# 1AC vs American NS

#### I affirm Resolved: The appropriation of outer space by private entities is unjust.

#### My value is justice since the word unjust implies justice.

#### My Value criterion is maximizing well-being because the most just thing to do is to help as many people as possible. Also, only this framework considers lives, since lives are what matter most. Saving lives is the most just thing possible, so we must prioritize maximizing well-being. Prioritize Extinction, since it has the biggest impact.

#### Definition of Appropriation of outer space, Trapp 13

TIMOTHY JUSTIN TRAPP, JD Candidate @ UIUC Law, ’13, TAKING UP SPACE BY ANY OTHER MEANS: COMING TO TERMS WITH THE NONAPPROPRIATION ARTICLE OF THE OUTER SPACE TREATY UNIVERSITY OF ILLINOIS LAW REVIEW [Vol. 2013 No. 4]

The issues presented in relation to the nonappropriation article of the Outer Space Treaty should be clear.214 The ITU has, quite blatantly, created something akin to “property interests in outer space.”215 It allows nations to exclude others from their orbital slots, even when the nation is not currently using that slot.216 This is directly in line with at least one definition of outer-space appropriation.217 [\*\*Start Footnote 217\*\*Id. at 236 (“Appropriation of outer space, therefore, is ‘the exercise of exclusive control or exclusive use’ with a sense of permanence, which limits other nations’ access to it.”) (quoting Milton L. Smith, The Role of the ITU in the Development of Space Law, 17 ANNALS AIR & SPACE L. 157, 165 (1992)). \*\*End Footnote 217\*\*]The ITU even allows nations with unused slots to devise them to other entities, creating a market for the property rights set up by this regulation.218 In some aspects, this seems to effect exactly what those signatory nations of the Bogotá Declaration were trying to accomplish, albeit through different means.219

## My Sole Contention is Mega-constellations

### Subpoint A

#### Megaconstellations violate the non-appropriation principle, Takaya et al 18

(“The Principle of Non-Appropriation and the Exclusive Uses of LEO by Large Satellite Constellations” Yuri Takaya-Umehara [Visiting researcher at the University of Tokyo since April 2017. She was affiliated to the Kobe University to provide a course on space law to post-graduate students (2011-2017). She chairs a working group on the formulation of global norms in space law organized by the Keio University since 2018. She obtained her Ph.D. degree at the IDEST of Paris XI University in France, LL.M. at the Leiden University in the Netherlands.] Quentin Verspieren [Ph.D. in public policy @ The University of Tokyo, Assistant Professor of Space Policy @UTokyo, General Manager, Global Strategy @ArkEdge Space Inc., Associate Research Fellow @ESPI] Goutham Karthikeyan [The University of Tokyo & Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS-JAXA)] 2018 https://www.researchgate.net/publication/328094878\_The\_Principle\_of\_Non-Appropriation\_and\_the\_Exclusive\_Use\_of\_LEO\_by\_Large\_Satellite\_Constellations SM)

