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SHANGHAI SILICON VALLEY WASHINGTON

Gerard J. Waldron

Covington & Burling LLP
One CityCenter
850 Tenth Street, NW
Washington, DC 20001-4956
T +1 202 662 5360
gwaldron@cov.com

REDACTED – FOR PUBLIC INSPECTION

November 2, 2016

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Notice of *Ex Parte* Presentation

IB Docket Nos. 11-109 and 12-340; IBFS File Nos. SES-MOD-20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091

Dear Ms. Dortch:

On October 31, 2016, the undersigned, as counsel to Ligado Networks LLC ("Ligado"), and Jake Rasweiler, an engineering consultant to Ligado, met with Ron Repasi, Michael Ha, and Paul Murray of the Office of Engineering and Technology; Charles Mathias and Paul Powell of the Wireless Telecommunications Bureau; and Robert Nelson of the International Bureau. During the meeting, Ligado responded to submissions of Iridium Communications Inc. ("Iridium") regarding Ligado's proposed ancillary terrestrial component ("ATC") user terminal operations at 1627.5-1637.5 MHz (the "Lower 10 MHz" uplink channel).

Iridium claims that Ligado's ATC user terminal operations on the Lower 10 MHz channel would generate unacceptable levels of out-of-band emissions ("OOBE") that would be incompatible with downlink operations of Iridium earth stations in an adjacent part of the "Big LEO Band" at 1617.775-1626.5 MHz.[1] Iridium thus proposes that Ligado not be allowed to use the Lower 10 MHz uplink channel for ATC purposes unless Ligado meets Iridium's demands and:

[1] Iridium stated in the September 1, 2016 filing that it has no concerns with respect to compatibility with Iridium's satellites nor with respect to Ligado's ATC emissions from a second 10 MHz uplink channel that is 19 MHz further away from Iridium. *See* Letter from Brian N. Tramont, counsel for Iridium, to Marlene H. Dortch, FCC Secretary, IB Docket No. 11-109 (Sept. 1, 2016) ("Iridium Letter").

(i) further reduces the level of OOBE from its ATC terminal operations on its Lower 10 MHz channel to an unspecified level beyond that contained in the License Modification Applications; and (ii) avoids operating ATC terminals on the Lower 10 MHz channel in certain unspecified exclusion zones around airports.

Ligado emphasized three critical points to put Iridium's assertions in their proper context:

- ***First***, Iridium's licensed downlink spectrum in the Big LEO band is allocated for MSS downlinks on a *secondary, non-interference basis*, and Iridium is licensed to use the band for downlinks on that same basis. Accordingly, Iridium's downlink operations are not entitled to interference protection from adjacent spectrum users operating under primary allocations, including Ligado.

- ***Second***, Ligado's ATC operating parameters have been fixed for years, and include operation of an unlimited number of 1 watt ATC user terminals under a specified OOBE mask. Significantly, in the pending License Modification Applications Ligado proposes to significantly reduce the level of its ATC user terminal emissions below its long-authorized parameters.

- ***Third***, Ligado's proposed ATC operating parameters are fully consistent with the broader operating environment in the spectrum adjacent to Iridium's downlinks, which is characterized by *millions* of MSS mobile earth terminals ("METs") authorized to uplink at significantly higher power levels than Ligado's 0.2 watt ATC terminals. Thus, Ligado's ATC operating parameters are *more* protective of Iridium than virtually all of the currently authorized uses of MSS spectrum adjacent to Iridium.

Before turning to these points Ligado presented Mr. Rasweiler's technical assessment of Iridium's assertions, which is discussed in detail below.

During the meeting, Ligado also explained that it is committed to working with the Commission and Iridium to identify a reasonable technical solution that would allow both networks to coexist in their adjacent licensed spectrum. Toward that end, Ligado explained that if doing so would enable the prompt grant of the License Modification Applications, Ligado would be willing to consider certain additional reductions to its OOBE levels with respect to Iridium's downlink spectrum, in addition to the reductions already proposed in Ligado's above-captioned License Modification Applications. Ligado explained that the likelihood of reaching such a resolution would be improved significantly if certain flawed assumptions underlying Iridium's September 1, 2016 technical showing were adjusted to reflect more accurate, suitable, and typical values, as well as to include certain factors that are typically included by the FCC in analyses such as this one. Copies of the tables Ligado presented showing the effect of these adjustments are being filed with the confidential version of this letter as Attachment A. By taking such considerations into account, Ligado expects a reasonable resolution could be achieved promptly without the need to address a variety of legal issues presented by Iridium's filings in this proceeding.

The following section details the adjustments to Iridium's analysis that Ligado believes are warranted, and demonstrates how certain reductions in Ligado's OOBE levels with respect to Iridium's downlink spectrum would ensure the compatibility of the two networks. The rest of the letter addresses various legal issues to ensure the record is complete and accurate.

I. IRIDIUM'S TECHNICAL ANALYSIS FAILS TO CONSIDER CERTAIN WIDELY-ACCEPTED FACTORS THAT SIGNIFICANTLY MINIMIZE THE INTERFERENCE CONCERN

The parties then discussed the technical analysis in Iridium's September 1 filing, and this discussion was led by Mr. Rasweiler, COO of SWI.[2]

Ligado reviewed the public copy of Iridium's September 1 filing, and, in accordance with the terms of the Protective Order in this proceeding,[3] retained outside engineering consultants to review the confidential version of the September 1 filing. This review found that Iridium's technical analysis was flawed for the following reasons:

- Iridium's calculations omit an important industry-accepted factor—antenna discrimination between terminals—which leads to Iridium significantly overestimating the interference from Ligado's terminals;

- Iridium's calculations contain a value for Required I/N of -6 dB even though the Commission uses a value of 0 dB in writing service rules;

- Iridium uses a free space path loss model for all distances calculated, from 10 meters to 4000 meters, even though the Commission has recognized the Walfish-Ikegami non-line-of-sight ("WI-NLOS") model as an appropriate model for real-world losses from obstructions, which can be expected at distances greater than 100 meters; and

- Iridium uses a terminal noise floor of -154.8 dBW/30kHz, even though in a 2014 filing with the Commission, Iridium advocated for a noise floor of -149.4 dBW/30 kHz.

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2 SWI is one the of the largest independently owned wireless consulting services firms in the United States and has local presences in North America, the United Kingdom, the Middle East and Asia. SWI is a leader in providing advanced ICT services to wireless, wireline, Public Safety, IoT, M2M and Enterprise domains. Mr. Rasweiler's CV is attached as Attachment D.

