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To: Ms Marlene H. Dortch, Secretary,
Federal Communications Commission
45 L Street N.E.
Washington D.C. 20554
by web upload

Sept 18th 2022

Re: SpaceX/Starlink Gen 2 proposal
IBFS File No. SAT-LOA-202000526-00055
IBFS File No. SAT-AMD-20210818-00105

Dear Ms Dortch

I am writing to propose that the FCC deny or indefinitely defer this application, while scientific studies and international discussions proceed that would enable a full assessment of the environmental and other risks presented. This and any similar proposals will certainly have a negative impact on professional astronomy, public stargazing, and indigenous access to the sky. At the same time, issues of debris risk, damage liability, atmospheric pollution, and commercial fairness are all potentially extremely serious. The scale of all these problems, how best to avoid them, and who is financially liable for their avoidance, is currently very uncertain, indeed contentious; but this is precisely the point. It would be unwise to proceed until all these issues clarify. I will repeat my words from my submission of April 2021 to an earlier Starlink application: I think history will not forgive us if we proceed with too much haste. This decision is not just about the Starlink project itself, or the US alone. Permission to proceed could open the international floodgates, to the disadvantage of all of us.

My background. I am a professional astronomer whose personal research will certainly be affected, but I am also keenly aware of the broader issues. I am the lead author of a Nature article called *The Case for Space Environmentalism*, and the author of the book *Losing The Sky*, which provides a non-technical summary and analysis of the issues from a personal and societal perspective, intended for the general public. In April 2021 I made a submission to FCC regarding the Starlink Generation-1 modification proposal (SAT-MOD-20200417-00037). In August 2021 I wrote an Amicus Brief for the case put before the US Courts of Appeals concerning the related FCC order, arguing that NEPA should apply to FCC decisions. That appeal was rejected by the Court, but on relatively narrow procedural grounds (see below).

Note that while part of my own work is connected with the Vera Rubin Observatory / LSST, and I have attended meetings with the various "Satcon" working groups and the new IAU Center for the Protection of the Dark and Quiet Sky (IAU-CPS), I am not a member of any of those working groups, deliberately so, in order to feel free to speak critically. Some members of major astronomical projects have signed NDAs in order to help co-operation with companies such as

SpaceX. I have not. The commercial co-operation that has taken place has been valuable, but again it is important that there is an independent strand. The FCC should not make the mistake of assuming that a handful of groups speak for all professional astronomy, let alone the millions of public stargazers and astrophotographers, or indigenous groups for whom the sky is important.

Context. In 2018, the number of active satellites was around 2000, and was outnumbered by defunct but still orbiting satellites. Since then, the number of active satellites has more than doubled, and for the first time, outnumbers defunct satellites. By the time the planned Starlink Generation 1 stable population of ~4400 is completed, the active population will have tripled. If a population of 30,000 additional Starlink Generation 2 satellites is approved, along with a small number of other well advanced constellation projects, the active population will have increased by almost a factor of 20. Meanwhile, the increasing scale of Starlink is driving efforts to deploy other massive LEO constellations; the number of planned satellites worldwide numbers over 400,000. Expanding any system, let alone such a poorly understood one as the space environment, by a factor of 200 in such a short timescale, seems crazy. At the very least, such ambition should be approached incrementally, while we note the reaction of the ecosystem.

Why are so many planned? Partly because of the desire for the smallest possible latency, driving systems towards LEO, which lowers ground coverage per satellite. Partly because LEO is cheaper to reach. Partly because of a rush to crowd out competitors. Partly because of a satellite version of "tulip mania", a competitive expanding bubble. Such a bubble may of course burst, but the expansion is so fast that the environmental damage may have happened before sanity returns.

Problems for astronomical science. Starlink satellites, and others, already routinely appear in wide field astronomical images, and the growth is clear. The Vera Rubin Observatory team have argued that the target should be to keep the brightness below 7th magnitude (one magnitude below naked eye visibility). This does not mean that there is no problem fainter than this brightness; simply that it avoids the very worst irrecoverable losses because of detector cross-talk, specifically for the Rubin system. The streaks are still many millions of times brighter than the objects normally being searched for in astronomical images. SpaceX have made attempts to reduce the brightness of their Gen-1 satellites, with the VisorSat and DarkSat tests, but both of these experiments were stopped, because of heating, drag, communications, and power problems.

