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Space for Progress, Earth for Keeps:

An Integrated Framework for Space and the Environment

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INTRODUCTION

These are boom times for the space business.

In the U.S. alone, satellite launches have surged more than 600% over the past decade,[1,2] and their pace is only expected to accelerate as the race to deploy data centers into orbit heats up.[3] What happens in space now touches almost every aspect of modern life, from agriculture to national security to navigation to internet access.

But as our activity in space picks up, so does the need to study its effect on Earth's atmosphere and find ways to prevent potential harm.

This paper is an attempt to jumpstart a nuanced conversation about how to address these environmental issues without sacrificing the benefits of our growing space presence, which are too great to lose and felt daily by everyday Americans.

In Washington, discussions about the space industry's impact on our atmosphere often focus on a binary question about whether or not there should be more regulation. This is a mistake that ignores the many major questions still in need of answers. We believe it would instead be beneficial to find a pragmatic, integrated path forward that engages both industry and government in identifying ways to maximize our rewards from space and minimize atmospheric effects.

Crafting this integrated approach will require tying together several different policy and scientific conversations.

To understand the potential harm side of the equation, it is essential to study the impact of rocket fuel emissions into the atmosphere and of satellites largely breaking up into particulate matter during reentry. While there are also concerns about the footprint of space activities on Earth from siting to discharges of pollutants, we already have established statutory and regulatory frameworks in place to govern them. Our focus in this report is on the less understood and unseen atmospheric and near-Earth environment.

To calculate the benefits, we need to broadly map the contributions that space-based science bring home in the areas of emergency and environmental management, agriculture, and conservation. Congress has fortunately resisted budget cuts to NASA and other climate agencies proposed by the Trump administration that would make this task much harder. But as we're thinking about the environmental return on investment in space, the conversation should be evolving from merely sustaining research to how we maximize the impact of data gleaned from space using new tools, partnership structures, and audiences.

There are five primary questions policymakers need answers to in order inform thoughtful, integrated solutions:

1. What exactly is the environmental impact of space activities on the atmosphere?
2. Do different fuels and materials used in space activities have differing impacts on the atmosphere and near-Earth environment?
3. If there is a negative environmental impact, are there ways of minimizing it beyond fuels and materials, such as changing concepts of operations?
4. How can we apply lessons learned from other industries and experiences to avoid repeating the mistakes of the past?
5. How can humanity squeeze as much environmental management and conservation benefit as possible out of space activities for people on Earth?

These questions are each insufficient on their own — they need to be considered holistically and in context with each other. But even before we learn their answers, there are clear next steps to be taken, covering a wide range of issues. They include:

- Fighting to continue funding for NASA Earth Science, National Oceanic and Atmospheric Administration (NOAA) climate research, and interagency research on the climate costs of space activities, as well as preserving capabilities housed at the National Center for Atmospheric Research (NCAR), which uses satellites and other kinds of sensors to detect atmospheric changes
- Building on the momentum of NASA programs that enable communities to productively engage with Earth systems information, including climate data
- Encouraging more partnerships between local and state governments, nonprofits, industry, and others to expand our knowledge of Earth systems
- Taking small steps now towards novel research and development initiatives, requiring and/or incentivizing government missions to carry sensors taking real-world (in situ) climate measurements whenever

feasible, and extensive industry engagement on this topic

SPACE TECHNOLOGY AND EARTH SCIENCE

It would be a grave mistake to think of our activities in space purely as an environmental hazard. While sending satellites into orbit might potentially pose risks to the atmosphere, space-based technologies have also become integral to modern conservation and climate efforts.[4, 5, 6]

Consider the terabytes of freely available data that are generated each day by publicly funded satellite systems. Conservation organizations, emergency planners, and natural resource managers all use this information to make timely decisions by pairing it with GPS data and sensors on the ground, as well as tools that harness the power of artificial intelligence.

For example, AI models trained on different kinds of sensor inputs can now detect illegal fishing, monitor agricultural resilience, assess drought impacts, and map fire damage with precision.[7, 8] Platforms like Skylight and SkyTruth are using machine learning to analyze reams of satellite data each day, translating imagery into insights for field teams and regulators.[9, 10] These capabilities are broad in reach, from large institutions to nonprofits, students, journalists, and local governments, democratizing environmental intelligence.

NASA and IBM's collaboration on geospatial AI foundation models is another key case in point. An AI foundation model means it has been trained on vast amounts of data that the AI uses to teach itself[11] — in this case, that data is from Landsat, one of NASA's longest-running Earth science missions, and the European Space Agency's Sentinel. Since its release to the public in August 2023, the portfolio has grown to include specialized foundation models designed for atmospheric research. Surya, the latest, can help predict how solar activity affects Earth, satellite infrastructure, and space-based technology in less time and with greater accuracy than previous methods. According to IBM, this ecosystem of models, tools, and benchmarks have been downloaded more than 600,000 times.[12]

NASA's latest Earth Science missions are having huge impacts too. Take the Surface Water and Ocean Topography (SWOT) satellite NASA operates with France's space agency, CNES. SWOT features advanced radar capable of measuring the height of nearly all the water on Earth's surface — oceans, lakes, and rivers — every 21 days.[13] A 2025 study marked the first application of SWOT in vegetated wetlands, revealing that the satellite could measure water levels in Florida's Everglades with centimeter-level accuracy, far exceeding pre-launch expectations. The researchers found a strong correlation between SWOT and gauge data across over 100 wooded wetland sites, demonstrating that SWOT can track subtle seasonal water level variations across vast and remote wetland ecosystems.[14] Since most wetlands aren't as closely monitored as the Everglades, this mission opens the door for the first time for those communities to use data from SWOT to more effectively manage their wetlands and preserve fresh water access for years to come.

