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Innovation, Science and Economic Development Canada
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Re: *Canada Gazette*, Part I, December 2024, Volume 158, Number 52, Consultation on Changes to Licensing Requirements and Conditions of Licence on Space Debris Mitigation. SMSE-013-24.

To Whom It May Concern:

This comment on Innovation, Science and Economic Development Canada's (ISED) Consultation on Changes to Licensing Requirements and Conditions of Licence on Space Debris Mitigation ("the Consultation") is provided by Fellows and Junior Fellows of the Outer Space Institute, a Canadian-led global network of space experts united in their commitment to highly innovative, transdisciplinary research that addresses grand challenges facing the continued and projected exploration and use of space.

Q.1. ISED is seeking comments on its proposal to require NGSO operators to provide a detailed assessment of the environment in which they plan to operate as part of the licence application, as described above.

Q.2. ISED is seeking comments on its proposal to require NGSO licensees to submit an updated assessment of the environment when applying for a licence amendment to change the authorised parameters. The assessment must include the same information described above.

In our view, these are reasonable proposals. We further encourage ISED to consider including light pollution estimates in the environment assessment, including any steps taken to meet the International Astronomical Union's recommendation of satellites being no brighter than V=7 mag or V = 7 + $2.5\log_{10}$(satellite altitude/550 km), whichever is fainter.[1]

We note that Canada is a member of the Group of Friends at the United Nations Committee on the Peaceful Uses of Outer Space, and is committed to preserving Dark and Quiet Skies.[2]

We further recommend that ISED consider taking steps toward requiring a full life cycle analysis of each satellite in a constellation and, of critical importance, the aggregate effects of the constellation. The analysis should consider emissions from launch; collision risks while on orbit, including raising and lowering satellites to and from their operational altitudes; and the consequences of end-of-life disposal plans, including atmospheric metal deposition from ablation, as well as casualty risks to people on the ground and in aircraft in flight.

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[1] Centre for the Protection of the Dark and Quiet Sky, Call to Protect the Dark and Quiet Sky from Interference by Satellite Constellations, IAU CPS, 14 March 2024, at: https://cps.iau.org/documents/49/techdoc102.pdf

[2] See Canada's recent statement at the 2025 Science and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space, at:
https://www.unoosa.org/documents/pdf/copuos/stsc/2025/Statements/15_Canada.pdf

Q.3. ISED is seeking comments on its proposal to impose a condition of licence requiring NGSO licensees to register with, use and maintain an SSA service and receive conjunction alerts.

We strongly agree with this proposal. However, in our view, it is insufficient alone. Operators should further be required to have a credible action plan for how the SSA service and corresponding alerts will be used, including thresholds for executing collision avoidance manoeuvres and procedures for addressing their potential downstream effects to the extent practicable. Moreover, the chosen SSA service should meet minimum performance standards to ensure operators rely on timely, accurate, and sufficiently precise data.

Q.4. ISED is seeking comments on its proposal to require NGSO operators, at the time of licence application, to provide an assessment of the probability of collision with both large and small objects as defined above and to state that these probabilities are less than 0.001 and 0.01, respectively. Applicants would also be required to provide information on how these assessments were derived.

This is a very important proposal. We agree with the intent and with the need to assess collision probabilities with both large and small objects, as defined. However, with satellite constellations, especially those with hundreds of satellites or more, the proposed probability limits are insufficient.

Specifically, if each spacecraft is treated independently, and there are 1000 spacecraft in a constellation each with an identical 0.001 collision probability, then the probability that there is at least one collision is $(1\text{-}0.999^{1000}) \approx 63\%$. Collisions with large objects will cause spacecraft to break up catastrophically, which will lead to severe changes in the debris environment. This collective probability cannot be ignored.

Altogether, there needs to be two tiers of collision assessment, given the current and near-future operating environment: (1) Per satellite collision probability thresholds for large and small debris, as already described, and (2) Constellation collision probability thresholds for large and small debris.

The first criterion can be tied to the lifetime of a single satellite, as already proposed, while the second may be best determined by using the anticipated lifetime of the constellation, although other timescale choices are possible. *Regardless of the approach, constellation-wide probabilities must be part of a meaningful debris mitigation regulatory environment.*

Q.5. ISED is seeking comments on its proposal to require all NGSO applicants, at the time of application as part of the space debris mitigation plan, to provide information on the number of expected collision avoidance manoeuvres, as well as how applicants will assess conjunctions and execute the required avoidance measures over the course of the satellite(s)' operational lifetime and de-orbit phases.

We support this proposal, which naturally connects with the proposals concerning Q.1, Q.2, and Q.4. Further to our comment on Q.4, we emphasize that constellation-wide manoeuvres should also be

reported, particularly if different shells and orbits are used, and should include raising and de-orbiting. Furthermore, expected manoeuvres should be compared with the actual manoeuvres during regular, required reporting during operation.

Q.6. ISED is seeking comments on its proposal to require Canadian NGSO licensees operating satellites in LEO to dispose of the associated satellites through re-entry into the Earth's atmosphere as soon as practicable but no later than five years following their end of operational life.

