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January 14, 2015

Via Electronic Filing

Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street SW
Washington, DC 20554

Re: *Iridium Constellation LLC Petition for Rulemaking,* RM-11697
Written *Ex Parte* Notice

Dear Ms. Dortch:

The Commission should reject Iridium Constellation LLC's ("Iridium's") ongoing effort to appropriate spectrum from its chief competitor, Globalstar, Inc. ("Globalstar"). As Globalstar has already detailed, adopting Iridium's proposal to grab spectrum above 1616 MHz would materially degrade Globalstar's service, to the detriment of its customers. The attached technical report from Roberson and Associates, LLC ("Roberson"), *Impact of Iridium Operations in 1616-1617.775 MHz on Globalstar Operations* (the "Roberson Report"), supplements the record by further demonstrating that Iridium's MSS operations at 1616-1617.775 MHz would have a substantial detrimental impact on Globalstar and its MSS customers within the United States and throughout North America.

In its latest effort – its "revised proposal" and subsequent filings – Iridium once again fails to justify revisiting the Commission's allocation of the Lower Big LEO mobile satellite service ("MSS") spectrum between Globalstar and Iridium.[1] After a four-year proceeding, the Commission "re-balanced" the Lower Big LEO band (1610-1626.5 MHz), by re-assigning more than three megahertz of Globalstar's spectrum to Iridium.[2] Under the Commission's order,

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[1] *See* Petition for Rulemaking of Iridium Constellation LLC (Feb. 11, 2013); Supplemental Comments of Iridium Constellation LLC, RM-11697 (May 5, 2014) ("May Iridium Supplement"); Opposition of Globalstar, Inc. to Petition for Rulemaking, RM-11697 (Dec. 2, 2013) ("December 2013 Opposition").

[2] *See Spectrum and Service Rules for Ancillary Terrestrial Components in the 1.6/2.4 GHz Big LEO Bands; Review of the Spectrum Sharing Plan Among Non-Geostationary Satellite Orbit Mobile Satellite Service Systems in the 1.6/2.4 GHz Bands*, Second Order on Reconsideration, Second Report and Order, and Notice of Proposed Rulemaking, 22 FCC Rcd 19733 (2007) ("*Big LEO Spectrum Order*"), *aff'd sub nom. Globalstar, Inc. v. FCC*, 564 F.3d 476 (D.C. Cir. 2009).

Globalstar's MSS system has an exclusive assignment of 7.775 megahertz of Lower Big LEO spectrum in the United States at 1610-1617.775 MHz, Iridium has an exclusive assignment of 7.775 megahertz at 1618.725-1626.5 MHz, and the two companies share a small segment, 0.95 megahertz, at 1617.775 MHz-1618.725 MHz.[3] Globalstar has invested in, and launched, a $1 billion second generation of satellites and has developed new products and business opportunities in reliance on the Commission's allocation decision. Globalstar's lenders similarly relied on the *Big LEO Spectrum Order* when they extended a loan of almost $600 million to Globalstar to finance the construction and launch of this second-generation constellation, and these parties continue to depend on a stable regulatory environment in this frequency band.[4] Any reassignment of spectrum now would entirely undermine the regulatory certainty needed for such multi-year projects.[5]

In its May 2014 "revised proposal," Iridium asked the Commission (i) to reassign the spectrum at 1617.5-1618.725 MHz to Iridium for its exclusive use, and (ii) establish sharing between Globalstar and Iridium within the 1616-1617.5 MHz band segment.[6] While Iridium claims to the Commission that it needs this additional spectrum to support its future growth and development, Globalstar is unaware of similar communications by Iridium to the investment community. Tellingly, there is no mention in any of Iridium's Securities and Exchange Commission ("SEC") filings about its alleged need to obtain more spectrum to support any future growth. In addition, given the fact that Iridium has received approximately $1.8 billion in financing for its Iridium NEXT project from some of the same institutions that financed Globalstar's second-generation constellation, it is unlikely that these institutions have been informed or believe that Iridium is short on spectrum.

With respect to the key technical issues, Globalstar in October 2014 submitted an *ex parte* letter urging the Commission to reject Iridium's revised proposal and explaining the

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[3] *Id*. ¶ 8.

[4] BNP Paribas has stated that "the Lenders relied upon the prior decisions of the Federal Communications Commission that allocated certain frequencies for Globalstar's exclusive use" *Ex Parte* Letter from Jean-Philippe Poirier, BNP Paribas, to Marlene Dortch, FCC Secretary, IB Docket No. 13-213, at 1 (Nov. 21, 2014). BNP Paribas – which is also helping to finance Iridium's next-generation constellation – further states that it "continue[s] to have concerns about any effort to reallocate any portion of Globalstar's spectrum with or to others, because such changes could have a material negative impact on Globalstar's operational and financial health." *Id*.

[5] Just as the Commission would deny any request from Verizon for the reassignment or sharing of AT&T's licensed wireless spectrum, the Commission should reject Iridium's demand that the Commission solve its alleged spectrum issues by giving it access to its closest competitor's frequencies.

[6] *See* May Iridium Supplement at ii, 7-8.

substantial harm that these proposed changes would cause to Globalstar.[7] In particular, Globalstar described the material degradation to its MSS operations that would result from the loss of its duplex channel at 1617.5-1618.725 MHz ("Channel 7"), and stated that expanded sharing between Globalstar's CDMA operations and Iridium's TDMA operations would result in widespread interference to Globalstar's services. In response, Iridium filed "Supplemental Comments" that purported to show that Iridium's operations above 1616 MHz would have little to no effect on Globalstar and its customers.[8]

The attached Roberson Report highlights the flawed nature of Iridium's conclusions and demonstrates definitively that the extension of Iridium transmissions from 1617.775 MHz down to 1616 MHz would have a severe detrimental impact on Globalstar's MSS operations and customers.[9] Iridium's comments significantly understated the harm to Globalstar that would result if Iridium's proposal were adopted. Given that Globalstar's satellites are already in orbit and their filter hardware cannot be modified, Iridium transmissions at 1616-1617.775 MHz would be received and repeated by Globalstar's "bent-pipe" satellites. As the Roberson Report explains, these Iridium signals would consume Globalstar satellite power, make that power unavailable to Globalstar's own subscribers, and reduce Globalstar's capacity.[10] *For every 2.3 Iridium users operating within a Globalstar spot beam, Globalstar's would lose the ability to serve one Globalstar customer.* Overall, Globalstar's MSS capacity would be reduced by 47% per affected satellite during peak periods of Iridium traffic. This loss of capacity would substantially impact Globalstar's MSS offerings just when they are needed most, in disasters when MSS usage spikes dramatically.

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[7] Letter from L. Barbee Ponder IV, Globalstar, to Marlene H. Dortch, FCC Secretary, RM-11697 (Oct. 24, 2014) ("October 2014 Opposition").

[8] Supplemental Comments of Iridium Constellation LLC, RM-11697 (Nov. 5, 2014) ("November Iridium Supplement").

[9] The harmful effects of Iridium operations below 1617.775 MHz on the Radio Astronomy Service ("RAS") provide the Commission with additional grounds to reject Iridium's latest proposal. In an October 21, 2014 *ex parte* letter, the National Radio Astronomy Observatory ("NRAO") indicated that expanding Iridium operations down to 1616.0 MHz would greatly increase the potential for interference into RAS below 1613.8 MHz. Letter from Harvey S. Liszt, Scientist and Spectrum Manager, NRAO, RM-11697, at 1 (Oct. 21, 2014). NRAO noted in its filing that it has benefited from Globalstar's strict compliance with the Commission's RAS-related restrictions in the Lower Big LEO band and the interference-free environment for RAS at 1610-1613.8 MHz. NRAO further stated its concern that "the obligation to protect radio astronomy might have to be relaxed in order to maintain Globalstar's commercial viability were it to lose the use of the spectrum requested by Iridium." *Id*.

[10] As the Roberson Report describes, Globalstar's satellite capacity is set by the transmitter power limits of each bent-pipe satellite as it re-broadcasts any received signals, including those from Iridium handsets operating below 1618.725 MHz.