NASA also works to ensure its data reaches beyond the scientific community by making it as easy to work with as possible — another clear boon for environmental efforts. The agency has adopted an open science policy that hard-wires rapid, free release of data, software, and publications.[15] NASA also began investing in advanced computer science programs well before missions launch, often using test flights and airborne instruments to prototype algorithms and workflows.[16, 17] Standards and policies now emphasize turning data around quickly — from near real time for hazards monitoring to within a day or two for recent major missions compared to traditional 30-day waits.[18, 19]

Just as important, NASA now builds real-world applications into mission planning from the start, with programs like the Early Adopters initiative ensuring that federal agencies that manage resources or respond to disasters — FEMA, USGS, and USDA — are at the table from day one.[20] And, to widen the aperture of uptake, NASA's Applied Remote Sensing Training (ARSET) program provides online and in-person trainings, building the capacity of professionals to use satellite data for decision-making in disaster management, agriculture, air quality, and other sectors.

Together, these changes mean that scientific discovery and real-world use are no longer on separate tracks when it comes to space missions: they are happening side by side, designed to make Earth observations rapidly relevant and practical. Now the question is how to expand this program to a broader audience, including normal, everyday Americans.

NASA is not the only home for important space-based research relevant to the climate. The NOAA and NCAR are giants in this area, too. Both use data from satellite systems to enhance humanity's understanding of the planet in practical ways. NOAA examines and predicts weather events with help from its Geostationary Operational Environmental Satellite (GOES) series as well as its polar orbiting satellites, while NCAR contributes to those efforts and provides data on air quality.[21, 22, 23]

As the cost to launch, design, and operate satellites has come down, the door has opened to unconventional partnerships in this arena outside the federal government. FireSat represents a new test case. The satellite initiative is led by the nonprofit Earth Fire Alliance in partnership with Muon Space, Google Research, the Gordon & Betty Moore Foundation, and Environmental Defense Fund. By 2030, the program will be able to detect wildfires as small as 5×5 meters and provide global coverage approximately every 20 minutes.[24] State agencies like CAL FIRE and the Texas A&M Forest Service are already signing up to participate in FireSat's Early Adopter Program, highlighting the value these satellites will provide. Beyond the wildfire detection constellation, the Earth Fire Alliance is also investing in software that visualizes satellite orbits and sensor coverage. This will make the raw data provided to fire and forest agencies even more useful operationally, because they will better understand when they'll get the next look at the patch of land in question, aiding in timely, informed decision-making.[25]

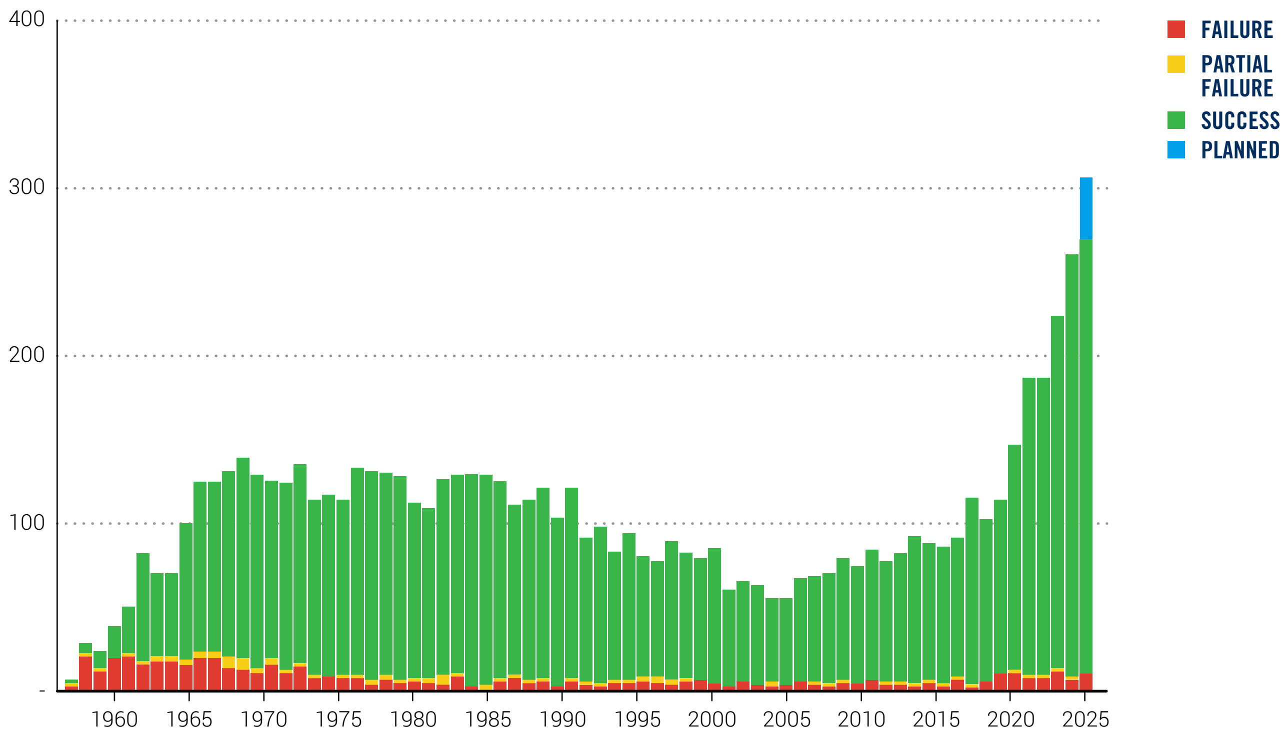
The FireSat partnership came together to use space for emergency management and preparedness benefits here on Earth in a manner that was still only in the idea phase a decade ago, on an issue that touches air quality, housing, and health. These partnerships are still new and time will tell if the model is scalable to other kinds of weather or climate phenomena. As space becomes easier and easier to access, it would be pragmatic to study FireSat's outcomes and figure out how to incentivize additional partnerships of this nature.

