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Satellite Constellation Internet Affordability and Need

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ABSTRACT

Large satellite constellations in low-Earth orbit seek to be the infrastructure for global broadband Internet and other telecommunication needs. We briefly review the impacts of satellite constellations on astronomy and show that the Internet service offered by these satellites will primarily target populations where it is unaffordable, not needed, or both. The harm done by tens to hundreds of thousands of low-Earth orbit satellites to astronomy, stargazers worldwide, and the environment is not acceptable.

Unified Astronomy Thesaurus concepts: Artificial satellites (68)

LOW-EARTH ORBIT SATELLITE CONSTELLATIONS

SpaceX's Starlink has launched over 700 low-Earth orbit satellites since May 2019. They plan to offer global broadband Internet with a final "constellation" of 42,000 satellites. Other operators have announced similar plans, and we are witnessing a new era of a sky filled with thousands of low-Earth orbit commercial satellites.

Recent studies (McDowell 2020; Hainaut & Williams 2020; Tregloan-Reed et al. 2020) raise concerns about the brightness of these constellations and the detrimental effect of large numbers of satellites to optical astronomy. This is because satellites reflect sunlight even after sunset, and global satellite coverage will cause bright streaks in astronomical images for large portions of the night at ground-based observatories worldwide.

Vera C. Rubin Observatory and its Legacy Survey of Space and Time (LSST, Ivezić et al. 2019) will be the optical astronomy facility most severely impacted by satellite constellations due to its wide field of view and large light collecting area. Tyson et al. (2020) estimate a 48,000 satellite constellation will result in at least 30% of LSST images containing a satellite trail. Other optical and near-IR observatories will also be significantly impacted. There are concerns for wavelengths outside optical (e.g., Gallozzi et al. 2020; Massey 2020) as well. For example, satellites directly transmit at 10–30 GHz[1] in bands used for astronomical observations. Depending on satellite transmitter quality, frequencies outside the nominal transmission bands can also be impacted (e.g., Deshpande & Lewis 2019).

Unfortunately, the solution is not as simple as moving telescopes into space. Prohibitive costs, inability to maintain instruments in space, constraints imposed by launch vehicle size, the short life expectancy from harsh conditions, and decades to plan and fund large missions make this infeasible.

The recent Satellite Constellations 1 Workshop Report (Walker et al. 2020) provides recommendations to mitigate the effects of satellite trails in optical and near-IR images. Final reports from the Conference on Dark and Quiet Skies for Science and Society[2] will soon be sent to the UN Committee on the Peaceful Uses of Outer Space.

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[1] https://docs.fcc.gov/public/attachments/FCC-18-38A1.pdf
[2] http://research.iac.es/congreso/quietdarksky2020/pages/home.php

SpaceX is collaborating with Rubin Observatory, and other satellite operators including Amazon Kuiper and OneWeb have begun dialogues with astronomers too. While early Starlink mitigations are promising, it is unrealistic to rely on the goodwill of satellite operators as a mitigation strategy. Hardware and software mitigations can minimize some scientific impacts, but they are a significant amount of work that has not been planned or budgeted for. They also do not address wider-reaching environmental or cultural effects of a drastically changed night sky.

AFFORDABLE INTERNET ACCESS?

While large low-Earth orbit satellite constellations will harm astronomy and may render certain orbits hazardous (Kessler et al. 2010; Hongqiang & Zhanyue 2020), such negative impacts could be considered acceptable if constellations offer substantial benefits. The rationale often given is a strong need for affordable Internet access worldwide. This need certainly exists, and SpaceX is currently offering free beta Starlink Internet to communities in need including emergency first responders and the Hoh Tribe in Washington. However, providing free Internet access to communities in need is not Starlink's primary goal, nor is it a sustainable business model. To the contrary, we show in Figure 1 that the cost of a satellite Internet subscription remains out of reach to the communities that need it most.