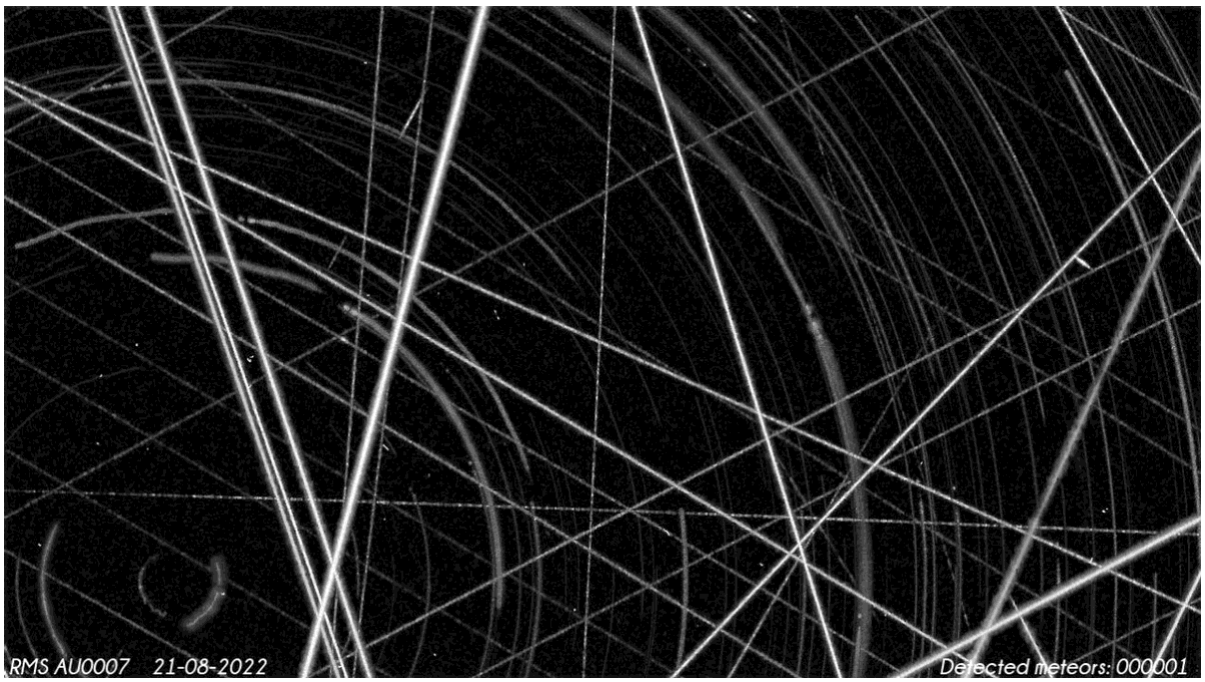
The SpaceX team recently released a document describing their continued attempts to develop new coatings and other methods of reducing reflected brightness, and encouraging other companies to take a similarly serious approach. This is very welcome. However, it is far from clear what the final in-orbit performance will be, and for example, whether occasional glints from specular reflection may cause worse effects than reduced average diffuse reflection. Furthermore, the planned Gen-2 satellites are an order of magnitude more massive, and the planned fleet is an order of magnitude larger. Even making optimistic assumptions about the success of the SpaceX technology in working practice, the total reflected light of the fleet will likely be at least an order of magnitude larger. Finally, I note that a larger fraction of the proposed Gen-2 fleet will be at lower altitudes. A satellite reflecting sunlight at 350km is typically six times brighter than one at 600km. This strategy also requires a large fleet turnover rate, so that perhaps there will always be several thousand satellites in their orbit raising phase, when they are much brighter – 3rd-5th magnitude. It would be irresponsible to approve the complete fleet of 30,000 additional satellites until real-world performance is actually known, and more thorough modelling has been completed.

The problem for radio astronomy is potentially far worse – satellites do not simply make spatially limited streaks, but rather, every satellite in the sky increases the noise that radio antennas have to cope with to "hear" faint astronomical objects. The key affected project under construction is the "Square Kilometre Array (SKA)" . As with Rubin, SKA scientists have been in active (but NDA restricted) conversation with SpaceX to discuss mitigations, involving avoiding frequencies adjacent to protected bands, and redirecting or switching off beams near agreed sites. It is a reasonable hope that Gen-2 satellites will have RF performance no worse than Gen-1, but of course ten times as many satellites will be above the horizon at any one time; and maintaining avoidance tactics will be much more difficult for both satellite operators and observatory operators. Furthermore, as with optical astronomy, it is important to realise that SKA, important though it is, is not the entire radio astronomy community.

Public access to the sky. A substantial fraction of Starlink Gen-2 satellites at any one time will be above naked eye visibility, and so will have a significant impact on general public stargazing, but especially on indigenous communities, who both value the night sky as part of their cultures, and typically live in the darkest sites where such impact will be most noticeable. It is already the case that in any reasonably dark site, there is always at least one satellite crawling across the sky, and often several. Given trends, soon there will be many at any one time. Even for casual stargazers, the initial reaction of "oh look, how interesting" will soon give way to annoyance and powerless despair, akin to seeing litter everywhere in a rural landscape. In recent years, indigenous communities have successfully demonstrated their legal right to clean air, which can be impacted by developments well outside their territories; the right to an unpolluted sky seems closely analogous, wherever the pollution originates.

For millions of keen amateur astronomers and astrophotographers around the world, the problem is inescapable. In a small telescope or a pair of binoculars, one sees stars to 9th magnitude or deeper. Every binocular field of view will have several satellites drifting across. Astrophotographers take exposures minutes or hours long, and it is now already almost impossible to take a picture with no satellite streaks. From discussions with local societies through to national and international forums and Facebook pages, it is clear that amateur astronomers are becoming increasingly affected. Below is a 77 minute exposure taken by Dave Thanatos in Salisbury UK, in May 2022. The telescope was pointed at a fixed position, causing the circular star trails. The idea was that meteors should be detected as streaks, and indeed there about 10 meteors in that image, but hundreds of satellites – good luck telling the difference!

