DAY ONE PROJECT

Averting Environmental Risks in the New Space Age

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March 2021

Summary

We face an existential crisis: Space is at risk of developing the equivalent of the ocean's "drifting island of plastic."[1] Air, space, and light pollution now present looming environmental threats created by the launch of new "mega-constellations" of thousands of satellites in the part of space near Earth called "Low Earth Orbit" (LEO). A "take risks and fail often" approach to new technology has been extended to space without consideration of the fact that mistakes in space cannot be cleaned up like they can on Earth.[2]

In 2019, a European Earth observation satellite came dangerously close to colliding with a newly launched mega-constellation satellite, having to perform a last-minute maneuver to avoid the satellite, whose operator did not respond to attempts to contact it. As the number of satellites in congested orbits increases exponentially, close calls like this are becoming more commonplace. And we are seeing an unexpected number of these satellites fail such that they do not even have the ability to try to avoid dangerous collisions.[3] As the movie *Gravity* illustrated, a collision in space can set off a chain reaction of further collisions, potentially destroying or disabling satellites and spreading large amounts of dangerous space junk. The recent introduction of thousands of satellites in LEO is also creating light and radio-frequency pollution that impairs the once-clear access to the cosmos for critical scientific-based research. Indifferent to these serious environmental issues, and largely unregulated, mega-constellation operators are rushing to launch as many satellites as possible before new rules are put in place.

The Biden-Harris Administration should direct the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA) to fully examine and address these critical environmental issues before the United States authorizes thousands more LEO satellites in mega-constellations. Three concrete steps are warranted: (i) determine the aggregate impact of all mega-constellations, (ii) conduct a thorough review of these "unprecedented"[4] new uses of space under the National Environmental Policy Act (NEPA), and (iii) adopt new rules that consider the full environmental impacts of mega-constellations before they are launched. In this regard, the Biden-Harris Administration should consider either (i) issuing an Executive Order instructing the FCC and the FAA to evaluate the environmental consequences associated with mega-constellations before

[1] Shivali Best, "'A disaster waiting to happen': Space junk left behind by humans has formed the equivalent of a 'drifting island of plastic' in low-Earth orbit, expert warns." *Daily Mail*, January 12, 2021, https://www.dailymail.co.uk/sciencetech/article-9138879/Orbiting-space-debris-new-drifting-island-plastic.html.

[2] Dr. Moriba K. Jah, Testimony to the U.S. Senate Committee of Commerce, Science and Transportation on "Reopening the American Frontier: Promoting Partnerships Between Commercial Space and the U.S. Government to Advance Exploration and Settlement," July 13, 2017, https://www.commerce.senate.gov/services/files/C2F571EA-F105-411A-8F86-DA2E2745CC68

[3] Morgan McFall-Johnsen, "About 1 in 40 of SpaceX's Starlink satellites may have failed. That's not too bad, but across a 42,000-spacecraft constellation it could spark a crisis." *Business Insider,* November 3, 2020, https://www.businessinsider.com/spacex-starlink-internet-satellites-percent-failure-rate-space-debris-risk-2020-10.

[4] Tim Fernholz, "Space Business: Extraordinary! Unprecedented!" *Quartz*, February 11, 2021, https://qz.com/emails/space-business/1971316.

permitting their launch or deployment, or (ii) proposing legislation that requires the FCC and the FAA to do the same.

Action -- or inaction -- by the Biden-Harris Administration will set the standard on which the global space industry will base its next design choices. Unless we act now, we may find that, as with climate change, we wish we had acted much sooner.

Challenge and Opportunity

Space near Earth is both a limited and a shared resource — a "commons" that must be protected. Currently, as leading experts recognize, certain satellite operators do not have an economic incentive to protect shared resources. The same is true for our atmosphere and our night sky.

These threats have developed because of recent changes in the marketplace and commercial cost/safety tradeoffs that have negative environmental impacts.

Many recent technological advances have eliminated the high cost of access to space that once fostered a responsible space ecosystem, and limited the number of objects in space. Previously, the rules to manage the risks were adequate. That is no longer the case. Today, self-interest and the public good are quickly diverging, as the cost of failure to an individual actor is far, far less than the collective risk of multiple individual failures — a long-anticipated "tragedy of the commons" in space.