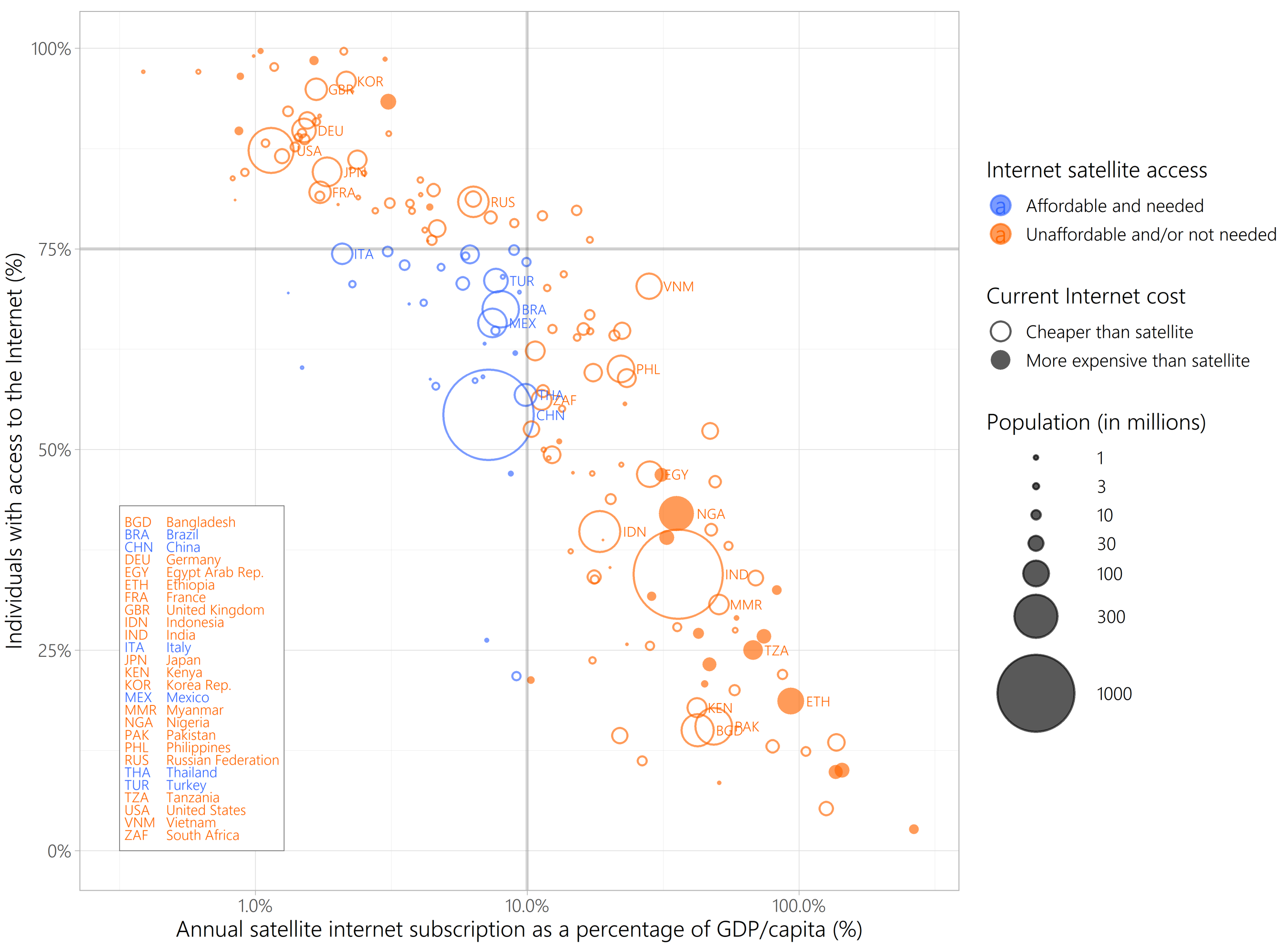

Figure 1. There is a small population that both needs and can afford satellite Internet service (blue circles). The remainder either does not need or cannot afford it (orange circles). For each country, we plot the estimated cost of satellite constellation Internet service as a percentage of gross domestic product (GDP) per capita against percentage of individuals currently with Internet access. Open circles indicate current ground-based Internet is cheaper than estimated satellite Internet. Circle size indicates the country's population. Affordable access is classed as $\leq 10\%$ of GDP per capita; need is classed as $\leq 75\%$ of the population currently having Internet access. Countries with >50 million inhabitants are labelled, accounting for 80% of the world population. Data and code at https://github.com/mrawls/sky-high-starlink & https://doi.org/10.5281/zenodo.4133883.

