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EAN 2017-05
April 14, 2017

FILED ELECTRONICALLY VIA IBFS
Mr. Jose P. Albuquerque
Chief, Satellite Division- International Bureau
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: Telesat Canada, Petition for Declaratory Ruling
Requesting Access to the U.S. Market for Its
Non-Geostationary Orbit Constellation, Call Sign S2976
IBFS File No. SAT-LOI-20161115-00108

Dear Mr. Albuquerque:

In response to your March 15, 2017 letter requesting additional information in evaluating Telesat Canada's ("Telesat") above referenced petition for declaratory ruling, Telesat provides the following information to your specific questions below. The staff questions are formatted in italics with Telesat's responses in plain text below. Footnote references in the Commission's letter to Telesat are removed for clarity:

1. A statement concerning whether it is Telesat's intent to seek registration of the Telesat NGSO FSS system by Canada consistent with the Convention on the Registration of Objects Launched into Outer Space.

Telesat plans to seek registration of the Telesat NGSO FSS system by Canada, consistent with the Convention on the Registration of Objects Launched into Outer Space.

2. Any software used to generate the EPFD results shown in the petition, including inputs and output results.

In Telesat's application (Petition for Declaratory Ruling) compliance with the epfd limits was provided in Section A6 of the Technical Exhibit and the calculations were shown in Tables 4 to Table 9 of that same Exhibit. The results were calculated using Microsoft Excel. For convenience, the tables are provided in Attachment 1 to this letter. The active Excel file is included with this filing.

The Excel file has six sheets labeled as “Table 4”, “Table 5”, “Table 6”, “Table 7”, “Table 8”, and “Table 9”. Each sheet provides the calculations for the corresponding table in the Petition, e.g., the Excel tab “Table 4” provides the calculations for Table 4 of Section A6 of the Technical Exhibit of the Petition.

3. Section 25.114(d)(l) of the Commission's rules requires that applicants provide an explanation of how the uplink frequency bands would be connected to the downlink frequency bands on their proposed satellite system. In order to better understand the beam and channel connections on the Telesat NGSO FSS system, we request that Telesat supplement its petition with a showing (e.g., a strapping table, chart, or spreadsheet) that clearly presents this information.

As described in Telesat’s application, each satellite of the LEO Constellation will provide a minimum of 16 steerable User beams and two steerable Gateway beams with the use of Direct Radiating Arrays (DRA). RF signals will be digitized, demultiplexed and demodulated; regenerating each signal on-board for packet switching. In addition, each satellite will have a maximum of four Inter-Satellite Link (ISL) terminals to redirect traffic when Gateways are not available or when traffic is required to be transmitted to a specific Gateway. Therefore, the switching capability on board the satellite will maximize connectivity, i.e. Gateway-User, User-User, User-Gateway, User-ISL, Gateway-ISL and ISL-ISL. With the use of on-board regenerative payloads and ISLs, the satellites are no longer limited to the pre-determined typical uplink/downlink channel connectivity of bent-pipe payloads.

As shown in the frequency plan of Figure 1 below, any uplink frequency band can be connected to any downlink frequency band. At a specific instant, if no Gateway is visible to a particular satellite, *e.g*. coverage is over water, all spectrum can be used for user uplink and downlink. Similarly, for Gateways located in the higher latitudes, with very few customers, most of the spectrum will be used for the Gateways. Although the bands are listed as Shared and User, the LEO Constellation design will allow maximum flexibility and efficiency.

