of the 74 pages were sent while the pager was onboard the plane and inflight. Of the paging messages received, delivery times ranged from less than a minute to 19 minutes with an average delivery time of just over 3 minutes. A number of pages were either not received or were received in error while the pager was inflight.

Table 4.2 Inflight Paging Results during March-June 1999 Trial Period

Parameter	
Total Number of Pages - Entire Travel Period	74
Total Number of Pages - Inflight	30
Minimum Delivery Time (minutes)	<1
Maximum Delivery Time (minutes)	19
Average Delivery Time (minutes)	3.1
Number of Missed Pages - Entire Travel Period / %missed	11 / 14.9%
Number of Missed Pages – Inflight / %missed inflight	7 / 23.3%
Number of Pages received with error / % received with error	8 / 12.7%

4.2 Discussion and Observations

Delivery Time

From Table 4.1, it can be seen that delivery times were comparable between the three methods of sending a message to the pager. The rather long maximum delivery time for the website method (116 minutes) occurred when testing the maximum message length allowed on the system. When the message sent was greater than the 120-character limit, the message would be truncated and would seem to take longer to be delivered. In one instance, a long message was broken up into two messages and both sent to the pager.

Errors and Truncation of pages

A number of pages were received either with minor errors or truncated as indicated in Table 4.1. The higher incidence of messages with errors for the website method of message transmission is attributed to the case where messages of greater than 120 characters were being sent to the pager. Otherwise, errors observed consisted of one or two missed characters and did not impact significantly on intelligibility of message.

Notification of missed pages

Messages sent to the pager are associated with a page counter. The page counter range is from 0 to 61, after which it rolls over. Page count "64" is reserved for notification of a pending voice mail message at the message centre. The pager verifies that messages are received by checking the page counter. If a message is received out of sequence, the pager notifies the user of a missed message. During the paging trials, notification of missed messages occurred thirty (30) minutes after receiving the out-of-sequence message. Thus, if Message X was missed, notification that it was missed was received on the pager 30 minutes after Message X+1 is received. It is unclear whether the thirty-minute time lag represents the time it takes the pager to figure out that a message was missed, or whether it represents the time that the pager waits before concluding that the message is missed.

Retrieval/Retransmission of Pages from Message Centre

Each Iridium phone and pager is given a personal mailbox where voice messages are collected. When a text or numeric message is sent to the pager, a copy of the message is also sent

to the user's personal mailbox where it is stored for two weeks. Users can retrieve voice, numeric, and text messages by calling the message centre as one would for an answering service. In addition, numeric and text messages stored in the personal mailbox can be retransmitted by the user. Thus, if a user received notification of a missed message, they could call the message centre and retransmit that particular message.

It is noted that International calling rates are charged if a user calls the message centre (1-888-588-2456) from outside North America. Thus, if a user wished to retrieve a voice message, a user would be charged International calling rates for that call. This would also apply if a user wanted to modify options settings on the pager or phone by calling the message centre.

MDA boundary issue

From the paging maps provided at the Iridium website under owner tools, it can be seen that Ottawa is situated on the boundary between MDA 122 and 123. Messages can be received in Ottawa and at DREO by a pager using either MDA setting. However, on one occasion, when an MDA of 122 was set on the pager, messages were not received in Carleton Place. Carleton Place is located about 55km west of Ottawa and about 35km west of DREO. This problem seemed to be rectified when the MDA was changed to 123. This serendipitous result raised the question of the overlap or resolution of the MDA boundaries. However, subsequent attempts to repeat the result were not conclusive as messages were received in Carleton Place with the MDA set to 122 on the pager. It was observed that when using the bundled phone to register on the Iridium system, thereby updating the pager's MDA, the MDA was automatically set to 123 when in Carleton Place.