In addition to diminishing Globalstar's capacity, Iridium operations at 1616-1617.775 MHz would degrade the quality of Globalstar's service to its subscribers. Today, Globalstar provides industry-leading, highly reliable, crystal-clear CDMA-quality voice and data services. As Iridium is no doubt aware, extending its operations down to 1616 MHz would reduce Globalstar's service quality and give Iridium an unjustified competitive boost. As the Roberson Report describes, during periods of peak traffic, Iridium transmissions at 1616-1617.775 MHz would increase Globalstar's total interference-plus-noise level by over 12% for each affected satellite, significantly higher than the limit of 3% for satellite systems referenced by Iridium.[11] Due to this increased interference, Globalstar customers would be unable to establish connections in low-signal locations where they are currently able to receive service.[12] Globalstar users would also suffer more dropped calls and interrupted data sessions.[13]

Increased interference to Globalstar's highly successful, safety-of-life SPOT services and its next-generation high-speed data services would be particularly significant for Globalstar, as the Roberson Report details. Much of Globalstar's simplex (and SPOT) "Channel C" is included in the 1616-1617.775 MHz band segment that would be used by Iridium. Unlike Globalstar's duplex services, Globalstar's more than five hundred thousand simplex and one-way SPOT devices are not able to adjust their transmit power to compensate for greater interference. In the event of interference, SPOT customers' emergency messages and location information might not be received, potentially jeopardizing those users' lives. In addition, Globalstar's next-generation, higher-speed data services (beginning next year) will have reduced spreading gain and decreased tolerance to interference. Iridium operations at 1616-1617.775 MHz would significantly degrade the geographic coverage and connectivity of these new data services.

Although not addressed in the Roberson Report, Iridium operations at 1616-1617.775 MHz would also threaten the commercial viability of Globalstar's aviation services. Globalstar needs these frequencies to provide its own space-based, next-generation air traffic management system. To meet applicable Federal Aviation Administration ("FAA") and RTCA, Inc. standards designed to protect the RAS as well as GPS and GLONASS, Globalstar's aviation terminals can

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[11] November Iridium Supplement at 6.

[12] Even if Iridium's peak usage were limited to one specific geographic region (such as after a natural disaster), the resulting interference would potentially degrade service to Globalstar's customers throughout the affected satellite's entire coverage area, which is approximately the size of the continental United States.

[13] Given Iridium's claim that it needs additional spectrum to meet the needs of its customers, Globalstar and Roberson and Associates assume, for the sake of this technical analysis, that Iridium will enjoy relatively full loading of its MSS system in the future. If Iridium is correct in its November supplement that only one time slot in each 90 millisecond TDMA frame will be utilized on its system, with a resulting duty cycle of only 9.2%, then Iridium clearly does not need more Lower Big LEO spectrum to support its operations. November Iridium Supplement at 8 and attached Exhibit 2, Technical Appendix, at 1-2.

only operate above 1616 MHz on duplex Channels 5-7.[14] If the Commission reassigned Channel 7 to Iridium and allowed sharing on Channels 5 and 6, such action would severely limit Globalstar's aviation communications capacity. This capacity hit could preclude the deployment of Globalstar's innovative ADS-B Link Augmentation System ("ALAS"), a space-based air traffic management solution, since ALAS equipment only uses Globalstar's channels above 1616 MHz. Globalstar, its technology partner ADS-B Technologies, LLC, the commercial airlines, airline passengers, and public safety would all suffer as a result. The only beneficiary of this action would be Iridium, which in 2013 announced an agreement to deploy an alternative ADS-B satellite delivery system that will compete directly with ALAS.[15]

The Roberson Report's technical analysis confirms the Commission's finding in the *Big LEO Spectrum Order* that spectrum sharing between TDMA and CDMA MSS systems is not technically feasible. In limiting sharing to less than one megahertz, the Commission in that order stated that its "own experience of satellite interference issues reinforces the decision the Commission made in 1994 to restrict TDMA and CDMA systems to different parts of the L-band, a decision based on the conclusion that fully-loaded TDMA and CDMA systems cannot share spectrum in a co-frequency, co-coverage manner without generally undesirable operational limitations."[16] The Roberson Report also substantiates the draft report on sharing between TDMA and CDMA systems in the Big LEO band prepared by the Electronic Communications Committee ("ECC") of the European Conference of Postal and Telecommunications Administrations ("CEPT"), referenced by the Commission in the *2007 Big LEO Spectrum Order*.[17] The ECC Draft Report concluded that, when both Iridium and Globalstar are fully loaded, sharing would result in unacceptable interference to Globalstar satellites. The Roberson Report eliminates any remaining doubt on this technical issue.

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[14] October 2014 Opposition at 6-7. If the Commission adopted Iridium's revised proposal, Globalstar would be left with almost no unencumbered spectrum in the Lower Big LEO band. As Globalstar has previously described in this proceeding, there are substantial constraints on MSS use of the Lower Big LEO band spectrum below 1616 MHz in order to protect GLONASS and GPS at 1574-1610 MHz and the RAS at 1610-1613.8 MHz. *See* December 2013 Opposition at 12-13, 15-16; October 2014 Opposition at 5-6.

[15] In April 2013, Aieron LLC, a joint venture between Iridium and NAV CANADA, announced an agreement to launch and integrate its ADS-B payloads on Iridium's next-generation satellites. Iridium Press Release, *Iridium Joint Venture, Aireon, Signs Long-Term Data Services Contract with NAV CANADA* (Apr. 29, 2013), http://investor.iridium.com/releasedetail.cfm?ReleaseID=760199.

[16] *Big LEO Spectrum Order* ¶ 16.

[17] *Id*. ¶ 16 (citing Electronic Communications Committee Within the European Conference of Postal and Telecommunications Administrations, *Draft ECC Report on Sharing Between MSS Systems Using TDMA and MSS Systems Using CDMA in the Band 1610-1626.5 MHz*, at 36 (Sept. 2006) ("ECC Draft Report"), appended as Attachment A to Letter from William T. Lake, Counsel to Globalstar, to Marlene H. Dortch, FCC, IB Docket No. 02-364 (Feb. 7, 2007).

* * *

In the *Big LEO Spectrum Order*, the Commission declared that its band plan would improve spectrum efficiency, provide an equitable distribution of the spectrum between the two MSS licensees in the band,[18] and "provide long-term certainty and stability in the Big LEO market."[19] Globalstar relied fully on the certainty and stability of that band plan when it designed, constructed, and launched a $1 billion, second-generation MSS constellation that operates at 1610-1618.725 MHz. The Commission should not undercut Globalstar's long-term commitment to the commercial success of its MSS business by handing over its most critical, unencumbered frequencies to Iridium, its closest competitor. The Commission should reject Iridium's anti-competitive regulatory maneuvers and quickly deny its Petition for Rulemaking.

Pursuant to section 1.1206(b)(2) of the Commission's rules, 47 C.F.R. § 1.1206(b)(2), this *ex parte* letter and the attached Roberson Report are being filed electronically for inclusion in the public record of the above-referenced proceeding.

Respectfully submitted,

/s/ *Regina M. Keeney*
Regina M. Keeney

Attachment

cc: Jose Albuquerque
Chip Fleming
Lynne Montgomery
Sankar Persaud
Troy Tanner

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18 *Big LEO Spectrum Order* ¶ 1.

19 *Id*. ¶ 17.

Roberson and Associates, LLC
Technology and Management Consultants

Impact of Iridium Operations in 1616-1617.775 MHz on Globalstar Operations

Prepared for Globalstar Inc., by:

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Date: January 14, 2015

Impact of Iridium Operations in 1616 to 1617.775 MHz on Globalstar Operations

Summary

Analysis of the Iridium Supplemental Comments of May 5, 2014 and November 5, 2014 (RM-11687) reveals that if Iridium's proposal for allowing Iridium operations in spectrum currently licensed exclusively to Globalstar between 1616 and 1617.775 MHz were put into effect, significant harm to Globalstar's operations would occur.

First, analysis of the respective Globalstar and Iridium subscriber device uplinks shows that for every 2.3 active Iridium user devices operating below 1617.775 MHz and within a Globalstar satellite uplink antenna beam, one less Globalstar user can be served, severely impacting Globalstar's ability to load its network and achieve commercial success. Taking into consideration the relative sizes of the Globalstar and Iridium beams and the number of Iridium users that could be supported in those beams with Iridium's TDMA system, approximately 2800 Iridium users could be active. Since the Globalstar satellite operates as a "bent-pipe" transponder that receives, translates, and retransmits all signals within its receive bandwidth, Iridium users operating within that bandwidth essentially "steal" Globalstar satellite transponder energy, robbing system capacity. These Iridium users would consume over 47% of Globalstar's overall capacity in the Globalstar uplink frequency band in those areas, a significant degradation. This degradation would be particularly harmful during disaster situations when terrestrial networks are inoperative and high traffic loads are presented to the satellite networks. Furthermore, Iridium interference reduces satellite capacity throughout the satellite orbit, not only when the interference is present, since the interference consumes battery energy that would otherwise be used for Globalstar satellite operations.