* LSC = large satellite constellations
* Outlines “L”SC thresholds

By investigating expected large satellite constellation projects and by reviewing existing interpretations of international space law, this paper argues that the exclusive use of specific LEO orbits by a large constellation of satellite could constitute a violation of the non-appropriation principle by means of occupation and by means of use, drawing a parallel between orbits as resources and the exploitation of tangible mineral resources in space. Based on this, the important question to be raised is what constitutes an exclusive use of a specific orbit. In other words, an important hurdle in the concrete evaluation of whether a planned or established constellation potentially violates the non-appropriation principle through an exclusive use of LEO resides in the lack of clear definition on what can be considered an exclusive use. While the authors claim that legal issue can be clearly solved in abstracto, it naturally shifts towards a regulatory challenge. This regulatory challenge consists in first defining qualitatively what is the exclusive use of an orbit before translating this definition into measurable, technical rules. In this paper, the authors define an exclusive use of an orbit by a state40 as any use that would prevent/hinder the usage of the same orbit by any other state. Translating this definition into an applicable regulation could consist in defining a threshold of orbital collision risk or a threshold of density of satellites along an orbit based on its altitude, shape, relative velocity of neighbouring objects, etc. It is however not the purpose of this space law paper. What is more appropriate here is to think about which organization or forum would be in charge of elaborating this technical definition. Serious candidates could be the ITU, with excellent track-record in dealing with the use of the GEO region but which would have to review its “first come, first served” principle, or the UNCOPUOS, aiming for the widespread adoption of a new piece of international law. Moreover, even if its rules suffer from a low implementation rates, the IADC would be an appropriate discussion platform thanks to its very deep technical focus. 6. Conclusion The various announced projects of LSC, also called mega-constellations, push existing regulations and practices to their limit, forcing researchers and practitioners around the world to rethink the applicability of existing space law principles to this new trend. In this paper, the authors, after providing background information on current LSC plans as well as recalling the legal status of the LEO region, investigate whether the deployment of an LSC having an exclusive use of an orbit constitutes a violation of the nonappropriation principle as stated in OST Article II. This paper concludes that: The exclusive use of an orbit by an LSC constitutes a violation of the non-appropriation principle by means of occupation due to the innate nature of orbit being a specific location in space that can be occupied, but most notably by means of use, considering orbits as “limited natural resources” and invoking parallels with the exploitation of natural resources in outer space; ITU’s “first come, first served” principle is reaching its limits with current LSC projects and should be re-evaluated; The main challenge ahead is not legal but technical and regulatory and consists in defining precisely what can constitute an exclusive use of an orbit and in translating such definition into a clear regulation or code of conduct.

#### Mega-constellations are coming now - space companies are planning to launch thousands of satellites – even low failure rates cause massive debris fields in orbit, Mcfall-Johnsen 20

[Morgan Mcfall-Johnsen, science reporter at Insider with a Bachelor of Science in Journalism from Northwestern University, 11-3-2020, "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, [https://www.businessinsider.com/spacex-starlink-internet-satellites-percent-failure-rate-space-debris-risk-2020-10[/Kankee](https://www.businessinsider.com/spacex-starlink-internet-satellites-percent-failure-rate-space-debris-risk-2020-10%5b/Kankee) [recut Lynbrook MD]