3 *LightSquared Request to Modify Its ATC Authorization; LightSquared Technical Working Group Report*, Protective Order, IB Docket Nos. 12-340 and 11-109, DA 16-1134 (rel. Oct. 4, 2016) ("Protective Order").

Table 2 of Iridium's filing, in which Iridium analyzes the potential for interference between a Ligado terminal and an Iridium terminal,[4] forms the baseline of Ligado's analysis. The flaws Ligado identified in this analysis are discussed in detail below and summarized in the table provided as Attachment B.

[BEGIN CONFIDENTIAL]

Table 1: Ligado - Iridium Interference Model
(Values Set Forth in Iridium Analysis Table 2)

Frequency	**1626.5**	**MHz**			
	FSPL	FSPL	FSPL	FSPL	
Ligado User Terminal OOBE limit	-49.20	-49.20	-49.20	-49.20	dBW/30 kHz
Separation Distance	10	100	1000	4000	Meters
Path Loss (free space)	56.7	76.7	96.7	108.7	dB
Iridium Reference RX antenna Gain at horizon	-3	-3	-3	-3	dBi
Received interference power density					dBW/30 kHz
Iridium user terminal noise floor	-154.8	-154.8	-154.8	-154.8	dBW/30 kHz
I/N					dB
Required I/N	-6	-6	-6	-6	dB
Iridium Margin					dB

[END CONFIDENTIAL]

1. Path Loss

The Iridium model uses free space path loss for each distance it considers, up to 4000 meters. However, under the Walfisch-Ikegami model, for distances greater than 20 meters path loss exceeds free-space conditions.[5] The Commission has recognized the Walfish-Ikegami non-line-of-sight ("WI-NLOS") model as an appropriate method for estimating real-world losses.[6] As the Commission has stated, signals being sent from a transmitter to a distant receiver may experience any number of disruptions due to their particular path such as reflections off large objects (*e.g.*, buildings), diffraction around or over objects, and scattering due to impinging on

4 *See* Technical Analysis of Ligado Interference Impact on Iridium User Links at 10, *found at* Letter from Brian N. Tramont, counsel for Iridium, to Marlene H. Dortch, FCC Secretary, IB Docket No. 11-109 (Sept. 1, 2016) ("Iridium Analysis").

5 *See* National Institute of Standards and Technology, Description of Hata, CCIR, and Walfisch-Ikegami Models, http://www.itl.nist.gov/div892/wctg/manet/calcmodels_dstlr.pdf.

6 *Id.*; *Flexibility for Delivery of Communications by Mobile Satellite Service Providers*, Report & Order and Notice of Proposed Rulemaking, 18 FCC Rcd 1962, at App'x C1 § 1.6 (2003).

smaller objects.[7] The WI-NLOS model accounts for these factors and is based on measured data and empirical formulation. WI-NLOS is also feasible to use under conditions where the transmitting and receiving antenna heights are close to the ground as depicted in the Iridium analysis, where each is 2 meters off the ground.

Therefore, a real-world view of path loss would evaluate distances greater than 20 meters—three of the four distances Iridium analyzes—using the WI-NLOS model. Ligado has used this approach in calculating the analysis shown in Table 2 below.[8] Ligado's WI-NLOS equations are taken from the National Institute of Standards and Technology ("NIST").[9] Due to the valid range of values for WI-NLOS, Ligado's analysis considers the Base Station Height (h_b) of 4 meters and Mobile Station Height (h_m) of 2 meters.[10]

Ligado also disagrees with Iridium's use of the Hata-Okumura propagation model.[11] The Hata-Okumura model is suited to a variety of conditions not present here. First, it is designed for a base station height of 30-200 meters, but Iridium's analysis considers both transmitter and receiver height to be 2 meters, well below the Hata-Okumura range. Second, Hata-Okumura is designed for distances of 1-20 kilometers, but the Iridium analysis extrapolated losses in the range of 100-1000 meters by combining Hata-Okumura and Free-Space Path Loss models. Third, Hata-Okumura applies to frequencies in the range of 150-1500 MHz, but Iridium's analysis is of 1626.5 MHz.

Ligado recognizes that there have been adaptations to the Hata-Okumura model by Cost-231 where the Cost-231 Hata model is valid for frequencies above 1500 MHz.[12] While Iridium did not stipulate the Cost-231 Hata, the Cost-231 Hata model is still invalid for base station antenna heights below 30 meters and separation distances less than 1 kilometer. As such, Iridium's September 1, 2016 analysis in section 3.1.4, Figure 2, Table 4, Table 6, **[BEGIN CONFIDENTIAL]** **[END CONFIDENTIAL]** are invalid.

It bears emphasis that Iridium itself has relied on path loss models other than free space in other submissions to the Commission. For example, Iridium's 2014 Supplemental Comments were devoted to the issues associated with expanded spectrum sharing between Iridium

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7 FCC, *Public Safety Tech Topic #17 - Propagation Characterization*, https://www.fcc.gov/help/public-safety-tech-topic-17-propagation-characterization.

8 While Ligado shows free space path loss for values greater than 20 meters in order to compare Iridium and Ligado's results, we are not stating that these are valid results for path loss.

9 *See* National Institute of Standards and Technology, Description of Hata, CCIR, and Walfisch-Ikegami Models, http://www.itl.nist.gov/div892/wctg/manet/calcmodels_dstlr.pdf.

10 *Id.*

11 *Id.*, *see also* Masaharu Hata, *Empirical Formula for Propagation Loss in Land Mobile Radio Services*, IEEE Transactions on Vehicular Technology (Aug. 1980).

12 Dieter J. Cichon and Thomas Kurner, *Digital Mobile Radio Towards Future Generation Systems: Cost 231 Final Report*, at ch. 4, http://www.lx.it.pt/cost231/final_report.htm.

and Globalstar.[13] In Exhibit 2, Table 1 Iridium analyzes a Globalstar handset's interference to an Iridium subscriber terminal (handset). For the analysis at a separation distance of 100 meters Iridium identified Ground Wave Propagation Loss ("d^4 loss"), which is greater than free-space path loss. Additionally, at 100 meters, the Iridium path loss value of 91.3 dB aligns closely with Ligado's WI-NLOS calculation of 90.5 dB.[14]

2. Antenna discrimination between terminals

Unlike propagation path loss models, which factor the signal loss propagating between two reference antennas, antenna discrimination considers the local antenna implementation conditions, including orientation and near field losses associated with the device, user and mounting position of the user terminal. While Iridium includes Iridium Reference RX antenna gain at horizon of -3 dBi, it fails to include other implementation factors that cause further signal losses common to the devices provided by Iridium and LTE devices proposed by Ligado. In particular, the Commission has recognized that the combined effect (considering both the transmitting and receiving antenna) of LTE antenna gain, body loss, and polarization mismatch causes a total of 20 dB in signal loss.[15] As such, any comprehensive analysis should include an additional 17 dB loss to account for discrimination between terminals (in addition to the 3 dB included in Iridium's initial calculation).