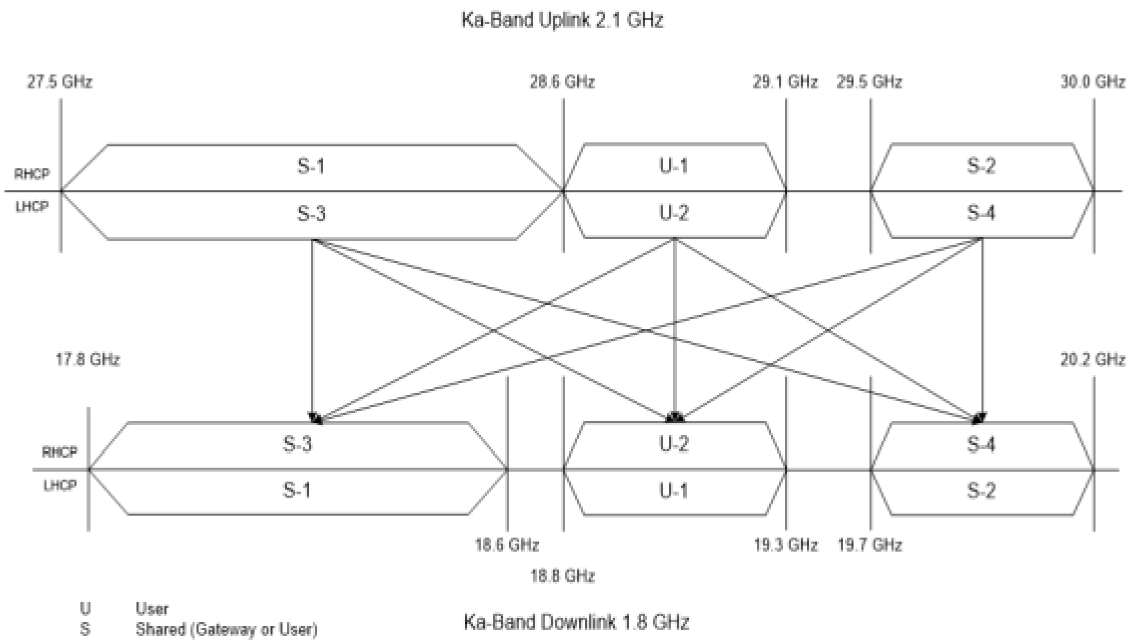

Figure 1 Telesat LEO Constellation Polarization and Frequency Plan

4. Commission rules require petitioners requesting U.S. market access for non-U.S. licensed space stations to provide a narrative description of the design and operational strategies that will be used to mitigate orbital debris. Alternatively, an applicant seeking market access for a non-U.S. licensed system can satisfy this requirement "by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority." Telesat states that it satisfies this requirement because the operations of its NGSO FSS system are subject to direct and effective regulatory oversight by the Canadian licensing authority - Innovation, Science and Economic Development Canada (formerly Industry Canada). Telesat states that Canadian regulations require that space debris mitigation measures be implemented "in accordance with best industry practices so as to minimize adverse effects on the orbital environment," and that Telesat's Canadian approval in principle specifies the same condition. Telesat also disclosed certain information concerning its orbital debris mitigation plans pursuant to Section 25.114(d)(14) of the Commission's rules. In order to assist in our assessment of whether Telesat has demonstrated that it is subject to direct and effective regulatory oversight, or alternatively, to permit analysis of the debris mitigation plans for the constellation, we request the following additional information:

a. Any additional information concerning the scope of oversight to which Telesat is subject, supported if possible by publicly available materials discussing the criteria applied by the Canadian regulatory authority. If an Orbital Debris Assessment Report or other documentation for the Telesat constellation has been prepared for or submitted to ISED, please submit a copy of that report.

The applicable Canadian regulation is contained in CPC-2-6-02, Issue 3 (Provisional), Licensing of Space stations, issued November 2013 at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf01385.html. Specifically, Section 3.3.3 states that for non-geostationary satellites licensing applicants must submit a plan for de-orbiting their satellites(s) in accordance with best industry practices, noting specifically the United Nations' space debris mitigation guidelines at www.unoosa.rog. The relevant excerpt from CPC-2-6-02 is provided at Attachment 2 to this letter. The relevant excerpt from Telesat's Canadian license application with respect to the commitment to debris mitigation is provided in Attachment 3 to this letter.

b. The accuracy within which the space station orbital parameters will be maintained for any orbit in which Telesat NGSO FSS satellites will operate, including apogee, perigee, inclination, and the right ascension of the ascending node(s).

