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Open Comment on the Consultation on the Policy, Licensing and Technical Framework for Supplemental Mobile Coverage by Satellite, *Canada Gazette*, Part I, June 2024, SMSE-006-24

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To Whom It May Concern:

This comment on Innovation, Science and Economic Development Canada's (ISED) Consultation on the Policy, Licensing and Technical Framework for Supplemental Mobile Coverage by Satellite (SMCS) ("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 use and exploration of space. This comment is further endorsed by the President of the Canadian Astronomical Society - Société Canadienne d'Astronomie (CASCA), the Executive Director of the Association of Canadian Universities for Research in Astronomy (ACURA), and astronomers from across Canada.

We, the undersigned,

- Recognize that enabling connectivity for all Canadians, including in remote areas, is a necessary step in furthering the safety, health, and prosperity of people across all areas of Canada
- Recall the ISED's policy objectives, including "to expand mobile services in unserved and underserved areas, including rural, remote, and Indigenous communities"
- Further recall the Spectrum Policy Framework of Canada's policy objective "to maximise the economic and social benefits that Canadians derive from the use of the radio frequency spectrum resource"
- Recognize that satellites bring many benefits to society, including aiding the closure of communication gaps
- Are concerned that new policies and rules will inadequately take into account the negative impacts of the proliferation of satellite systems, both globally and in Canada
- Are mindful that striving to maximise economic and social benefits without taking into account negative impacts can cause environmental harm and further fail to maximise economic and social benefits for the long-term
- Acknowledge that section 7.4 of the Consultation recognizes a need for SMCS to coexist with radio astronomy
- Emphasise that the proliferation of satellite systems is not just a concern for radio astronomy, but also one for optical astronomers and stargazers in Canada and abroad
- Note that ISED recognizes the need for regional and international harmonisation in its approach to licencing SMCS systems
- Highlight that Canada has made substantial investments in telescopes and observatories throughout the world, including ground-breaking observatories at the Dominion Radio Astrophysical Observatory in BC, such as the Canadian Hydrogen Intensity Mapping Experiment (CHIME), Canadian Galactic Emission Mapper (CGEM), and the Canadian Hydrogen Observatory and Radio-transient Detector (CHORD), as well as international facilities

such as the Atacama Large Millimetre/submillimetre Array (ALMA), and the Square Kilometre Array Observatory (SKAO)

- Further highlight Canadian investments in the Canada-France-Hawaii Telescope, the Gemini Observatories, and a wide range of domestic observatories for research, education, and appreciation of the natural night sky

In this comment, we focus only on radio and optical astronomy impacts. However, we emphasise that satellite proliferation comes with unintended consequences, including space debris, atmospheric alteration from launches and ablation of satellites during their reentry, and casualty risks to people on the ground, in airplanes, and at sea from uncontrolled reentering space objects.

We urge ISED to require SMCS operators, during the licencing process, (1) to demonstrate that they will minimise interference with radio astronomy facilities, (2) to include light pollution mitigation plans, and (3) establish coordination agreements with Canadian observatories and Canadian international partner observatories.

Astronomy is a fundamental way that humanity explores and uses outer space. Observations allow scientists to study gas in the early universe, explore the epoch of the first stars, peer into the central parts of galaxies, discover new worlds, study the Solar System, and search for Earth-impacting asteroids and comets. The cosmos holds objects of tremendous energy scales, and is a natural laboratory for testing physical processes that cannot be tested on Earth, as well as searching for new physics. Astronomy has been central to discoveries and innovations that have had broad implications for society, science, and technology.[1] Radio observations of quasars through Very Long Baseline Interferometry are even central to maintaining Earth's reference frame, which is critical for fundamental infrastructure, including GPS.[2]

As the Consultation noted, some regions of the spectrum are protected for radio astronomy. With this in mind, astronomers do not get to pick where the cosmos emits radiation. As such, astronomers have had to rely on building observatories in areas that have minimal terrestrial interference. However, the facilities are so sensitive that even radio-quiet sites still have substantial inference. Astronomers have already invested heavily in radio interference mitigation algorithms, and continue to do so – but there remains substantial data loss.

The Dominion Radio Astrophysical Observatory, operated by the National Research Council of Canada, is located in such a radio-quiet site with federal, provincial, and local legislative protections,[3] but still experiences substantial terrestrial interference. The Algonquin Radio Observatory's location was also chosen as an attempt to avoid terrestrial radio interference.