Fig. 1: Antenna discrimination between terminals

References

FCC 15-99

	TX	RX	Total		
LTE Antenna Gain	-6	-6	-12	dBi	Paragraph 122
Body Loss	3	3	6	dB	Paragraph 123
Polarization Mismatch (loss)	2		2	dB	Paragraph 124
Additional Antenna discrimination between terminals			**-20**	dB	

FCC 12-151

	TX	RX	Total		
Combined antenna gain and head/body loss	-10	-10	**-20**	dB	Paragraph 142

13 *See* Supplemental Comments of Iridium Constellation LLC, RM-11697, RM-11685, IB Docket No. 12-213 (Nov. 5, 2014) ("Iridium 2014 Supplemental Comments").

14 *See* Iridium 2014 Supplemental Comments at Exhibit 2 p. 3.

15 *See Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, Report & Order, ET Docket No. 14-165 GN Docket No. 12-268 at ¶¶ 122-124 (2015) ("FCC 15-99"); *Service Rules for Advanced Wireless Services in the 2000-2020 and 2180-2200 MHz Bands*, Report & Order and Order of Proposed Modification, WT Docket No. 12-70 ET Docket No. 10-142 WT Docket No. 04-356 at ¶ 142 (2012) ("FCC 12-151").

3. Iridium user terminal noise floor

In the Iridium Analysis, Iridium identifies its user terminal noise floor as -154.8 dBW/30kHz. This is inconsistent with the value Iridium provided as its terminal noise floor in November 2014, which was -149.4 dBW/30 kHz.[16] The appropriate values, based on Iridium's 2014 filing, would be:

Iridium terminal receiver noise bandwidth	45.2	dB
Iridium terminal receiver sensitivity	-119	dBm
Normalization to dBW/30 khz	-149.4	dBW/30kHz

4. Required I/N

While Iridium asserts the required I/N is -6 dB, Ligado recognizes and defers to the FCC's recommended value of 0 dB.[17]

5. Received interference power density

Factoring in WI-NLOS calculated values for path loss and the additional discrimination between terminals, Ligado calculates Received Interference Power Density in Table 2 below. As shown in Table 2, with a more realistic path loss model and the additional discrimination between terminals, the Iridium margin values are significantly higher than those shown in the Iridium Analysis.

16 *See* Iridium 2014 Supplemental Comments at Exhibit 2 p. 3.

17 *Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands*, Report & Order, WT Docket No. 12-357 at ¶ 144 (2013); *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, Report & Order, ET Docket No. 14-165 GN Docket No. 12-268 at ¶ 128 (2015).

[BEGIN CONFIDENTIAL]

<u>Table 2: Ligado - Iridium Real-World Interference Model</u>

Frequency	**1626.5**	**MHz**	Med City				
	FSPL	FSPL	WI-NLOS	WI-NLOS	FSPL	FSPL	
Ligado User Terminal OOBE limit	-49.20	-49.20	-49.20	-49.20	-49.20	-49.20	dBW/30 kHz
Separation Distance	10	100	100	1000	1000	4000	Meters
Path Loss	56.7	76.7	90.5	146.6	96.7	108.7	dB
Iridium Reference RX antenna Gain at horizon	-3	-3	-3	-3	-3	-3	dBi
Additional Antenna discrimination between terminals	-17	-17	-17	-17	-17	-17	dB
Received interference power density							dBW/30 kHz
Iridium user terminal noise floor	-149.4	-149.4	-149.4	-149.4	-149.4	-149.4	dBW/30 kHz
I/N							dB
Required I/N	0	0	0	0	0	0	dB
Iridium Margin							dB

[END CONFIDENTIAL]

6. I/N

Utilizing Iridium's terminal noise floor value of -149.4 dBm/30 kHz and the received interference power density, Ligado's calculation for I/N is found in Table 2 above.

7. Iridium Margin

Considering the Required I/N above, the resulting Iridium margin is calculated and shown in Table 2 above. Ligado's results show that Iridium Margin for WI-NLOS at a separation distance of 100 meters is **[BEGIN CONFIDENTIAL]** and **[END CONFIDENTIAL]** at 1000 meters. As outlined previously, free-space path loss is not appropriate for low terminal heights and distances of 1000 meters and 4000 meters. However, Ligado's calculations show that when industry-accepted factors are considered, *Iridium's margin is greater than 0 even using free-space path loss*.

Given that Ligado's analysis shows the Iridium margin is **[BEGIN CONFIDENTIAL]** **[END CONFIDENTIAL]** at 100 meters, the Iridium margin calculated in Tables 3, 4, 5 and 6 of the Iridium Analysis will be revised greater and positive given that those tables consider distances of 1, 5, and 10 kilometers. Figure 4, and Tables 3, 4, and 5 of the Iridium Analysis therefore are no longer relevant because they consider multiple users and/or distances at which Iridium's interference concerns are not valid.

Ligado further analyzes the Iridium margin considering the d4 path loss value Iridium provided in its November 2014 filing of 91.3 dB for 100 meters.[18] The results are shown in Table 3 below. Ligado's results show that Iridium's margin will be 11.1 dB using d4 path loss values.

[BEGIN CONFIDENTIAL]

Table 3: Ligado - Iridium Real-World Interference Model

Frequency	**1626.5**	**MHz**		
	FSPL	FSPL	D4	
Ligado User Terminal OOBE limit	-49.20	-49.20	-49.20	dBW/30kHz
Separation Distance	10	100	100	m
Path Loss	56.7	76.7	91.3	dB
Iridium Reference RX antenna Gain at horizon	-3	-3	-3	dBi
Additional Antenna discrimination between terminals	-17	-17	-17	dB
Received interference power density			-160.50	dBW/30 kHz
Iridium user terminal noise floor	-149.4	-149.4	-149.4	dBW/30 kHz
I/N			11.10	dB
Required I/N	0	0	0	dB
Iridium Margin			11.1	dB

[END CONFIDENTIAL]

8. Probabilistic Considerations

Ligado's analysis above represents a static and worst case scenario. Iridium asserts that it is relying on the final report of the Commerce Spectrum Management Advisory Committee ("CSMAC") Working Group 1 ("WG-1") in assessing potential interference from Ligado. However, in that report, CSMAC acknowledged that "[i]n order to provide a uniform set of information to apply in a wide variety of analysis, a number of simplifying assumptions have been made that may continue to result in analysis showing a greater level of interference than would actually occur."[19]