The space station orbit parameters will be maintained as follows:

Apogee or Perigee Altitude	±300 meters
Inclination	±0.04 degrees
Right Ascension of the Ascending Node	±1 deg

c. The intended orbital parameters of the "Decaying Lower Orbit" to be used for end-of-life disposal, or, if range of possible orbits depending on available fuel is intended, a characterization of the likely distribution of satellites within that range.

Telesat has carried out a preliminary analysis for the deorbiting phase risks. This has resulted in a circular orbit of 590 km. This orbit will stay nearly circular as its altitude decays through re-entry. Likewise, inclination will remain nearly identical to that of the operational orbit during the orbit decay period. Telesat is currently analyzing a more efficient elliptical orbit configuration with lower perigees for de-orbiting to minimize the fuel usage, time in the disposal orbit and debris generation.

d. Please provide an analysis of collision risk for satellites during the passive disposal phase, i.e., after all propellant is consumed, for a 140 satellite deployment, assuming 100% reliability. As part of that analysis, please provide an assessment of how many conjunctions and/or collision avoidance maneuvers might be required of the International Space Station, assuming it is in operation throughout the period in which disposals occur. To the extent replenishment or deployment rates can be expected to involve more than 140 satellites through 2035, please also provide an analysis assuming such rates.

For the preliminary analysis for circular orbit passive disposal phase of a single satellite, the probability of collision with debris of size greater than 10 cm predicted by the NASA DAS software is 0.00008 for the polar constellation, and 0.00004 for the inclined constellation. Typical lifetimes in the disposal phase are 2 to 8 years depending on the solar cycle with an average of 5 years. Assuming a satellite mean mission duration (MMD) of 7 years, the deorbit rate would be 11 satellites per year for the polar constellation and 14 satellites per year for the inclined constellation. A rough and very conservative scaling of the single satellite collision probability is to assume that at most up to 55 (5 years*11 satellites/year) for the polar constellation are in the passive disposal phase, and likewise at most 70 satellites for the inclined constellation. Then the accumulated collision probability is 0.0044 for the polar constellation, and 0.0028 for the inclined constellation. These analyses will be refined for elliptical disposal orbits, which are expected to reduce the collision risks further still. Such elliptical orbits can be tailored to provide maximum separation, depending upon each individual satellite's initial parameters for de-orbit. With respect to the frequency of conjunctions with the International Space Station each decaying spacecraft will spend less than 3 months within 20 km of the ISS altitude, and with the above failure rates up to about 6 satellites would be in the altitude region at a time. Currently ISS debris avoidance maneuvers are less than one or two per year with more than 100 catalogued debris objects within a +/-20 km altitude range, so it is not expected that the additional decaying debris will have a significant impact on ISS collision avoidance activities.

e. Please provide an analysis of collision risk, assuming rates of satellite failure resulting in the inability to perform collision avoidance procedures of 10, 5 and 1 percent. This analysis should include a study performed assuming all failures occur at the mission altitude, but may also include additional studies specifying alternative assumptions concerning the orbital locations (such as injection altitude) at which failures might occur.

The constellation satellites will have redundancies in satellite control and operations. Processes will be in place to enable removal of spacecraft from active orbits, in the case of components/subsystem failure. In the event of a complete failure of the orbit control systems at the mission orbit that precludes nominal deboost to 25-year lifetime orbit, Telesat spacecraft will be subject to collision with other uncontrolled resident space objects, and space debris.

