Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
SPACEX SERVICES, INC.	)	IBFS File Nos. SES-LIC-20190816-01062 and -01063; SES-LIC-20190827-01110; and SES-LIC-20190906-01170 and -01171
Applications for Ka-band Gateway Earth Station Authorizations	)	

RESPONSE OF SPACEX SERVICES, INC.

SpaceX Services, Inc. ("SpaceX") hereby responds to the comments filed by WorldVu Satellites Limited ("OneWeb") on the five applications for Ka-band gateway earth station authorizations referenced above.[1] OneWeb is the only party to file comments, and it focuses on a single aspect of SpaceX's application – the maximum number of spacecraft that will communicate simultaneously with each proposed gateway location. OneWeb requests that SpaceX "clarify" that number and asserts that the answer could affect the interference environment for other non-geostationary orbit ("NGSO") satellite systems that operate in the same Ka-band spectrum.[2]

To the extent not already clear from its applications, SpaceX hereby confirms that up to eight satellites will communicate simultaneously with each gateway location. As OneWeb notes, SpaceX initially anticipated that four satellites would be the maximum at any given time.[3] However, nothing in the licenses issued to SpaceX limits its operations to a specific number of antennas at each gateway site. Rather, the Commission imposed limitations on parameters such

1 *See* Comments of WorldVu Satellites Limited, IBFS File Nos. SES-LIC-20190816-01062, et al. (Oct. 25, 2019) ("OneWeb Comments").

2 *See id.* at 2-3.

3 *See id.* at 2 n.4.

as power flux-density ("PFD") and equivalent power flux-density ("EPFD") in various frequency bands and authorized SpaceX to operate within those applicable limitations.[4] As part of its iterative approach, SpaceX determined that it could improve coverage and capacity by providing more options for beam routing and redundancy for routing traffic around gateways impacted by weather. SpaceX can optimize its system by operating up to 8 antennas per gateway site rather than four as originally anticipated – yet still remain within the limitations imposed in its license.

In order to maintain the aggregate PFD level of its downlink transmissions, SpaceX will reduce the PFD of its main beams by 3 dB. By cutting the power in half, SpaceX will maintain the same worst-case PFD at each earth station location even though twice as many satellites may be transmitting simultaneously. Thus, OneWeb's conjecture that doubling the number of transmitting satellites would result in a 3 dB increase in long-term interference is incorrect.[5]

Similarly, SpaceX has provided input data files to the International Telecommunication Union ("ITU") for its 2018 modification that include up to eight SpaceX satellites transmitting simultaneously to each gateway site.[6] As OneWeb noted, the EPFD analysis SpaceX provided in connection with its modification application assumed eight SpaceX satellites for each Ka-band gateway earth station site.[7] Accordingly, both the analysis presented to the Commission and the data presented to the ITU (which will be used in the ITU's own EPFD analysis) are consistent with having up to eight satellites simultaneously transmitting to a gateway site, as proposed in these applications.

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4 *See, e.g., Space Exploration Holdings, LLC*, 34 FCC Rcd. 2526, ¶ 32 (b), (d), (e), (j), and (k) (IB 2019).

5 OneWeb Comments at 3.

6 Those materials are available at https://www.itu.int/ITU-R/space/asreceived/Publication/DisplayPublication/8956 (STEAM-2B) and https://www.itu.int/ITU-R/space/asreceived/Publication/DisplayPublication/8959 (USASAT-NGSO-3B-R).

7 *See* OneWeb Comments at 2 n.5 (citing Further Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083, at A1 (filed Feb. 21, 2019)).

OneWeb also insinuates – without any supporting analysis – that allowing SpaceX to operate with up to eight transmitting satellites per gateway rather than four could negatively affect the NGSO interference environment. It baldly asserts, for example, that this change would result in a 100% increase in in-line interference events.[8] To the contrary, this change will have no such effect as demonstrated by the following analysis.