Internationally, the Canadian federal government is investing $269 million over eight years for Canada to be a member of the Square Kilometre Array Observatory (SKAO). While the observatory is

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[1] See e.g. the National Radio Astronomy Observatory.
https://public.nrao.edu/radio-astronomy/the-science-of- radio-astronomy/

[2] Naranjo, Laura, "Beacons in the Sky Help Measure Earth's Orientation in Space", NASA Earth Data, 26 November 2023.
https://www.earthdata.nasa.gov/learn/sensing-our-planet/beacons-in-the-sky-help-monitor

[3] See NRC Canadian Hydrogen Intensity Mapping Experiment (CHIME).
https://www.canada.ca/en/national-research-council/news/2017/09/canadian_hydrogenintensitymappingexperimentchime.html

based in South Africa, Canadian industry is guaranteed procurement opportunities, with contracts already awarded.[4] As Honourable François-Philippe Champagne explains:

Canada has been a long-standing leader in astronomy and the exploration of the universe, and Canada's membership in the Square Kilometre Array Observatory will give Canadian researchers access to the world's most powerful radio-telescope. Beyond astronomical discovery, SKAO-related technologies have the potential to enhance the everyday life of Canadians, through better networks, and in other areas like more accurate and advanced driver assistance systems in cars.[5]

Radio astronomy faces a potential existential threat from SMCS; SpaceX's Starlink constellation already produces unintended radio emissions that are degrading the SKAO spectrum before it even begins operations.[6] The ISED's acknowledgement of the need for coexistence with the radio astronomy service is necessary, but active, ongoing steps will be needed to ensure that this aim is reached.

In response to **Q4**, as noted above, while radio astronomy has protections for specific bands, many fundamental discoveries and advancements have been enabled by access to the broad radio spectrum, typically through the establishment of radio-quiet sites often at great expense due to their remoteness.

Such existing practices to protect radio astronomy, which are already insufficient, will no longer be possible with persistent interference from overhead satellite transmissions and orbital electronics noise. Astronomical research in the radio will only become possible in the sliver of spectrum allocated for this purpose, greatly limiting its discovery and use potential, as well as compromising Canada's leadership in astronomical research and space exploration.

The following are some of the ways in which SMCS could interfere with radio astronomy:

- Sidelobe propagation can cause harmful interference, even when efforts are made to limit satellite transmissions when passing over radio-quiet sites and observatories.
- SMCS signals are stronger than other satellite signals and could lead to saturation of telescope electronics, causing the whole receiver passband to be lost.
- Interference can be caused by electronic noise from satellite components at frequencies well below the satellite downlink frequencies.[7]
- Unintended electromagnetic radiation can have dire consequences for radio astronomy when considering the aggregate effects of all satellites planned for LEO,[8] making international coordination along with national action necessary.

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[4] MDA Space Press Release, "MDA Space Awarded contract for Square Kilometre Array Project", 3 June 2024. https://mda.space/article/mda-space-awarded-contract-for-square-kilometre-array-project

[5] NRC, Canada becomes member of SKAO radio astronomy project. https://www.canada.ca/en/national-research-council/news/2024/05/canada-becomes-member-of-skao-radio-astronomy-project.html

[6] Grigg et al. "Detection of intended and unintended emissions from Starlink satellites in the SKA-Low frequency range, at the SKA-Low site, with an SKA-Low station analogue", Astronomy and Astrophysics, 12 October 2023. https://www.aanda.org/articles/aa/full_html/2023/10/aa47654-23/aa47654-23.html

[7] Di Vruno et al. "Unintended electromagnetic radiation from Starlink satellites detected with LOFAR between 110 and 188 MHz." Astronomy and Astrophysics, 10 August 2023. https://doi.org/10.1051/0004-6361/202346374

[8] Falle et al. "One million (paper) satellites." Science, 12 October 2023. https://doi.org/10.1126/science.adi4639

In addition to the above impacts to radio astronomy, satellite systems used for SMCS could also significantly impact optical astronomy due to their large antenna sizes. For example, AST SpaceMobile's BlueWalker 3 satellite has a 64.3 square metre phased-array antenna, making it as bright as the brightest stars in the sky, reaching an apparent magnitude of 0.4, hundreds of times brighter than the current International Astronomical Union recommendation of magnitude 7.[9,10] AST SpaceMobile is planning for an entire constellation of 248 satellites with much larger antennas — approximately 330 square metres each. As SMCS capabilities proliferate, ground-based observatories will be unable to avoid these bright satellites, which will lead to data loss and time wasted on telescopes funded by Canada, including the Canada-France-Hawaii Telescope (Hawaii) and Gemini Observatory (Hawaii and Chile). Additionally, these very bright SMCS satellites impact recreational stargazing and aurora watching, which many remote communities use as a source of revenue in the form of tourism.