The NASA DAS model cannot currently be used to predict collision probabilities at altitudes above approximately 700 km. However, by using average collision probabilities as calculated by DAS below 700 km, an extrapolation has been made to altitudes above 700 km. An approximate assessment of the most significant risk of collision with objects greater than 10 cm, at 1000 km and 1248 km is made below. Telesat has performed these calculations by reference to the number of its satellites (between 9 and 12) in each of its planned orbital planes, as the failure of satellite in one orbital plane would have no material risk to satellites operating in a different plane. Applying this approach and rounding up so that the failure of one satellite would equate to a failure of 5% of an orbital ring and the failure of two satellites would equate to the failure of 10% of an orbital ring, these calculations indicate a single failed spacecraft probability of collision of 0.0012 and 0.0002, respectively, over a 12-year period. For a two-spacecraft failure at the mission orbit, the overall collision probability would approximately double to 0.0024 and 0.0004 over 12 years, for the polar and inclines constellations respectively.

Active satellites will perform collision avoidance maneuvers.

A collision probability analysis of satellite injection orbit failures will be carried out once the mission design requirements have matured. Currently it is intended to launch into the vicinity of the final orbits, with the same inclinations and minor altitude differences to allow for nodal regression to the right ascending node where the orbit will be adjusted to final parameters. Any failures in such orbits are expected to be consistent with the collision probability estimates above. More specific analyses will be carried out as part of the final mission design.

f. Any additional information you may wish to provide concerning human casualty risk resulting from satellite disposal, such as outcomes based on higher fidelity analysis, or any risk or loss mitigation strategies under development.

One of the critical requirements for the satellite design is to ensure the materials, processes and assemblies are selected, designed, and integrated such that the probability of survival of spacecraft components through the re-entry into earth's atmosphere is extremely remote. The design will be assessed using NASA DAS (Debris Assessment Software) and modified as required to ensure that the human casualty risk resulting from the de-orbiting of the satellites is less than 1 in 10,000, in accordance with the applicable guidelines. Such requirements for design and analysis needs will be discussed and agreed as part of the selection of the spacecraft supplier.

g. Any information or analysis you may wish to provide with respect to treatment of this application under the Commission's environmental processing rules.

Telesat has imposed as one of the critical requirements for the satellite design that the materials, processes and assemblies are selected, designed and integrated such that the probability of survival of any component through re-entry into earth's atmosphere is extremely remote. Therefore, the risk that a component not only survives but strikes an environmentally protected target is infinitesimal.

5. For optical inter-satellite links, please provide the wavelength, power, duty cycle, beam diameter at emitter, and beam divergence. In addition, please provide the power margin at the receiver at maximum operating distance.

The specific design is yet to be finalized, however the following parameters are under consideration:

- Candidate Laser wavelength(s): 1060, 1065, 1070, 1075 and 1550 nm
- Laser radiated power (for respective candidate wavelengths noted above): 4.0, 4.0, 4.0, 4.0 and 8.0 Watts, respectively for the 5 wavelengths noted above
- Duty cycle: will vary from continuous link, to intermittent connection of various periods.

* Beam diameter at emitter: 10 cm
* Beam divergence (for respective candidate wavelengths noted above): 21.1 urad (1/e^2, full angle), 21.2 urad (1/e^2, full angle), 21.3 urad (1/e^2, full angle), 21.4 urad (1/e^2, full angle), and 30.8 urad (1/e^2, full angle)
* Power margin at the receiver at maximum operating distance (for respective candidate wavelengths noted above, at 6000 km): 6.20 dB, 6.13 dB, 6.06 dB, 5.98 dB, and 7.00 dB

6. Please indicate whether optical inter-satellite links will be coordinated with other systems proposed in FCC applications and with the U.S. Department of Defense's laser clearing house, and, if such coordination has commenced, please address the status of coordination.

> The optical inter-satellite links will have very narrow beams directed between Telesat's satellites. As such the potential to cause interference is expected to be very low to nil. Nevertheless, coordination will be conducted with operators of other systems using optical links if and to the extent required by the International Bureau. Telesat is discussing with the Bureau the scope of coordination requirements involving the U.S. Department of Defense's laser clearing house. If and to the extent that such coordination is required, it will also be undertaken. Neither coordination has commenced.

Should the Commission require additional information, I can be reached at eneasmith@telesat.com or 1-613-748-8700 x3279.