THE UNANSWERED ENVIRONMENTAL QUESTIONS

While satellites contribute greatly to conservation efforts, emergency management, climate, agriculture, and our understanding of the Earth's climate, the overall growth in space activity brings new environmental concerns, too. This is not unique to the space industry; many innovations, such as AI, have raised major ecological questions even as intense global competition created pressure to roll them out quickly. As in those other sectors, it's vital that we work to understand the space industry's potential ripple effects while continuing to advance progress.

And the time for that work is now.[26] There are 100,000 satellites expected to be in orbit by 2030,[27] and SpaceX alone has filed to launch one million orbital data centers into space in the coming years.[28] At least eight other companies are planning their own orbital data center constellations.[29] That will require thousands of launches and result in satellite reentries at a far higher rate. Both rocket launch and satellite reentry involve the release of emissions and particulates like black carbon, aluminum, and CO2, and more into the upper atmosphere. At this time, there are more questions than answers when it comes to understanding the effects. Scientists are still learning how space activities generate these particulates and emissions, as well as how to accurately model what their impact may be on the atmosphere. Depending on the rocket fuel used, rocket launches emit black carbon, chlorine gas, water, and other emissions into the upper atmosphere. There has not yet been research on emissions generated by all popular fuels; there is extremely limited research on the impact of these emissions more generally.[30] Studies today model rocket launch climate impacts using estimates that are reasonable but aren't based on actual observations and measurements from modern, real-world rocket launches. The dearth of good data introduces inherent uncertainty into these models despite scientists relying on the best possible information available. This was identified by a federal interagency research proposal as the largest research gap in this field.[31]

FIGURE 1: LAUNCH STATISTICS (1957-2025)



Source: Wikipedia, Timeline of Spaceflight

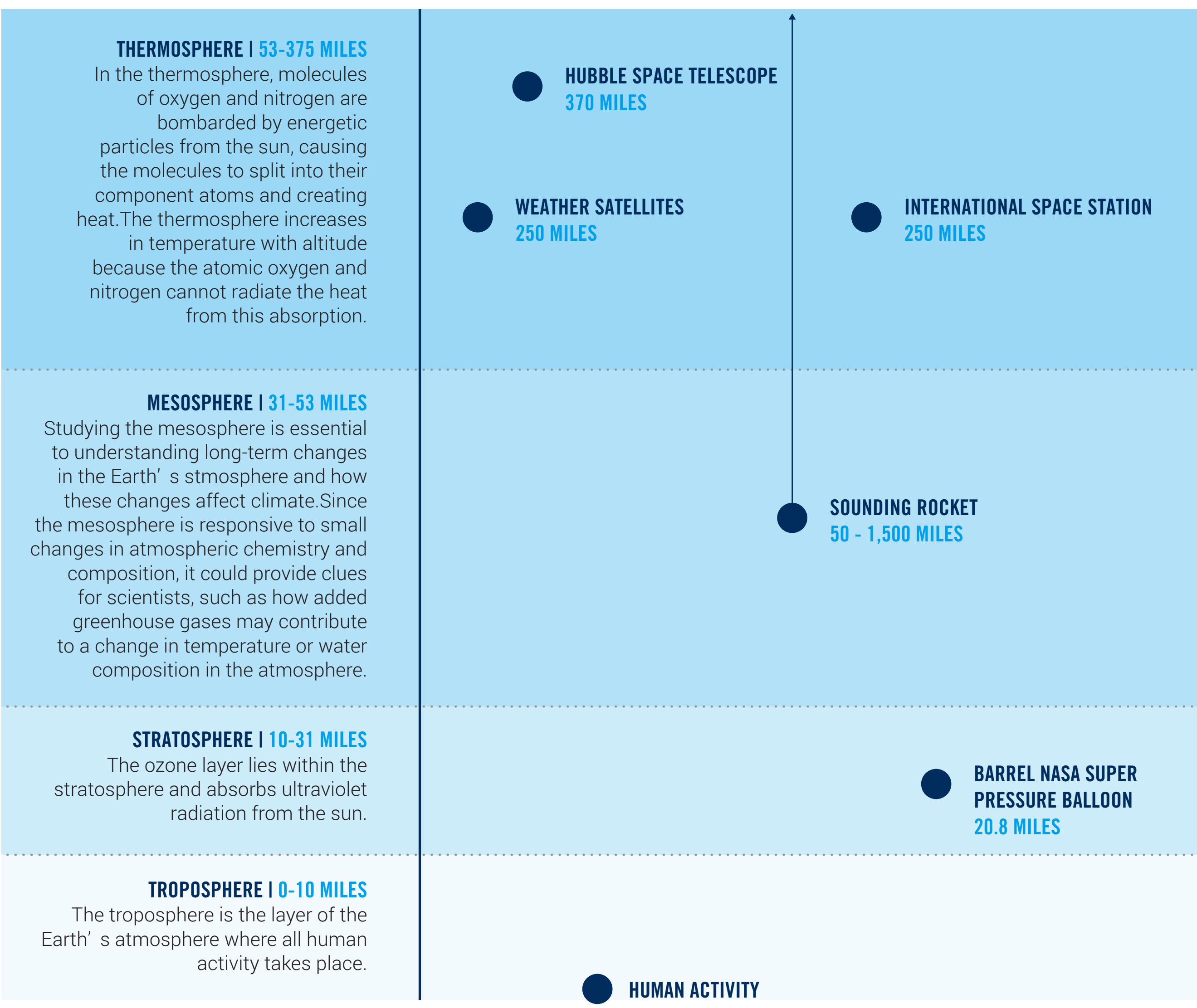
The impact of satellite reentry is not well understood either. Satellites are typically designed to largely burn up as they reenter the atmosphere, protecting human lives and property from big, high-velocity pieces of debris that would otherwise hurtle towards Earth's surface. The alternative is to leave the hardware in space where it becomes orbital debris, taking up valuable real estate and endangering other space assets.[32] Recent research found that "the population of reentering satellites in 2022 caused a 29.5% increase of aluminum in the atmosphere above the natural level." The finding is significant because aluminum oxide particles could provide a surface for ozone-depleting chemical reactions to occur, though there is uncertainty around whether and how often those reactions are, in fact, happening.[33] This area urgently needs study, lest we undermine the substantial and successful international work done decades ago to protect the ozone layer, which absorbs most of the Sun's UV radiation that is harmful to human health.[34]

