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March 19, 2004

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

RE: IB Docket No. 02-364 Ex Parte Presentation

Dear Ms. Dortch:

On December 18, 2003, Iridium Satellite, LLC filed responses to certain questions posed by the International Bureau to amplify the record in the above-referenced docket. The information provided by Iridium Satellite confirmed many of the technical points that Globalstar, L.P. ("GLP"), has submitted to this docket in prior filings.

Accordingly, GLP is submitting the enclosed "Analysis of Iridium's December 18, 2003 Response" for the record to confirm the following points:

- There are several features of the Iridium system design and network that limit Iridium's capacity much more significantly than availability of L-band spectrum.
- Measurements of actual usage on the Iridium system indicate that Iridium is currently using less than 5% of its available spectrum in the Continental United States.
- Grant of access for Iridium to additional spectrum in the Middle East region alone did not result in Iridium's claimed improvement in call acquisition failure rate in that region after April 11, 2003.
- Given the Iridium system design and projected subscriber growth, Iridium Satellite should be able to serve users in the Continental United States for over 20 years into the future with its currently available 5.15 MHz in L-band.

The enclosed analysis confirms GLP's view that Iridium has not demonstrated factually a need for additional L-band spectrum and that the record in this docket does not support any change to the existing Big LEO spectrum plan.

Globalstar also filed a response on December 18, 2003, to a letter from the International Bureau and requested that the response be withheld from public disclosure. In fairness, Globalstar will withdraw its request for confidentiality and place its December 18, 2003 response in the public file.

Pursuant to Section 1.1206(b)(1), this letter and the enclosure are being filed electronically over the Commission's Electronic Comment Filing System.

Respectfully submitted,

GLOBALSTAR, L.P.

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Enclosure

cc: The Honorable Michael K. Powell
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The Honorable Jonathan S. Adelstein
The Honorable Michael J. Copps
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March 2004

Analysis of Iridium's December 18, 2003 Response

1. Summary

In its December 18, 2003 response ("Response") to International Bureau questions in IB Docket No. 02-364,[1] Iridium finally provided sufficient information about its system operations to allow Globalstar to test its previous analyses submitted to this docket. Iridium's own data confirm that the Iridium system does not use spectrum efficiently and that system design features which limit Iridium's capacity cannot be counterbalanced or undone with additional spectrum.

Globalstar has recently measured Iridium's actual usage of its assigned spectrum in the United States. These measurements show that Iridium is only using approximately 4.2% of its available spectrum for subscriber calls.

Also, Globalstar performed a simple traffic analysis that demonstrates beyond dispute that access to additional spectrum could not have been the source of improvements in call success rates that Iridium has claimed.[2] Moreover, given its current and projected usage, Iridium has sufficient spectrum with its Big LEO system to meet demand through the expected life of its constellation.

2. Iridium System Design Features That Limit Spectrum Efficiency

Iridium states on page 30 of its Response that "there simply is no system capacity constraint in the Iridium system—with the one glaring exception of the limitation in available L-band spectrum/traffic channels." This statement is contrary to any satellite system designer's experience, and is contradicted by Iridium's own data. Four examples are provided below.

2.1 Gateway capacity limitations

Globalstar's analysis shows that there are design features of Iridium's gateways which limit its overall capacity. Without even knowing the details of Iridium's claimed dynamic spectral resource management (Response, at 11-12), it is possible to calculate traffic demand that is to be uplinked or downlinked to the small number of Iridium gateways. This satellite-gateway traffic demand shows that the satellite-to-gateway links are clearly a factor that limits system capacity.

This analysis is made more difficult by Iridium's conflicting statements about how many simultaneous calls each gateway can handle. Specifically, in its answer to Question 11, on page 32, Iridium states that its satellite-to-gateway uplinks and downlinks have a maximum burst rate of 3.125 Mbps each, which is reduced to 2.75 Mbps each after accounting for framing and

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[1] See Letter from Peter D. Shields to James L. Ball, IB Docket No. 02-364 (Dec. 18, 2003).