Very truly yours,

/s/
Elisabeth Neasmith
Director, Spectrum Management and Development

Attachments:
1: EPFD Results
2: Excerpt from CPC-2-6-02, Canadian Regulation on Debris Mitigation
3. Excerpt from Telesat's Canadian Application Regarding Orbital Debris Mitigation

ATTACHMENT 1
EPFD RESULTS
(Relates to Question 2)

Table numbers below correspond to the table numbers of Section A6 of the Technical Exhibit of Telesat's PDR.

epfd limits at the Earth's surface for downlink transmissions

Table 4 of the Petition: Minimum discrimination angle calculation for the Polar Orbits in the band 17.8-18.6 GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1B**			TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	1	2	5	3	10	1.8
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-175.4	-178.4	-185.4	-182	-185	-164
epfd limit for the constellation [dB(w/m^2/MHz)]	-161.4	-164.4	-171.4	-168.0	-171.0	-150.0
epfd limit for each satellite (since $N_a = 2$) [dB(w/m^2/40 kHz)]	-178.4	-181.4	-188.4	-185	-188	-167
epfd limit for each satellite (since $N_a = 2$) [dB(w/m^2/MHz)]	-164.4	-167.4	-174.4	-171.0	-174.0	-153.0
Peak EIRP density [dB(W/Hz)]	-50	-50	-50	-50	-50	-50
Peak EIRP density [dB(W/MHz)]	10	10	10	10	10	10
Minimum satellite to Earth distance [km]	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**
D/λ for f=17.8 GHz	59.3	118.7	296.7	178.0	593.3	107.2
D/λ for f=18.6 GHz	62	124	310	186	620	112.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=17.8 GHz	43.2	49.9	57.8	53.4	63.9	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=18.6 GHz	43.5	50.3	58.2	53.8	64.2	49.4
$G_r(\varphi)$ for f=17.8 GHz[dBi]	-0.3	3.5	4.4	3.4	10.8	17.0
$G_r(\varphi)$ for f=18.6 GHz[dBi]	0.1	3.8	4.8	3.8	11.2	17.4
φ [deg] for f=17.8 GHz	14.8	10.4	9.6	10.5	5.3	3.0
φ [deg] for f=18.6 GHz	14.3	10.1	9.3	10.2	5.1	2.9
Minimum downlink discrimination angle (φ) that should be met [deg]	14.8					

epfd limits at the Earth's surface for downlink transmissions

Table 5 of the Petition: Minimum discrimination angle calculation for the Inclined Orbits in the band 17.8-18.6GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1B**			TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	1	2	5	3	10	1.8
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-175.4	-178.4	-185.4	-182	-185	-164
epfd limit for the constellation [dB(w/m^2/MHz)]	-161.4	-164.4	-171.4	-168.0	-171.0	-150.0
epfd limit for each satellite (since N_a = 2) [dB(w/m^2/40 kHz)]	-178.4	-181.4	-188.4	-185	-188	-167
epfd limit for each satellite (since N_a = 2) [dB(w/m^2/MHz)]	-164.4	-167.4	-174.4	-171.0	-174.0	-153.0
Peak EIRP density [dB(W/Hz)]	-50	-50	-50	-50	-50	-50
Peak EIRP density [dB(W/MHz)]	10	10	10	10	10	10
Minimum satellite to Earth distance [km]	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**
D/λ for f=17.8 GHz	59.3	118.7	296.7	178.0	593.3	107.2
D/λ for f=18.6 GHz	62	124	310	186	620	112.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=17.8 GHz	43.2	49.9	57.8	53.4	63.9	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=18.6 GHz	43.5	50.3	58.2	53.8	64.2	49.4
$G_r(\varphi)$ for f=17.8 GHz[dBi]	1.7	5.4	6.3	5.3	12.8	18.9
$G_r(\varphi)$ for f=18.6 GHz[dBi]	2.0	5.8	6.7	5.7	13.1	19.3
φ [deg] for f=17.8 GHz	12.4	8.8	8.1	8.9	4.5	2.5
φ [deg] for f=18.6 GHz	12.0	8.5	7.8	8.6	4.3	2.4
Minimum downlink discrimination angle (φ) that should be met [deg]	12.4					