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18 *See* Iridium 2014 Supplemental Comments at Exhibit 2 p. 3

19 Commerce Spectrum Management Advisory Committee Working Group 1, Final Report: 1695-1710 MHz Meteorological-Satellite, App. 3 - 2 (2013). WG-1 also assumes all Physical Resource Blocks (PRB) are occupied at all times. These represent the radio resources used by the terminals served by a base station. These are unlikely to be used at 100% capacity, and moreover all of the resources will not be in use by a single user and will therefore be distributed within the coverage of the base station among all the active users that are transmitting. Furthermore, WG-1 assumes 100 percent of terminals are used outdoors, and that all terminals have data in their Radio Link Control (RLC) layer buffer at

Iridium's calculations assume Ligado handsets will be transmitting outdoors, at full power, and continuously. Each of these assumptions is an unlikely worst-case scenario. Indeed, it is impossible for all devices in an area to be operating at full power all of the time. Considering how wireless devices typically operate, any Ligado-Iridium interference will be completely consistent with the "manageable" levels of interference Iridium currently receives from Globalstar and Inmarsat—levels Iridium states are manageable precisely because of probability.[20]

First, the Iridium Analysis ignores the losses associated with in-building usage, which alone eliminates most of the interference concerns. Due to the need to have satellite visibility, Iridium users will not be operating indoors, thus eliminating interference concerns for any use cases in which Ligado's handsets are operating indoors. In addition, due to the short range at which strong signals may impact Iridium users (as demonstrated above), there is only a small portion of a Ligado base station footprint where interference concerns can stem from full-power Ligado terminals. Less than one percent of the Ligado base station coverage area would experience negative Iridium margin at a separation distance up to 20 meters for 18 outdoor users in the urban case using the WI-NLOS path loss model.

Second, even considering the situation at short range where interference is indicated by the calculations, the majority of Ligado users will be transmitting at less than full power, with 83.9 percent of users expected to be attenuated more than 14 dB in urban use cases, based on the CSMAC WG-1 report.

Finally, wireless users typically transmit intermittently. As such, interference can only occur if the Iridium user is in close proximity, outdoors, while a Ligado user is transmitting at or near full power.

As Iridium has acknowledged, interference scenarios currently exist between MSS terminals. Moreover, Globalstar has stated that "unacceptable interference will occur when [Globalstar and Iridium] terminals" are within 40-50 meters of each other.[21]

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In sum, the Iridium Analysis overstates the actual likelihood of Iridium's terminals experiencing any harmful interference. The real-world effect of Ligado's proposed ATC operations would be comfortably in line with the existing spectrum environment.

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all times. In reality, terminals send data in bursts when needed and do not have a continual flow of data queued up to send all the time.

20 Iridium Analysis at 3

21 *See* Globalstar, L.P. Response to FCC Public Notice DA 02-554, Docket Nos. 01-185 and 95-18, at 7, 12 (filed March 22, 2002).

II. IRIDIUM'S CLAIMS MUST BE ASSESSED IN LIGHT OF LONG ESTABLISHED COMMISSION DECISIONS.

For the reasons discussed above, Iridium's concerns on a technical level can be resolved since Iridium's technical analysis dramatically overstates the scenarios in which Ligado user terminals, operating in accordance with the parameters set forth in the License Modification Applications, would emit levels of unwanted energy that are incompatible with Iridium's downlink earth station operations. As Ligado explained to the Commission and has explained to Iridium, as well, Ligado is committed to achieving a technical resolution that affords substantial additional protection to Iridium. In the event that a technical resolution is not achieved, it is important that the record correctly reflect the legal and regulatory framework that governs the relationship between Iridium's use of its downlink spectrum and neighboring spectrum uses:

- ***First***, Iridium's licensed downlink spectrum in the Big LEO band is allocated for MSS downlinks on a *secondary, non-interference basis*, and Iridium is licensed to use the band for downlinks on that same basis. Accordingly, Iridium's downlink operations are not entitled to interference protection from adjacent spectrum users operating under primary allocations, including Ligado.

- ***Second***, Ligado's ATC operating parameters have been fixed for years, and include operation of an unlimited number of 1 watt ATC user terminals under a specified OOBE mask. Significantly, in the pending License Modification Applications Ligado proposes to significantly reduce the level of its ATC user terminal emissions below its long-authorized parameters.

- ***Third***, Ligado's proposed ATC operating parameters are fully consistent with the broader operating environment in the spectrum adjacent to Iridium's downlinks, which is characterized by *millions* of MSS mobile earth terminals ("METs") authorized to uplink at significantly higher power levels than Ligado's 0.2 watt ATC terminals. Thus, Ligado's ATC operating parameters are *more* protective of Iridium than virtually all of the currently authorized uses of MSS spectrum adjacent to Iridium. This suggests that: (i) Iridium would be able to coexist with Ligado's operations; and (ii) Ligado's operations would be far more compatible with Iridium earth stations than the millions of METs authorized to uplink at much higher power levels and in a manner that would dwarf Ligado's ATC emissions.

The following sections expand on these points discussed with the Commission.

A. <u>Iridium's MSS Downlink Operations Are Secondary to Ligado's Primary ATC Operations</u>

The United States Table of Frequency Allocations, codified at Section 2.106 of the Commission's rules, compiles the various domestic allocations of the radiofrequency spectrum. These allocations fall into two broad categories. "Primary" allocations allow operations in the designated spectrum on a priority basis, as long as such operations are consistent with the allocated service and associated rules. By contrast, "secondary" allocations allow operations only on a "non-interference" basis with respect to adjacent primary operations; thus, a station licensed on a secondary basis must: (i) not cause harmful interference to primary operations and (ii) may not claim interference protection from primary operations.[22]

The portion of the Big LEO Band used by Iridium for MSS space-to-Earth (*i.e.*, downlink) transmissions to earth stations is allocated for such use on a *secondary basis*. The Commission adopted this allocation at Iridium's request, and in doing so specifically explained that classifying Iridium downlink operations as secondary would mean that Iridium earth stations "cannot claim protection from harmful interference from stations of a primary service."[23] The same condition has been consistently reiterated in Iridium's various licenses—including most recently those for the Iridium NEXT network issued by the Commission earlier this year.[24] In contrast, the part of the L Band in which Ligado is licensed has been allocated for ATC use on a *co-primary basis* for over thirteen years,[25] and Ligado has been authorized to conduct primary ATC operations for over a decade.[26]

Because Iridium's downlink operations are secondary and Ligado's ATC operations are primary, Iridium has no legal basis for insisting that its earth stations are entitled to "protection" or attempting to block or limit the grant of the License Modification Applications based on unwanted energy emitted from Ligado's adjacent licensed spectrum uses.[27] Yet, that is precisely what Iridium is attempting to do.