[2] See Order, DA 03-3926, released Dec. 11, 2003 (granting Iridium extension of Special Temporary Authority to use an additional 1.25 MHz of L-band spectrum).

protocol overheads. Iridium states that this 2.75 Mbps rate can be supported on each of a satellite's four feederlink antennas to four separate gateways. However, as stated in Iridium's response to Question 12, there are only two operational Iridium gateways, each with three antennas (plus a backup antenna in Arizona). Thus, at present there are only six operational gateway antennas (three at each operational site), which can, in theory, be tracking six satellites worldwide at any one time (one for each antenna). Three of these operational antennas are dedicated to Department of Defense (DOD) traffic and are not available for commercial traffic in, to, or from the Continental U.S. (CONUS).

The parameters of the Iridium constellation limit the view of the gateways such that at times the Hawaiian and Arizona gateways can view only one satellite each. At these times, two antennas at each gateway are connected only to one satellite each at the same time.[3] When this occurs, there is only 4*2.75 Mbps, or 11 Mbps of data being communicated to/from the satellites to the Earth for the entire Iridium constellation. This is approximately 4500 calls at 2.4 kbps or 2250 calls at 4.8 kbps.

Each satellite can, on average, only support 11 Mbps/66, or 0.167 Mbps data going from the satellite to the earth. At Iridium's current data rate of 2.4 kbps, this means an average of about 70 calls per satellite. Adding to this number the Iridium subscriber unit-to-Iridium subscriber unit (ISU-ISU) calls that do not go through the gateways still leads to an extremely small number of calls per satellite, especially considering that the ISU-ISU calls consume twice the number of satellite resources that the gateway-to-ISU calls consume.

On page 26, Iridium states its satellite capacity as about 576 simultaneous calls per satellite for a Middle East type dual distribution of traffic. At various other places, such as page 27, Iridium states its per-satellite capacity as between 362 and 1705 calls over CONUS (59 beams), which translates to 294 to 1387 calls per satellite with 48 beams.[4] In any case, it appears that about 294 to 1387 calls per satellite can be handled simultaneously in the current spectrum. Iridium wants to offer 4.8 kbps data rates to all these users by obtaining access to more L-band spectrum. Therefore, assuming the number of calls per satellite stayed the same as now, each satellite would carry between 294*4.8 kbps and 1387*4.8 kbps or 1.4 Mbps to 6.6 Mbps of data. Taking the lowest value here, that is, 1.4 Mbps per satellite, and assuming half of the capacity is meant for ground-to-ISU traffic, then 66 satellites would need a total of 47 Mbps to be sent through the gateway on satellite-to-gateway links that are currently limited to 11 Mbps.

As explained above, currently, the two gateways can only handle a capacity of 11 Mbps, with each having two antennas fully engaged (with crosslink traffic conveying the data from other satellites to the ones in view of the gateways). This throughput level is clearly inadequate for the constellation. In fact even with the current data rate of 2.4 kbps, the gateway links are incapable of handling this low level of traffic in the system. This problem cannot be cured by granting Iridium access to additional L-band spectrum. Thus, Iridium's own data support

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[3] See Response, at 33, Question 14.

[4] One of several inconsistencies in Iridium's Response appears on page 26. Iridium states that the single-beam cluster carries 181 calls, leading to 362 calls per dual-cluster satellite, rather than the per CONUS area as sought by the question.

Globalstar's conclusion that factors other than an L-band spectrum shortage are limiting the Iridium system capacity.[5]

2.2 Crosslink capacity limitations

Another design feature that limits Iridium's spectrum efficiency is its crosslinks. On page 30 of the Response, Iridium states that Motorola, the designer of the Iridium System, found that "the crosslink network...provided a generous margin against worst case system loading conditions." Iridium concludes that the system crosslinks do not contribute to limits on system capacity. However, an analysis of Iridium's traffic capacity based on its response to Question 7 (pp. 25-26) establishes that the crosslink is not in fact "over-engineered," and could well be a limiting factor, or at least could become the limiting factor if L-band traffic capacity were to be increased.