epfd limits at the Earth's surface for downlink transmissions

Table 6 of the Petition: Minimum discrimination angle calculation for the Polar Orbits in the band 19.7-20.2 GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1C**				TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	0.7	0.9	2.5	5	3	10	1.6
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-187.4	-190.4	-196.4	-200.4	-182	-185	-157
epfd limit for the constellation [dB(w/m^2/MHz)]	-173.4	-176.4	-182.4	-186.4	-168.0	-171.0	-143.0
epfd limit for each satellite (since $N_a = 2$) [dB(w/m^2/40 kHz)]	-190.4	-193.4	-199.4	-203.4	-185	-188	-160
epfd limit for each satellite (since N_a = 2) [dB(w/m^2/MHz)]	-176.4	-179.4	-185.4	-189.4	-171.0	-174.0	-146.0
Peak EIRP density [dB(W/Hz)]	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4
Peak EIRP density [dB(W/MHz)]	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Minimum satellite to Earth distance [km]	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**
D/λ for f=19.7 GHz	46.0	59.1	164.2	328.3	197.0	656.7	107.2
D/λ for f=20.2 GHz	47.1	60.6	168.3	336.7	202.0	673.3	109.9
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=19.7 GHz	40.9	43.1	52.7	58.7	54.3	64.7	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=20.2 GHz	41.2	43.3	52.9	58.9	54.5	65.0	49.2
$G_r(φ)$ for f=19.7 GHz[dBi]	-8.1	-8.9	-5.3	-3.3	10.7	18.1	30.4
$G_r(φ)$ for f=20.2 GHz[dBi]	-7.9	-8.7	-5.1	-3.1	10.9	18.3	30.6
φ [deg] for f=19.7 GHz	30.4	32.8	20.5	17.5	5.4	2.7	0.9
φ [deg] for f=20.2 GHz	29.8	32.1	20.1	17.2	5.3	2.7	0.9
Minimum downlink discrimination angle (φ) that should be met [deg]	32.8						

epfd limits at the Earth's surface for downlink transmissions

Table 7 of the Petition: Minimum discrimination angle calculation for the Inclined Orbits in the band 19.7-20.2GHz

Applicable Table from Article **22** of the ITU Radio Regulations	TABLE **22-1C**				TABLE **22-4A1**		TABLE **22-4B**
Reference GSO earth station antenna diameter [m]	0.7	0.9	2.5	5	3	10	1.6
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-187.4	-190.4	-196.4	-200.4	-182	-185	-157
epfd limit for the constellation [dB(w/m^2/MHz)]	-173.4	-176.4	-182.4	-186.4	-168.0	-171.0	-143.0
epfd limit for each satellite (since $N_a = 2$) [dB(w/m^2/40 kHz)]	-190.4	-193.4	-199.4	-203.4	-185	-188	-160
epfd limit for each satellite (since N_a = 2) [dB(w/m^2/MHz)]	-176.4	-179.4	-185.4	-189.4	-171.0	-174.0	-146.0
Peak EIRP density [dB(W/Hz)]	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4	-56.4
Peak EIRP density [dB(W/MHz)]	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Minimum satellite to Earth distance [km]	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**	**1248**
D/λ for f=19.7 GHz	46.0	59.1	164.2	328.3	197.0	656.7	107.2
D/λ for f=20.2 GHz	47.1	60.6	168.3	336.7	202.0	673.3	109.9
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=19.7 GHz	40.9	43.1	52.7	58.7	54.3	64.7	49.0
$G_{r,max}$ [dBi] using ITU-R Rec. S.1428 for f=20.2 GHz	41.2	43.3	52.9	58.9	54.5	65.0	49.2
$G_r(\varphi)$ for f=19.7 GHz[dBi]	-6.2	-7.0	-3.4	-1.4	12.6	20.0	32.3
$G_r(\varphi)$ for f=20.2 GHz[dBi]	-5.9	-6.8	-3.2	-1.2	12.8	20.3	32.5
φ [deg] for f=19.7 GHz	25.5	27.5	17.6	15.1	4.5	2.3	0.7
φ [deg] for f=20.2 GHz	25.0	26.9	17.4	14.9	4.4	2.2	0.7
Minimum downlink discrimination angle (φ) that should be met [deg]	27.5						