Second, critical analysis of the link budget calculations in the Iridium supplemental comments reveals errors that undermine Iridium's conclusion that no harm would occur to Globalstar users from the interference generated by Iridium subscribers operating in Globalstar's licensed spectrum. The Iridium analysis underestimates by a factor of 4 the number of Iridium TDMA timeslots that would be active during the highest traffic periods , and also underestimates by 58% the amount of Iridium interference that would occur in a single Globalstar beam, taking into account the different Globalstar and Iridium antenna beam footprints. A corrected calculation demonstrates that the amount of interference generated by Iridium users is equivalent to over 12% of the total interference-plus-noise budget of the Globalstar uplink, significantly exceeding the recommended limit of 3% referenced by Iridium.

Finally, the link margin available to Globalstar users in the antenna beam where Iridium users are active will also be decreased, degrading user quality of service. Globalstar's simplex channel C (1615 to 1617.5 MHz) is used worldwide outside of North America. If Iridium operates on what is currently Globalstar's exclusively licensed spectrum in this spectrum band, Iridium transmissions will interfere with Globalstar's simplex and Spot® transmissions in a similar way that they

interfere with Globalstar's duplex users. Since simplex user devices do not have closed loop power control, the Globalstar system cannot compensate for the interference created by the Iridium users to simplex transmissions, degrading simplex user performance and causing lost messages, a disastrous result in life-critical situations. The operation of Iridium devices in Globalstar's frequencies will also negatively impact Globalstar's new second-generation high-speed data services planned for deployment by Globalstar, since these services take full advantage of Globalstar's uplink communication link quality.

In summary, the rule changes proposed by Iridium that would introduce Iridium users and interference in the region 1616 to 1617.775 MHz will substantially degrade Globalstar's capacity and adversely affect satellite power consumption and user quality of service.

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1. Introduction

1.1 Iridium Proposal for Spectrum Sharing

In its Supplemental Comments of May 5, 2014,[1] Iridium LLC proposes changes that would result in additional interference to the Globalstar system in the frequency band 1616 to 1617.775 MHz currently assigned exclusively to Globalstar. In Iridium's proposal, the spectrum between 1616 and 1617.5 MHz would be authorized for shared Iridium and Globalstar use, and the spectrum between 1617.5 and 1617.775 would be assigned exclusively to Iridium. This report describes the results of a technical analysis conducted by Roberson and Associates, LLC of the harm to Globalstar's mobile satellite services that would result from allowing Iridium operations in the 1616-1617.775 MHz frequency region.

1.2 Globalstar Overview

Globalstar currently operates both full-duplex and simplex "bent-pipe" global mobile satellite services using a constellation of non-geostationary low earth orbit satellites.[2] The Globalstar system architecture consists of earth station "gateways" which interconnect with terrestrial networks and communicate to the satellites using a 5096-5250 MHz uplink and a 7 GHz downlink. User information from duplex and simplex user devices is transmitted to the satellites in 1.23 MHz and 2.5 MHz CDMA channels, respectively, in the frequency band 1610-1618.725 MHz (L-Band). The satellite translates the CDMA channels conveying voice or data information from the user devices to the 7 GHz band for transmission to the gateway. For duplex services, frequency translating repeaters on the satellite convert CDMA channels on the 5 GHz gateway uplink to 2483.5-2500 MHz at the satellite for retransmission to the user devices.

2. Description of 1616-1617.775 MHz Band Interference Scenario

2.1 Iridium Interference to Globalstar: Reference Diagram

Figure 1 illustrates the interference scenario created by Iridium user devices transmitting in spectrum currently licensed exclusively to Globalstar. Transmissions from new Iridium user devices operating between 1616 and 1617.775 MHz and within the Globalstar satellite receive antenna beam footprint generate additional interference to the Globalstar system. The degraded received signal at the satellite, consisting of the desired Globalstar transmissions, plus noise and Iridium device interference, is then translated to the 7 GHz downlink, ultimately degrading the desired Globalstar received signals and Globalstar capacity. At the same time, the Iridium

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[1] *Iridium Supplemental Comments, May 5, 2014, RM-11687.*

[2] F. Dietrich, P. Metzen, and P. Monte, "The Globalstar Cellular Satellite System," *IEEE Transactions on Antennas and Propagation,* Vol. 46, No. 6, June 1998.

interference consumes Globalstar satellite transponder power when the interfering signals are transmitted on the downlink.

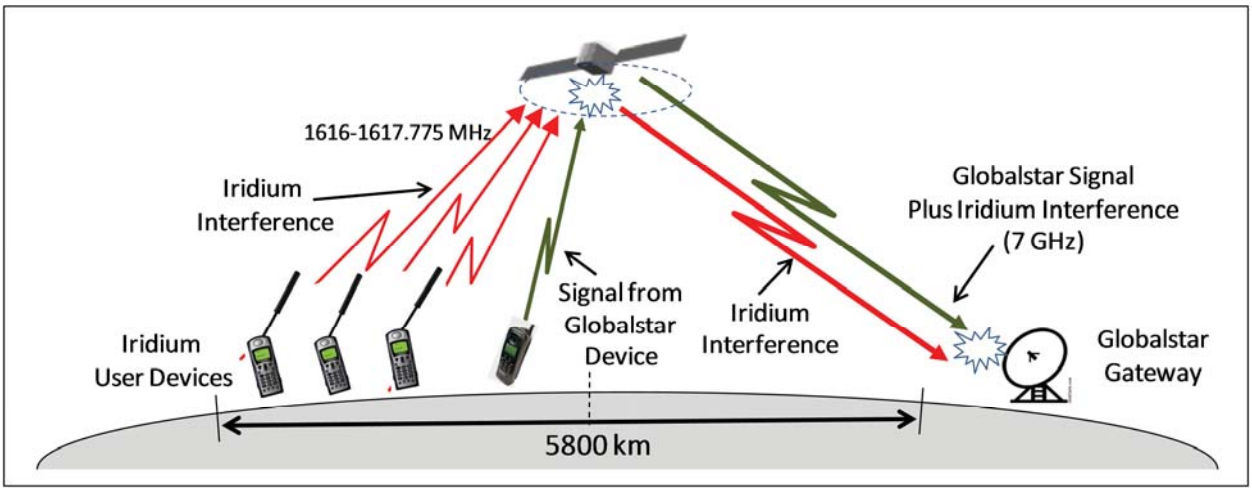

Figure 1: Globalstar Interference Scenario, 1616-1617.775 MHz

All Iridium user devices operating between 1616 and 1617.775 MHz within a Globalstar satellite receive "footprint" contribute to additional interference at the Globalstar satellite. The Globalstar satellite receive footprint is generated by a central antenna beam surrounded by 15 peripheral beams, as shown in Figure 2.[3] When projected on the earth's surface, the beams create a footprint approximately 5800 km in diameter. Therefore, even if the Globalstar peak traffic is confined to a relatively small geographic area, for example, due to disaster communication demands, Iridium users within the entire Globalstar uplink footprint create interference to Globalstar users in that area.

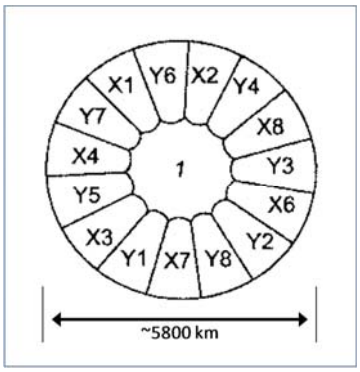

Figure 2. Globalstar Satellite Receive Antenna Pattern for User Device Uplink Transmissions (representation)

[3] F. Dietrich, P. Metzen, and P. Monte, "The Globalstar Cellular Satellite System," *IEEE Transactions on Antennas and Propagation,* Vol. 46, No. 6, June 1998.

2.2 Globalstar Frequency Plan and Iridium Interference

Figure 3 depicts the scenario for additional interference created in the frequency domain by Iridium user devices transmitting in the 1616 to 1617.775 MHz frequency band.[4] In this diagram, the Globalstar CDMA duplex channels are numbered, and the Globalstar CDMA simplex channels are identified alphabetically.