For this purpose, we consider an exemplary dynamic comparison of the downlink I/N from SpaceX satellites operating at 550 km altitude to a OneWeb Ka-band earth station with a different number of simultaneous downlink main beams to a location (denoted as "N_co"). The analysis assumes that the earth stations of both SpaceX and OneWeb are collocated at a site proposed by OneWeb for one of its gateways: either Southbury, CT (Latitude 41° 27' 6.4" N, Longitude 73° 17' 21.6" W) or Santa Paula, CA (Latitude 34° 24' 7.2" N, Longitude 119° 4' 23.5" W).[9] These present two representative locations at either end of the U.S. The analysis accounts for the interference caused by the main beams placed at the earth station location and the sidelobes from the SpaceX satellites which are in-line with the OneWeb satellite.[10] A representative Ka-band downlink frequency of 18.5 GHz has been used. The operational parameters of the OneWeb NGSO system and the SpaceX NGSO system (both as currently authorized and as proposed for modification) are set forth below.[11]

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8 OneWeb Comments at 3.

9 *See* IBFS File Nos. SES-LIC-20180727-02076 (filed July 27, 2018) ("Southbury Gateway Application") and SES-LIC-20190422-00538 (filed Apr. 22, 2019) ("Santa Paula Gateway Application").

10 It is assumed these in-line SpaceX satellites place their main beams at least 10deg away from the direction to the earth station.

11 The orbital parameters for OneWeb's NGSO system and the GSO Exclusion Angle are taken from its NGSO market access application. See IBFS File No. SAT-LOI-20160428-00041 (filed Apr. 28, 2016). The avoidance angle is chosen to target I/N < -12.2 dB (or $\Delta T/T < 6\%$) for about 99.9% of the time. All other radiofrequency parameters are drawn from OneWeb's Southbury and Santa Paula Gateway Applications.

Orbital Parameters

Parameters	SpaceX	SpaceX	OneWeb
Planes	24	72	18
Satellites/plane	66	22	40
Inclination [deg]	53	53	87.9
Altitude [km]	550	550	1200
Total satellites	1584	1584	720

Radiofrequency Parameters

Parameters	SpaceX		OneWeb
	Case 1	**Case 2**	
N_co	4	8	-
PFD [dBW/m^2/MHz]	-116.3	-119.3	-
Min. ES Elevation Angle [deg]	25	25	5
GSO Exclusion Angle [deg]	18	18	6
Sat TX Antenna Type	Rec.1528 (LEO)	Rec.1528 (LEO)	-
Sat TX Max Gain [dBi]	34.5	34.5	-
ES RX Antenna Type	-	-	Section 25.209(a)(1)
ES RX Max Gain [dBi]	-	-	54.6
Satellite Tracking	Random	Random	All Visible
NGSO Avoidance Angle [deg]	10	7.07	-

Note that there are two main differences in the specifications for SpaceX's satellite operations when changing N_co from 4 to 8 beams. First, as discussed above, PFD of the main beam is reduced by 3 dB. Second, as a result, the NGSO Avoidance Angle is reduced accordingly to keep the total in-line exclusion area the same in both cases (no change for the likelihood of actual in-line events). Reduction of the NGSO Avoidance Angle reflects the fact that satellites operating at lower power must be closer together to trigger a 6% $\Delta T/T$ in-line event.

The dynamic simulation considers all eligible OneWeb satellites at each time step (qualified by the minimum elevation angle and the GSO exclusion angle) to place downlink beams at the chosen gateway location. For each eligible OneWeb satellite at that time step, the simulation identifies all eligible SpaceX satellites that satisfy the minimum elevation angle, GSO exclusion angle, and mainbeam NGSO avoidance angle parameters from this OneWeb satellite-to-gateway

pointing. Of those identified SpaceX satellites, N_co satellites are randomly chosen to place mainbeams at the collocated gateway location. The simulation is carried over a long duration of time to get a stable histogram of I/N distribution. The results of this analysis are presented in Figures 1 through 4 below, comparing I/N with a maximum of four or eight simultaneously transmitting satellites at each earth station site for the current constellation and the proposed modification.