Contrary to Iridium's claims,[28] nothing in Section 25.255 alters this conclusion.[29] Section 25.255 does not create new substantive rights for secondary licensees, nor does it alter the

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22 *See* 47 C.F.R. § 2.105(c).

23 *Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile Satellite Service in the 1610-1626.5/2483.5-2500 MHz Frequency Bands*, CC Docket No. 92-166, FCC 94-261, at ¶ 8 n.21 (1994).

24 *See Iridium Constellation LLC*, 31 FCC Rcd 8675, at ¶ 3 n. 9 (2016) ("MSS uplink operations in the 1617.775-1626.5 MHz band are allocated on a primary basis worldwide. MSS downlinks in that band are secondary to other services."); *see also Motorola Satellite Communications, Inc.*, 10 FCC Rcd 2268, at ¶ 16 (1995) (confirming that Iridium downlinks are secondary in nature regardless of whether that condition appears explicitly on the face of Iridium's license).

25 As discussed above, the Commission conferred primary status upon ATC by adding a footnote to the U.S. Table of Frequency Allocations providing that ATC is encompassed within the existing primary allocation for MSS in the L Band. Notably, in the 2003 ATC Order, the Commission explicitly refused to make ATC a secondary service as requested by Iridium. *See Flexibility for Delivery of Communications by Mobile Satellite Providers in the 2 GHz Band, the L-Band, and the 1.6/2.4 GHz Band*, 18 FCC Rcd 1962, at ¶ 61 (2003) ("*2003 ATC Order*").

26 *See generally Mobile Satellite Ventures Subsidiary LLC*, 19 FCC Rcd 22144 (2004) ("*MSV ATC Order*").

27 *See* 47 C.F.R. § 2.105(c).

28 Iridium Letter at 2.

relative rights and priorities of network operators under the U.S. Table of Frequency Allocations.[30] Section 25.255 does not "undo" the legal conclusion that Iridium *must* accept some level of unwanted energy from ATC operations in adjacent spectrum. Nor does it entitle Iridium to protection from all such unwanted energy. In this respect, Section 25.255 must be interpreted in light of the spectrum environment the Commission established in authorizing ATC operations, which calls for Iridium to accept a specified level of unwanted energy from Ligado's ATC operations.[31] Any interpretation of Section 25.255 that would require Ligado to comply with stricter OOBE limits simply because Iridium's secondary spectrum use may receive an expressly anticipated level of OOBE from primary ATC operations would stand the U.S. Table of Frequency Allocations on its head. Indeed, Iridium itself has acknowledged in another context that protecting secondary earth stations (*i.e.*, Iridium's in this case) as if they were primary would effect an improper *de facto* elevation of the allocation priority of those earth stations.[32]

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[29] 47 C.F.R. § 25.255. Section 25.255 in part establishes a dispute resolution procedure that can be invoked if and when legally cognizable "harmful interference" actually occurs during real-world operations—*i.e.*, where the adjacent user is not secondary and otherwise has a right to be protected. In this respect, Section 25.255 is similar to Section 25.274(e) of the Commission's rules, which creates similar procedures for resolving instances of "harmful interference" between earth station operators. 47 C.F.R. § 25.274(e).

[30] Iridium claims the Commission has interpreted Section 25.255 to impose an "absolute obligation on the MSS/ATC operator to resolve any harmful interference to other services." *See* Letter from Iridium to FCC, IB Docket No. 11-109 (Sept. 26, 2016) (citing *Spectrum and Service Rules for Ancillary Terrestrial Components in the 1.6/2.4 GHz Big LEO Bands*, 23 FCC Rcd 7210, at ¶ 35 (2008). Significantly, that case applies Section 25.255 only in managing legally cognizable "harmful interference" into another primary service; namely, interference from Globalstar's primary ATC operations into *primary* BRS operations. Moreover, the Commission was careful to cabin its statement about Section 25.255 to ATC interference into other *primary services*: "ATC enjoys no rights *vis-à-vis other primary services* in the same or adjacent bands." *Id.* (emphasis supplied). That situation is readily distinguished from this one, in which the relevant Iridium operations are s*econdary* and thus not legally entitled to protection from ATC.

[31] The *2003 ATC Order*, which promulgated Section 25.255, clearly calls for Iridium to accept a specified level of unwanted energy from Ligado's ATC operations. Among other things, the order: (i) establishes specific levels of unwanted energy that Iridium is expected to accept (*2003 ATC Order* ¶ 178); (ii) explains that the prophylactic technical limits governing ATC operations are intended to permit some level of unwanted energy to be emitted by adjacent spectrum uses (*id.* ¶ 104 n.273); and (iii) refuses to adopt Iridium's proposal to make ATC secondary because this would mean that primary spectrum uses would not be required to coordinate with ATC operators (*id.* ¶ 61).

[32] *See* Comments of Iridium Constellation LLC, IB Docket No. 12-267, at 6 (Mar. 2, 2015) ("If the same service rules apply to primary earth station operations and secondary and non-conforming earth station operations, then secondary and non-conforming earth stations will improperly be elevated to quasi-primary status.").

B. Ligado's ATC Operating Parameters Have Been Fixed and Known for Years

The Commission's ATC rules, together with the specific ATC authorizations granted to Ligado, define ATC operations in its licensed spectrum. These rules have made plain the nature of future ATC operations. Because these rules and authorizations applicable to Ligado's ATC operations have not changed in any material sense for years, adjacent operators—including Iridium—have had more than adequate advance notice of the nature of those operations.

The power and OOBE levels at which Ligado's user terminals would operate pursuant to the License Modification Applications are well within the ATC user terminal power and OOBE levels that have been authorized and in place for years. With respect to in-band power levels, the Commission's ATC rules (finalized in 2005) allow MSS/ATC licensees to deploy an unlimited number of 1 watt user terminals in the 1626.5-1660.5 MHz band—including the Lower 10 MHz channel at issue here.[33] With respect to OOBE, the *2003 ATC Order* (adopted more than thirteen years ago) finds that "Big LEO systems *must be capable* of tolerating MET emissions in the 1610-1626.5 MHz band that range from -47 dBW/4KHz to -58 dBW/4kHz."[34] The Order further explains that maintaining OOBE within limits consistent with that standard would avoid the possibility of causing cognizable interference to Iridium.[35] Notably, the permitted level of OOBE under Ligado's current ATC authorizations is consistent with that -58 dBW/4 kHz limit at the edge of Iridium's downlink band (*i.e.*, 1626.5 MHz). The Commission expressly found that operations consistent with that limit would not increase "the likelihood of objectionable interference."[36] Under these circumstances, it was entirely reasonable for Ligado to design *its* network in a manner consistent with the -58 dBW/4 kHz limit and to expect other operators, including Iridium, to be able to coexist on the basis of that OOBE limit.