One example is the needless choice of using large numbers of economically expendable satellites that have high negative environmental impacts, when fewer and more reliable satellites can achieve the same goals without those impacts. This threat to the commons both in space and here on Earth is manifested in the many thousands of LEO satellites being launched into space, with one company alone planning to launch over 40,000 satellites in the near future.[5] By comparison, mankind has launched only about 9,000 satellites total since space exploration began seven decades ago.[6] The International Telecommunication Union (ITU) and national regulatory filings indicate that around 100,000 LEO satellites could be launched in the coming decade. Indeed, the FCC has authorized or received applications for constellations that will consist of about 100,000 LEO satellites operating at any given time, and when expected replacements are factored in, many multiples of that number will launch and ultimately vaporize in the atmosphere over a 15-year license term.

[5] Loren Grush, "A Future with Tens of Thousands of New Satellites Could 'Fundamentally Change' Astronomy: Report." *The Verge*, August 26, 2020, https://www.theverge.com/2020/8/26/21401455/satellite-mega-constellations-astronomy-spacex-amazon-oneweb-bright-internet-space.

[6] Michael Sheetz, "Why in the next Decade Companies Will Launch Thousands More Satellites than in All of History." *CNBC*, December 17, 2019, https://www.cnbc.com/2019/12/14/spacex-oneweb-and-amazon-to-launch-thousands-more-satellites-in-2020s.html.

A leading provider of collision-threat analysis tools has notionally depicted the scale of the satellite constellations expected to deploy in LEO over this decade, in the following figure:

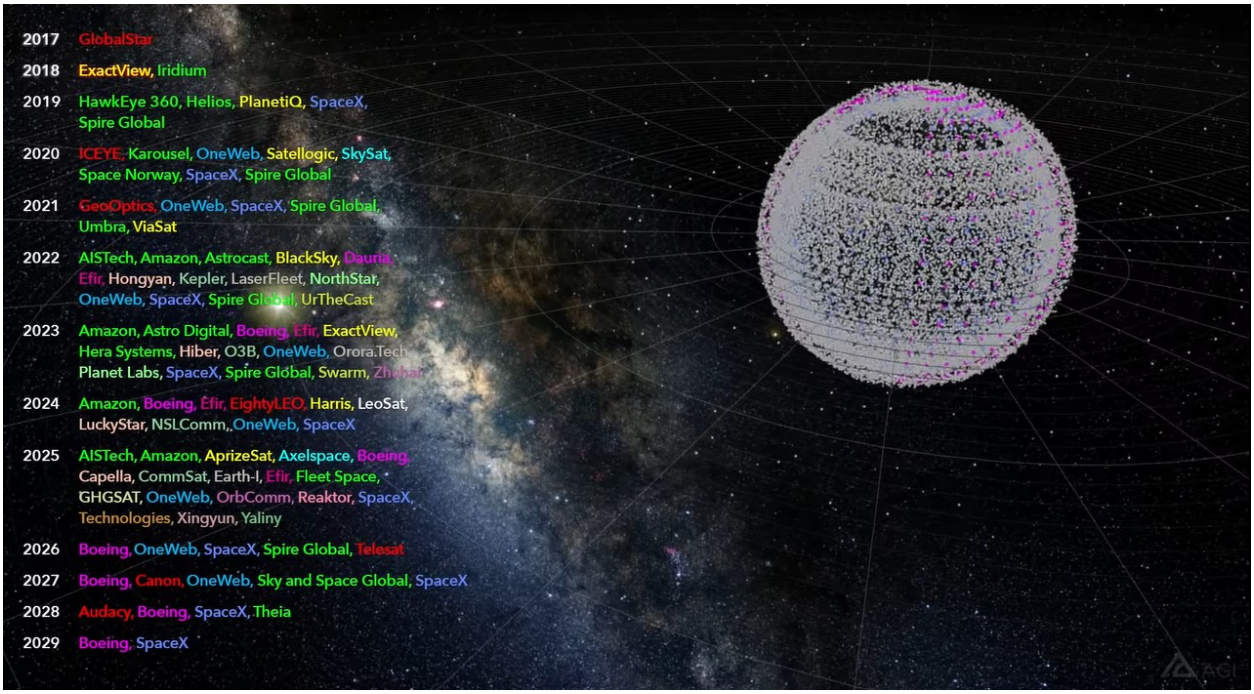

Figure 1: Illustrative LEO Constellation Deployment (2017-2029)[7]

Mega-constellations in LEO raise a number of significant environmental threats:

- Air pollution: When the satellites in LEO mega-constellations fail or wear out (ranging from soon after launch to five or ten years later), they are designed to vaporize as they reenter our atmosphere. That process releases chemical compounds that linger in the stratosphere and can affect climate change and the ozone layer.[8] As those defunct satellites are constantly replaced, the release of pollutants continues.
- Space pollution: When satellites in mega-constellations collide with existing space debris or with other satellites and rocket bodies, they produce wide-ranging environmental harm in the form of lethal fields of high-speed space junk that persist for decades or more and pollute orbits used by others. Such risks grow with the size of mega-constellations — which threaten far more potential collision events than other satellite systems — and not all collisions can be avoided. Cost/safety tradeoffs that prioritize using large numbers of low-cost, economically-

[7] S. Alfano, D. Oltrogge, R. Shepperd, "Leo Constellation Encounter and Collision Rate Estimation: An Update." 2nd IAA Conference on Space Situational Awareness (ICSSA), Washington, D.C., January 14-16, 2020, https://www.documentcloud.org/documents/6747529-LEO-CONSTELLATION-ENCOUNTER-and-COLLISION-RATE.html.

[8] L. Organski, C. Barber, S. Barkfelt, M. Hobbs, R. Nakagawa, Dr. M. Ross, Dr. W. Ailor, "Environmental Impacts of Satellites from Launch to Deorbit and the Green New Deal for the Space Enterprise." Aerospace Corporation (December 2020); Debra Werner, "Aerospace Corp. Raises Questions about Pollutants Produced during Satellite and Rocket Reentry." *SpaceNews*, December 15, 2020, https://spacenews.com/aerospace-agu-reentry-pollution/.

expendable satellites over fewer and more reliable satellites increase the risk further: satellites that cannot maneuver cannot avoid collisions.

- Light and radio-frequency pollution: These unprecedented new uses of space are a source of disruption to critical scientific research that relies on optical and radio-based astronomy. This impairment is caused by light and radio-frequency pollution emitted by large numbers of satellites in LEO constellations. Massive LEO constellations also pose a threat to the continued majesty of the night sky as countless visible light trails from large numbers of these satellites fill the sky, impairing stargazing and astrophotography.

Polluting Our Air and Affecting Climate Change

Mega-constellations are designed so their defunct satellites reenter the atmosphere and vaporize, releasing chemical compounds, including aluminum oxides. The Aerospace Corporation (an advisor to the U.S. Space Force) reports that this massive increase in the number of satellites reentering the atmosphere and releasing chemical compounds and particles could contribute to climate change through radiative forcing and ozone depletion.[9] Most of the reentering mass vaporizes into small particles consisting of a "zoo of complex chemical types."[10] The stratosphere where this pollution gathers is home to the fragile ozone layer that protects the Earth from UV radiation.

None of these risks is currently being examined, or even considered, by the FCC as the United States authorizes mega-constellations to serve the United States. Authorization includes permission for initial deployment and the subsequent deployment of an unlimited number of replacement satellites over a license term in the case of U.S.-licensed systems, and, in the case of constellations licensed by other Administrations, permission to serve the United States with those constellations.

Polluting Space

The operation of large numbers of LEO satellites in mega-constellations significantly raises the risk of collisions in space. This is particularly true when those satellites do not retain a high level of reliable maneuverability for as long as they remain in orbit. Satellites that cannot maneuver cannot avoid collisions with other satellites or the large amounts of lethal space junk already in LEO orbits. The resulting collisions can be catastrophic—fragmenting the satellite into thousands of pieces on new space junk that spread into and impact orbits hundreds of kilometers above

[9] Organski, Barber, Barkfelt, Hobbs, Nakagawa, Ross, Ailor, "Environmental Impacts of Satellites from Launch to Deorbit and the Green New Deal for the Space Enterprise."; Werner, "Aerospace Corp. Raises Questions about Pollutants Produced during Satellite and Rocket Reentry."

[10] Martin N. Ross & Leonard David, "An Underappreciated Danger of the New Space Age: Global Air Pollution." *Scientific American*, February 2021. https://www.scientificamerican.com/article/an-underappreciated-danger-of-the-new-space-age-global-air-pollution/.

and below the collision. This new space junk essentially becomes high-speed, unguided missiles that pose a collision risk to other satellites.[11]

The following figure from the European Space Agency depicts the growing number of space objects in the LEO region (2000 km and below).[12] A significant portion of recent increases is attributable to LEO satellites themselves, as well as the fragmentation of those satellites after collisions.[13]