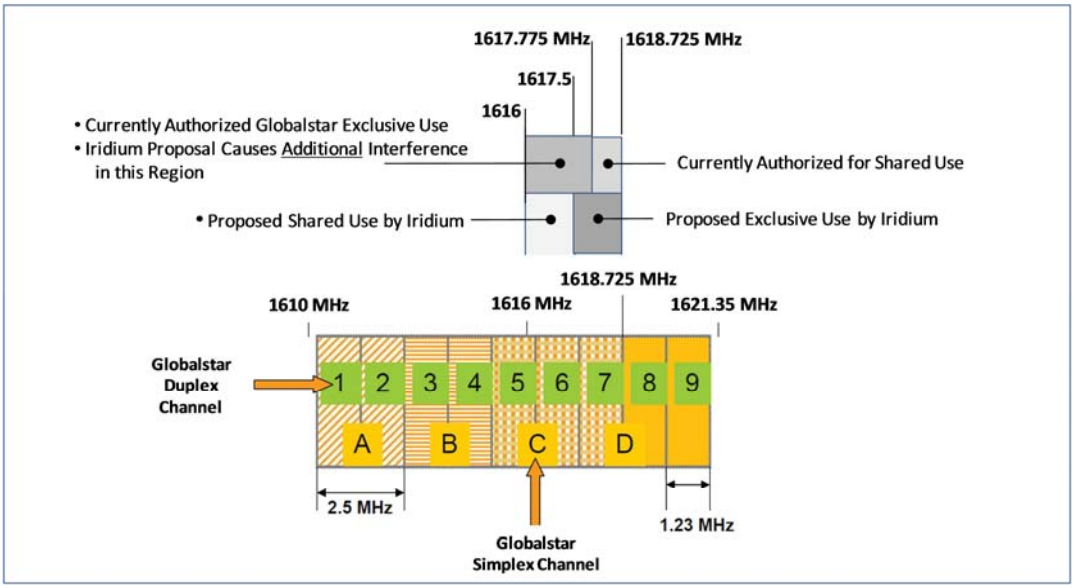

Figure 3: Interference Scenario Created by Iridium User Devices

In Iridium's proposal, the spectrum between 1616 and 1617.775 MHz, currently licensed exclusively to Globalstar, would be reassigned for Iridium use: The spectrum between 1616 and 1617.5 MHz would be authorized for shared Iridium and Globalstar use, and the spectrum between 1617.5 and 1617.775 MHz would be assigned exclusively to Iridium. The spectrum between 1617.775 and 1618.725 MHz, currently authorized for shared Globalstar and Iridium use, would also be assigned exclusively to Iridium. If the Iridium proposal was adopted, besides eliminating the ability of Globalstar to use its duplex channel 7, Iridium's operations would cause interference to Globalstar's system in the spectrum between 1616 and 1617.775 MHz.

3.0 Analysis of Impact of Iridium Interference to Globalstar

3.1 Concepts and Approach to Analysis

Code Division Multiple Access (CDMA) technology has been used for many years to provide shared access to a radio channel by transmissions from multiple users, not only for terrestrial cellular systems, but also for satellite systems. In CDMA, users are assigned unique, specially designed code sequences which modulate the transmitted signal and enable a properly designed and synchronized

[4] See *Opposition of Globalstar, Inc. to Petition for Rulemaking*, RM-11697, December 2, 2013.

receiver to decode the signal of an individual user. The fundamental concepts of CDMA are described in detail in many journal papers and textbooks.[5,6,7,8] For example, Chapter 6 in *Introduction to Spread Spectrum Communications*[6] provides a general analysis of the concepts used in CDMA both to share spectrum and to quantify the mitigation of various types of interference including narrowband jammers.

Iridium's system is TDMA-based and would present an undesirable interference to the CDMA-based Globalstar system. The Iridium system would act, in effect, as a form of "jamming." The general principle of interference mitigation in CDMA depends upon the fact that a desired CDMA user transmission is direct-sequence spread before transmission using a known digital sequence, and the reverse operation is done at the receiver. Thus, assuming perfect synchronization and a perfect channel, the spreading-despreading operations cancel out one another for the desired user. The user data begins and ends having narrowband attributes. During transmission, however, the bandwidth of the desired signal has been increased to a much larger bandwidth corresponding to the chip rate of the CDMA spreading code. In the case of Globalstar, that spreading code rate is 1.23 M chips/sec and the bandwidth approximately 1.23 MHz. Narrowband interference (e.g. Iridium transmissions) is linearly added to the spread waveform during transmission. During the receiver despreading process, the undesired signal is multiplied by the despreading CDMA code and its bandwidth is spread to approximately the transmission bandwidth of the desired signal. The despreading operation in the CDMA receiver also despreads the desired waveform to its pre-spread form and spreads interference to the full CDMA bandwidth of the system. The received desired signal plus interference is passed through a matched filter to detect the desired information. This matched filter may be approximated by a band pass filter having bandwidth equal to the information bit rate. Thus, the despreading operation has transformed the interference power to wideband interference, which may be analyzed as equivalent wideband Gaussian noise in the CDMA transmission bandwidth.

With the above concepts as a basis, Gilhousen,[9] in what has become a classic analysis, calculated the capacity of a terrestrial cellular CDMA system. For a satellite system, the underlying concepts are unchanged from the standpoint that received interference power from other CDMA users, or any other source, affects capacity in exactly the same manner. Thus, either narrowband or wideband interference received at the same power level as a CDMA interfering signal (i.e. not the desired signal) have the same effect on performance. The formula for CDMA capacity is given by:

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[5] A.J.Viterbi, *CDMA: Principles of Spread Spectrum Communications,* Addison-Wesley, 1995, ISBN 0-201-63374-4

[6] R. Peterson, et al., *Introduction to Spread Spectrum Communications,* Prentice-Hall,1995, ISBN 0-02-431623-7

[7] M. Simon et al., *Spread Spectrum Communications Handbook,* McGraw-Hill 1994, ISBN 0-07-057629-7

[8] J. Holmes, *Spread Spectrum Systems for GNSS and Wireless Communications,* ARTECH House, 2007, ISBN 978-1-59693-083-4

[9] K. Gilhousen et al., *On the Capacity of a Cellular CDMA System,* IEEE Transactions on Vehicular Technology, Vol. 40, No. 2, May 1991.

$$N = 1 + \frac{W/R}{E_b/N_o} - \frac{\eta}{S}$$

Where

W = spread bandwidth (1.23 MHz)

R = information rate (4800 bps)

$\frac{E_b}{N_o}$ = required signal-to-interference plus noise ratio for acceptable link performance

η = background noise in the total transmission bandwidth. The source of this noise is not relevant.

S = desired signal received power (assume all CDMA signals are received at the same power level)

For the purposes of this analysis, the key in this formula is the last term $-\eta/S$, which says that each S Watts of increased received power reduces CDMA capacity for other users by one unit. Stated differently, the total interference power η can be thought of as factor α times the desired received CDMA user power$S$. Then the equation becomes

$$N = 1 + \frac{W/R}{E_b/N_o} - \frac{\alpha \times S}{S} = 1 + \frac{W/R}{E_b/N_o} - \alpha$$

This formula illustrates that CDMA capacity is reduced by one unit for each unit that α increases. *The CDMA system does not distinguish Iridium interference power from CDMA other-user interference power*. The degradation in Globalstar capacity resulting from Iridium interference can therefore be calculated by considering the total received Iridium interference power relative to the CDMA power. This analytical approach can be used to assess the degradation to Globalstar capacity due to operation of Iridium devices in Globalstar uplink frequencies.

In general, the degradation can be of two types. The first is the degradation due to interference into the CDMA channel on the satellite's uplink channels, adding to the overall noise plus interference level, as described above. This is the interference-limited case. The second type applies to the case where the satellite's total transmit power on the downlink channel is limited to a certain set value (again, the Globalstar system operates as a "bent pipe" system, in which the satellite's transponder re-broadcasts uplink signals to Globalstar's earth gateway stations using a different downlink channel). In this case, any undesired interference energy received within the satellite's uplink passband (even if it falls outside of the CDMA channels) is re-broadcast by the transponder, and so subtracts from the total power available to transmit desired signals. This is the power-limited case. Both types of degradation will occur with Iridium operations extended below 1617.775 MHz.

3.2 Detailed Calculation of Globalstar Capacity Degradation due to Iridium Interference

The detailed analysis described here calculates the loss in Globalstar capacity due to a fully loaded Iridium system operating in the same satellite footprint and bandwidth as a Globalstar system. At a minimum, this is the situation that would occur in a disaster scenario in which terrestrial systems would be impaired or inoperative and satellite systems would be operating at their capacity limits. The analysis is based on the fundamental concepts described above.

The first step in the analysis is to evaluate the received power at the Globalstar satellite from one Globalstar user and also from one Iridium user. This calculation uses a detailed link budget that considers: 1) the subscriber unit average transmit power; 2) Globalstar antenna gain; 3) free space path loss; 4) power control; and 5) cross-polarization losses. The results of this calculation are: a) -161.5 dBW average power for one Iridium user, b) -157.8 dBW average power for one Globalstar user. Using these values, the power from one Iridium user is equivalent to 0.427 of the power from one Globalstar user[10]. Stated another way, at the Globalstar satellite receiver, 2.34 Iridium users create the same interference power as a single Globalstar CDMA user.