Location of pager on plane

For the inflight paging tests, it was observed that the pager had to be situated close to the window to consistently receive messages on the pager. In the case where the pager was in a briefcase below the seat, none of the messages were received. When the pager was located in the middle of the plane, messages were missed or received in error almost half the time. The results are consistent with those obtained by the service provider, Infosat, who conducted paging tests in various locations in a building [1]. Table 4.3 shows the percentage of messages received as a function of location of the pager.

Table 4.3 Infosat Telecommunications Inc., Pager Performance Tests in Office Tower [4]

Floor Level	Located at Centre of Building	Located by Window
Top	60%	93%
Middle	40%	93%
Bottom	35%	83%

Aeronautical MDAs

During the flight from Ottawa to San Diego on 06 April, 1999, an inflight or aeronautical MDA of 2021 was used for coverage during the flight. However, it was observed that the aeronautical MDA was not broad enough to cover the actual flight plan of the Ottawa to SanDiego flight. Subsequently, on the return flight, land MDAs were used and modified over

the course of the flight. In this case, the pager was in the briefcase and set underneath the seat beside the window. Two messages were received in this instance. For flights from Ottawa to Toronto, and Ottawa to Washington, land MDAs were used. When the pager was clipped on the back of the seat by the window, all messages were received. The aeronautical MDA for the flight from Ottawa to London (2022) did cover the flight path and resulted in all the messages being received onboard the plane with the pager clipped on the back of the seat by the window. When the pager was situated in the middle of the plane, some messages were received with errors. The service provider (Infosat) has indicated that if coverage for a frequently used area is required, special MDAs could be set up by Iridium.

Number of MDAs for pager

The Iridium system allows three (3) MDAs to be set for the pager at any one time. This is considered to be too few in cases where a user is travelling by air and is required to use land MDAs which cover their flight path. In addition, if there is an issue regarding MDA boundaries, then two MDAs would be required to ensure delivery of messages to the pager which is located along the MDA boundary. However, the service provider has indicated that new MDAs may be defined for special applications for frequently used routes not covered by existing MDAs.

User Options Settings

While the ability to modify user options settings by calling the message centre is a convenient and useful tool, one aspect that was lacking is the ability to review a pager's or phone's settings without having to go through the entire menu system. Thus, the ability to list the current settings for both the phone and pager would be a desired capability.

4.4 Issues Outstanding

The issue of how broad the overlap between adjacent MDAs is yet to be determined. Future attempts to send messages to the pager located in one MDA but with pager set for an adjacent MDA are being carried out to examine further the resolution of the MDA boundaries.

Although this Technical Memorandum focuses on the paging service only, mention has been made about the "Follow-me" paging service. With "Follow-me" paging, a user is supposed to be able to select which of the two devices, or both, is used to receive text messages. Tests are currently underway to examine the different combinations of settings for the Message Delivery Notification and Message Destination user options.

4.5 Paging Service for Military Application

With the relatively short delivery times and successful reception of messages observed during the trials, the Iridium paging service would be suitable for military application in an unclassified environment. As the pager is a receive-only device, short messages would still be delivered without worrying about security concerns over emissions which may compromise the recipient's position. Similarly, with a bundled phone and pager, a pager could be used to receive messages while the phone could be reserved for use when necessary. The pager's compact size relative to the phone for portability is also an advantage, as both devices require line-of-sight view of the satellite. Disadvantages for military use may be the 120-character limit on message length as well as not being able to send classified messages to the pager.

5 CONCLUSIONS

The MSC group at DREO carried out an evaluation of the Iridium paging service during the period March to June 1999. Two scenarios were examined for the paging service. The first is where the pager is stationary within one MDA. The second consists of inflight paging tests where the pager is mobile. A series of messages were transmitted to the pager. Parameters observed include delivery time and error performance. Average delivery times for the stationary and inflight tests were 5-7 minutes and 3 minutes respectively. These results meet, if not exceed the advertised delivery time of 7 minutes to a maximum of 15 minutes. Messages received with errors generally consisted of one or two characters garbled or missing and did not greatly impact on intelligibility of the message. Missed messages could be attributed to not having a clear line-of-sight to the satellite, and thus, location of the pager was an important consideration. Another factor in not receiving messages was not having the MDAs properly set.