epfd limit at the geostationary orbit for uplink transmissions

Table 8 of the Petition: Calculation of the uplink discrimination angle needed to meet the uplink epfd limit

NGSO earth station antenna diameter [m]	1	3.5
NGSO earth station antenna pattern	ITU-R Rec. S.1428	ITU-R Rec. S.1428
epfd limit for the constellation [dB(w/m^2/40 kHz)]	-162	-162
Maximum number of co-frequency operating NGSO earth stations visible by a GSO satellite	78	78
epfd limit for each satellite [dB(w/m^2/40 kHz)]	-180.9	-180.9
Minimum distance between the NGSO transmitting earth station and the GSO satellite [km]	35786	35786
Peak uplink power spectral density fed into the NGSO transmitting earth station [dB(W/Hz)]	-67	-67
Peak uplink power spectral density fed into the NGSO transmitting earth station [dB(W/40 kHz)]	-21.0	-21.0
D/λ for f=27.5 GHz	91.7	320.8
D/λ for f=30 GHz	100	350
$G_t(\theta)$ for f=27.5 GHz[dBi]	2.12	2.12
$G_t(\theta)$ for f=30 GHz[dBi]	2.12	2.12
θ [deg] for f=27.5 GHz	11.9	11.5
θ [deg] for f=30 GHz	11.9	11.5
Minimum uplink discrimination angle (θ) that should be met [deg]	11.9	

<u>**epfd limit at the geostationary orbit for downlink transmissions**</u>

Table 9 of the Petition: Demonstration of compliance with the ITU epfd limit at the geostationary orbit for downlink transmissions

	Polar Orbits	Inclined Orbits
Satellite peak downlink EIRP density [dB(W/Hz)]	-50	-50
Satellite transmit antenna gain discrimination toward the GSO arc compared to the beam peak [dB]	15	25
Maximum satellite downlink EIRP density toward the GSO arc [dB(W/Hz)]	-65	-75
Geostationary orbit to Earth distance [km]	35786	35786
NGSO to Earth distance [km]	1000	1248
Minimum distance between NGSO satellite and the geostationary orbit [km]	34786	34538
Peak power flux density generated by each satellite at the geostationary orbit under worst-case assumption [dB(W/m^2/40 kHz)]	-180.8	-190.7
Maximum number of satellites in Polar Orbits or Inclined Orbits visible by a GSO satellite at any given time	50	30
Peak power flux density generated by all satellites of the Polar Orbits or Inclined Orbits at the geostationary orbit under the worst-case assumption [dB(W/m^2/40 kHz)]	-163.81	-175.97
Peak power flux density generated by all 117 satellites at the geostationary orbit under worst-case assumption [dB(W/m^2/40 kHz)]	-163.55	

ATTACHMENT 2
EXCERPT OF CPC-2-6-02
(Relates to Question 4.a.)

3.3 Other Requirements

3.3.3 Space Debris Mitigation Plan

For geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in compliance with Recommendation ITU–R S.1003-2, *Environmental Protection of the Geostationary Satellite Orbit*.

For non-geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in accordance with best industry practices.

While Industry Canada's focus is on de-orbiting satellites in a manner that minimizes risk to operating satellites, applicants should also be aware of and work toward compliance with the broader United Nations (UN) space debris mitigation guidelines.[6] These guidelines cover many elements, including limiting debris released during normal operations; minimizing the potential for break-ups during operational phases; limiting the probability of accidental collision in orbit; avoiding intentional destruction and other harmful activities; minimizing potential for post-mission break-ups resulting from stored energy; limiting the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission; and limiting the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission.