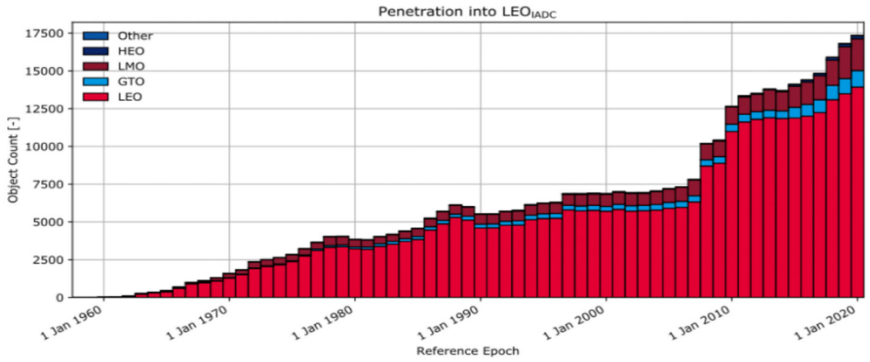

Figure 2: Evolution of Absolute Number of Objects in the Low Earth Orbit (LEO) Region, Including Objects in Geostationary Transfer Orbit (GTO), Low and Medium Earth Crossing Orbits (LMO), Highly Eccentric Earth Orbit (HEO)[14]

Collisions can have a devastating impact, sending large clouds of high-speed shrapnel-like space junk into surrounding orbits. This space junk can disable or destroy other satellites that are critical for connectivity, mapping, weather, and defense purposes — and it can persist for decades and even a century or more, making access to space riskier and more expensive. Thus, satellites in mega-constellations that fail or degrade such that they can no longer be reliably maneuvered while they remain in orbit present undue risks to space and everyone who seeks to utilize space. Of great concern are the cost/safety tradeoffs being made in mega-constellation designs that value low-cost, economically expendable satellites over constellations with fewer and more reliable satellites. Making that tradeoff reduces the likelihood of successfully maneuvering to avoid collisions.

Under current policies, mega-constellations continue to be authorized by the FCC under risk standards that were developed for single satellites and that are wholly inadequate for mega-constellations. Today, the FCC seeks to ensure that the risk of a single satellite colliding with another space object is less than one in 1,000 for the expected lifetime of that satellite. That approach does not consider the additive risk from each satellite in a mega-constellation and the

[11] McFall-Johnsen, "About 1 in 40 of SpaceX's Starlink Satellites May Have Failed. That's Not Too Bad, but across a 42,000-Spacecraft Constellation It Could Spark a Crisis."
[12] European Space Agency Space Debris Office, "ESA's Annual Space Environment Report" (2020): 16.
[13] Ibid 13.
[14] Ibid. 6.

unlimited number of replacements that could be launched over a 15-year license term. This would allow for catastrophic collisions very frequently, as depicted below:

# of Satellites in Orbit	Allowed Mean Time Between Collisions in Years (Days)
1,000	5
5,000	1
10,000	0.5 (180 days)
50,000	0.1 (36 days)
100,000	0.05 (18 days)

Table A: Application of Current Approach to Collision Risk[15]

When even a single collision can have devastating effects, effectively sanctioning many collisions is simply an untenable policy. Collision risk scales with LEO constellation size and the number of LEO constellations, and this aggregate risk is not being considered in the current authorization process. Moreover, the tools the FCC uses today to evaluate collision risk do not factor in a number of relevant risks, including:

- Increased risk of collisions due to known changes in the orbital environment.
- The risk of collisions with all sizes of space objects (not just those ≥ 10 cm and ≤ 1 cm).
- The continued reliability of command and propulsion capabilities needed to allow satellites to maneuver to avoid collisions.
- The risk of intra-system collisions within any of these mega-constellations.
- Known risks with maneuvering techniques used to attempt to avoid collisions.

If mega-constellations are allowed to continue to deploy without a full and complete analysis of these issues and the adoption of suitable mitigation measures, competition and innovation in space may come to a standstill. The Organization for Economic Cooperation and Development (OECD) calls the deployment of mega-constellations a "game changer" and warns of the prospect for a never-ending spiral of collisions that would eventually render LEO unusable and possibly impenetrable — foreclosing access to and innovation in space for generations.[16]

Polluting Dark and Quiet Skies

Mega-constellations present threats to ongoing critical scientific research in the fields of optical astronomy and radio astronomy. The question of how these threats should be mitigated has not yet been resolved. They include three types of interference: (i) satellites in the night sky reflecting

[15] Note: Calculations are based on 5-year satellite design life.