The 2022 study referenced above only looks at the impact of one common material used in satellite production — aluminum — and develops a model based on knowledge from a singular set of real-world (in situ) observations. Thus, it has serious limitations. There has been nascent research using LIDAR to detect another particle — lithium — following a spacecraft reentry event, which is a breakthrough for a field that has struggled to detect particulate matter resulting from such events in an attributable manner, though to date it has only been used for one study.[35]

This underscores the need for a deeper look. Astronomer Jonathan McDowell notes that "the amount of space debris vaporizing in Earth's atmosphere has more than doubled in the past few years."[36]

Another interesting wrinkle is the impact that climate change will have on human operations and assets in space. A recent MIT study found that climate change is causing the thermosphere — the portion of the atmosphere that most satellites orbit in — to contract. The researchers note that this could reduce the carrying capacity of the most crowded orbits by 50% to 66% by the end of the century.[37] In other words, industry has a vested interest in understanding and mitigating their climate impacts, too.

FIGURE 2: DIAGRAM OF THE LAYERS OF EARTH'S ATMOSPHERE



Source: NASA

The bottom line, says astrophysicist John Barentine, is that "The climate is an incredibly complex system, and when you rapidly perturb that system, you run the risk of chaos."[38] As we see rocket launch cadence accelerating alongside satellite reentries, the time is ripe to expand knowledge on potential impacts to mitigate risk.

THE CHALLENGES AHEAD

There is significant work to be done in maximizing the environmental benefit of space activities, understanding the environmental costs, and incentivizing partnerships between a diverse set of actors that can complement federal efforts.

Making better use of the extraordinary environmental data generated by many space missions should be one area of focus. This data was historically siloed within the scientific and aerospace communities. While the U.S. government has made great strides towards expanding access to that data, there is still room for improvement.

But today the greater challenge is funding. The Trump administration proposed massive cuts to Earth science, weather, and climate-relevant programs in its FY26 budget[39] — meaning the data our nation has enjoyed is in danger of going dark. The administration also proposed dismantling the National Center for Atmospheric Research altogether. The White House has stated it will rehome National Center for Atmospheric Research capabilities it considers "vital," such as weather forecasting, but it is challenging to see how that is possible given the exquisite and highly sensitive infrastructure at the site.[40]

So far, Congress has rejected these proposals. The final enacted appropriations language for fiscal year 2026 wisely restored funding for Earth Science, NOAA, and the National Center for Atmospheric Research.[41] But the Office of Management and Budget has already made headlines for withholding NASA science funds that were appropriated.[42] It's clear sustained advocacy and vigilance are needed to ensure appropriated funds are spent by the agencies and avoid future attacks in the coming years.[43, 44] Inflation compounds the problem as it means a flat funding level buys almost 3% less in real terms.[45]

TABLE 1: SELECTED EARTH SCIENCE, WEATHER AND CLIMATE-RELEVANT BUDGET LINES: FY26

	ENACTED FY25	PRESIDENT'S BUDGET REQUEST FY26	HOUSE MARK-UP FY26	SENATE MARK-UP FY26	ENACTED FY26
NASA EARTH SCIENCE	$2.195B	$1.036B	$1.325B	$2.166B	$2.153
NOAA	$6.1825B	$4.8638B	$5.795B	$6.141B	$6.1709B
NCAR	$127.66M	$77M	Not specified	Not specified	Not specified

Flat funding comes at a time when decades of U.S. leadership in remote sensing and Earth science research is shrinking. China's industry has "closed the gap with the United States … in most applications and sectors," particularly in multispectral and hyperspectral satellite imaging, radar, and positioning systems that form the backbone of modern Earth observation.[46] Beijing is scaling these satellite-based capabilities into manufacturing and applications, such as LiDAR for autonomous vehicles and small-drone platforms, and is in position to capture emerging Earth observation markets.