[6] The United Nations' space debris mitigation guidelines can be found online at www.unoosa.org/pdf/bst/COPUOS_SPACE_DEBRIS_MITIGATION_GUIDELINES.pdf.

ATTACHMENT 3
EXCERPT FROM TELESAT'S CANADIAN APPLICATION
REGARDING ORBITAL DEBRIS MITIGATION
(Relates to Question 4.a.)

Space Debris Mitigation Plan

ITU Recommendation ITU-R S.1003-2 provides guidance about disposal orbits for satellites in the geostationary satellite orbit. For non-geostationary low earth orbit, the debris mitigation guidelines are issued by Inter-Agency Space Debris Coordination Committee (IADC), which consists of participants from all major space-faring nations. The main thrust is similar to ITU-R S.1003-2, i.e. limiting the debris generation from launch of any space system to the end of its mission. The LEOVantage spacecraft design specifications will include specific requirements to address the IADC guidelines. Telesat will modify and adapt its established operational processes to ensure that the satellite constellation is managed over its life to meet the objectives of the IADC guidelines. Further details are provided below.

Post-Mission Disposal Plans

Post-Mission Orbit. In accordance with the IADC guidelines, the LEOVantage s will be removed from their operational orbits to de-orbit at the end of their operational lives. The orbit at the end of the mission will be adjusted to ensure that the spacecraft orbit degrades and the satellite burns up on entry into the atmosphere.

Propellant for De-orbit. The propellant needed to achieve the minimum de-orbit altitude is based on the change in velocity (delta-V) required. In the LEOVantage spacecraft specification, Telesat will require the spacecraft manufacturer to include an allocation in the propellant budget to ensure that sufficient propellant is reserved to provide the required delta-V for de-orbits. Telesat will carefully track propellant usage over the life of the satellite to ensure that the satellite de-orbit is planned at a time that ensures that this reserve of fuel is available, along with additional fuel margin to allow for uncertainties in propellant accounting, orbital determination and maneuver execution. Any remaining propellant will be consumed by further reducing the orbit until combustion is no longer possible. The remaining propellant and pressurant will be vented, placing the propulsion system on the satellite in "safe" mode.

Propellant tracking is accomplished using a bookkeeping method in accordance with industry standard. Using this method, the ground control station tracks the number of jet seconds utilized for station keeping, momentum control and other attitude control events. The amount of fuel used is determined from the number of jet seconds. This process has been calibrated using data collected from thruster tests conducted on the ground and has been found to be accurate to within a few months of life on the satellite.

Design and Operational Strategies that are used to Mitigate Orbital Debris

Debris Release Assessment. Telesat has assessed the normal operations and post-mission disposal procedures and has determined that no debris will be released by the LEOVantage constellation. To protect from small body collisions, the spacecraft hardware of LEOVantage satellites will be designed so that individual faults will not cause the loss of the satellite.

All critical components (e.g. computers and control devices) will be built within the structure and shielded from external influences. Items that cannot be built within the spacecraft nor shielded (e.g. antennas) will be designed with robust margins to be able to mitigate impact.

The spacecraft will be designed with the capability to be controlled through multiple antennas. The likelihood of all such antennas being damaged during a small body collision is minimal. The wide angle antennas that will be implemented on the spacecraft are basically open waveguides that point towards the earth. (There is one set on each side of the spacecraft and either set could be used to successfully de-orbit the satellite). These wide angle antennas would continue to operate even if struck and bent.

Assessment Regarding Collision with Larger Debris and Other Space Stations. For all its operational satellites, Telesat continuously monitors and minimizes the probability of the satellite becoming a source of debris through collisions with large debris or other operational satellites.

Telesat has arrangements to receive close approach warnings from the Joint Space Operations Center operated by the U.S. Air Force. Telesat routinely coordinates with other operators to maintain safe separations.