[16] Organisation for Economic Co-operation and Development (OECD), "Space Sustainability: The Economics of Space Debris in Perspective." *OECD Science, Technology and Industry Policy Papers*, no. 87 (April 2020): 7, 18, 26. https://read.oecd-ilibrary.org/science-and-technology/space-sustainability_a339de43-en#page1.

sunlight that interferes with optical research telescopes; (ii) artificial radio wavelength emissions that interfere with radio telescopes; and (iii) light pollution that impacts naked eye viewing of the night sky. Indeed, the disruptive nature of the growing number of mega-constellation trails in the night sky is evident from a variety of reports.[17] Nevertheless, the effect of fully-deployed mega-constellations on the visibility of the night sky and on professional astronomical observations has not been adequately considered as a policy matter.

The threats of mega-constellations to critical astronomy-based scientific endeavors were recently addressed by a leading group of experts under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), which included the UN Office of Outer Space Affairs (UNOOSA) and the International Astronomical Union, among others. Their recent report and recommendations emphasize that "[c]utting edge astronomical discoveries can only continue on the basis of an unobscured and undisturbed access to the cosmic electromagnetic signals," and detail why mega-constellations are a threat to astronomy.[18] As the report explains in detail, further work to mitigate the adverse impacts of LEO mega-constellations is urgently needed, and appropriate limits must be adopted and enforced by individual national governmental authorities.[19]

Tragically, there is no apparent systematic means for addressing these matters in the United States. Historically, these threats have not been addressed by the FCC in authorizing the deployment and operation of LEO mega-constellations. In fact, some mega-constellation proponents have asserted that the FCC does not even have jurisdiction over the "visibility of satellites," and have resisted calls for the FCC to fulfill its statutory obligation under NEPA, and consistent with standing Executive Orders, to examine the environmental impact of deploying thousands of satellites.

Plan of Action

As the Biden-Harris Administration sets its agenda, protecting the environment in space and on Earth and keeping space accessible for all should be of utmost importance and an immediate priority.

The last Administration recognized that these operators have little incentive to protect the "commons" that is our environment, but still failed to act. Indeed, the prior Administration allowed

[17] *See,* e.g., Ryan Whitwam, "Starlink Satellites Ruin NEOWISE Comet Photo." *ExtremeTech,* July 27, 2020, https://www.extremetech.com/extreme/313200-starlink-satellites-ruin-neowise-comet-photo; Samantha Lawler, "Will SpaceX's Starlink satellites ruin stargazing?" *EarthSky,* November 22, 2020, https://earthsky.org/human-world/will-spacex-starlink-satellites-ruin-stargazing.

[18] United Nations Office for Outer Space Affairs, International Astronomical Union, IAC, NOIR Lab. "Dark and Quiet Skies for Science and Society: Report and Recommendations." Online Workshop (December 29, 2020): 12. https://www.iau.org/static/publications/dqskies-book-29-12-20.pdf.

[19] Ibid 15, 34.

more mega-constellation satellites to be launched while it said it would consider new rules that remain unadopted. The Biden-Harris Administration should chart a new course.

- First, the Biden-Harris Administration should immediately cease the existing practice of authorizing constituent parts of an individual mega-constellation without considering the aggregate impact of (i) all of the parts of that constellation, (ii) all of the other mega-constellations that are authorized or in the process of being authorized, and (iii) other mega-constellations that are likely to be developed and deployed as a natural response to the lack of regulatory oversight.

- Second, the Biden-Harris Administration should order a thorough review of the environmental threats caused by each of these unprecedented new uses of space, including consideration of suitable mitigation techniques such as meeting the same objectives with fewer and more capable satellites. In this regard, the Biden-Harris Administration should consider either (i) issuing an Executive Order instructing the FCC and the FAA to evaluate the environmental consequences associated with mega-constellations before permitting their launch or deployment, or (ii) proposing legislation that requires the FCC and the FAA to do so. Such an Executive Order would be consistent with the Carter Administration's prior directive that federal agencies evaluate major actions significantly affecting the environment of the global commons.[20]

- Third, the Biden-Harris Administration should adopt rules that require that the total impact of a mega-constellation be considered before providing authorization to launch from or serve the United States. Indeed, acting FCC Chairwoman Jessica Rosenworcel has recognized that "this rush to develop new space opportunities requires new rules. Despite the revolutionary activity in our atmosphere, the regulatory frameworks we rely on to shape these efforts are dated."[21] Acting Chairwoman Rosenworcel has also warned that the FCC's history of approving LEO constellations without addressing these risks means the U.S. will be "junking up our skies" if we do not move faster in adopting new rules.[22] Operators should be required to provide sufficient assurances at the application stage about how they will mitigate those impacts. Periodic "health checks" should be conducted to ensure operators are living up to their commitments, and when they do not, the Biden-Harris Administration should take appropriate action, including freezing authority for further launches.