The Commercial Space Federation warns that these advances — backed by disciplined state investment and rapid expansion of remote sensing and satellite constellations — now "fundamentally alter the competitive and strategic landscape for the United States and its partners," posing direct risks to American leadership in Earth observation and industrial competitiveness.[47] To contextualize this, "the global market was valued at $452 billion in 2022 and is projected to reach $1.44 trillion by 2030."[48] These cuts are harmful to the very innovative public-private partnerships the nation should be encouraging, as government programs directly and indirectly contribute to the innovation, talent, and success of the robust U.S. commercial space sector in remote sensing as well as other fields.

Setting budget matters aside, the U.S. has simply put much of its critical research related to the environmental impact of our activities in space on hold. NOAA had been leading the federal work, but its projects on the topic were frozen by the Trump administration.[49] Academics have called for remote and in-situ sampling, model improvement, and emissions inventorying, some of which NOAA was starting to conduct.[50] An interagency working group — including NOAA — had collaborated on a paper evaluating what's currently known about the environmental impacts of space and where key gaps exist in the world's knowledge base. They found substantial gaps in knowledge and proposed a research program to address them with interagency, international, and industry partners.[51] This research program is unfortunately now sitting on the shelf.

The U.S. is not the only major source of public investment in Earth science. The European

Union also funds research in the discipline — and unlike the United States, is increasing its spending.[52] Earth observation alone comprises 16% of the budget at ESA, which recently received a 30% increase for the next three years.[53] Beyond funding, ESA is leading an orbital sustainability experiment with its end-of-life management of the Cluster mission — comprising "targeted reentries" of four identical satellites — which started with Salsa in September 2024.[54] ESA collects data on how spacecraft burn up under different atmospheric conditions. 2027's Draco mission is a dedicated satellite designed to be destroyed, where it will record and transmit live data from the inside of a fiery reentry before its own demise. This will be helpful as the world seeks additional insights on what happens during reentry. But it will not make up for the U.S. abdicating its leadership on the issue.

RECOMMENDATIONS

Where do we go from here? Minimizing the environmental costs of our space activities and maximizing the benefits will require answering major, unresolved scientific questions. But in the meantime, there is a clear path forward.

Recommendation: Sustain Funding for NASA, NOAA, and NCAR Research on Space's Environmental Impact

Congress successfully rejected the administration's disastrous cuts to NASA, NOAA, and NCAR, but that doesn't mean the fight is over. There's no guarantee that the agencies will spend their appropriated funding — they certainly haven't to date — and inflation means static funding amounts to a budget reduction. NASA Earth science, NOAA, and NCAR funding should be increased, given its significance to our understanding of the climate and weather patterns, disaster relief, and industries across the globe, like agriculture and insurance. Congress should also reject the administration's proposal to disband NCAR, given that it is home to vital climate modeling, weather forecasting, and observation platforms.

Research funding for a multi-agency effort involving NASA, NOAA, NCAR, universities, and the private sector focused on understanding the environmental costs of space activities is vital too. The knowledge gaps pertaining to space's environmental impact are well-known, and there were early-stage interagency efforts to develop a research program to scientifically quantify those effects. What's lacking is political will and funding.

Recommendation: Keep Open Science and Innovation

Federal agencies should continue investing in the translation of publicly funded geospatial data into free and accessible formats for practitioners and non-technical audiences. Examples of this trajectory already exist. The U.S. Drought Monitor integrates NASA satellite data — such as GRACE groundwater and soil moisture measurements and evapotranspiration indices derived from remote sensing — and is used by the U.S. Department of Agriculture and state agencies to inform drought relief and water management programs.[55, 56] NASA's Disaster Response Coordination System has also applied SAR flood maps during events like Hurricane Helene in 2024, when Sentinel-1 radar data allowed FEMA and state partners to assess flooding despite heavy cloud cover.[57] These cases illustrate how satellite data, once limited to specialists, are increasingly embedded in operational decision-making. The ultimate goal should be to produce tools and trainings that are relevant and easy to use at the individual level through the ARSET program or other mechanisms.

Recommendation:
FireSat as a Model to Test and Learn From

FireSat should be treated as a test case. By studying its structure, governance, data delivery, and adoption pathways, NASA and its public and private sector partners can learn how to combine technical innovation with usability. This approach could be adapted to other hazard domains. In a time of fiscal constraints, engaging nonprofit and other funding sources to provide additional complementary Earth science data is extremely productive.

Recommendation: Path Forward on Responses to Space's Environmental Impact

Once there is a clear scientific record on the environmental costs of space activities, the nation should fund research and development efforts to create innovative, efficient materials and fuels that work for space activities, as well as incentives for industry to transition to them. The cost-sharing model used by NASA's aeronautics projects is likely a starting point for how to engage in this kind of R&D, both given the clear benefits for public and private actors and given the need for any alternative to be usable by industry. There is already some exciting international R&D happening in this space, such as in Japan with the experimental all-wood satellite, LignoSat, that launched late last year.[58]

There are also actions that agencies sponsoring space activities, like NOAA, the Department of Defense, NASA, and others, can take to help gather data now, such as testing the feasibility of government missions carrying sensors taking real-world (in situ) climate measurements and incentivizing or requiring it when it is possible. Given the dearth of in situ observations, collecting this data should be a top priority.