SpaceX is launching satellites into space by the dozens to realize Starlink, a globe-encircling constellation of spacecraft that beam affordable, high-speed internet across Earth. So far, the scheme — envisioned by SpaceX founder Elon Musk in 2015 — seems to be working. The aerospace company has even opened a public beta test across the northern US and southern Canada for $99 a month, plus $499 for a startup kit. "Other countries to follow as soon as we receive regulatory approval," Musk tweeted on October 8. However, the unprecedented project has left a trail of seemingly unresponsive spacecraft in its wake. All of the satellites are designed to be maneuverable in space using an ion engine, and even deorbit themselves to burn up in Earth's atmosphere. But satellites with malfunctioning communication or propulsion systems can fly uncontrolled and pose a hazard to other satellites, and even astronauts, circling Earth. SpaceX launched its first batch of 60 prototypes in May 2019 and, to date, has flown 895 total Starlink internet satellites. But so far around 2.5% of those spacecraft may have failed, according to data collected by Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics. "I would say their failure rate is not egregious," McDowell told Business Insider in early October. "It's not worse than anybody else's failure rates. The concern is that even a normal failure rate in such a huge constellation is going to end up with a lot of bad space junk." Some of those failures may be intentional tests, but how many (if any) is not publicly known because SpaceX hasn't released such information. As a result, astronomers like McDowell have resorted to analyzing satellite-movement data gleaned from SpaceX and the US government, showing which Starlink satellites have fallen back toward Earth and which ones are not maneuvering. (McDowell's failure calculations do not include 45 "version 0.9" satellites that SpaceX is known to have intentionally deorbited.) Before the end of October, McDowell was measuring a 3% apparent failure rate, but a recent reanalysis indicates improvement in the newest Starlink batches. Of the last 413 "version 1.0" satellites, only one appears to have died, giving these batches a failure rate of just 0.2%. Still, McDowell notes that many of these satellites have only been in space for a few months, so more of them are likely to fail going forward. "Nevertheless it does seem that the reliability of the satellites has noticeably increased," he tweeted on October 29. SpaceX has permission from the US government to launch nearly 12,000 Starlink satellites through 2027, though it's asked to launch 30,000 more for a total of nearly 42,000. In either case, SpaceX is on track to form a "megaconstellation" that outnumbers all prior spacecraft ever launched by humanity. If 3% of the maximum planned Starlink constellation fails, that could mean 1,260 dead, 550-pound satellites the size of a desk aimlessly circling the planet. A 2.5% failure rate could mean more than 1,000 inoperative spacecraft. There were about 3,200 nonfunctional satellites in Earth's orbit as of February, according to the European Space Agency. Many of these dead spacecrafts regularly threaten to collide with others and create a space-debris crisis. In mid October, for example, satellite trackers flagged a "very high risk" close pass between a dead satellite and a discarded rocket body, with one company calculating a 10% chance of collision. (Fortunately, they didn't.) SpaceX says its satellites will naturally deorbit, or burn up in Earth's atmosphere, if their propulsion systems don't work. But that process can take up to five years, according to Starlink's website. In the meantime, defunct satellites rocket around Earth faster than a bullet, with nobody to steer them away from other spacecraft that may fly in their path. SpaceX did not acknowledge Business Insider's requests for comment. However, in filings to the Federal Communications Commission, SpaceX has downplayed the risk, stating that it "views satellite failure to deorbit rates of 10 or 5 percent as unacceptable, and even a rate of 1 percent is unlikely." If 1% of its satellites did fail with no capacity to maneuver, the company said, "there is approximately a 1 percent chance per decade that any failed SpaceX satellite would collide with a piece of tracked debris." The company also claimed that its practices "effectively eliminate the chance that such rates will ever