In order to calculate the incremental degradation of Iridium interference on the Globalstar system due to the additional spectrum allocated for Iridium use, a calculation of the total number of additional Iridium users within a Globalstar satellite footprint and within the appropriate bandwidth must be performed. Table 1 summarizes this calculation. Item a) of the table is the number of Iridium users supported in a single TDMA Iridium channel; this number is indicated in publicly available Iridium documents[11]. Item b) of the table is the total number of Iridium channels in the band 1616 to 1617.775 MHz[12]. This value is calculated based upon the Iridium channel spacing of 41.7 kHz[13]. There are four users per Iridium channel so item c) is four times item b). Item d) of the table represents the number of Iridium beams within the entire Globalstar satellite footprint and within the band of interest. The Globalstar satellite footprint size was calculated using a footprint diameter of 5800 km[14]; the resulting 26,420,794 km^2 footprint was presumed to have 16 equal sized beams as projected onto the earth's surface[15]. The Iridium satellite footprint[13] is 15,299,900 km^2 and contains 48 beams also presumed to be equally sized. The ratio of the resulting beam sizes is therefore 5.18, on the average. Iridium does not use every channel in every beam. Rather, there is a frequency reuse pattern that varies between 5 and 12. This means that between 1/5 and 1/12 of the channels are used in any Iridium footprint. The table below presumes a reuse of 5 as given in item e). Item f) is the total number of Iridium users possible in the

[10] Calculated using 1/10^((-157.8 –(-161.3))/10)
[11] C. Fossa, *A Performance Analysis of the Iridium Low Earth Orbit Satellite System,* Air Force Institute of Technology, AFIT/GE/ENG/98J-01, 29 June 1998.
[12] The frequency range of 1616 to 1617.775 is used, as this represents the new frequency bands in which Iridium would operate, that fall within the Globalstar satellite passband.
[13] S. Pratt et al., An *Operational and Performance Overview of the Iridium Low Earth Orbit Satellite System*, IEEE Communications Surveys, Spring 1999.
[14] UCLA Computer Science Department course notes, CS 216, Winter 2002
[15] In reality, the central beam is slightly smaller in size, so this calculation represents the average area.

bandwidth 1616 to 1617.775 MHz. This value is calculated from other values in the table; specifically item f) is 170.4 *5.18 /5= 177.2. This is the total number of Iridium users in a Globalstar beam (not channel) within the specified frequency band. Globalstar system engineers state that the center Globalstar beam is somewhat smaller than the outer beams and have provided items g), h), and i). The total number of equivalent beams in the footprint is item i) of the table or 15.7 beams per footprint. Multiplying item f) by item i) yields a total of 2782 Iridium users within the entire Globalstar footprint within the band 1616 to 1617.775 MHz. This number accounts for Iridium frequency reuse (5), the number of Iridium beams within one Globalstar beam (5.18), the Iridium frequency spacing (41.7 kHz), and the difference in satellite footprints between Globalstar and Iridium. Item k) of the table was discussed previously and represents the number of Iridium users that result in the same received power at the satellite as a single Globalstar user. Dividing item j) by item k) gives the total equivalent number of Globalstar users represented by all Iridium users in a fully loaded Iridium system in the band 1616 to 1617.775 MHz.

In summary, detailed analysis shows that very significant degradation in Globalstar capacity is caused by Iridium operations in the Globalstar uplink frequencies. In particular, one Globalstar unit of capacity is lost for each 2.34 Iridium users added. Further, assuming a Globalstar fully loaded capacity[16] of 2500 users per satellite, a fully-loaded Iridium system in the same band segment incrementally decreases Globalstar capacity by 47% per affected satellite. The capacity limit of 2500 users per satellite is set by the transmitter power limits of the Globalstar satellite as it re-broadcasts its received signals. Therefore, the Iridium signal energy received by the satellite, which is re-broadcast as well, effectively steals the calculated amount of capacity from the Globalstar system. Reiterating, this degradation would occur during periods of peak traffic demand, such as would occur during and after natural or manmade disasters when capacity is most urgently needed. Significantly, all Iridium users within the entire Globalstar satellite receive footprint with 5800 km diameter contribute to the additional interference that steals Globalstar capacity, not just the Iridium users also within the disaster area.

In the analysis above, it is assumed that the time-pulsed interference signals from the approximately 2800 Iridium terminals visible in the Globalstar footprint arrive at the satellite receiver in a random manner. On this basis, the resulting capacity loss of 47% is a reflection of the amount of interfering power as averaged over the Iridium TDMA frame. In actuality, the signals on the Iridium TDMA channels, which are tightly synchronized in time with respect to the Iridium satellite, will have random delays with respect to the Globalstar satellite, and these delays will shift based on the relative position and velocity of the Globalstar satellite. Therefore, while in many cases the received pulses will contribute randomly to interference, in some time intervals portions of the interference pulses will arrive nearly synchronously, causing interference power "spikes" of higher power at the Globalstar receiver. In such cases, the capacity loss to the Globalstar system will be even more severely impacted (if only for a short time interval), potentially causing as much as a 100% capacity loss.

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[16] D. Chang and O. de Weck, "Basic Capacity Calculation Methods and Benchmarking for MF-TDMA and MF-CDMA Communication Satellites," *International Journal of Satellite Communications, 2004.*

Table 1. Effect of Iridium Interference on Globalstar System

	Description	Value	Units	Comments
a	Number of Iridium users per Iridium channel	4.0000		Four Iridium time slots per channel[17]
b	Number of Iridium channels in 1616 to 1617.775 MHz (total band is 1.775 MHz)	42.5966	users	Iridium channel spacing is 41.67 kHz.[18] = 1.775/0.04167
c	Number of Iridium users in 1616 to 1617.775	170.3864	users	= a*b Does not account for Iridium frequency reuse plan
d	Number of Iridium beams in a Globalstar outside beam	5.1800		Globalstar footprint[19] diameter is 5800 km. Footprint area = 26,420,794 km^2 or 1,651,299 km^2 per beam assuming all 16 equal. Iridium footprint[16] is 15,299,900 km^2 or 318,747 km^2 for each of 48 beams. 1.651/0.319 = 5.18
e	Assumed frequency reuse in 5.2 beams	5.0000		Section 5.3 of ECC report[20] states that re-use factor for Iridium varies between 5 and 12. The value of 5 is the worst case for this analysis, and was also used in the Iridium analysis.
f	Maximum number of Iridium users transmitting towards a Globalstar satellite.	177.2018	users	There are 170.4 *5.18 /5= 177 Iridium users in a Globalstar beam.
g	Number of Globalstar outer beams per satellite.	15.0000		Globalstar system descriptions.
h	Globalstar Inner beam coverage/Outer beam coverage area	0.7000		From Globalstar, Inc.
i	Globalstar Outer beam coverage area to satellite coverage area factor	15.7000		g + h
j	Total number of Iridium users transmitting to a Globalstar satellite	2782.0686	users	= f * i This calculation accounts for Iridium frequency reuse as well as number of Iridium beams per Globalstar beam.

[17] C. Fossa et al., *An Overview of the Iridium Low Earth Orbit Satellite System,* IEEE 1998.
[18] S. Pratt et al., *An Operational and Performance Overview of the Iridium Low Earth Orbit Satellite System*, IEEE Communications Surveys, Spring 1999
[19] UCLA Computer Science Department course notes, CS 216, Winter 2002.
[20] *Sharing Between MSS Systems Using TDMA and MSS Systems Using CDMA in the Band 1610 – 1626.5 MHz,* Electronic Communications Committee of CEPT, ECC Report 95, February 2007

k	Number of Iridium users equivalent to one Globalstar user	2.34		Based upon detailed link budget calculations provided in the appendix. Received Iridium single user power = -161.5 dBW. Received Globalstar single user power = -157.8 dBW. = 1/(10^((157.8-161.5)/10))
l	Number of equivalent Globalstar users that a fully loaded Iridium system represents.	1188.9	users	In band 1616 to 1617.775 MHz.

4.0 Critique of Interference Analysis Performed by Iridium

In the Supplemental Comments filed by Iridium in November of 2014[21], in the Technical Appendix[22], Iridium provides a link budget analysis of interference from Iridium handsets transmitting on uplink frequencies used by Globalstar terminals[23], purporting to show that the resulting interference is within acceptable bounds. However, there are several errors in this analysis which result in an underestimation of the interference levels. In this section, these errors are noted and discussed, and corrections are provided, leading to a more accurate estimation of such interference. The Iridium analysis with corrections is provided in Appendix A.