Importantly, nothing in the pending License Modification Applications modifies these in-band power or OOBE limits in a manner that would increase the potential level of unwanted energy from Ligado's network into Iridium's earth stations. To the contrary, the License Modification Applications expressly seek to *reduce* the authorized in-band power and OOBE levels of Ligado's ATC user terminals. Specifically, grant of Ligado's pending License Modification Applications would reduce the authorized in-band transmit power of its mobile terminals by 80 percent, and also would reduce significantly its OOBE into the GPS band at 1559-1610 MHz. Ligado's proposed OOBE reduction with respect to the GPS band correspondingly would reduce emissions into the Big LEO band, which lies between Ligado's licensed spectrum and the GPS band. Stated differently, any unwanted energy from Ligado ATC terminals would be significantly more constrained if the License Modification Applications were

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33 *See Flexibility for Delivery of Communications by Mobile Satellite Service Providers in the 2 GHz Band, the L Band, and the 1.6/2.4 GHz Bands*, Memorandum Opinion and Order and Second Order on Reconsideration, 20 FCC Rcd 4616, at ¶ 50 (2005).

34 *2003 ATC Order* ¶ 178.

35 Ligado's ATC terminals would comply with that limit across Iridium's spectrum, and in fact would outperform that limit across most of Iridium's spectrum.

36 *See SkyTerra Subsidiary LLC,* 25 FCC Rcd 3043, at ¶ 42 (2010).

granted than it would be if Ligado operated under the *status quo*—its longstanding ATC authorizations.

C. Ligado's ATC Operating Parameters Are Consistent with the Broader Operating Environment Surrounding Iridium's Downlink Spectrum

It bears emphasis that any unwanted energy resulting from Ligado's low-powered ATC user terminals would be far less than that which Iridium already is required to tolerate (and apparently can tolerate) from other adjacent spectrum users. Specifically, more than 5 million METs are authorized to uplink in the United States using spectrum adjacent to that used by Iridium, including in connection with the Globalstar and Inmarsat satellite networks.[37] These METs include both portable terminals used for voice and data connections (*e.g.*, handsets and laptop-sized terminals that can be used anywhere a person may be or a vehicle may travel) and terminals installed on motor vehicles, trailers, cargo containers, and trains, which are operated in urban areas, around airports, and on roads.

These METs are typically licensed at uplink power levels that are significantly higher than the maximum power level at which Ligado's ATC user terminals would operate (5 times to 10,000 times higher), and under OOBE limits that are significantly less restrictive than the limits by which Ligado has committed to abide. It follows that these MET uplinks would generate far more unwanted energy with respect to Iridium's downlink operations than Ligado's proposed ATC operations. Indeed, Iridium's own analysis shows that its user terminals would receive more unwanted energy from a nearby MET uplinking to Globalstar's satellite network[38] than is expected from a Ligado ATC terminal.

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37 *See, e.g.*, Licenses for Call Signs E970381 (authorizing Globalstar to operate over 3.5 million METs), E130033 (authorizing ViaSat to operate 500,000 METs to communicate with Ligado), E000725 (authorizing SkyBitz to operate 450,000 METs to communicate with Ligado and Inmarsat), E090032 (authorizing Inmarsat to operate 150,000 METs), E100192 (authorizing ORBCOMM to operate 100,000 METs to communicate with Inmarsat), E030120 (authorizing AmTech Systems to operate 100,000 METs to communicate with Ligado and Inmarsat), E930367 (authorizing Ligado to operate 100,000 METs), E980179 (authorizing Ligado to operate 100,000 METs), E030055 (authorizing ORBCOMM to operate 50,000 METs to communicate with Inmarsat), E050276 (authorizing Airbus to operate 40,000 METs to communicate with Inmarsat), E990083 (authorizing National Systems & Research Co. to operate 40,000 METs to communicate with Ligado), E050348 (authorizing USSecurenet to operate 40,000 METs to communicate with Inmarsat), E020074 (authorizing Honeywell International to operate 25,000 METs to communicate with Inmarsat), E090029 (authorizing Comtech to operate 25,000 METs to communicate with Ligado and Inmarsat), E980159 (authorizing Satcom Systems to operate 25,000 METs to communicate with Ligado), E050249 (authorizing Inmarsat to operate 20,000 METs), and E980203 (authorizing OuterLink to operate 20,000 METs to communicate with Ligado).

38 *See Iridium Ex Parte Submission*, RM-11697, IB Docket No. 13-213, at Table 1 (Nov. 5, 2014).

Perhaps the best indication that Ligado's proposed mobile handsets/terminals would not pose any threat to Iridium's mobile handsets/terminals extends from real-world experience with the hundreds of millions of terrestrial wireless devices and METs that have operated throughout the United States in and adjacent to the 1626.5-1660.5 MHz band for years, at higher transmit power levels and with less restrictive OOBE limits than the one Ligado has committed to meet. Under these circumstances, granting the License Modification Applications and allowing Ligado to commence operations with 0.2 watt user terminals could hardly be expected to have any material impact on Iridium's downlink operations. For the same reasons, imposing further constraints on Ligado's ATC terminal operations (*e.g.*, limiting operations in the vicinity of airports, as Iridium proposes) would not alter the environment created by other authorized adjacent spectrum uses, to which Iridium already must adapt. Nor would doing so be expected to materially change the operating environment in which Iridium is expected to operate. Notably, the Commission has previously rejected requests to "protect" Iridium's network by imposing OOBE limits on adjacent spectrum users that are stricter than the OOBE levels applicable to the METs and other spectrum users already operating in the vicinity of Iridium's secondary downlink band.[39]

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Ligado is committed to working cooperatively with Iridium, as Ligado has with other adjacent-band users, to reach agreement on operating parameters that allows Ligado and its neighbors to use their spectrum to its full potential. The technical analysis submitted by Iridium overstates the potential effect of Ligado's operations by employing unrealistic assumptions about the existing spectrum environment in which Iridium and Ligado operate. Ligado is hopeful that the more realistic assessment presented herein will assuage Iridium's concerns and facilitate the parties' ability reach agreement on appropriate operating parameters, as Ligado has with other stakeholders.