occur." Dead satellites can collide and build up a space-debris crisis SpaceX is not alone in pushing to launch large numbers of internet satellites. OneWeb, which the UK government recently purchased out of bankruptcy, has already launched 74 satellites for its proposed constellation of 48,000, while Amazon aims to launch more than 3,200 for its Kuiper fleet. It's unclear how many dead satellites those constellations might also leave in orbit. Since nobody can maneuver them, failed satellites sometimes hurtle toward other spacecraft — including the International Space Station and its crew of astronauts. Even if a satellite crashes into another satellite with no humans on board, it can create perilous conditions. "We replace two satellites with essentially two shotgun blasts of debris," Dan Ceperley, the CEO of satellite-tracking company LeoLabs, told Business Insider in January. That month, two dead satellites almost crossed paths and exploded into hundreds of thousands of bits of debris. It wouldn't have been the first such explosion, and it doesn't take many to exacerbate the debris problem. In 2007, China tested an anti-satellite missile by obliterating one of its own weather satellites. Two years later, one American and one Russian spacecraft accidentally collided. Those two events alone increased the amount of large debris in low-Earth orbit by about 70%. India conducted its own anti-satellite missile test in 2019, and the explosion created an estimated 6,500 pieces of debris larger than an eraser. All in all, more than 500 such "fragmentation events" have created nearly 130 million bits of debris in Earth's orbit. Those chunks of debris zip around the planet at more than 17,500 mph, or roughly 10 times the speed of a bullet. That's not only a problem for robotic spacecraft, but ones carrying people. Just last month, a piece of debris careened within a mile of the football field-sized space laboratory. To avoid a collision, mission controllers fired the thrusters of an attached Russian cargo spaceship to maneuver the station out of possible harm's way. The three crew members sealed themselves inside an ISS segment with a Soyuz spaceship, so they could escape if the debris struck. If the space-junk problem gets extreme, a chain of collisions could spiral out of control and surround Earth in a practically impassable field of debris. This possibility is known as the Kessler syndrome, after Donald J. Kessler, who worked for NASA's Johnson Space Center and calculated in a 1978 paper that it could take hundreds or even thousands of years for such debris to clear up enough to make spaceflight safe again. "It is a long-term effect that takes place over decades and centuries," Ted Muelhaupt, who leads The Aerospace Corporation's satellite system analysis, previously told Business Insider. "Anything that makes a lot of debris is going to increase that risk." The sheer number of objects in Earth's orbit may already be having a Kessler-like effect, as Rocket Lab CEO Peter Beck described last week."This has a massive impact on the launch side," he told CNN Business, adding that rockets "have to try and weave their way up in between these [satellite] constellations." Starlink is already a space-debris hazard SpaceX has barely launched 2% of its planned constellation, but it has already had a close call. In September 2019, the European Space Agency had to maneuver one of its spacecraft at the last minute to avoid possibly colliding with a Starlink satellite. The chance of that crash was 1 in 1,000. While that may sound low, NASA routinely moves the ISS for chances of 1 in 100,000. The ESA said it had to move its satellite because SpaceX had "no plan to take action." SpaceX said it missed the ESA emails about the issue due to a "bug" in its communications systems. Overall, close approaches like that seem to be happening more frequently. "We are seeing recently a decided uptick in the number of conjunctions," Dan Oltrogge, an astrodynamicist at Analytical Graphics, Inc, where he uses a software that has been assessing conjunction data since 2005, told Business Insider. "And it looks to be very well aligned with the new large-constellation spacecraft that have been launched." As new satellite constellations launch, regulatory agencies like the FCC may need to evaluate how many dead spacecraft they're willing to accept. "What is an acceptable failure rate?" McDowell said. "That, I'm maybe not competent to have an opinion on."