Only three MDAs are available to be set concurrently for the pager. This is considered insufficient for a mobile user who cannot make use of aeronautical route MDAs. Although, the service provider has indicated that additional MDAs may be defined for heavily used routes not covered by existing MDAs.

Based on delivery performance and the ability to reach a user virtually anywhere, the paging service would be considered suitable for military use where short, unclassified messages need to be disseminated.

Additional tests are being carried out to evaluate the "Follow-me" paging features where the phone and pager bundled so that messages can be received either on the phone or the pager.

6 REFERENCES

[1] www.iridium.com

[2] www.flatoday.com

[3] Tom, C. and Wagner, L., "Evaluation of Iridium Satellite Phone Voice Service for Military Applications", DREO Technical Memorandum, 1999

[4] Rahemtulla, M., "***Report on Iridium Testing – Voice and Paging Services***", under DND Contract W7714-8-0195/001/SV, July 1999.

Appendix A Log Sheet for Paging Tests

Pager Test	Name:

Date dd/mm/yy	Page from	Time of page	Page To	Time page rec'd	Page #	Comments (location of pager, signal strength, errors, misc)

Appendix B Eudora Send – Script to send Emails to pager

```
delay 21720
tell application "Eudora Pro"
        activate
        set newPage to make new message at end of mailbox "Out"
        set field "To:" of message newPage to "881630272051@iridium.com"
        set field "From:" of message newPage to "lyle.wagner@dreo.dnd.ca"
        set field "Subject:" of message newPage to "First Page"
        set field "Cc:" of message newPage to "caroline.tom@dreo.dnd.ca"
        set signature of (message newPage) to none
        set body of message newPage to "Page sent. " & (current date) &
                "First page of 25, Hello again from Canada, next in 14 min"
        queue newPage
        connect with sending
end tell
delay 840
repeat with i from 2 to 25
        tell application "Eudora Pro"
        activate
                set newPage to make new message at end of mailbox "Out"
                set field "To:" of message newPage to "881630272051@iridium.com"
                set field "From:" of message newPage to "lyle.wagner@dreo.dnd.ca"
                set field "Subject:" of message newPage to "First Page"
                set field "Cc:" of message newPage to "caroline.tom@dreo.dnd.ca"
                set signature of (message newPage) to none
                set body of message newPage to "Page "& i & " of 25 sent & (current date) &
                        "Next page in 30 min"
                queue newPage
                connect with sending
end tell
delay 1800
end repeat
tell application "Eudora Pro"
        activate
        set newPage to make new message at end of mailbox "Out"
        set field "To:" of message newPage to "881630272051@iridium.com"
        set field "From:" of message newPage to "lyle.wagner@dreo.dnd.ca"
        set field "Subject:" of message newPage to "First Page"
        set field "Cc:" of message newPage to "caroline.tom@dreo.dnd.ca"
        set signature of (message newPage) to none
        set body of message newPage to "Page sent. " & (current date) &
                "Last page."
        queue newPage
        connect with sending
end tell
```

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Iridium is the first satellite-based personal communications system offering global service via an interconnected constellation of low earth orbit (LEO) satellites communicating directly with handheld terminals. The total constellation of satellites was launched over a 12-month period ending May 1998. Voice service commenced in November 1998 followed by paging services in March 1999. This Technical Memorandum describes an evaluation of the Iridium paging service carried out by the Military Satellite Communications (MSC) Group at Defence Research Establishment Ottawa (DREO) during the period March to June 1999. Paging tests were performed under two principle scenarios: stationary and inflight paging. Performance parameters observed include delivery time and message error performance.

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Personal Communications System
Satellite Communication