As noted above, Iridium claims that a set of 59 beams can handle 362 to 1705 simultaneous calls, and so, a set of 48 beams (i.e., a single satellite) can handle 294 to 1387 calls. If each beam transmits at 4.8 kbps, the data rate that Iridium wants to provide, the throughput demand would be between 1.4 and 6.6 Mbps per satellite.

For satellites that are not in view of any gateway, this traffic must pass through the appropriate intersatellite links (ISL). There are four ISLs per satellite, but that does not translate into an ISL throughput of four times the single ISL throughput, because of the constellation geometry. There are currently only two operating Iridium gateways, and they are close to one another; accordingly, there are particular paths that calls must go through in order to connect to the ground. Satellites that are far from gateways and in planes 1 and 6 can only relay their data through a limited set of satellites in order to get to a gateway. Therefore, it is likely that only two or three ISLs are useful; that is, these satellites will be at the far end of a chain of satellites leading to the gateway, and so some of their ISLs will be in directions that are of no use in relaying data. For satellites that are closer to the gateways, only two ISLs are useful and for satellites near the gateways, only one ISL is useful (the one that connects to the satellite that is in view of the gateway). As the satellites get closer to the gateways, there is more traffic being carried but there are fewer ISL options. A larger load is thus placed on satellites close to gateways that must funnel all the traffic to the ground.

On page 30 of its Response, Iridium states that each ISL can carry 5.12 Mbps of data on the co-plane links and 5.27 Mbps on the cross-plane links. Also, as stated in various places, the crosslinks must continuously share adjacent beam loading information as part of the dynamic channel allocation. For example, on page 14, Iridium states that "beam/channel assignments are continuously passed (shared) between satellites every 4.32 seconds, with the underlying data-exchange process being referred to as a 'near-neighbor update.'" Thus, some part of the maximum 5.12 and 5.27 Mbps data rates for the ISLs must be devoted to this near-neighbor

[5] The statement that each satellite-to-gateway link can support 2.75 Mbps (page 32) also contradicts the statement (page 33) that "a single Iridium satellite-to-gateway Ka-band link can support a maximum of up to approximately 10,000 simultaneous calls." The latter would require the satellite-to-gateway link to support 10,000*2.4 kbps or 24 Mbps.

update, without which it appears that Iridium cannot even achieve its current level of spectrum efficiency.

Given that up to 6.6 Mbps of traffic may need to be transferred over a single ISL to carry the maximum number of simultaneous calls at 4.8 Mbps, it does not appear that the ISL links are "over-engineered" at the 5.12 Mbps rate claimed by Iridium. This is not surprising. Globalstar has repeatedly pointed out that the design of any real satellite system is necessarily constrained by many factors, typically: satellite power, gateway link capacity and, for satellites with on-board processing, the additional constraints of on-board processing power and crosslink capacity. Crosslink capacity is apparently a very real constraint on Iridium's capacity and its ability to use higher data rates.

2.3 On-board processing power limitations

Iridium's Response makes clear that on-board processing power limitations have a significant impact on its overall system capacity. Specific examples of this limitation are referenced in several places in the Response.

(a) The Space-Vehicle Real-Time (SVRT) design (pages 13-14) requires substantial on-board processing. The SVRT in effect performs most of the resource allocation functions which, in the Globalstar system, are performed at the gateways, and which require large amounts of processing power. In particular, the statement on page 14 that "[e]ach one of the 3168 beams in the Iridium system continuously maintains/updates its own data base of nearby beams and the current channels in use on these nearby beams" implies a tremendous need for onboard processing power.

(b) On page 10, in response to questions about the Call Image Records (CIR) being limited to 150 per satellite, Iridium states that "[t]he CIR cutoff is 'hard-coded' into the satellite software and was intended to preserve satellite onboard computer processing resources for other more time critical processes (e.g., ongoing call management)." In other words, Iridium does not have sufficient on-board processing power to run all programs at the same time up to the level at which they are engineered. Some elements have to be cut off in order to provide power when use of another element increases.