[20] "Executive Order No. 12114—Environmental effects abroad of major Federal actions," *Federal Register*, January 4, 1979, § 2-3(a), https://www.archives.gov/federal-register/codification/executive-order/12114.html.
[21] Statement of now-acting FCC Chairwoman Jessica Rosenworcel, "FCC Hearing on Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System," March 29, 2018, https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0329/FCC-18-38A2.pdf.
[22] Monica Alleven, "U.S. Risks 'Junking up Our Skies' with Space Debris: Rosenworcel." *FierceWireless*, August 1, 2019, https://www.fiercewireless.com/wireless/u-s-risks-junking-up-our-skies-space-debris-rosenworcel.

Early Prevention Is Critical

While there are a number of important steps needed to manage these issues, the most critical step is to prevent more harm before it occurs, by addressing these issues at the application stage, where US agencies authorize the deployment of satellites.

For decades, the FCC has been the agency authorizing the deployment and operation of commercial satellites, and their ability to serve the United States. In that role, the FCC has also for decades addressed the safe flight of commercial satellites and the potential for them to contribute to the space junk problem. The FCC is also mandated by statute to factor in public interest considerations that are not within the charter of other agencies. The FCC has had a rulemaking proceeding on safe flight and space junk issues pending for over two years.[23] More generally, the FCC is also obligated to consider the requirements of NEPA and implement directives and orders as to the environmental impact of FCC actions.

Other agencies study or oversee different aspects of these issues. For example, the FAA authorizes the launch of satellites from U.S. soil and is obligated to consider NEPA in that context. The National Aeronautics and Space Administration (NASA) has studied the effects of space junk on the long-term sustainability of physical access to space but has not addressed: (i) the risks associated with space junk disrupting vital communications networks in the near term, (ii) the impact on Earth of a steady stream of thousands of satellites vaporizing and polluting our atmosphere, or (iii) the disruptions to ongoing scientific research that mega-constellations create.

Congress, industry leaders and other experts have recognized the need for increased awareness of the growing number of trackable objects in space. It is apparent that this challenging task only becomes more difficult as space fills up with more uncontrollable space junk. To date, the Department of Defense has had a lead role in this task. More recently, there have been calls by Congress and others in the industry to bring this mandate under the Office of Space Commerce (OSC), a division of the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce.[24] OSC would be charged with collecting space situational awareness data from government, foreign and commercial sources as well as with developing a space traffic management function to prevent operational satellites from colliding with space junk. This function is incredibly important, and it must be facilitated by ensuring that operators are building, deploying and operating satellite systems in a manner that minimizes the chance of collisions and creating increased space junk in the first place.

We should also work closely with our international allies to put rules in place that ensure safe and shared access to space, a clean atmosphere, and a dark and quiet night sky. The United Nations'

[23] FCC, "Mitigation of Orbital Debris in the New Space Age," Notice of Proposed Rulemaking, 18-159 (November 2018), https://docs.fcc.gov/public/attachments/FCC-18-159A1.pdf; Further Notice of Proposed Rulemaking, 20-54 (April 2020), https://docs.fcc.gov/public/attachments/FCC-20-54A1.pdf.

[24] "Wicker Introduces Space Preservation and Conjunction Emergency Act," U.S. Senate Committee on Commerce, Science, and Transportation, October 21, 2020, https://www.commerce.senate.gov/2020/10/wicker-introduces-space-preservation-and-conjunction-emergency-act.

COPUOS and UNOOSA have started to address some of these issues, but the existing UN COPUOS guidelines on space junk were adopted over 13 years ago, before the New Space Age. They do not address the risks presented by mega-constellations that the FCC has recently acknowledged or the environmental harms discussed above. Moreover, these guidelines are not legally binding. Under the leadership of UN Ambassador Linda Thomas-Greenfield and Special Presidential Envoy for Climate John Kerry, we should ensure there is international action in this area and shared responsibility regarding space and Earth.

Of course, any guidance at the multinational level must be applied and enforced at the national level to be effective. Recent reports from OECD and the COPUOS working group emphasize the need for a national-level focus on the environmental threats created by mega-constellations. The United States (through the FCC) must implement rules for the licensing of commercial satellites and otherwise address the environmental threats posed by mega-constellations to ensure that US companies, government agencies, and scientists have continued safe and reliable shared access to these finite resources.