Below is another example, a long exposure of the South Celestial Pole from a light-polluted suburban location in Western Australia. The satellites recorded were brighter than most visible stars. This image was not taken by a telescope, but by what is essentially a simple security camera - part of a network of such simple cameras, used by amateur astronomers around the world to spot meteors – there is one in that image, swamped by satellites. (The Global Meteor Network is led by Denis Vida; the image below was recently tweeted by Dave Rollinson).



Displaced costs. Professional astronomers are hard at work studying the problem, and developing new software to try to minimise damage to observations, or avoid satellite passes, or partially recover corrupted data. This all costs effort, and so money. Sometimes observations taken by the Rubin Observatory, or the Hubble Space Telescope, or the Square Kilometre Array, or indeed any more modest astronomical facility, will simply have to be repeated – costing even more taxpayer dollars. This is the classic "displaced cost" problem of an environmental issue, with a commercial organisation exploiting what seemed to be a free resource – orbital space – but actually externalising the true cost of using it. Amateur astronomers are also expending private effort developing new imaging techniques and software

Regulatory development. Industry, scientists and government are increasingly realising the importance of sustainability in space, and the looming problems of debris, space security, damage liability, and competitor interference, as well sky pollution and atmospheric pollution. The White House has recently made two announcements, one from the NTSC, and one from VP Harris, regarding developing plans to minimise debris, and responsible space behaviour more generally. The FCC itself has recently announced a proposed ruling regarding post-mission disposal, to mitigate potential crowding by imposing a new 5 year rule. A new UK initiative explicitly recognises sky pollution as a key issue. Meanwhile, concerned nations have introduced proposals for resolutions at the upcoming ITU Plenipotentiary Conference to raise awareness of these issues and drive the adoption of new rules around the world. Regulatory issues are being discussed by COPUOS of course, and may come to a head in next year's UN Summit for the Future. In this rapidly evolving situation, commercial companies naturally feel a pressure to get their ambitious plans under the wire before the regulatory shake-up is complete – but this is exactly what a responsible agency such as the FCC should resist. Of course part of the problem is that many of the issues – such as debris and sky pollution - do not have an agreed regulatory home at the moment. Temporarily, it is down to the FCC and other national regulators to consider those matters as responsibly as possible, and to avoid taking actions that soon will seem badly inconsistent with the new international framework that will have emerged.

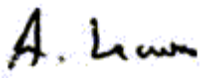
Environmental legislation. The case for which I wrote my Amicus Brief, which evolved into the Nature article *The Case for Space Environmentalism*, involved Viasat Inc. and the Balance Group making the case that under NEPA, FCC should have carried out an Environmental Assessment before approving the Starlink modification proposal (SAT-MOD-20200417-00037). The Court ruled that neither party had appropriate "standing" and therefore the Court did not "reach the merits of their claim". The idea that a NEPA environmental review should occur in the context of a proposal to the FCC such as the Starlink one, was therefore untested – but in my opinion remains extremely strong. Viasat did not succeed in establishing standing as Environmental Appellants because of the requirement to show injury that is "actual, imminent or certainly impending" rather than "a speculative possibility of future injury". The Balance Group's stated injury was deemed to be not backed by sufficiently concrete evidence. This issue of standing is now not relevant because both the National Resources Defence Council, and the International Dark Sky Association, through their submissions of 2022 September 7th, have petitioned the FCC to take action in this proceeding under NEPA. Notably, the Court decision does *not* show that the FCC were correct in choosing to ignore NEPA, only that the appellants did not demonstrate actual injury caused by the order in question. Although an *appeal* requires actual rather than possible injury, an *Environmental Assessment* required under NEPA must of course consider injury that *may* happen to many possible future parties. Furthermore, the wording of the discussion in the Court opinion implies that they did not rule out including the effect of harms arising from activities in orbital space as part of the environmental harms covered by

NEPA. Overall it would seem unwise for FCC to continue its insistence that it can apply a categorical exclusion under NEPA to space licensing. Meanwhile SpaceX have plunged ahead trying to complete the Gen-1 system as fast as possible. The environmental arguments apply *a fortiori* to the Gen-2 proposal.

Precedent setting. This letter has been submitted in the context of the review of the SpaceX Starlink Gen-2 proposal. However, clearly, some even more seriously disturbing proposals are in the pipeline. The decision on the Starlink Gen-2 proposal, and the reasons given for it, will set a precedent. If it is allowed to go ahead, it will seem hard to deny those later proposals, with the possibility of hundreds of thousands of satellites adding to the increasing harm.

Yours sincerely,

Andy Lawrence



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The Nature article *The Case for Space Environmentalism* is publicly available at https://rdcu.be/cL3JI