Respectfully submitted,

/s/
Gerard J. Waldron
Michael Beder
Counsel to Ligado Networks LLC

cc: Ron Repasi
Michael Ha
Paul Murray
Charles Mathias
Paul Powell
Bob Nelson

[39] *See AMSC Subsidiary Corp.*, 10 FCC Rcd 10458, at ¶¶ 23-24 (1995) (refusing to impose further limits on AMSC's lower L-Band MSS operations in part because further limits would be more restrictive than OOBE from many other MSS and lower L-Band uses).

Attachment A – Ligado Technical Analysis Charts (**<u>CONFIDENTIAL)</u>**

Attachment B – Comparison of Iridium and Ligado Technical Approaches (**<u>REDACTED)</u>**

Attachment C – Iridium's L-Band Neighborhood
(Excerpt from Iridium *ex parte* presentation filed Sept. 26, 2016,
IB Docket No. 11-109 *et al.*)

Attachment D – CV of Jake Rasweiler

Attachment A

Ligado Technical Analysis Charts
(**<u>CONFIDENTIAL)</u>**

Attachment B

Comparison of Iridium and Ligado Technical Approaches
(**REDACTED – FOR PUBLIC INSPECTION)**

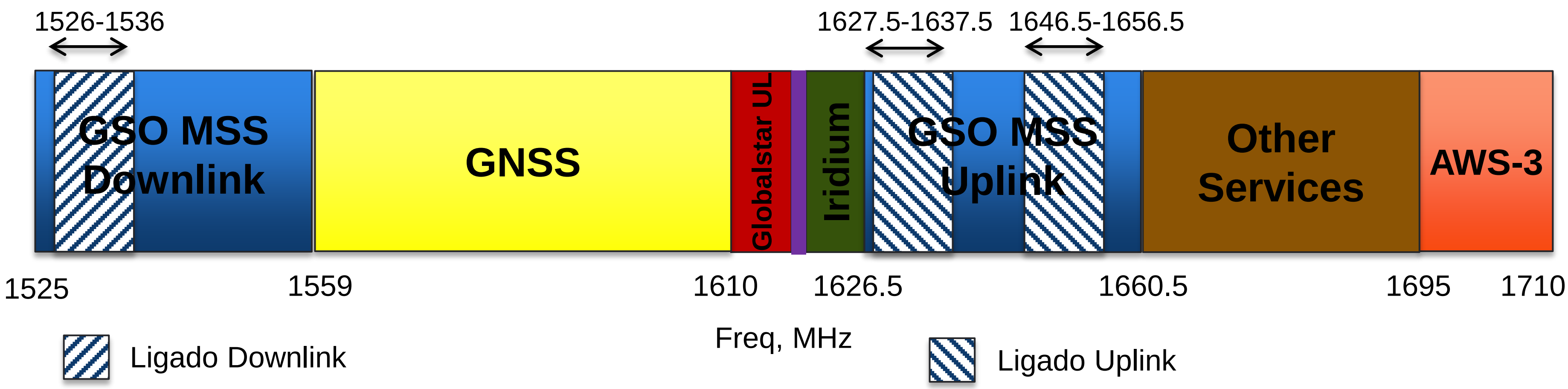
Comparison of Iridium and Ligado Technical Approaches

Factor	**Value in Iridium's Filing**	**Ligado's Value**
Ligade User Terminal OOBE Limit	-49.2 dBW/30 KHz	-49.2 dBW/30 KHz
Separation Distance	10, 100, 1000, 4000 meter cases	10, 100, 1000 meter cases
Path Loss	Free space and Hata-Okumara	1. Free-Space: 10m 2. Iridium D4: 100 m 3. Walfisch-Ikegami Non-Line-of-Sight: 100m, 1000m
Iridium Reference RX antenna gain at horizon	-3 dB	-3 dB
Received interference power density		
Iridium user terminal noise floor	-154.8 dBW/30 kHz	-149.4 dBW/30 kHz
I/N		
Required I/N	-6	0
Additional Antenna discrimination between terminals	NOT INCLUDED IN IRIDIUM'S APPROACH	-17 dB
Iridium Margin		

Attachment C

Iridium’s L-Band Neighborhood

Iridium's L-Band neighborhood



- Iridium currently licensed to operate in 1617.775-1626.5 MHz
- 8.725 MHz total spectrum to provide uplink and downlink service links

Attachment D

CV of Jake Rasweiler

John J Rasweiler V – MBA, MSEE, PE, PMP Certified
7 Whitney Circle, Glen Cove, NY 11542
Home: (516) 759-3031 ♦ Cell: (516) 761-2235 ♦ Email: jrasweil@gmail.com ♦ www.linkedin.com/jakerasweiler/

EXECUTIVE OFFICER ♦ BUSINESS STRATEGY ♦ METROPOLITAN AREA NETWORKS ♦ SMALL CELL STRATEGY
TELECOM NETWORK & IT LEADERSHIP ♦ ENGINEERING CONSULTING ♦ FORTUNE 50 GLOBAL BUSINESS DEVELOPMENT

Executive leader with global expertise in Wireless Technology, Metropolitan Area Networking, 4G and Small Cell network planning, operations, and technology strategy.

- Technologies: DOCSIS, LTE, GPRS, LPWA, Wi-Fi
- Created and launched Solution as a Service (SaaS) with GE and SAIC in utility and petroleum sectors
- Built first state-wide Cisco Powered Smart Grid network in United States
- Led engineering for largest market at Sprint Nextel, Inc. (New York)
- Global Experience: Argentina, Brazil, Canada, Croatia, Ireland, Israel, Italy, Japan, Mexico, Nigeria, Russia, Singapore, South Korea, Taiwan, and others

AREAS OF EXPERTISE

- Technology Strategy
- Metropolitan Area Networks
- DAS & Small Cell
- Digital Oil Field Solutions & Analytics
- SCADA/Process Management Systems
- Grid Automation & Modernization
- Leadership for 250+ member team
- P&L Responsibility
- Global Operations
- Investor Relations
- Early Stage Strategic Business Development
- Building / Operating Networks & SaaS
- Senior Level Telecom Network Management
- Product Management and Development
- Project Management
- R&D: HW/SW Applications
- Multi-site Datacenter Management
- Network Security

PROFESSIONAL SUMMARY

SUBLIME WIRELESS, INC. **2011 - Present**

CHIEF OPEATING OFFICER, White Plains, NY (1/2014 – Present)
PRINCIPAL & CHIEF STRATEGY ADVISOR, White Plains, NY (1/2011 – 12/2013)

Company operations and strategic consulting services lead for 300+ member consulting, project management and engineering services firm