The Biden-Harris Administration has already demonstrated its commitment to science-based policymaking and to the environment.[25] That initiative should include a rigorous examination of the environmental threats posed by mega-constellations to our shared resources in space and here on Earth. The U.S. should lead in establishing sustainable environmental policies in the New Space Age — not continue existing practices that perpetuate the current reckless rush to fill space with mega-constellations before suitable rules and policies can be put in place. If the Biden-Harris Administration acts expeditiously, America can get in front of these threats and lead the world.

Conclusion

The standard the Biden-Harris Administration sets today with respect to mega-constellations -- whether by action or inaction -- is what the global satellite industry will soon follow. It is unquestionable that mega-constellations pose a variety of significant environmental threats, and that NEPA requires these issues to be fully examined. By instituting and applying high standards for environmental protections, the Biden-Harris administration can ensure our shared space resources are used safely and in a manner that limits environmental harm both in space and on Earth.

[25] The White House, "FACT SHEET: President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government." January 27, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/.

Frequently Asked Questions

Satellites are not new – why should this be an early priority for the administration?

A new and very different use of space is occurring in the form of constellations of thousands, or even tens of thousands, of satellites in the part of space nearest Earth, and known as "Low Earth Orbit" (LEO), which is already congested with space objects. These "mega-constellations" are considered "game changers" and even their proponents describe these proposals as "unprecedented" in nature.[26] These mega-constellations are being advanced without a full evaluation on the environmental costs they impose, and without regard for whether the same objectives could be achieved in a more environmentally friendly manner — or if the missions to be served by these mega-constellations are in fact worth the environmental consequences. Leading third parties have detailed the expected environmental harms from these mega-constellations: air pollution, space pollution, and light and radio-frequency pollution.[27] Mistakes in space cannot be cleaned up like they can on Earth. It would be common sense to prevent junking up space in the first place. Moreover, decisions made — or not made — during the course of this year as more mega-constellations satellites are approved for deployment will set the standard for the global space industry and the design of additional satellite constellations in LEO.

Are there sufficient environmental impacts on Earth to warrant environmental review?

Yes. The vaporization of mega-constellation satellites when they deorbit and reenter the atmosphere releases chemical compounds that could contribute to climate change through, among other things, radiative forcing and ozone depletion.[28] That process poses a new source of air pollution in the form of small particles comprising "a zoo of complex chemical types" that will "form around an 85-kilometer altitude, then drift downward, accumulating in the stratosphere…"[29] The stratosphere where this pollution gathers is home to the fragile ozone layer that protects the Earth from UV radiation.[30] Scientists anticipate that the fact that these pollutants are directly injected into the uppermost layers of the atmosphere (top down) means that they can cause significantly greater harm than pollutants that emanate from Earth (bottom up).

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[26] OECD, "Space Sustainability: The Economics of Space Debris in Perspective"; Fernholz, "Space Business: Extraordinary! Unprecedented!"

[27] Werner, "Aerospace Corp. Raises Questions about Pollutants Produced during Satellite and Rocket Reentry"; OECD, "Space Sustainability: The Economics of Space Debris in Perspective"

[28] Organski, Barber, Barkfelt, Hobbs, Nakagawa, Ross, Ailor, "Environmental Impacts of Satellites from Launch to Deorbit and the Green New Deal for the Space Enterprise"; Werner, "Aerospace Corp. Raises Questions about Pollutants Produced during Satellite and Rocket Reentry."

[29] Ross & David, "An Underappreciated Danger of the New Space Age: Global Air Pollution."

[30] Environmental Protection Agency (EPA), "Health and Environmental Effects of Ozone Layer Depletion." September 24, 2018, https://www.epa.gov/ozone-layer-protection/health-and-environmental-effects-ozone-layer-depletion.

Particularly under these circumstances where many experts have issued calls to arms about the significant environmental effects of mega-constellations, there is no excuse for turning a blind eye by failing to conduct an environmental review. A key purpose of NEPA is to ensure that agencies look before they leap, particularly when presented with previously unanticipated circumstances that may have a significant environmental effect.[31]

Could the space industry be naturally incentivized to operate responsibly in space?