4.1 Duty Cycle / Time Slot Usage

In the Iridium link budget analysis, a -10.4 dB duty cycle factor is applied to the Iridium handset transmit power, based on the fact that a mobile terminal on the Iridium system will use only one time slot in each frame of the TDMA channel[24]. This reflects a duty cycle of 9.2% (i.e. one 8.28 ms time slot in each 90 ms frame). While this is correct for a single terminal, for a loaded system during the busy hour (which Iridium's analysis is stated to address), 4 time slots in each frame in the TDMA frame would be utilized by transmitting terminals.[25] The Iridium analysis does not account for this usage, and the correct aggregate duty cycle on the uplink channel would be 36.8%. The use of all four time slots leads to a 6 dB increase in the aggregate Iridium interference power compared to the Iridium analysis.

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[21] *Iridium Constellation LLC, Petition for Rulemaking, RM-11697*; Supplemental Comments of Iridium Constellation LLC, RM-11697, IB Docket No. 13-213, RM-11685 (filed Nov. 5, 2014) ("Iridium Nov. 5, 2014 Supplemental Comments").
[22] *Id*, Exhibit 2: Technical Appendix.
[23] *Id*, Table 2: Iridium Terminal to Globalstar Satellite Interference Link Budget ("Table 2").
[24] Table 2, row 2 left.
[25] The TDMA channels used in the Iridium system consist of 4 uplink and 4 downlink time slots in each TDMA frame, supporting 4 individual users on the channel – see C. Fossa et al., "*An Overview of the Iridium Low Earth Orbit Satellite System*," *Proceedings of IEEE Aerospace and Electronics Conferenc*e, 1998.

4.2 Relative Spot Beam Coverage Areas

In a satellite communication system, ground coverage is effectively partitioned into cells over which frequency reuse may be performed, by means of dividing the satellites' transmit and receive antenna patterns into concentrated "spot beams." The spot beams used in the Iridium system are significantly smaller, in terms of geographic area, than those in the Globalstar system. As a result, multiple Iridium spot beams exist in each Globalstar spot beam. The link budget analysis in the Iridium filing assumed that each Globalstar spot beam would comprise the same ground area as 3 Iridium spot beams[26]. This value was an estimate that appeared in a prior filing with the FCC by Globalstar in 2004.[27] A more rigorous analysis of the respective terrestrial coverage areas of each system's spot beams, as provided in section 3.2 above (specifically, row d) of Table 1), leads to a more accurate figure for the number of Iridium spot beams per Globalstar beam: 5.18 Iridium beams in a single Globalstar beam, on average. This ratio of 5.18-to-3 represents an increase in the number of Iridium channels appearing in each Globalstar spot beam, which, for a loaded Iridium system, translates to an increase of 2.4 dB in the aggregate Iridium interference level compared to the Iridium analysis.

4.3 Nominal Handset Power

The link budget analysis performed by Iridium specified the nominal power of an Iridium handset (during a TDMA burst) as 4.5 dBW, based on the handset's effective isotropic radiated power ("EIRP")[28]. The specifications for an Iridium handset give its maximum power as 8.5 dBW[29], but this value would vary due to power control in the Iridium handset (which varies in 1 dB steps from 0 to 8 dB of attenuation of the transmit power). A study performed by the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administration (CEPT)[30] derived the expected probability distribution of Iridium power control, based on Rician fading. From this distribution, the average value for Iridium handset power control is determined to be 5.8 dB. The average handset power would in that case be just 2.7 dBW; based on this analysis, the Iridium analysis actually overestimated the nominal handset power, and the Iridium interference power of a single user device, by 1.8 dB.

4.4 Combined Impact of Errors in Iridium Interference Analysis

Taking all the errors described above together, the link budget analysis reported by Iridium underestimates the aggregate uplink interference from Iridium handsets by a total of 6.6 dB.

The link budget analysis performed by Iridium then calculated the ratio of the power density of the aggregate interference to that of the total intra-system interference plus noise (Io + No) at the

[26] Table 2, row 17 left.
[27] *Review of the Spectrum Sharing Plan Among Non-Geostationary Satellite Orbit Mobile Satellite Service Systems in the 1.6/2.4 GHz Bands*; Petition for Reconsideration of Globalstar LLC, IB Docket No. 02-364, ET Docket No. 00-258 (filed Sept. 8, 2004).
[28] Table 2, row 1 left.
[29] ECC Report 95, *Sharing Between MSS Systems Using TDMA and MSS Systems Using CDMA in the Band 1610-1626.5 MHz*, at 10 (Feb. 2007) ("ECC Report").
[30] "ECC Report", at 20-21.

Globalstar satellite receiver to be -15.6 dB[31], or 2.8%[32]. This is less than 3%, the value referenced by Iridium as the limit of acceptable interference and described in the ECC report mentioned above.[33] However, with the 6.6 dB correction to the Iridium calculation, the ratio of aggregate interference to (Io + No) becomes -9.0 dB, or roughly 12.5% per affected satellite - over 4 times the power compared to the Iridium referenced limit value of 3% in the frequency band 1616 to 1617.775 MHz. The corrected Iridium calculations make it clear that the interference to Globalstar satellite operations caused by newly introduced operations of Iridium into Globalstar's uplink frequencies will result in high levels of interference and degradation of service to Globalstar's subscribers in this band.

The calculation here addresses the interference limited case, rather than the power limited case (as explained at the end of section 3.1). There is a 12.5% degradation to Globalstar's interference plus noise level, which would translate to a degradation of capacity of the same order[34]. For the power-limited case treated in section 3, there is a capacity degradation of over 47% per affected satellite, indicating that the power limitation would be the dominant cause of degradation to Globalstar – a fact overlooked in the Iridium analysis.

4.5 Relative Interference levels and Iridium Interference Impact

The corrected link budget analysis above shows that the aggregate interference from a loaded Iridium system will exceed the recommended value of 3% of the Globalstar system's intra-system interference plus noise (Io + No) floor by a substantial amount. Iridium claims that the 3% criteria is overly conservative, stating that at 3%, the aggregate interference would still be 15 dB below the (Io + No) floor. The implication that such interference levels are insignificant represents a fundamental misunderstanding of CDMA-based communications. CDMA systems are designed such that the desired signals themselves are received at power levels far below the (Io + No) floor and, in many instances, below the thermal noise floor itself. A CDMA signal *appears as* noise (or rather, is noise-like) and only becomes a recognizable information signal after the demodulation / de-spreading process recovers the desired signal. From this standpoint, *anything* which adds to the overall (Io + No) level in a measurable way degrades performance by reducing capacity or by decreasing the signal-to-noise ratio of user transmissions.

The Iridium analysis also states that interference from Iridium units will have minimal impact on Globalstar operations because the TDMA Iridium signals are much narrower in bandwidth versus the spread-spectrum CDMA signals transmitted by Globalstar. CDMA, Iridium claims in its analysis, has some form of special immunity to narrowband interference, because of the processing gain employed in the spreading / de-spreading operation. While it is true that spread-spectrum systems are able to withstand narrowband interference better than non-spread-spectrum systems, it is erroneous to regard them as immune to such interference. As was shown in Section 3, on an equal

[31] Table 2, row 23 left.
[32] Table 2, row 24 left.
[33] ECC Report, at 21.
[34] More correctly, the degradation of Globalstar system capacity would relate to the ratio of the aggregate Iridium interference to Globalstar's intra-system interference, without the noise component.

power basis, narrowband signals cause exactly the same amount of interference to a CDMA system as other wideband CDMA signals.

4.6 Globalstar Degradation in Disaster Situations

In a typical disaster situation, there will be a specific geographic area creating great demand for Globalstar satellite capacity due to impaired or non-existent terrestrial communications in that area. Iridium users throughout the entire Globalstar uplink footprint of 5800 km, not just within the disaster area, will create additional interference that steals Globalstar capacity needed for emergency services during and after the disaster.

5.0 Degradation to Globalstar System Services and Service Quality

In addition to the harm caused to the system capacity of the Globalstar duplex channels, there will be additional degradation to specific user services on the Globalstar network, the service quality the Globalstar users receive, and the overall capacity of the satellite, as the result of Iridium's operations on Globalstar's uplink frequencies.

5. 1 Impact on Globalstar System Quality of Service

The high level of interference that the Globalstar system would experience on its uplink frequencies due to Iridium operations will not only impact the Globalstar system's capacity, but also the user quality of service. The user's ability to establish an initial connection to the system and to maintain calls with acceptable quality will be degraded. Locations where subscribers once received reliable connections will experience dropped calls, and locations at the edges of the Globalstar service footprint which previously were able to establish a link with the system, although at low signal levels, will be unable to establish a link at all. This will also be the case in obstructed areas where signal power is also reduced. The rise in the overall interference-plus-noise floor will be such that even at maximum handset power levels, there will still be insufficient signal energy to establish connections.