- Provided expert witness testimony in Federal court regarding wireless technology
- Conducted and delivered engineering analysis related to radio and filter technology including Ex Parte submission to FCC
- Supported large-scale (nationwide) design, deployment and optimization wireless operator projects for CDMA, LTE, VoLTE, Land Mobile Radio and Internet of Things (IoT) Low-power Wide-Area (LPWAN) networks

ON-RAMP WIRELESS, INC. **2011 - 2013**

CHIEF STRATEGY OFFICER, San Diego, CA (3/2012 – Present)
CHIEF OPERATING OFFICER, San Diego, CA (1/2011 – 3/2012)

Senior executive leading strategic market development and industrial solutions, manufacturing and operations for patented software analytics and wireless communication automation company serving the global Oil & Energy sector (AMI and SCADA) and M2M markets. Strategic investors include ConocoPhillips, GE and Enbridge

Key Results

- Licensed technology to GE Energy Management, GE Oil & Gas, SAIC, and Korea Telecom for use in critical infrastructure applications
- Pioneer market research, and execute segment entry into utility, oil & gas and other M2M markets securing commercial relationships with Emerson, Koncar (Croatia), Shell (Nigeria), Chevron, East Central Energy and others leading to >$50M in contracted revenue (8x prior lifetime revenue-to-date)
- Working with GE Intelligent Platforms and Frog Consulting developed positioning and launch strategy for GE's RMCS automation platform with key supermajors
- Hands-on experience and product knowledge of upstream, midstream and down-stream Oil & Gas segments; AMI and grid automation/modernization
- Deployed networks globally in the US, South Korea, China, Japan, Nigeria, and Ireland for electric grid, gas pipeline and oil field automation

ARCADIAN NETWORKS, INC. **2006 - 2011**

CHIEF TECHNOLOGY OFFICER, Valhalla, NY (11/2007 – 12/2011)
VICE PRESIDENT IT, ENGINEERING & NETWORK OPERATIONS, Valhalla, NY (4/2006 – 11/2007)

Senior executive leading technical strategy, IT, customer facing technical services and project management for specialized wireless carrier and manufacturing company building private, wireless broadband networks for electric utilities, oil & gas producers, and energy companies. Founded in 2005, the company raised $90M in working capital and launched service in 2006 with the construction of the largest 700 MHz wireless network in the US for Great River Energy of Maple Grove, Minnesota. Primary investors: Goldman Sachs, IDB/CLAL Industries, and Gilo Ventures

Key Results

- Hands-on leader developing system architecture (SOA), industrially hardened wireless products, and secure networks supporting VOIP, SCADA, and IP video

John J Rasweiler V – MBA, MSEE, PE

- Built entire technical organization and commercialized statewide Smart Grid network and operations center (NOC) for 30+ utilities and 400,000+ AMI/AMR meters
- Contracted to utility customers including Great River Energy, Green Mountain Power and First Energy
- Developed architecture and wrote Cisco-powered and grant proposal earning Sempra Energy $28 Million in US Department of Energy grants
    - https://www.smartgrid.gov/sites/default/files/pdfs/project_desc/SDGE-Project-Description_0.pdf
    - https://www.sdge.com/sites/default/files/regulatory/GridCommDO%20Application.pdf
- Achieved Cisco Powered Designation for Integrated Access Broadband Services - Smart Grid Ecosystem member (see below)
    - http://www.cisco.com/web/MT/news/09/news_210909.html

Cisco_Arcadian_CS.pdf

NEXTEL COMMUNCATIONS, INC. (SPRINT NEXTEL CORPORATION) **1997 - 2006**

REGIONAL SENIOR DIRECTOR - NY/NEW ENGLAND, White Plains, NY (10/2005 – 3/2006)
SENIOR DIRECTOR RF ENGINEERING – NEW YORK METRO, White Plains, NY (1/2003 – 12/2005)
DIRECTOR TECHNICAL SERVICES, Garden City, NY (9/2001 – 12/2002)
ENGINEERING & OPERATIONS SENIOR MANAGER – NEW YORK CITY, White Plains, NY (5/1998 – 9/2001)
RF ENGINEERING TEAM LEADER, White Plains, NY (11/1997 – 4/1998)

Senior technical lead for the New York Metropolitan Area responsible for network management, long-term planning, sales engineering, site development, legal review, construction project management, material procurement, equipment engineering and wireless site maintenance

Key Results
- Accountable for 250+ member team serving 13% of Nextel's total network revenue / annual capital and operating budgets >$150 million
    - Maintained network quality while supporting largest growth (>35%) of any Nextel area in 2004
    - Improved network quality by 40% while reducing capital spending by one-third in 2002
    - Supported annual network growth as high as 300%
    - Achieved as high as 168% of targeted bonus objectives
- Led rapid network recovery efforts following 9/11 World Trade Center attacks resulting in public sector customer acquisitions including CIA, Secret Service, FBI and NYPD (largest public safety accounts in US)
- Successfully designed citywide fiber-based wireless light pole project throughout New York City
- Trained and supported Nextel International markets including Sao Paulo, Rio de Janeiro, and Buenos Aires on network design
- Founding member of national Engineering Standards committee 2000 to 2006

MCCAW CELLULAR COMMUNICATIONS INC. (AT&T WIRELESS SERVICES) **1994 - 1997**

SENIOR ENGINEER, New York, NY (6/1996 - 11/1997)
RF ENGINEER, Paramus, NJ (1/1995 - 6/1996)
ASSISTANT RF ENGINEER, Paramus, NJ (1/1994 - 12/1994)

High performing engineer promoted to technical supervisor of eight member team responsible for Manhattan network design

Key Results
- Pioneered deployment of cost-saving urban cellular network architecture used as model for AT&T nationwide deployment
- Presented network growth plans to executive management including CEO
- Provided urban planning and consulting support for large markets including Los Angeles, Moscow, Japan and Taiwan
- Presented at international conferences in Singapore and London

EDUCATION & CERTIFICATIONS

Master's Degree: M.B.A. Management
FORDHAM UNIVERSITY, Graduate School of Business Administration: New York, NY, 8/1997

Master's Degree: M.S. Electrical Engineering (fiber optics):
POLYTECHNIC INSTITUTE OF NYU (New York University - formerly Polytechnic University), Brooklyn, NY, 1/1995

Bachelor's Degree: B.A. Physics and Economics (dual major)
COLGATE UNIVERSITY, Hamilton, NY, 5/1992

New York State Licensed Professional Engineer (P.E.): Lic.#080608 (active 2003-2011)

Project Management Professional (PMP): #319142 (2006-2010)

ACHIEVEMENTS

PATENTS
Antenna. U.S. Patent Number: D383463, September 9, 1997
Antenna for Enhanced Radio Coverage. U.S. Patent Number: 5638081, June 10, 1997