The FCC has long recognized the lack of economic incentives for individual actors to act responsibly with respect to the shared resource that is space.[32] Changes in the space industry have eliminated the incentives to achieve safe-space operations that previously existed.[33] The cost of launch has dropped precipitously, reducing the cost of access to space. Economies of scale that enable small, inexpensive payloads are driving investment in inexpensive and economically expendable satellites. When the cost of space access is high, self-interest motivates high standards of care because the cost of failure is high. The term "space-qualified" once meant the industry's highest standards for quality and reliability, even in the harsh conditions of space. Those high costs once fostered a safe space ecosystem: the number of objects in space was limited, and the rules to manage the risks were adequate. With economic barriers gone, self-interest and the public good are quickly diverging. The cost of failure to an individual actor is far, far less than the collective risk of multiple individual failures — a long-anticipated "tragedy of the commons" in space.

Is this a choice between better broadband and a clean environment?

Not at all. Many different advances in satellite technology over the past several years are providing significant increases in both broadband speeds and capacity for consumers. Satellite operators have proposed systems with fewer, more reliable satellites that can achieve the same objectives as mega-constellations, and without high levels of negative environmental impacts.

Professor Andy Lawrence, author of *Losing the Sky*, recently said it best: "Giving people better Internet, and keeping Capitalism healthy and competitive, is quite possible *without* thousands of low orbit satellites. Why should we accept arbitrary degradation and pollution when it's not even necessary?"[34] Particularly when experts, including the FCC, recognize that many satellite operators do not have a natural incentive to protect common natural resources (space, the atmosphere, Earth) for the benefit of others, it is essential to adopt regulations and licensing approaches that ensure we can both have access to the most advanced technology and also maintain a safe and clean environment. Many options exist, and the number and reliability of

[31] 40 C.F.R. § 1501.4.
[32] FCC, "Mitigation of Orbital Debris in the New Space Age," Notice of Proposed Rulemaking (November 2018), Par. 88-89; Further Notice of Proposed Rulemaking (April 2020), Par. 25.
[33] Statement of now-acting FCC Chairwoman Jessica Rosenworcel, FCC Hearing on Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System.
[34] Andy Lawrence, *Losing the Sky* (Edinburgh: Photon Publications, 2021), 70.

satellites in a LEO constellation is a design choice that companies can make to ensure that consumers have both better broadband and assurances of a safe and clean environment.

Aren't LEO orbits the safest place to operate?

There is no direct correlation between the altitude at which a LEO satellite system operates and the risk of collision involving that system. A number of factors come into play in assessing safety, including the density of objects in a given orbit. Some orbits are denser than others, meaning that satellites and space junk are less dispersed. In fact, "the most crowded section is between 500 and 1000 km up. It's the densest region, it's the Highway 401 of space."[35] Then you have to consider the defunct satellites and space junk in higher orbits that will naturally deorbit through lower orbits and create collision risks. The scale of a given constellation (number of satellites) and its design are also major factors in assessing collision risk.

Aren't LEO orbits naturally "clean"?

Satellites that cannot maneuver cannot avoid collisions. And when they do collide, even collisions at 550 km would pollute orbits many hundreds of kilometers above and below, with large fields of fast-moving shrapnel-like space junk that would traverse other orbits for decades or a century, as well as impair use of those orbits and harm many other users of space. Furthermore, having satellites in lower orbits does not solve the atmospheric pollution issue. And as leading experts explain, mega-constellation satellites in low orbits are most visible when most ordinary people are looking at the sky, as well as when key optical astronomical observations need to take place.[36] These satellites also can be visible all night in summer because of the relationship of the Sun to the Earth at that time of year.[37] Moreover, interference with radio astronomy does not depend on the time of day because the glare of the interfering signals beams down all of the time.[38]

Why is this not a matter for an international body like the United Nations Office of Outer Space Affairs through the Outer Space Treaty?

To be sure, there is a role for international cooperation to ensure a clean atmosphere, safe and shared access to space, and a dark and quiet night sky. But only national regulators can ensure that actually occurs in how they fulfill their obligations regarding shared use of space in national licensing and policy-making decisions. Recent reports from OECD and the UN's COPUOS working group emphasize the need for a national-level focus on the environmental threats created by mega-constellations.

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[35] Asher Isbrucker, "Kessler Syndrome: What Happens When Satellites Collide." *Medium*, November 2, 2018, https://asherkaye.medium.com/kessler-syndrome-what-happens-when-satellites-collide-1b571ca3c47e.
[36] Lawrence, *Losing the Sky*, 22.
[37] Ibid.
[38] Ibid, 48.

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About the Day One Project

The Day One Project is dedicated to democratizing the policymaking process by working with new and expert voices across the science and technology community, helping to develop actionable policies that can improve the lives of all Americans. For more about the Day One Project, visit dayoneproject.org