5. 2 Impact on Globalstar Simplex Services

This report has focused on the impact of Iridium operations on Globalstar's baseline duplex services. The frequencies in the 1.6 GHz band on which Iridium subscribers would be transmitting serve as uplink channels for these services. However, Globalstar's simplex services are another important class of services which will also be impacted. These services also use these uplink channels, including Globalstar's popular SPOT® line of consumer devices for personal tracking, emergency location reporting, and messaging[35]. As shown in Figure 3, a substantial portion of Simplex Channel C lies in the proposed frequency band that would be used by Iridium.

Interference in the Simplex channels presents a particular impairment to Globalstar operations. Since there is no return downlink channel, simplex channels are not able to adjust their transmit

[35] http://www.findmespot.com/en/ - last visited Dec. 18, 2014.

power to compensate for increased interference levels (i.e., there is no closed-loop power control). In this case, critical location and emergency messages will simply be lost when excessive interference occurs. Since the SPOT® service's value is personal safety in life-threatening situations, any degradation of this service due to Iridium interference is not acceptable.

5. 3 Impact on Globalstar Second Generation Services

In addition to the current suite of simplex and duplex voice and data services, Globalstar is planning to deploy a new generation of high-speed data services, beginning in 2016, with uplink and downlink data speeds of up to 256 kbps for mobile service[36]. Because of the higher bit rates, the overall spread spectrum processing gain of the data signals will be reduced from those that currently exist at legacy data rates (2400 to 9600 bps). The result is that the signals for the new high-speed services will have decreased tolerance to interference. Increased interference by Iridium will degrade the performance of these new services as measured by reduced geographic coverage and interrupted data sessions.

5.4 Impact on Globalstar Due to Battery Capacity

During an orbital period, a Globalstar satellite alternates between "light" periods when it is illuminated by the sun, and "dark" periods when the sun is eclipsed by the earth. When the sun is visible to the satellite, its batteries are charged by solar panels; when the sun is not visible to the satellite, the finite amount of energy stored in the batteries is utilized to maintain continuous satellite operations.

The capacity of the Globalstar satellite batteries and also the charging capability of its solar panels were engineered to be in deliberate balance with Globalstar energy consumption requirements, with enough additional capacity to handle Globalstar peak loads and take into account decreased energy efficiency over the life of the satellite. The additional satellite power consumed by the Iridium interference steals satellite battery energy that would not otherwise be consumed, upsetting the balance between battery capacity, battery energy consumption, and battery charging.

As a result of this additional battery energy being depleted, a Globalstar satellite's capacity is degraded not only during the time interval when Iridium interference is actually present as described in Section 3, but also during the entire duration of the satellite orbit, and potentially for several successive orbital periods, depending on the intensity of the Iridium interference.

[36] FCC ex parte Letter from L. Barbee Ponder to Marlene H. Dortch, RM-11697, Oct. 24, 2014, at 4.

6.0 Conclusions

6.1 Degradation to Globalstar Due to Iridium Operations in 1616-1617.775 MHz

Iridium's analysis significantly underestimates the interference and the harm to Globalstar that would result from a decision to allow Iridium to operate in spectrum between 1616 and 1617.775 MHz, currently licensed exclusively to Globalstar.

An accurate analysis of the impact of Iridium operations to Globalstar in the frequency band 1616 to 1617.775 MHz reveals that the following degradation to Globalstar would result:

1. Reduction in Globalstar Subscriber Capacity Due to Consumption of Satellite Downlink Amplifier Power

   Iridium interference power will be received and repeated by the Globalstar power amplifiers, consuming satellite downlink amplifier power, stealing power from Globalstar users, and decreasing satellite capacity.

   a. Globalstar will lose the ability to serve 1 subscriber for every 2.3 Iridium users operating within the same Globalstar spot beam.
   b. Globalstar capacity will be reduced 47% per affected satellite, during peak periods for Iridium traffic. The ability to serve users in disaster situations when high traffic intensity occurs will be impaired.

2. Reduction in Globalstar Users' Quality of Service
   a. Failure to establish connections in low-signal locations that are currently served.
   b. Increased dropped voice calls.
   c. Increased interrupted data sessions for current services. Failure to deliver emergency messages (Globalstar Spot simplex service).
   d. Increased interrupted data sessions and reduced capacity, due to message retransmissions, for second generation (high-speed data) services.

3. Reduction of Globalstar Capacity Throughout Its Orbital Period

   As a result of additional Globalstar battery energy being consumed while Iridium interference is present, less battery energy is available to maintain Globalstar satellite operations and capacity for the duration of the Globalstar orbital period.

4. Increased Interference Levels

   For each affected satellite, the total interference-plus-noise level to Globalstar will increase to over 12% of the Globalstar interference-plus-noise budgeted amount, significantly higher than the limit of 3% for satellite systems referenced by Iridium.

5. Degradation During Disaster Situations
   Iridium users throughout the *entire* 5800 km Globalstar receive footprint will create additional interference that steals Globalstar satellite capacity needed for emergency services during disaster situations, even in the case of geographically limited disaster areas.

6.2 Recommendation

Iridium's proposal to operate in the spectrum between 1616 and 1617.775 MHz, currently licensed to exclusively Globalstar, should not be accepted.

Appendix A: Critique and Corrections to Interference Calculation by Iridium

The Tables below identify the errors in Iridium's calculation of the interference to Globalstar created by Iridium users sharing spectrum in the frequency band 1616-1617.775 MHz.

Table 2a. Interference Calculation by Iridium, with Corrections

Derived and corrected from Iridium Table 2 in "SUPPLEMENTAL COMMENTS OF IRIDIUM CONSELLATION" Nov. 6, 2014.	**original values**	**units**	**corrected values**	**A Reference list follows this table.**
Iridium handset nominal e.i.r.p. (burst) [one user]	4.50	dBW	8.50	Ref 1009 p 10 says Iridium handset max power is 8.5 dBW. Ref 1048 says average power is 0.6 W (-2.2 dBW) and peak is 7 W. (8.45 dBW) Ref 1049 gives 8.45 dBW peak; -1.91 average over burst. Iridium uses power control (accounted for in row 6) resulting in lower average transmit power.
Duty cycle of Iridium transmission burst relative to the total time frame	-10.40	dB	-10.36	Burst structure is described in Ref 1006. One user UL transmits 8.28. ms out of a frame of 90 ms. This results in -10.18 dB. There are 4 UL transmissions in a 90 ms burst. See also 1009 p10.
RAA ADDED: Power control model	0.00	dB	-5.79	Ref 1008 Section 5 for Globalstar. Ref 1007 for Globalstar. Will use Ref 1009 Figure 15 for Iridium. Used Figure 15 to calculate the probability density and then averaged using linear power control numbers.
Average Tx EIRP	-5.90	dBW	-7.65	B4 - B5 + B6 This represents a **single use**r slot.
Globalstar satellite altitude	1414.00	km	1414.00	Confirmed in Table 3-9 of Ref 1007
Typical Globalstar satellite slant range [to Iridium]	1952.00	km	1952.00	Table 3-9 of Ref 1007 gives 1487.1 km max. for Globalstar. Iridium to Globalstar would be different. We will presume 1952 is close enough.

Frequency	1.62	GHz	1.62	
Path loss	162.43	dB	162.43	Table 3-9 of Ref 1007 gives 160.1 dB free space loss.
Globalstar sat. antenna gain	14.60	dB	14.60	Ref 1046 calculates an antenna gain of 17.0 dB.
Cross-polarization isolation	6.00	dB	6.00	Globalstar system experts suggest a lower number may be appropriate.
Single received Iridium handset interference power	-159.73	dBW	-161.48	for a single Iridium user per frame
Number of Iridium channels per Globalstar channel	29.50		29.50	From 1009 Fig 7, Globalstar CDMA channels are 1.23 MHz. From 1010 (also 1006) Iridium channel spacing is 41.7 KHz. Ratio is 29.49.
Iridium channel reuse	5.00		5.00	From Section 5.3 of 1009. 5 is the minimum reuse number.
Maximum realizable Iridium channels per Globalstar channel (rounded up)	5.90		5.90	Globalstar CDMA channels are 1.23 MHz. From 1010 Iridium channel spacing is 41.7 KHz. Ratio is 29.49. B18/B19 = B20
Approximate number of Iridium spot beams per Globalstar spot beam	3.00		5.18	**Globalstar:** Ref 1045 gives footprint diameter of 5800 km area = 26,420,794 total or 1,651,299 km2 per beam assuming all equal. This corresponds to a beam radius of 725 km. Ref 1046 gives single beam diameter of 1150 km diameter or 1,038,689 km2 per beam **Iridium**: Ref 1013 p 18 gives 15,299,900 km2 for the Iridium footprint. Resulting in 48 beams each with area 318,747 kmsq Using the numbers from ref 1045and 1013 --> 1.651/0.319 = 5.18
Maximum realizable Iridium channels per Globalstar channel, per Globalstar spot beam	17.70		30.56	From Section 5.3 of 1009. Depends upon Iridium reuse factor of 5.
Aggregate Iridium uplink interference power per Globalstar channel and spot beam	-147.25	dBW	-146.63	=D16 + 10log10(D22)
Globalstar sat TX bandwidth	60.90	dB-Hz	60.90	=10*LOG10(1230000)
Aggregate Iridium uplink interference power density (one slot per frame)	-208.15	dBW/Hz	-207.53	=D23 - D24 This number still for a single user per Iridium channel.
Aggregate Iridium uplink interference power density (four slots per frame)			-201.51	Account for 4 Iridium users per frame. 10log10(4)
Aggregate Iridium uplink interference density to Globalstar receiver noise density, Io/No	-6.55	dB	0.09	