In Figure 1, we use Starlink as an example, but emphasize the calculation is similar for other satellite Internet providers. We parameterize affordability as the estimated annual cost of a satellite Internet subscription as a percentage of gross domestic product (GDP) per capita. We adopt a conservative estimate of $60 monthly for satellite Internet service. This is lower than the $80 monthly mentioned by SpaceX President Gwynne Shotwell[3] and in line with an internal note stating SpaceX plans to make $40 billion annually with 30 million subscribers in 2025[4]. We use Internet access and GDP data from 2018, which are publicly available from the UN International Telecommunication Union (ITU), the UN specialized agency for information and communication technologies[5], and the World Bank[6].

The UN Sustainable Development Goal 9 (SDG9) is "Investing in Information and Communication Technologies (ICT) access and quality education to promote lasting peace" (United Nations 2019). In developing countries, fewer than 50% of people have access to the Internet, and in the least developed countries, it falls to fewer than 20%[7]. To satisfy SDG9, there is a need for massive investment in ICT in remote and vulnerable communities in developing countries as well as improved Internet access in developed rural areas[8]. SpaceX aims to provide low-latency Internet to 80–100 million households, or 3–4% of the world's population[9], with a bandwidth suitable only for low- to mid-density populations[10]. Technological constraints suggest other satellite operators can offer a similar service.

Given this, it would appear satellite constellation Internet can contribute to SDG9, particularly in the "blue" countries in Figure 1. However, the estimated $80 monthly cost of a Starlink subscription is prohibitive to all countries in greatest need of access, and this does not include start-up costs of $100–300[11] per user. In countries where the majority of the population lives on less than a few dollars per day, the ability to spend $80 per month for Internet access is infeasible. Even if subscriptions are heavily subsidised (e.g., $20-30 per month), it still remains inaccessible for many. Additionally, some countries are already working to provide cheaper ground-based broadband. For example, Nigeria already has 4G mobile Internet for $27 monthly[12]. For the few people that both need and can afford satellite Internet, the majority reside in China, a country currently developing their own constellations[13].

QUESTIONING THE NEED FOR SATELLITE CONSTELLATIONS

The choice between Internet access and astronomy is not a binary one, but we are racing toward a tipping point of no return and a future with tens to hundreds of thousands of satellites. While there undeniably is a need for high-speed, accessible, affordable Internet access, corporate satellite constellations are not humanitarian projects that freely provide infrastructure for SDG9. Figure 1 demonstrates that satellite constellations will not on the whole provide Internet to those who need it most. The rush to launch tens of thousands of satellites should be fundamentally reconsidered.

We use Starlink as an example in this Note because SpaceX is the first company to launch hundreds of satellites and engage in discussion with astronomers. This collaboration is likely the best-case scenario, since other operators currently have no financial or regulatory motive to ensure they darken or otherwise mitigate the effects of their satellites. We recognize that satellite constellations are accepted by many as the new norm, and that simply not launching them may be perceived as unrealistic. We emphasize that we are not advocating for a world with zero satellites, and we sincerely appreciate continued dialogues with satellite operators to implement a variety of technical mitigations. At the same time, the night sky is an invaluable resource that must not be exploited for profit. It must be protected, not just for the freedom of scientific exploration and cultural heritage now, but for future generations.

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The earliest form of Figure 1 was created by Victor Chemin and shared on Twitter. Lucianne Walkowicz presented it in a talk at DotDotAstro (https://www.dotastronomy.com/alpha), after which this Note was drafted.

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