(c) Iridium claims that increased usage in the Middle East region by Coalition forces during Spring 2003 strained its system capabilities. On page 28, Iridium states that "the tremendous regional traffic load had so over loaded the SVRT processor that numerous satellite reboots were occurring, raising serious concerns within Iridium that satellite damage might occur if this condition persisted." Iridium states that, when the flow control threshold was lowered on April 11 through Special Temporary Authority that granted access to more L-band spectrum, "the refined flow control reduced the satellite reboot events." All this points to the fact that on-board processing power clearly has a major impact on system capacity.

As Globalstar has pointed out on previous occasions, this change in flow control threshold explains why call acquisition failures on Iridium dropped on April 11, while the total number of calls per satellite did not increase.[6] Iridium continues to claim that the improvement was due to the increased L-band spectrum granted under the STA on April 11, but as Globalstar has pointed out, there is still no explanation why the number of calls per satellite did not exceed about 350 even after the FCC granted the STA.

(d) On page 3, in response to the question of whether Iridium can use different frequencies over different geographic areas, Iridium states that limited protection for the Radio Astronomy Service is possible, but that the Iridium software cannot "provide a practical means to control frequency usage on a country-by-country basis." It also states that "[s]atellite on-board memory limitations, coarse geographic selectivity and practical processor computation limits prevent this limited capability from being expanded to provide frequency selectivity on a country-by-country basis." Clearly, this means that Iridium cannot, with its current generation of satellites, allocate frequencies on a regional basis. If a frequency is assigned to a user in one region of the world, it must be used by Iridium in other regions of the world as well.[7] This is a highly inefficient system design that has nothing to do with the amount of spectrum assigned to the system. The response to this question of frequency allocation on a country-by-country basis demonstrates that Iridium made irreversible design decisions which now prevent it from being able to use L-band spectrum efficiently.

2.4 Reserving certain frequencies for simplex traffic and overhead channels

On page 12 of the Response, Iridium attacks Globalstar's frequency plan, in which separate 1.25 MHz CDMA channels are assigned to service types such as MSS voice/data, aviation, simplex telemetry and ATC. First, it is not true, as Iridium implies, that the Globalstar allocation is "static" in the sense that certain channels are permanently assigned, by system design, to certain services. Rather, as explained in Globalstar's July 25, 2003 Reply Comments in this docket, external restrictions such as protection of RAS and GNSS services have necessitated Globalstar's use of certain frequencies for certain discrete services such as aviation.

On the other hand, Iridium itself states (page 19, fn. 16) that "[t]he remaining 0.5 MHz in Iridium's current 5.15 MHz band is, as required by the design of the current satellite hardware, used exclusively for simplex (paging and ringing) services, leaving only 4.65 MHz for duplex (i.e., voice and data) traffic." In other words, Iridium does exactly what it attacks Globalstar for doing. In addition, Iridium states on pages 25-26 and in footnote 22 that "1 MHz [is] utilized for overhead functions (satellite handoff, access, etc)." It is not clear whether this overhead allocation is actually 0.5 MHz or 1 MHz, and whether it is different from the reserved 0.5 MHz

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[6] See *infra* § 4.

[7] This contradicts Iridium's claim (page 13) that "the serving satellite searches the entire assigned operating band . . . for the channels with the highest carrier-to-interference ratio" in making channel assignments.

that is referenced in footnote 16, since in both cases Iridium refers to 4.65 MHz L-band spectrum being available for call loading. In any case, Globalstar, by contrast, does not reserve frequencies for such overhead functions. In Globalstar's design, access channels and satellite handoff and other overhead functions are distributed throughout the available spectrum.

3.0 Iridium Spectrum Usage Measurements

In order to evaluate Iridium's claims, Globalstar engineers monitored Iridium's use of the L-band uplink at Globalstar's Clifton, Texas, gateway. The results of this test indicate that Iridium is currently **using approximately 4.2% of its available spectrum** in the Continental United States (this is an average over the eight busy hours of the day).