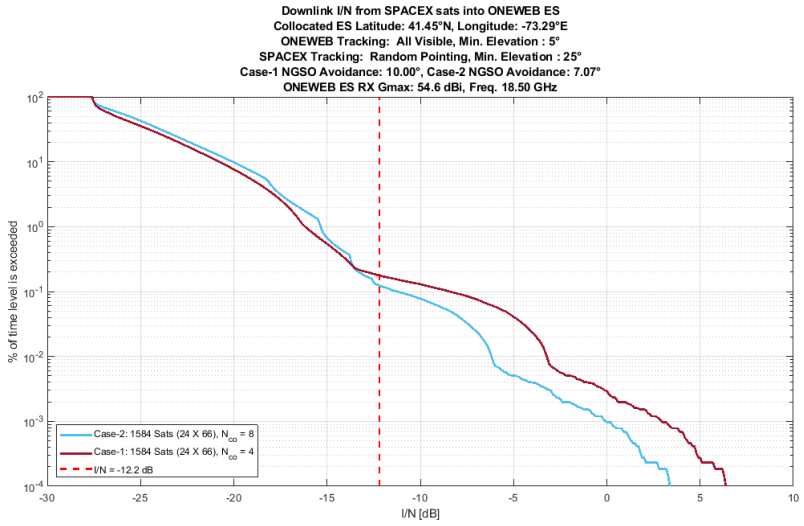

Figure 1. Comparison of I/N for Four vs. Eight Transmitting Satellites – Southbury, CT, Existing Constellation

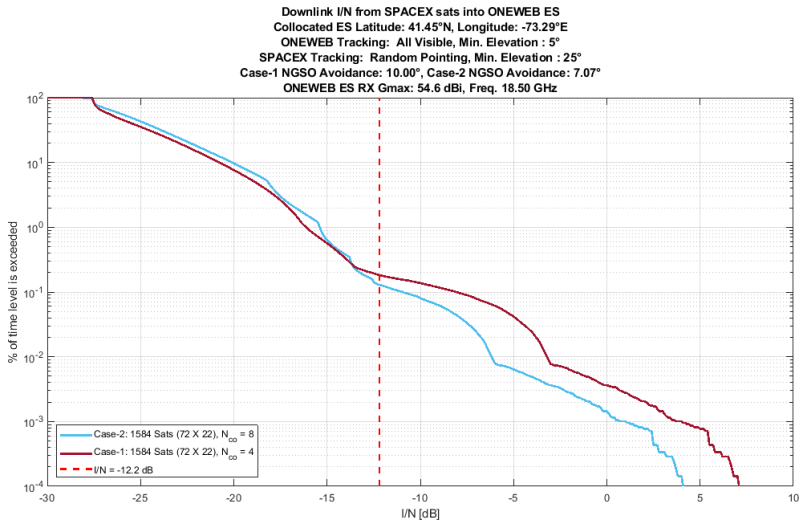

Figure 2. Comparison of I/N for Four vs. Eight Transmitting Satellites – Southbury, CT, Modified Constellation

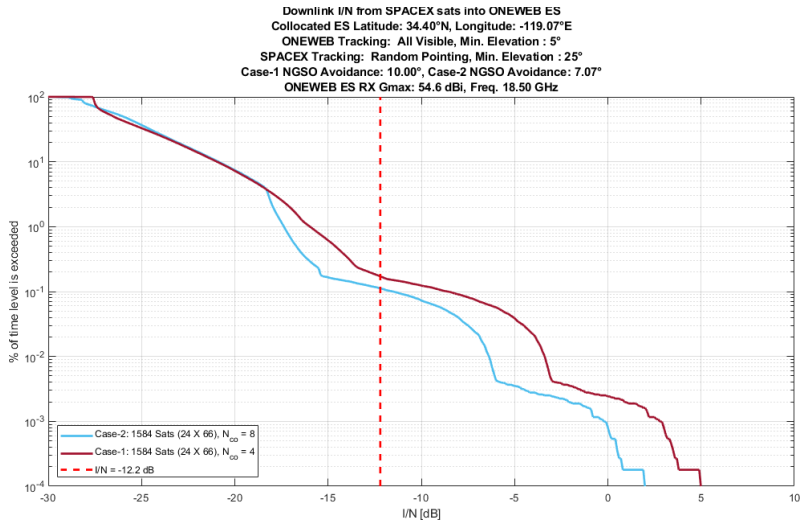

Figure 3. Comparison of I/N for Four vs. Eight Transmitting Satellites – Santa Paula, CA, Existing Constellation