#### Large constellations cause debris and collisions, Murtaza et al 20

[Abid Murtaza, educator at the School of Electronic and Information Engineering at Beihang University pursuing a Ph.D. in space technology applications with Beihang University, Syed Jahanzeb Hussain Pirzada, educator at the School of Cyber Science and Technology at Beihang University pursuing a Ph.D. in space technology applications with Beihang University, Tongge Xu, Associate Professor with the School of Cyber Science and Technology at Beihang University, and Liu Jianwei, educator at the School of Electronic and Information Engineering at Beihang University, 03-09-2020, “Orbital Debris Threat for Space Sustainability and Way Forward (Review Article),” IEEE, [https://ieeexplore.ieee.org/abstract/document/9028136]/Kankee](https://ieeexplore.ieee.org/abstract/document/9028136%5d/Kankee) [recut Lynbrook MD]

Despite the potential as mentioned above, the big question on their impact on the space debris environment has also become the most critical concern for every space concern entity. Concerning the space debris collision threat, SpaceX and OneWeb have both selected an altitude (above 1100 km) that is less densely populated. Additionally, both have told the FCC that their constellation will comply with international mitigation standards, such as reentry to earth Earth’s atmosphere being accomplished within approximately one year after completion of their mission. Additionally, OneWeb’s Orbital Debris Mitigation Plan reports that the probability of a OneWeb satellite becoming disabled as a result of collisions with small debris is 0.003, while SpaceX stated that “there is approximately 1% chance per decade that, any failed SpaceX satellite would collide with a piece of tracked debris” [97]. Apart from the claims of SpaceX and OneWeb, some studies have been performed to understand the effect of these constellations on the space environment and the reliability and collision possibilities of the mega constellation with this populated debris environment [10], [98], [99]. A study shows that there is substantial uncertainty in the prediction of the reliability of mega constellation satellites, with considerable risk to the space environment. This is because much of the information about mega constellation satellites, including the detailed designs, is not available [10]. Another recent study shows that a high probability exists for the occurrence of at least one catastrophiccollision, i.e., 5% for OneWeb and 45.8% for SpaceX constellations, during an operational phase of 5 years [97]. The study [98] showed that it was estimated that an impact of approximately 3 cm in diameter would lead to a catastrophic collision of a OneWeb sized satellite, while the proposed size of a SpaceX constellation satellite is larger than a OneWeb satellite. The study also shows that the satellites in the constellation would have a 35% probability of fragmenting during the described mission lifecycle catastrophically. Thus, what we can confidently say is that despite the claims of mega constellation proposers, there are serious concerns, doubts, and uncertainty about the interaction of debris and satellites in mega constellations that exist. NASA has recently completed a parametric study to understand how significantly proposed large satellite constellation can contribute to the existing orbital debris problem. The objective was to quantify the potential negative debris-generation effects from mega constellation to the LEO environment and provide recommendations for mitigation measures [99]. The results show that for the 25-year decay rule at the end of their missions, with a 90% reliability of post-mission disposal, the additional debris population increase with respect to that without these big constellations is approximately 290% in 200 years. Even with 95% post-mission disposal reliability for the mega constellation spacecraft, the additional population increase is still close to 100% as shown in Fig. 12. While with 99% post-mission disposal, the additional population increase is reduced to 22%. The cumulative numbers of catastrophic collisions are shown in Fig. 13, which shows that in 90% scenario a non-linear increase from 27 to a total of 260 catastrophic collisions in 200 years. In 95% scenario, the total number of catastrophic collisions is 90 in 200 years. Based on results from this study NASA recommended that 99% spacecraft PMD reliability is needed to mitigate the serious long-term debris generation potential from mega constellation similar in scope to the study scenarios. Besides this, there are many aspects which are nevertheless not under the control of anyone, such as a collision of two large retired satellites or rocket bodies. Additionally, there could be many hypothetical scenarios that could lead to a catastrophic collision. For example, the accuracy error in tracking the debris data thorough SSN, the human or technical errors in estimated the timing of the collision threats, failure in a collision avoidance maneuver by satellites due to onboard control problems or anomalies in the propulsion system, and any deliberate political reasons and so on. Additionally, so far there is no legal restriction of using ASAT. So, what if the use of ASAT continues in future just like India did recently? Also what if the war between two advanced nations extends from ground to space that could result in the use of ASAT weapons to destroy the satellites of enemies? Thus, the argument is that there could be any reason for a catastrophic collision, and one or more such accident could make the situation worse, which would have severe consequences for everyone especially such as Kessler syndrome. Hence, we can say that mega constellation projects, despite their potential benefits are not going to help in improving debris and space environment in any way; instead, fair chances of worsening of debris and space environment can be envisioned from the above discussion. It might be negligence if we deliberately continue to underestimate debris challenge and its potential threat to the space environment in the future. SECTION VII.Legal and Regulatory Issues

#### Private actors are uniquely key to avoid debris cascades – they have lower safety standards and won’t cooperate with others, Yuan 21

[Alda Yuan, Public Health Analyst U.S. Department of Health and Human Services and visiting attorney at the Enivornmental Law Institute with a JD from Yale, 2021, “FILLING THE VACUUM: ADAPTING INTERNATIONAL SPACE LAW TO MEET THE PRESSURES CREATED BY PRIVATE SPACE ENTERPRISES,” Hein Online, [https://heinonline.org/HOL/P?h=hein.journals/denilp49&i=27]/Kankee](https://heinonline.org/HOL/P?h=hein.journals/denilp49&i=27%5d/Kankee) [recut Lynbrook MD]