This kind of data is an essential piece to an informed conversation about the path forward. An integrated approach also takes into account industry actions as new credible information comes to light. For example, industry has been interested in and actively moving towards cleaner fuels like methalox. There are a variety of reasons for this, including the environmental footprint of the fuel.[59] In addition, there are positive instances of industry making changes to materials when they present a threat to humans. The most recent example is SpaceX's modifications to some of its components to ensure their spacecraft fully burns up upon reentry.[60] This underscores the need for time to allow for iteration, learning, and engagement with industry ahead of any attempts to solve problems with new regulation.

CONCLUSION

As the environmental footprint of activities in space expands, U.S. policymakers must find ways to reduce risks without impairing the competitiveness of America's dynamic space economy. The next steps towards that goal aren't rocket science, though in a political climate that undermines the importance of pushing scientific frontiers to improve the lives of Americans, they certainly seem challenging. Congress must engage with this topic to ensure the appropriate balance between environmental concerns and economic competitiveness is struck in an evidence-based manner.

ABOUT THE AUTHORS

Mary Guenther is the Head of Space Policy at the Progressive Policy Institute. In this role, Mary focuses on evaluating and developing policy solutions that address how the United States government's relationship with space actors should evolve and how to best harness the benefits of space for people here on Earth.

Prior to joining PPI, Mary served as the Vice President of Space Policy at the Commercial Space Federation (CSF). In that role, Mary drove consensus on space policy issues amongst roughly 90 member companies representing various facets of the commercial space economy and engaged with lawmakers, executive agencies, and the public to get those policy solutions implemented.

Prior to CSF, Mary served as a Professional Staff Member at the United States Senate Committee on Commerce, Science, and Transportation focusing on space, science, emerging technology, cybersecurity, and manufacturing policy. In that role, she worked with colleagues to author and pass through the Senate the CHIPS and Science Act as well as a variety of smaller pieces of legislation.

Susie Perez Quinn is a Principal at Plum & Talon where she advises organizations operating at the center of federal decision-making. She brings decades of experience leading complex operations inside the legislative and executive branches of government that allocate funding, conduct investigations, and set national policy direction. She served as Chief of Staff and Senior Advisor at NASA during historic mission execution, overseeing agency operations and cross-government coordination during the James Webb Space Telescope deployment and the Artemis I launch. Before NASA, she spent nearly two decades in the U.S. Senate — including 17 years in the US Senate, culminating as Chief of Staff to Senator Bill Nelson — directing legislative strategy and appropriations negotiations across defense, space, and environmental portfolios. During the COVID-19 pandemic, she led government relations at the National Governors Association and organized a coalition that secured $500 billion in direct federal assistance.

References

1 "Historic Number of Launches Powers Commercial Satellite Industry Growth – Satellite Industry Association Releases the 28th Annual State of the Satellite Industry Report," Satellite Industry Association, May 13, 2025, https://sia.org/historic-number-of-launches-powers-commercial-satellite-industry-growth-satellite-industry-association-releases-the-28th-annual-state-of-the-satellite-industry-report/.

2 Jeff Foust, "Launch Activities Hits 20-Year High in 2014," *Space News*, December 31, 2014, https://spacenews.com/launch-activity-hits-20-year-high-in-2014/.

3 Micah Maidenburg and Becky Peterson, "Bezos and Musk Race to Bring Data Centers to Space, *The Wall Street Journal*, December 10, 2025, https://www.wsj.com/tech/bezos-and-musk-race-to-bring-data-centers-to-space-faa486ee.

4 "NASA Sea Level Change," NASA, accessed March 9, 2026, https://sealevel.nasa.gov/.

5 Marine Drouilly et al., "Spotted! Remote Camera Traps Used in a Novel Design Reveal a Perilous situation for the Critically Endangered Northwest African cheetah (Acinonyx jubatus hecki) in a Conflict-Affected Protected Area in Benin," *Ecological Solutions and Evidence* 6, no.2 (2025). https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/2688-8319.70036.

6 "Satellite Oceanography," National Marine Fisheries Service, accessed March 9, 2026, https://www.fisheries.noaa.gov/national/science-data/satellite-oceanography.

7 Solomon Kica et al., "SWOT Water Surface Elevation in Herbaceous Wetlands of Florida's Everglades," *Geophysical Research Letters* 52, no.9 (2025). https://doi.org/10.1029/2025GL114956.

8 Thomas M. Pavelsky et al., "Applications of AI in Earth Observation for Environmental Management," *arXiv preprint* (2024), https://arxiv.org/abs/2505.03808

9 "Skylight," Allen Institute for AI, accessed March 10, 2026, https://allenai.org/skylight.

10 "Earth Observation Leadership," IBM Research, accessed March 10, 2026, https://research.ibm.com/blog/earth-observation-leadership https://skytruth.org/about/technology/.

11 "What Are Foundation Models?," Google Cloud, accessed March 9, 2026, https://cloud.google.com/discover/what-are-foundation-models

12 "Earth Observation Leadership," IBM Research, accessed March 10, 2026, https://research.ibm.com/blog/earth-observation-leadership https://skytruth.org/about/technology/.