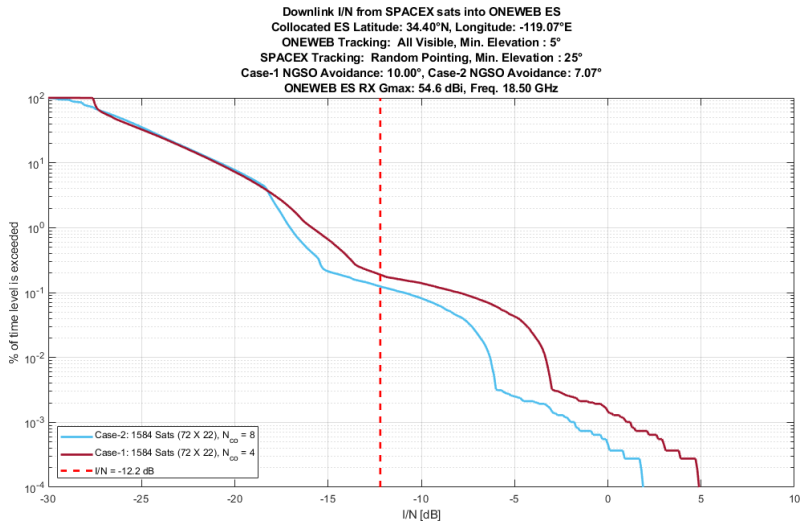

Figure 4. Comparison of I/N for Four vs. Eight Transmitting Satellites – Santa Paula, CA, Modified Constellation

As these figures illustrate, there is no overall increase in interference to OneWeb's collocated gateway earth stations in the region of the figure where in-line events occur (i.e., where I/N > -12.2 dB). Those occasions where I/N is slightly higher for eight satellites rather than four all occur in the region where $\Delta T/T < 6\%$ – i.e., where there is no in-line event with either four or eight satellites. Accordingly, those very slight exceedances have no material impact on spectrum sharing among NGSO systems.

Figures 5 through 8 below show the in-line events from the perspective of OneWeb's highest elevation satellite (used as an example for gathering statistics in the simulation) to the Southbury, CT site for the SpaceX constellation as currently authorized and as modified. As the figures show, the number of in-line events and their maximum and average duration are significantly reduced when switching from N_co = 4 to N_co = 8.