C. Non-state Actors Introduce Practical Challenges that Endanger the Future of Space Travel If companies are permitted to access space without a proper legal framework or sufficient coordination, the practical risks may doom the project of humanity in outer space for the near future. The opening anecdote dramatized the risks, but the fact that a chain of cascading destruction might preclude the use of whole bands of outer space or make launches impossible is not farfetched. 99 Indeed, it is already happening.0 Because space missions always create debris and there is a correlation between the number of objects orbiting earth and the chances of collision, which thereby creates more debris, even no further activity in space will eventually result in a belt of debris encircling the earth.10 1 This cascade effect, called the Kessler Syndrome, 102 has the potential to speed up astronomically if activities in outer space expand without contingent regulation and mitigation measures.1 1 3 At current rates and in the absence of a catastrophic event, lower earth orbit, in particular, might reach a tipping point within the next ten to fifty years.1 4 If the space debris problem is permitted to reach this tipping point, access to space may well be cut off for the near future because it will be impossible to launch satellites.1 5 Given that we do not have the technology to clean up debris yet, space travel faces an existential threat. In light of this, most space-faring states cooperate, working together to develop guidelines and pool resources to track the debris already orbiting the earth to minimize the chances of a collision.106 Given the high speeds the debris travels at, approximately 10 km/second,107 and the amount of damage even tiny pieces can do, 108 the existing tracking systems are not an absolute fix. At these speeds, a piece of debris weighing a mere two grams can produce an impact force equivalent to a kilogram of TNT.109 More than three hundred thousand pieces of debris greater than one cm in diameter," and therefore capable of causing enormous damage, orbit the earth while the US Space Surveillance Network (SSN) system can only track objects over five cm in diameter." There are millions of fragments smaller than one cm, which are impossible to track and yet can still cause significant damage.11 2 Still, the tracking system is important. In the last twenty years, the International Space Station has carried out several avoidance maneuvers to avoid potential collision with pieces of space debris being tracked by the SSN system.113 Between April of 2011 and April of 2012, the ISS performed four evasive maneuvers." 4 On two additional occasions, the crew fell back to the Soyuz since there was no time to set up an evasive maneuver." 5 This sort of cooperation works given the limited number of actors involved and the aligned interests of the nation-state parties. Commercial space companies do not have the same incentives to cooperate to share data and new technologies. This is why many have called for the creation of a new convention on managing orbital debris. 16 However, escalation of the Kessler Syndrome is not the only problem that might arise by failing to accommodate for the rise of the commercial corporations, so such a convention would not eliminate the threat. For instance, many satellites use nuclear power sources (NPS), which can break up upon reentry." As early as 1978, the Cosmos-954 incident scattered radioactive debris over Canada.118 Other accidents of this type could raise fallout concerns, especially if they occur over more densely populated regions. In an attempt to alleviate this risk and decrease the chances of collisions, various nations have cooperated to design and standardize methods of decommissioning satellites. 119 One strategy is to supply spacecraft with additional fuel and nudge it out of orbit so it will burn up in the atmosphere over the ocean. 120 Another is to push the ailing satellite into a graveyard orbit. 121 These methods require additional research and design and incur additional costs. 12 2 Private companies may not spontaneously take the steps necessary to comport with the common practices of space-faring nations. Thus, the rise of private corporations, while opening up new possibilities, may also threaten space travel itself and the international legal order in which coordination currently occurs. The coordination necessary to prevent and manage the unique problems that arise in space requires a more pragmatic framework. Directly binding private non-state actors benefits the international community because it prevents abusive practices and permits the coordination of efforts that make space safer. However, it will also benefit the private sector by providing companies with a background legal structure, neutral dispute resolution, and common guidelines to even the playing field. More importantly, if companies not subject to regulation and oversight are permitted to operate in outer space, disasters cannot be effectively prevented. In that case, space exploration and the benefits stemming from it might be closed off for all. III. SPACE IS A GLOBAL COMMONS UNDER CUSTOMARY INTERNATIONAL LAW

#### 3 impacts:

#### More space debris means we trap ourselves on Earth, Weiner 17

(Sophie Weiner, I’m a writer, journalist and occasional DJ living in Brooklyn, NY. I enjoy writing about the internet, technology, science, politics, art, and how they intersect. , 2017, accessed on 1-13-2022, Popular Mechanics, "If We Don't Act Soon, Space Junk Might Trap Us On Earth", https://www.popularmechanics.com/space/a26885/space-junk-cleanup/) [Lynbrook MD]