In response to **Q26** on the protection of radio astronomy services: the existing protection criteria as set out in recommendation ITU-R RA 769-2 and ITU-R RA 1513-2 are a good starting point for SMCS licensing. Nonetheless, the following outlines several weak points in these recommendations in the face of SMCS space stations:

- ITU-R RA 769-2. The first recommendation encourages astronomers to choose sites as free as possible from interference. This becomes irrelevant with SMCS signals coming from directly overhead and eliminating the protection that remote sites and geological features provide radio observatories.
- ITU-R RA 769-2. The fourth recommendation states that proposed frequencies take into account that it is difficult for radio astronomy services to share frequencies with other services. ISED's careful consideration of this issue is admirable. Paragraph 119 (7.4) notes that the proposed 600MHz band for SMCS is adjacent to the radio astronomy 608-614MHz band, and harmonics of the proposed 700MHz and 800MHz may overlap with allocated radio astronomy frequencies. It does not, however, acknowledge what will be done to minimise these effects.
- ITU-R RA 769-2 2.1 discusses that it is impractical to suppress unwanted emissions from GSO satellites when telescope beams are pointed directly towards a satellite, and the ways in which a telescope should adjust pointing to still obtain sky coverage. Increasing the number of satellites in orbit makes this telescope maneuverability significantly harder, both due to the higher on-sky density of satellites and due to the more frequent orbital maneuvers that will be executed by satellites to avoid collisions, making their orbits change and making it much more computationally difficult for astronomers to know the current positions.
- ITU-R RA 769-2 2.2 recommends non-GSO satellites follow the sidelobe model of ITU-R S 1428 "until such a time as a more representative model for radio astronomy antennas is obtained". This recommendation was last updated in 2003. With a more than tenfold increase in the number of active satellites since then, now is the time to create a more representative model.

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[9] Nandakumar et al. "The high optical brightness of the BlueWalker 3 satellite." Nature, November 2023. https://doi.org/10.1038/s41586-023-06672-7

[10] International Astronomical Union Centre for Protection of the Dark and Quiet Sky from Satellite Constellation Interference, "Call to Protect the Dark and Quiet Sky from Harmful Interference by Satellite Constellations", 14 March 2024. https://cps.iau.org/documents/49/techdoc102.pdf

We therefore urge ISED to:

1. Require meaningful coordination agreements between satellite operators and the National Research Council of Canada, such that the interests of both optical and radio astronomy are protected, with ongoing assessment of the efficacy and adherence to those agreements.
2. Require light pollution mitigation plans in the licensing process.
3. Take appropriate measures to ensure radio observatories, those within Canada and those used by Canadians as part of an international consortium, are protected from satellite systems, including SMCS.
4. Enforce power flux density requirements for cellular usage around designated observatories in Canada, and worldwide where Canadian-funded observatories operate.
5. Require as part of the SMCS licensing process:
   (a) High-fidelity analyses and field testing of the impact on radio astronomy observatories.[11]
   (b) A demonstration that SMCS signals will not saturate receiver chains.
   (c) Testing of the spatial beams and the sidelobe propagation to ensure that interference with radio observatories can be avoided.
   (d) Testing for electronic noise from satellite components.
6. Consider, throughout the licensing process, the aggregate effects of SMCS satellite systems.
7. Consider, throughout the licensing process, the aggregate effects all satellite systems, including increased satellite density causing heightened on-orbit collision risks, atmospheric pollution due to launches and reentries, and ground casualty risks due to reentries.[12]
8. Provide funding to develop solutions to reduce radio frequency interference from SMCS.

Canada has an internationally respected astrophysics research program making use of radio and optical observatories. Both the scientific community and the Canadian government have invested significant time, effort, and funds in the creation and maintenance of our radio and optical astronomy facilities. SMCS operations, if unregulated or underregulated, will undermine these efforts, potentially severely.

One of the mandates of ISED is to serve the public interest; another is to progress knowledge. While SMCS may advance connectivity across the nation, it will simultaneously interfere with Canadian leadership in science and space exploration, as well as other critical activities. We urge ISED to take these important considerations into careful account.

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[11] See recommendations by the National Science Foundation in the United States and its submission in regard to SCS rulemaking (GN Docket No. 23-65), "A Preliminary Assessment of Potential Impacts to Radio Astronomy Systems from Supplementary Coverage from Space".
https://www.fcc.gov/ecfs/document/10216300156387/2

[12] Lawler. "A New, Deadly Era of Space Junk Is Dawning, and No One Is Ready" Scientific American, 11 July 2024.
https://www.scientificamerican.com/article/spacex-dropped-space-junk-on-my-neighbors-farm-heres-what-happened-next. See also Boley and Byers, "Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth", Scientific Reports, 11, 10642, 2021.
https://www.nature.com/articles/s41598-021-89909-7

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