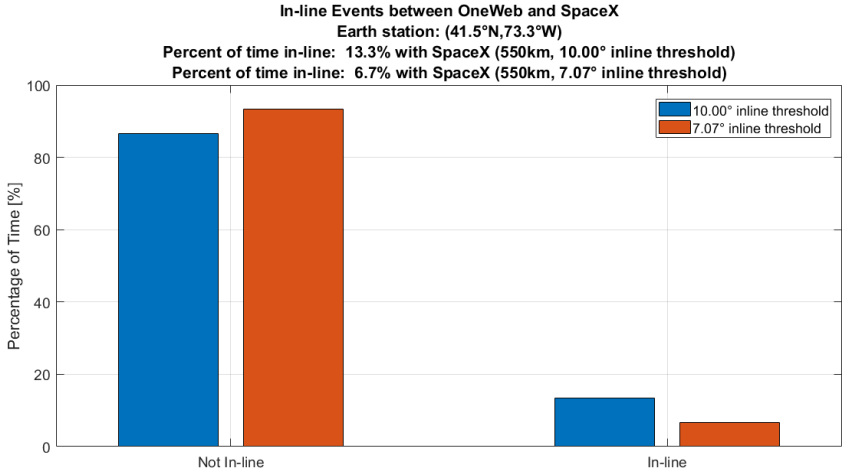

Figure 5. Number of In-Line Events – Existing Constellation

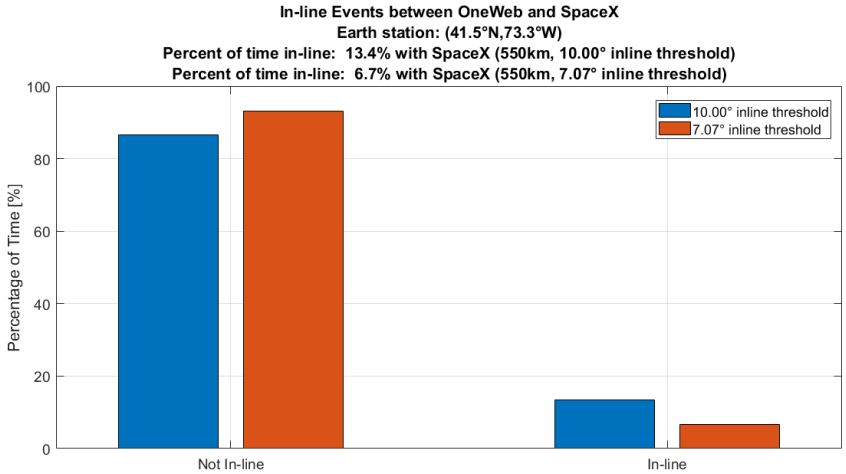

Figure 6. Number of In-Line Events – Modified Constellation

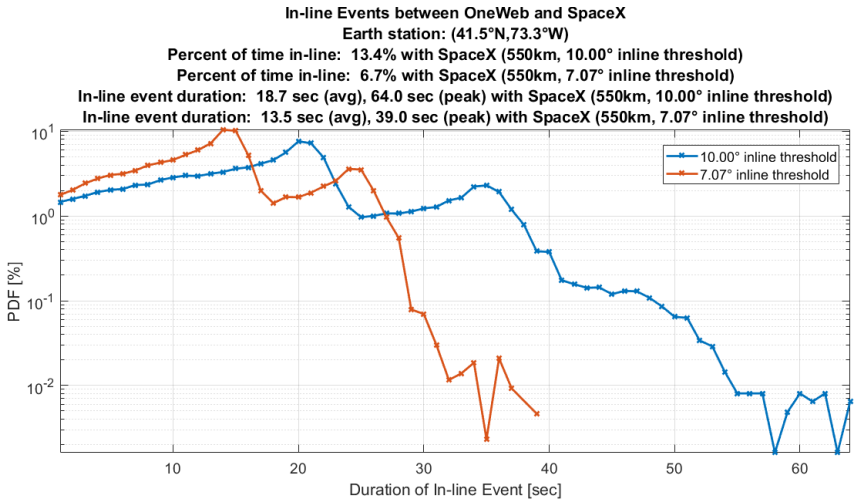

Figure 7. Duration of In-Line Events – Existing Constellation

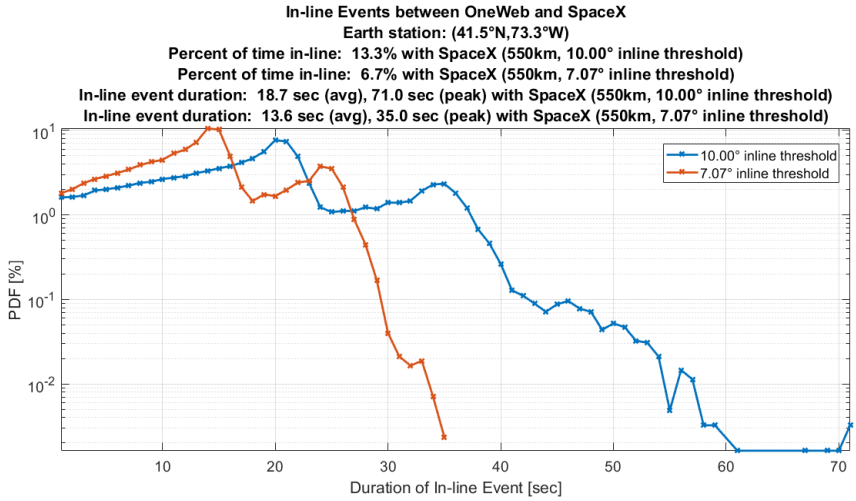

Figure 8. Duration of In-Line Events – Modified Constellation

Figures 9 and 10 below show the number of OneWeb eligible satellites (i.e., over 5 degrees minimum elevation, over 6 degrees from the GSO arc, not in-line with a SpaceX satellite) from the perspective of OneWeb's Southbury, CT earth station. As the figures show, the number of eligible satellites actually increases when switching from N_co = 4 to N_co = 8.