Test mechanism. Globalstar satellites have "bent-pipe" transponders, which convert any uplink L-band signals falling in the 1610-1626.5 MHz frequency range (that is, including Iridium uplink transmissions) into specific C-band feederlink frequencies. Accordingly, it is easy to monitor the C-band downlink from Globalstar satellites (or, as shown in the example here, the down-converted, S-band intermediate frequency or "IF") at a gateway antenna to determine Iridium usage over the entire footprint of the Globalstar satellite being tracked by the gateway antenna. Such measurements were made at Clifton over the course of three days (January 21-23, 2004) from approximately 9 a.m. to 5 p.m. local time. Spectrum analyzer data were collected to determine how much of Iridium's assigned L-band uplink was actually in use. Sweep times of 50 milliseconds were used, and data were collected in the "peak hold" mode of the spectrum analyzer for time periods of 5 to 10 minutes for each chart generated. Thus, TDMA bursts could be captured even if a single user was present and transmitting an uplink during the TDMA frame, and any users who happened to transmit during the 5 to 10 minute period were captured. An example of the resulting data is shown in Figure 1, in which about 32 Iridium carriers are seen in the IF bandwidth corresponding to eight Globalstar beams.

Test Results. A compilation of the collected data shows that as satellites sweep through different areas around Clifton, the average number of Iridium carriers per Globalstar beam seen in any 1.23 MHz of spectrum between 1620.1 and 1626.5 MHz (corresponding to Globalstar channels 9 through 13) is about 0.75.

If Iridium were completely efficient in its use of this spectrum, and actually using carriers that are spaced 41.67 kHz apart, one would expect 29 carriers in each 1.23 MHz (with a full frequency reuse pattern) or about six carriers per 1.23 MHz per Iridium beam if Iridium used the factor of 5 frequency reuse that is claimed in its 1992 minor amendment filed with the FCC.[8] Since, on average about three Iridium beams fall into one Globalstar beam, this means there should be 18 Iridium carriers per Globalstar beam on average. At no time did Globalstar engineers see more than 5 Iridium carriers in any 1.23 MHz range on any Globalstar beam, and as stated above, on average only 0.75 carriers per Globalstar beam per 1.23 MHz channel were observed. Therefore, Iridium is using 0.75/18 or only 4.2% of its spectrum. A similar set of measurements conducted at Clifton in August 2003 showed that Iridium had an average of 0.5 carriers per 1.23 MHz. While the level of Iridium traffic seems to have increased slightly from

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[8] See Motorola Satellite Communications, Inc., Minor Amendment (dated Aug. 8, 1992)

August 2003 to January 2004, it is clear that Iridium is still severely under-utilizing its spectrum in the Continental United States.