13 "Surface Water and Ocean Topography (SWOT)," NASA Jet Propulsion Laboratory, accessed March 10, 2026, https://podaac.jpl.nasa.gov/SWOT.

14 Solomon Kica et al., "SWOT Water Surface Elevation in Herbaceous Wetlands of Florida's Everglades," *Geophysical Research Letters* 52, no.9 (2025). https://doi.org/10.1029/2025GL114956.

15 "Science Information Policy," NASA, accessed March 10, 2026, https://science.nasa.gov/researchers/science-information-policy/.

16 "Advanced Information Systems Technology (AIST)," NASA Earth Science Technology Office, accessed March 10, 2026, https://esto.nasa.gov/aist/.

17 "ACCESS Competitive Programs," NASA Earthdata, accessed March 10, 2026, https://www.earthdata.nasa.gov/about/competitive-programs/access.

18 "NISAR Mission," NASA, accessed March 10, 2026, https://science.nasa.gov/mission/nisar/.

19 "MODAPS Near Real-Time Processing System," NASA Earth Observing System Data and Information System (EOSDIS), accessed March 10, 2026, https://nrt3.modaps.eosdis.nasa.gov.

20 "AGU Fall Meeting Abstract: 2020AGUFMSY026.08," NASA Astrophysics Data System, accessed March 10, 2026, https://ui.adsabs.harvard.edu/abs/2020AGUFMSY026.08/abstract.

21 "Celebrating 50 Years of GOES Satellites," accessed March 10, 2026, NOAA National Environmental Satellite, Data, and Information Service (NESDIS), https://www.nesdis.noaa.gov/our-satellites/currently-flying/goes-east-west/celebrating-50-years-of-goes.

22 Elizabeth Baker, "NSF-NCAR Satellites Deployed to Measure Air Quality over Four Countries in Asia," *Meteorological Technology International,* February 14, 2024, https://www.meteorologicaltechnologyinternational.com/news/data/nsf-ncar-satellites-deployed-to-measure-air-quality-over-four-countries-in-asia.html.

23 "Satellite Remote Sensing," National Center for Atmospheric Research (NCAR), accessed March 10, 2026, https://weather.ral.ucar.edu/satellite/.

24 "FireSat Protoflight Commences, Ushering in a New Era of Wildfire Monitoring & Detection," Earth Fire Alliance, accessed March 10, 2026, https://www.earthfirealliance.org/press-release/protoflight-launch.

25 Sandra Erwin, "FireSat Adds Orbit-Visualization Software to Help Firefighters Plan Around Satellite Passes," *Space News*, February 4, 2026, https://spacenews.com/firesat-adds-orbit-visualization-software-to-help-firefighters-plan-around-satellite-passes/.

26 "Historic Number of Launches Powers."

27 "Around 100,000 Satellites Are Expected to Be in Orbit by 2030," European Space Agency (ESA), accessed March 10, 2026, https://www.esa.int/ESA_Multimedia/Images/2025/04/Around_100_000_satellites_are_expected_to_be_in_orbit_by_2030.

28 Micah Maidenburg and Becky Peterson, "Bezos and Musk Race to Bring Data Centers to Space, *The Wall Street Journal*, December 10, 2025, https://www.wsj.com/tech/bezos-and-musk-race-to-bring-data-centers-to-space-faa486ee.

29 Sabastian Moss, "SpaceX Files for Million-Satellite Orbital AI Data Center Mega Constellation," Data Center Dynamics, January 31, 2026, https://www.datacenterdynamics.com/en/news/spacex-files-for-million-satellite-orbital-ai-data-center-megaconstellation/.

30 Surendra P. Sharma, "Impact of Spaceflight on Earth's Atmosphere: Climate, Ozone, and the Upper Atmosphere," NASA Technical Memorandum NASA/TM-20240013276 (California: NASA Ames Research Center, 2024), https://ntrs.nasa.gov/api/citations/20240013276/downloads/NASA-TM-20240013276-V6.pdf.

31 Sharma, "Impact of Spaceflight."

32 "NASA's Efforts to Mitigate the Risks Posed by Orbital Debris," NASA Office of Inspector General, January 27, 2021, https://oig.nasa.gov/wp-content/uploads/2024/02/ig-21-011.pdf.

33 José P. Ferreira et al., "Potential Ozone Depletion From Satellite Demise During Atmospheric Reentry in the Era of Mega-Constellations," Geophysical Research Letters 51, no. 11 (2024), https://doi.org/10.1029/2024gl109280.

34 "Aura's Ozone," NASA, August 26, 2024, https://science.nasa.gov/mission/aura/ozone/.

35 Robin Wing et al., "Measurement of a Lithium Plume from the Uncontrolled Re-Entry of a Falcon 9 Rocket," Communications Earth & Environment 7, no. 1 (2026), https://doi.org/10.1038/s43247-025-03154-8.

36 Tereza Pultarova, "The World's next Big Environmental Problem Could Come from Space," MIT Technology Review, December 9, 2024, https://www.technologyreview.com/2024/12/09/1108076/satellite-reentry-atmospheric-pollution/.

37 William E. Parker, Matthew K. Brown, and Richard Linares, "Greenhouse Gases Reduce the Satellite Carrying Capacity of Low Earth Orbit," Nature Sustainability 8, no. 4 (2025): 363-372, https://doi.org/10.1038/s41893-025-01512-0.