Q.7. ISED is seeking comments on its proposal to require NGSO applicants in LEO to provide a detailed technical assessment that the probability of success for the chosen post-mission disposal method is 0.9 (90%) or greater for any individual space station and 0.99 (99%) or better for each satellite that is part of a constellation. ISED is also seeking comments on the definition of a constellation as two or more NGSO satellites in the same mission.

We agree with both Q.6 and Q.7, but see our response to Q.8. We also agree with the definition of a constellation as two or more satellites in the same mission.

Q.8. ISED is seeking comments on alternative criteria that could be considered for the effective disposal of satellites in LEO (e.g. more emphasis on probability of success over timelines).

We strongly emphasize the need to have a strict criterion for post-mission disposal (PMD) success for satellites within constellations. We note that a constellation of 100 satellites each with a PMD success probability of 99% would mean there is a 63% chance of a failure over the system. With 1000 satellites in a constellation, a failure is essentially guaranteed. Thus, ISED should consider whether further tiering is needed as a balance between ensuring small constellations are not held to excessive standards and having very little failure tolerance for large constellations that consume extensive orbital resources. For illustrative purposes only, the criterion could be the probability necessary for a 50% or better chance of complete deorbit success across the constellation per cycle (complete replacement of all elements in the constellation), but not less than 99% per satellite. For 10, 100, 1000, and 10000 satellites, that would be a PMD success per satellite of 99%, 99.3%, 99.93%, and 99.993%. Again, this is just to highlight possibilities while emphasizing that a 99% PMD success rate per satellite will be insufficient for large constellations.

Further to sustainability efforts, the post-mission disposal plan should include consideration of the impacts of the satellites on dark and quiet skies, particularly if the satellites will be much brighter than the IAU recommendation during de-orbiting. For example, certain de-orbiting mechanisms, such as drag sails, could create excessive brightness if mitigations are not considered during the design phase, while electrodynamic tethers could create unintended electromagnetic radiation that interferes with Canadian radio observatories and experiments.

Finally, licensing requirements should be included that address the impacts of de-orbiting satellites, especially large constellations, on the atmosphere. This could begin with reporting requirements. Information about the yearly tonnage of elements such as, for example, aluminum, lithium, magnesium, hafnium, and titanium expected to be deposited in the atmosphere due to ablation would be incredibly helpful for broader space sustainability efforts.

Q.9. ISED is seeking comments on post-mission disposal approaches and required probabilities of success for satellites in MEO and HEO, with a focus on long-term space sustainability. Additionally, ISED is seeking input on the challenges operators may face in complying with such regulations.

Note, in providing comments, respondents are requested to address the impact of MEO and HEO space debris regulations on other orbits (e.g. LEO), the differences between the space debris environments in LEO and MEO/HEO, post-mission disposal techniques, disposal timeframes and reliability and other related factors.

We acknowledge that this is a very difficult problem, especially given the rapid growth of satellite systems in LEO. However, it is clear that leaving objects in orbit, either in a minimum eccentric growth disposal orbit (essentially a MEO "graveyard orbit") or a very long decay orbit, is incompatible with the long-term sustainability of outer space. Moreover, while dynamical resonances can be used to remove satellites at low energy costs, many are uncontrolled with long timescales. As such, there could be coordination problems, especially when passing through a crowded LEO.

In the end, with few exceptions, only a directed de-orbit will tend to be sustainable and can be coordinated with other operators, including in LEO. Yet, we acknowledge that this has its own challenges.

For HEO, there are certain orbital resonances that can lead to relatively fast and predictable re-entries. Using such orbital resonances should be allowed provided the disposal plan provides adequate justification and demonstrates the feasibility of successfully using the selected resonance to achieve a fast and predictable re-entry with minimal interruption to LEO operations.

Q.10. ISED seeks comments on its proposed requirement that applicants provide detailed information on their operations, possible constraints posed to the ISS and other crewed missions as a result of such operations, and plans to minimize such constraints, as part of the licence application.

This is an easy "yes". But see comment for Q.12 below.

Q.11. ISED seeks comments on its proposal to require an active propulsion system, with redundancy, for station-keeping and collision avoidance (regardless of whether propulsion is necessary to de-orbit within 5 years) for all NGSO satellites operating at altitudes above 400 km. Comments should include views on the advantages or drawbacks of mandating propulsion systems as well as details on (if any) specific methods of manoeuvrability that should be mandated (e.g. chemical or electric propulsion, sails, etc.).

We agree that propulsion systems for satellites above orbital habitats or crewed missions are critical for maintaining a safe operational environment. However, this approach would be most effective if coupled with an internationally agreed upon space traffic management (STM) protocol, as it is one thing to be able to move, and another to decide who moves and when. Developing such a protocol will take time, so current rule-making may be best served by including options for reevaluation of any propulsion system as

STM evolves. In the short term, Canadian requirements for active propulsion systems should come with clear requirements to conduct collision avoidance manoeuvres under specific circumstances, such as to avoid orbital habitats, or when collision probabilities with active satellites and mapped debris reach a certain threshold, unless otherwise directed.