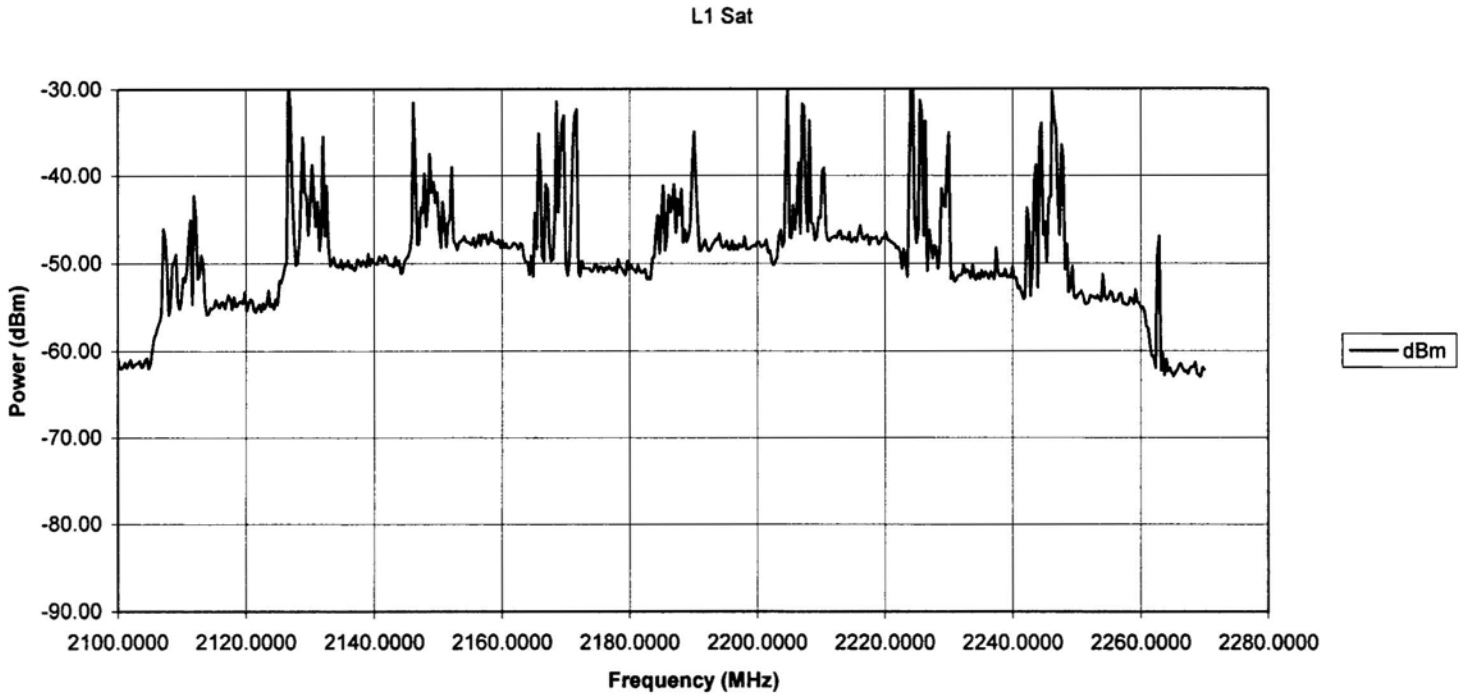

Figure 1: A typical 50 msec sweep at Clifton showing about 32 Iridium carriers in 8 Globalstar beams; data collected at 2 GHz Intermediate Frequency at Clifton gateway on January 22, 2004 at 4:55 pm local time.

As stated above, the analysis of Iridium call traffic in the United States is based on peak hold measurements. Pursuant to this analysis, even if only one-quarter of the TDMA slots on an Iridium carrier is occupied, then that carrier is counted as a frequency carrier being used by Iridium. This liberal counting process is further exaggerated by the dynamic allocation of frequencies resulting from different Iridium beams passing over a given user. In those instances, the user would change frequencies as the beams change and that call would then appear to be using several frequencies. The counting process also does not account for satellite power or other limitations because the Clifton measurements have merely shown which Iridium frequencies are in use.

If Globalstar were to use a similar counting method to measure its use of the available CDMA spectrum, that is, a measurement which merely considers spectrum usage and no other restrictions (satellite power, feederlinks), then the analysis would demonstrate that Globalstar is using approximately 66% of the CDMA L-band spectrum in the United States.

4. Iridium's Use of Additional Spectrum

Iridium has claimed that it has been able to use additional L-band spectrum, authorized by STA, to improve its service quality.[9] The following analysis demonstrates that any improvement achieved by the Iridium system in service quality was not the result of its temporary access to additional spectrum channels.

Iridium states that, before April 11, 2003, its system had about 180,000 daily call acquisition failures in the Middle East Region, and that the grant of 1.23 MHz of additional L-band spectrum on April 11 reduced these failures dramatically by April 13, 2003.[10] As Globalstar has previously noted, the number of simultaneous calls per satellite on the Iridium system remained constant at around 350 both before and after April 11, 2003.[11]

As shown below, the drastic reduction in acquisition failures reported by Iridium would have required approximately 206 additional per satellite peak circuits to handle the claimed traffic and reach an average of 2% call acquisition failure rate. Yet, Iridium maintains that only 350 circuits per satellite were provided both before and after April 11.