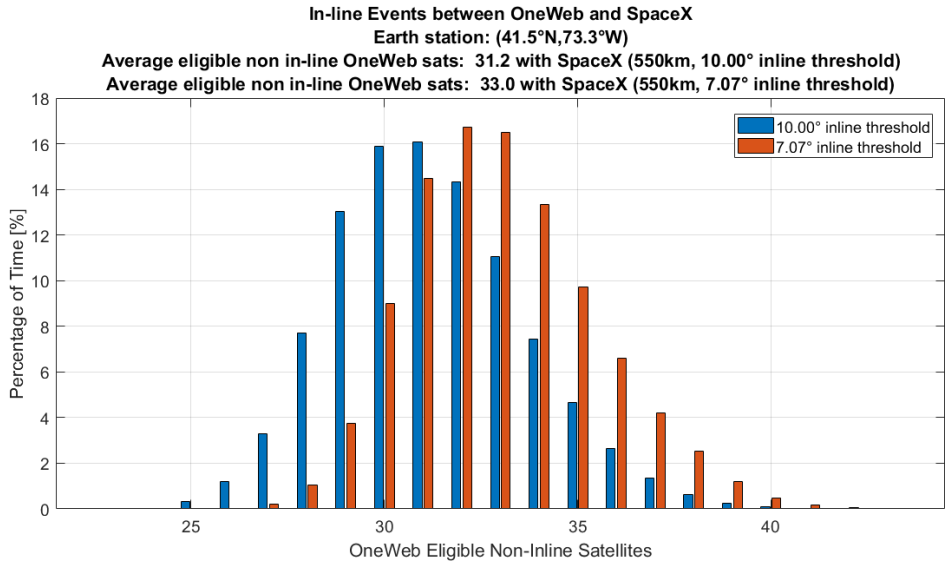

Figure 9. Number of Eligible OneWeb Satellites In View – Existing Constellation

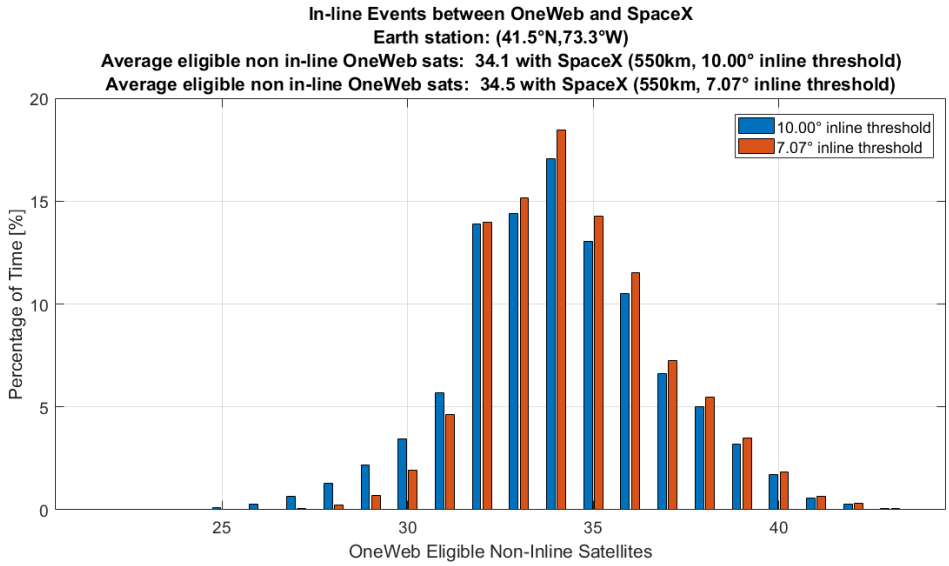

Figure 10. Number of Eligible OneWeb Satellites In View – Modified Constellation

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In summary, SpaceX intends to operate up to eight space stations simultaneously with each of its proposed Ka-band gateway earth stations. It will do so consistent with its NGSO authorization. And it will not cause any material change to the NGSO interference environment

compared to operating with a maximum of four space stations simultaneously. Accordingly, there is no reason for the Commission to delay granting the five pending applications.

Respectfully submitted,

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CERTIFICATE OF SERVICE

I hereby certify that, on this 7th day of November, 2019, a copy of the foregoing pleading was served via First Class mail upon:

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