Ratio of aggregate Iridium uplink interference density to Globalstar receiver noise plus interference density	-15.71	dB	-9.07	=B24-B55
	2.68	%	12.39	corresponds to -15.7 dB (or -9.1 dB) from row 28

Table 2b. Interference Calculation by Iridium, with Corrections

Globalstar handset nominal e.i.r.p.	-10.00	dBW	-3.98	Ref 1052 states max power 0.400 W (-3.98 dBW) for handset and 0.794 W for car kit. This does not account for possible power control nor voice activity.
RAA added power control	0.00		-6.00	same notes as in E6
Globalstar transmit bandwidth	60.90	dB-Hz	60.90	same as D24
Globalstar e.i.r.p. density	-70.90	dBW/Hz	-64.88	=10*LOG10(1230000)
Globalstar satellite altitude	1414.00	km	1414.00	confirmed in Table 3-9 of Ref 1007
typical Globalstar satellite slant range	1952.00	km	1952.00	Table 3-9 of Ref 1007 gives 1487.1 km max. for Globalstar. Iridium to Globalstar would be different. To be conservative RAA has used the Iridium-calculated number.
Frequency	1.62	GHz	1.62	
Path loss	162.43	dB	162.43	Table 3-9 of Ref 1007 gives 160.1 dB free space loss. This number correct for range provided.
Globalstar sat. antenna gain	14.60	dB	14.60	Ref 1046 calculates an antenna gain of 17.0 dB. RAA has used the Iridium-calculated number to be conservative in the comparison.
Globalstar sat. received power from single handset	-157.83	dBW	-157.81	=D41 + D42-D49+D50 This is for a single user.
Globalstar sat received power density (spread)	-218.73	dBW/Hz	-218.71	=D53-D43 Note this is for a single user.
Globalstar sat. noise power density	-201.60	dBW/Hz	-201.60	Ref 1053
Globalstar's self-proclaimed sat Rx intrasystem interference density	-193.00	dBW/Hz	-193.00	Ref 1053.
Globalstar sat Rx noise plus intra-system interference density	-192.44	dBW/Hz	-192.44	=10*LOG10(10^(D53/10)+10^(D54/10))

References

The following is the reference list for the notes in Tables 2a and 2b:

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1010 R. Hobby, *An Introduction to the Iridium System,* Institution of Electrical Engineers, 1998.

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1048 *Iridium Subscriber Unit*, NAL Research Corporation, URL: http://www.nalresearch.com/NetRef_IridiumSubscriberUnit.html

1049 *Iridium Subscriber Unit License Information,* Motorola Inc. date unspecified.

1052 Globalstar, Data Sheet for GSP-1700 ISU.

1053 Globalstar, *Petition for Reconsideration of Globalstar LLC,* IB Docket No. 02-364, 8 September 2004.

Appendix B: Company Profile

Profile: Roberson and Associates, LLC
Roberson and Associates, LLC, is a technology and management consulting company with government and commercial customers that provides services in the areas of RF spectrum management, RF measurements and analysis, and technology management. The organization was founded in 2008 and is composed of a select group of individuals with corporate and academic backgrounds from Motorola, Bell Labs, IBM, IITRI (now Alion), independent consulting firms, and the Illinois Institute of Technology. Together the organization has over 400 years of the high technology management and technical leadership experience with a strong telecommunications focus.

Profiles: Roberson and Associates, LLC, Staff
Dennis A. Roberson, President and CEO, Roberson and Associates
Mr. Roberson is the Founder, President and CEO of Roberson and Associates, LLC. In parallel with this role he serves as Vice Provost for Research and Research Professor in Computer Science at Illinois Institute of Technology where he has responsibility for IIT's corporate relationships including IIT's Career Management Center, Office of Compliance and Proposal Development, Office of Sponsored Research and Programs, and Technology Transfer efforts. He also supports the development and implementation of IIT's Strategic Plan, the development of new research centers, and the successful initiation and growth of IIT related technology-based business ventures. He is an active researcher in the wireless networking arena and is a co- founder of IIT's Wireless Network and Communications Research Center (WiNCom). His specific research focus areas include dynamic spectrum access networks, spectrum occupancy measurement and spectrum management, and wireless interference and its mitigation, all of which are important to the Roberson and Associates mission. He currently serves on the governing and / or advisory boards of several technology-based companies. Prior to IIT, he was EVP and CTO at Motorola and he had an extensive corporate career including major business and technology responsibilities at IBM, DEC (now part of HP), AT&T, and NCR. He is and has been involved with a wide variety of Technology, Cultural, Educational and Youth organizations currently including the FCC Technical Advisory Council and Open Internet Advisory Committee, the Commerce Spectrum Advisory Committee, and the National Advisory Board for the Boy Scouts of America and its Information Delivery Committee, and the Board of HCJB Global. He is a frequent speaker at universities, companies, technical workshops, and conferences around the globe. Professor Roberson has BS degrees in Electrical Engineering and in Physics from Washington State University and a MSEE degree from Stanford.

Kenneth J. Zdunek, Ph.D. –V.P. and Chief Technology Officer
Dr. Zdunek is Vice President and the Chief Technology Officer of Roberson and Associates. He has over 35 years of experience in wireless communications and public safety systems. He is a Fellow of the IEEE, recognized for his leadership in integrating voice and data in wireless networks. Concurrently he is a research faculty member in Electrical Engineering at the Illinois Institute of Technology, in Chicago, Illinois, where he conducts research in the area of dynamic spectrum access and efficient spectrum utilization, and teaches a graduate course in wireless communication system design. Prior to joining Roberson and Associates, he was VP of Networks Research at Motorola. Dr.

Zdunek was awarded Motorola's patent of the year award in 2002 for a voice-data integration approach that is licensed and extensively used in GSM GPRS. He holds 17 other patents, included patents used in public safety systems and second and third generation cellular networks. He directed the invention and validation of Nextel's iDEN™ voice-data air interface and IP based roaming approach, and was the principal architect of Motorola's SmartNet™ public safety trunking protocol suite. In the 1990's, he directed a Spectrum Utilization and Public Safety Spectrum Needs Projection submitted to the FCC in support of the 700 MHz spectrum allocation for Public Safety. He was awarded the BSEE and MSEE degrees from Northwestern University, and the Ph.D. EE degree from the Illinois Institute of Technology. He is a registered Professional Engineer in the State of Illinois. He is past president, and a member of the board of directors of the Chicago Public Schools Student Science Fair, Inc.

Roger Peterson, Ph.D., Senior Principal Investigator

Roger Peterson is a Lifetime Fellow of the IEEE and co-author of four textbooks on digital communications and spread spectrum technology. He has more than 30 years of experience in digital communications technology and has served as associate editor for spread spectrum for the *IEEE Transactions on Communications*. Prior to joining Roberson and Associates he was a Fellow of the Technical Staff at Motorola Labs where, most recently, he was responsible for system-level capacity analysis of relay-assisted WiMax systems. He is the author of numerous technical papers and holds six issued US patents. He received the BS, MS, and PhD degrees in electrical engineering from the Illinois Institute of Technology.

Michael L. Needham, Principal Engineer

Mike Needham joined Roberson and Associates in November of 2013 with more than 28 years of experience in corporate research and development. His most recent position was Distinguished Member of the Technical Staff in the Applied Research Center at ARRIS (formerly Motorola Mobility/Google). He has worked in a broad range of technologies in the areas of wireless communication and media delivery systems including: network architecture design, specification, and analysis; data protocol design; radio system modeling; and media analytics. He has 25 issued U.S. patents, with several pending, and many years of experience in intellectual property assessment and management. Mr. Needham also has numerous publications in technical journals and conferences. He holds B.S. and M.S. degrees in electrical engineering from the University of Illinois in Urbana-Champaign.