Until the reliability of sails for making operationally required collision avoidance manoeuvres is demonstrated, we suggest requiring chemical or electrical propulsion only. A mechanism should exist for evaluating new propulsion systems as they become available.

As mentioned above, sails could further create problems for dark and quiet skies should their brightness not be taken into account. Furthermore, unintended electromagnetic radiation from propulsion systems should be minimized.

Q.12. ISED also seeks comments on whether 400 km and above, is the appropriate altitude at which to require systems to have propulsion, or whether it should be lower – e.g. 375 km – to provide a sufficient separation distance from the ISS. Respondents are requested to provide detailed responses.

Many non-manoeuvrable satellites are launched from the ISS, so if this practice continues, we do not recommend at this time requiring an altitude lower than the ISS. The ISS also changes its altitude, making a firm altitude, such as 400 km, impractical unless it is paired with language that would accept launches from human habitats in outer space.

Moreover, the ISS may only function until 2030 (approximately), and China's Tiangong space station may at times operate below 400 km. Plans also exist for private space stations, with the operational altitudes not yet determined.

We therefore recommend that: (1) No firm altitude limit be adopted, with the regulations instead designed to ensure, to the extent practicable, that non-manoeuvrable satellite operations are restricted to be below orbital habitats and (2) limits on non-manoeuvrable satellites should be reevaluated as the orbital environment evolves.

We emphasize that non-manoeuvrable satellites are a conjunction risk to other on-orbit operations, including crewed spaceflight missions and active satellites, as well as future debris cleanup efforts. As the density of objects in LEO increases, non-manoeuvrable satellites at any altitude will become incompatible with safe orbital operations. We further emphasize that a catastrophic collision at even a low altitude will place debris on elliptical orbits that will cross much if not all of LEO.

Q.13. ISED is seeking comments on its proposal to require that applicants for FSAs for NGSO systems attest that they have an space debris mitigation plan in place for the constellation, and that they indicate whether that plan was required by the applicant's own licensing/filing administration.

Q.14. ISED seeks comments on requiring the submission of the relevant space debris mitigation plan for information, at its discretion.

We think ISED should go a bit further and require that FSAs for NGSOs demonstrate that their systems meet ISED requirements or have reasonably consistent requirements. For instances where requirements are not met, ISED should have a process for determining whether a minimum number of requirements are met. Preventing forum shopping for loose regulations is necessary for space sustainability and fair market access.

Q.15. ISED is seeking comments on its proposal to make the updated spectrum licence application requirements for new licence applications for space stations effective as of the date of the publication of the decision resulting from this consultation.

Q.16. ISED is seeking comments on its proposal to apply the updated conditions of licence to all existing and new NGSO space station spectrum licences, effective on the date the decision is published. For existing licences, the updated conditions of licence would only apply to satellites launched two years after the publication of the decision, noting that existing licences include licences issued up to 126 days after the decision is published.

Given the rapid development of LEO, we encourage ISED to make the new requirements effective promptly. This is better for sustainability and for giving companies certainty. The noted grace period for existing licences is a reasonable compromise.

Additional comments not covered by Q.1. - Q.16:

We thank ISED for holding this consultation, and extend an invitation for further discussion with the members of the Outer Space Institute.

We further emphasize that large environmental changes are occurring in the orbital environment and the atmosphere due to the rapid increase in satellite launches and reentries. NGSO operators should address the environmental impacts of their satellites and constellations as part of the licensing process. Space is often viewed as being outside the Earth environment and thus not requiring environmental impact assessments, but the disposal plan for all satellites currently in LEO is full or partial ablation in Earth's atmosphere. Recent research has shown that metals from satellite and rocket body reentries are already measurable in the upper atmosphere[3], and that the possible effects[4] of additional metals from ablation include increased atmospheric opacity, temperature changes, and ozone depletion. Moreover, as was

[3] "Metals from spacecraft reentry in stratospheric aerosol particles", Murphy et al. 2023, *PNAS* https://www.pnas.org/doi/10.1073/pnas.2313374120

[4] "Atmospheric impacts of the space industry require oversight" Shutler et al. 2022, *Nature Geoscience* https://www.nature.com/articles/s41561-022-01001-5

recently demonstrated by the uncontrolled reentry in 2024[5] that dropped potentially lethal debris on Canadian farmland, anything that does not ablate during an uncontrolled reentry becomes a casualty risk to people on the ground and to the crew and passengers of aircraft in flight.[6]

Finally, while not specifically mentioned in the consultation, we recognize that Canada is an Artemis partner and will be active in the exploration and use of the Moon. As such, we encourage ISED to consider debris mitigation plans for lunar orbits and cislunar space.

Sincerely,

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[5] "SpaceX space junk crashed onto Saskatchewan farmland, highlighting a potential impending disaster," Boley & Lawler 2024, *The Conversation Canada* https://theconversation.com/spacex-space-junk-crashed-onto-saskatchewan-farmland-highlighting-a-potential-impending-disaster-233322

[6] "Airspace closures due to reentering space objects," Wright et al. 2025, *Nature Scientific Reports* https://www.nature.com/articles/s41598-024-84001-2