Claimed daily call acq. failures	180000 April 8-11, 2003
Call acq. failures per hour	22500 Assuming 8 peak hrs/day
Peak fraction of simultaneous calls	0.13157 From Globalstar experience
Average call length (mins.)	3.9 From Globalstar experience
Average additional load needed	192.4342105 erlangs, to serve failing callers
Peak circuits needed	206 Assuming 2% blocking

Table 1: Iridium System Traffic Requirements

This analysis demonstrates that access to additional spectrum alone did not result in the improved call acquisition failure on the Iridium system after April 11, 2003. As Globalstar has repeatedly noted, a change in some other aspect of Iridium system operations or user calling patterns resulted in the improved call acquisition rate. Accordingly, the April 2003 data alone do not support Iridium's assertion that access to additional spectrum improved its capacity and service quality.

5. Projected Iridium Spectrum Needs

On page 27 of its Response, Iridium states that over CONUS, its system can provide (in 5.15 MHz spectrum) between 362 and 1705 simultaneous circuits, depending on the geographical distribution of users, with the higher number being applicable for uniformly distributed traffic.

Traffic engineering, as shown in Table 2, indicates that with 1705 circuits, Iridium should be able to serve approximately 190,000 subscribers with only 2% blocking in the busy hour.

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[9] See Comments of Iridium Satellite, at 14-15 (filed July 11, 2003).

[10] Id.

[11] See Globalstar Joint Reply Comments, Tech. App., at 2-3 (filed July 25, 2003).

Currently, Iridium claims about 80,000 subscribers worldwide. Unfortunately, for purposes of this analysis, Iridium has declined to provide a count of its U.S. subscribers in response to the Bureau's Question 5. Globalstar believes that it has proportionately more U.S. subscribers than Iridium has. However, based on Globalstar's subscriber distribution, we will assume that approximately 15,000 Iridium subscribers operate primarily in CONUS.[12] Assuming, again generously, that Iridium's current traffic levels were built up over a period of two years and that the same rate of growth continues, there would be 7,500 subscribers per year added in CONUS. With the optimal (uniform) traffic distribution, Iridium should be able to serve this projected traffic in CONUS for over 23 more years, with no additional spectrum.

Peak circuits in CONUS, uniform distribution	1705	Minimum
Average traffic load, Erlangs	1703	With 2% blocking
Peak fraction of METs calling simultaneously	0.131578947	Assumed
Average call length (mins.)	3.9	Assumed
Number of CONUS subs served in busy hr.	189,992	
Current worldwide Iridium subscribers	80000	
Current CONUS Iridium subscribers, estimated	15000	
Estimated yearly growth rate for CONUS subscribers	7500	Assuming current growth
Estimated years before CONUS capacity used	23.33	

Table 2: Projected Iridium Spectrum Needs

Iridium argues that it needs additional spectrum to facilitate voice and data service offerings at 4.8 kbps, rather than its current 2.4 kbps. The higher data rate will have the effect of halving Iridium's capacity because the 4.8 kbps service requires two time slots rather than the one required by 2.4 kbps service. If relief of capacity constraints is the goal of Iridium's request for more spectrum, then it could seek improvements through more efficient modulation or compression of data to a lower bit rate, rather than additional spectrum. If use of a more efficient modulation is too costly, then Iridium could use a more efficient vocoder, rather than one that doubles the inefficiency, and still improve capacity without additional spectrum.

[12] Globalstar is estimating based on its own experience, subtracting the 20,000 phones deployed pursuant to Iridium's contract with the Department of Defense, which, we believe, are almost entirely deployed overseas, and taking 25% of the remaining global subscriber base claimed by Iridium (Response, at 15), leaving approximately 15,000 subscribers in the United States.

Engineering Certification

I hereby certify under penalty of perjury that I am the technically qualified person responsible for preparation of the engineering information contained in the foregoing "Analysis of Iridium's December 18, 2003 Response"; that I am familiar with the relevant sections of the FCC's Rules, the proposals set forth in the "Notice of Proposed Rulemaking" in IB Docket No. 02-364, and the information contained in the foregoing analysis; and that information in the analysis is true and correct to the best of my knowledge and belief.

Signed this 18th day of March 2004.

Paul A. Monte

Director, Systems & Regulatory Engineering
Globalstar L. P.