38 Tom Perkins, "Trump Administration to Stop US Research on Space Pollution, in Boon to Elon Musk," *The Guardian*, May 7, 2025, https://www.theguardian.com/us-news/2025/may/07/space-pollution-elon-musk.

39 "The President's FY 2026 Discretionary Budget Request," The White House Office of Management and Budget, May 2, 2025, https://www.whitehouse.gov/omb/information-resources/budget/the-presidents-fy-2026-discretionary-budget-request/.

40 Rachel Frazin, "Vought Says National Science Foundation to Break up Federal Climate, Weather Research Center," *The Hill*, December 17, 2025, https://thehill.com/policy/energy-environment/5652674-ncaf-research-faces-cuts/.

41 Via NSF - NCAR is not referenced in the legislation.

42 Audrey Decker, "White House Withholds NASA Science Funds," *E&E News*, February 11, 2026, https://www.eenews.net/articles/white-house-withholds-nasa-science-funds/.

43 U.S. Congress, Senate, *Commerce, Justice, Science, and Related Agencies Appropriations Act of 2026*, S 2354, 119th Congress, introduced in Senate July 7, 2025, https://www.congress.gov/bill/119th-congress/senate-bill/2354.

44 U.S. Congress, House, *Commerce, Justice, Science, and Related Agencies Appropriations Act of 2026*, HR 5342, 119th Congress, introduced in House September 12, 2025, https://appropriations.house.gov/sites/evo-subsites/republicans-appropriations.house.gov/files/evo-media-document/fy26-commerce%2C-justice%2C-science%2C-and-related-agencies-bill-text.pdf.

45 "Consumer Price Index - January 2026," Bureau of Labor Statistics, February 13, 2026, https://www.bls.gov/news.release/pdf/cpi.pdf.

46 "China's Remote Sensing," OTH Intelligence Group LLC, December 2024, https://www.uscc.gov/sites/default/files/2024-12/Chinas_Remote_Sensing.pdf.

47 "Redshift: The Acceleration of China's Commercial and Civil Space Enterprise & The Challenge to America," Commercial Space Federation, September 2025, https://commercialspace.org/wp-content/uploads/2025/09/CSF-Redshift-v6.pdf.

48 "China Commands 47% of Remote Sensing Research, While U.S. Produces Just 9%, NYU Tandon Study Reveals," NYU Tandon School of Engineering, November 4, 2025, https://engineering.nyu.edu/news/china-commands-47-remote-sensing-research-while-us-produces-just-9-nyu-tandon-study-reveals.

49 Tom Perkins, "Trump Administration to Stop US Research on Space Pollution, in Boon to Elon Musk," *The Guardian*, May 7, 2025, https://www.theguardian.com/us-news/2025/may/07/space-pollution-elon-musk.

50 Christopher M. Maloney et al., "Investigating the Potential Atmospheric Accumulation and Radiative Impact of the Coming Increase in Satellite Reentry Frequency," *Journal of Geophysical Research: Atmospheres* 130, no. 6 (2025), https://doi.org/10.1029/2024jd042442.

51 Surendra P. Sharma, "Impact of Spaceflight on Earth's Atmosphere: Climate, Ozone, and the Upper Atmosphere," NASA Technical Memorandum NASA/TM-20240013276 (California: NASA Ames Research Center, 2024), https://ntrs.nasa.gov/api/citations/20240013276/downloads/NASA-TM-20240013276-V6.pdf.

52 Rachel Jewett, "Europe Takes Space Spending to Next Level With ESA Ministerial Council," *Via Satellite*, December 2, 2025, https://www.satellitetoday.com/government-military/2025/12/02/europe-takes-space-spending-to-next-level-with-esa-ministerial-council/.

53 Yojana Sharma, "Europe Plays Catch-up with Larger Budget for Space Agency," *University World News*, November 28, 2025, https://www.universityworldnews.com/post.php?story=20251128161003573.

54 "Frequently Asked Questions: Cluster's Salsa Reentry," European Space Agency, https://www.esa.int/Science_Exploration/Space_Science/Cluster/Frequently_asked_questions_Cluster_s_Salsa_reentry.

55 "U.S. Drought Monitor Inputs," U.S. Drought Monitor, https://droughtmonitor.unl.edu/ConditionsOutlooks/Inputs.aspx.

56 "How NASA Data Stabilizes Global Markets," NASA Scientific Visualization Studio, September 15, 2025, https://svs.gsfc.nasa.gov/60003.

57 Alexander Handwerger, Catalina Taglialatela, and Cassandra Nickles, "OPERA: Mapping Flood Waters in the Face of the Storm," NASA Earthdata, November 8, 2024, https://podaac.jpl.nasa.gov/DataAction-2024-11-08-OPERA-Mapping-Flood-Waters-in-the-Face-of-the-Storm.

58 Samantha Mathewson, "Japan to Launch World's 1st Wooden Satellite in September," *Space*, June 4, 2024, https://www.space.com/japan-september-launch-first-wooden-satellite.

59 Wessel Wessels, "Using Liquid Methane As Rocket Fuel - Benefits And Drawbacks," Headed For Space, August 30, 2022, https://headedforspace.com/using-liquid-methane-as-rocket-fuel/.

60 "Updates," SpaceX, accessed March 2026, https://www.spacex.com/updates.

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