The tiny pieces of junk orbiting the Earth could have a major impact on space exploration. Not everything we send into space comes back down. In fact, there are millions of pieces of junk, ranging from tiny flecks of paint to entire satellites currently taking up space around the Earth's atmosphere. As of now, space agencies are already tracking 750,000 pieces of space debris orbiting the Earth. This space pollution is a major problem--because of how fast objects orbiting Earth travel, even a paint fleck a few millimeters long can cause serious damage when it hits something. The more that this space junk proliferates, the harder and harder it will be to send anything up into space. We could literally trap ourselves on Earth if we're not careful. Luckily, scientists are working on ways to prevent this. One NASA program called Space Debris Elimination proposes shooting atmospheric gasses into space to destabilize the debris' orbit and send it plummeting back to Earth, where it will burn up in our atmosphere. Another proposal from the ESA tackles the larger pieces of debris, like old satellites. Their idea is to send a machine into space called the E-DeOrbit, which would literally shoot a net at old satellites and drag them back into the atmosphere with a small rocket. Neither of these solutions would address the millions of tiny bits of trash floating around the Earth, so the best idea for now is to prevent more from building up. If not, we could find ourselves trapped in a prison of our own making.

#### Satellites are key to environmental monitoring – debris collapses it and causes climate extinction, Biggs 18

(Ben Biggs 18, PhD Researcher in Computer Vision and Deep Learning at the University of Cambridge, “How Satellites Can Protect Planet Earth From Disaster”, HowItWorks Daily, 12/22/2018, https://www.howitworksdaily.com/how-satellites-can-protect-planet-earth-from-disaster/)

It might not look it, but our planet is a fragile place. A delicate balance of pressure, temperature and gases keeps us alive, as our atmosphere lets in enough heat for us to thrive – but not too much that we get too toasty. For many years our planet has looked after itself with ease. Now, with humans on the scene, things are changing more than ever, from climate changetomass deforestation. If our planet is going to survive long into the future it’s going to need our help. Fortunately, we’ve got plenty of missions that are working for the benefit of our world already. Using observation satellites in orbit, scientists have been monitoring Earth for decades, watching how the planet pulsates and changes over time. From orbit we can watch how species migrate, identify and predict environmental changes and even fix problems. A great example of this was the global effort to repair a hole in the ozone above the Antarctic back in 1987. Two years prior, scientists had discovered that chemicals known as chlorofluorocarbons (CFCs) – produced by fridges and aerosols, among other things – were causing the hole to grow. As a result countries around the world agreed to phase out the use of CFC as part of the Montreal Protocol. In early 2018, NASA announced that its Aura satellite had watched the hole successfully close, with it expected to fully repair as early as 2060. It was proof that we could work together to change the planet for the better. Aura is part of a broader NASA project called the Earth Observing System (EOS). This programme, which began in 1997, has seen NASA launch missions and instruments into orbit. This has included the groundbreaking Landsat series of satellites, which have provided surface images of the whole globe. Then there’s the Terra mission that launched in 2009 and studies clouds, sea ice and more from orbit. Most of these satellites are in polar orbits, which means they orbit the planet from top to bottom so that it rotates underneath and gives them a global view. Planning for the EOS began back in the 1980s, with NASA keen to regularly fly instruments for at least 15 years. “Human activity has altered the condition of the Earth by reconfiguring the landscape, by changing the composition of the global atmosphere, and by stressing the biosphere in countless ways,” they noted in a handbook in 1993. “There are strong indications that natural change is being accelerated by human intervention.” More than two dozen missions have been launched as part of the EOS to date. Among the programme’s many accomplishments, scientists watched as an ice shelf collapsed on the Antarctic Peninsula in 2002 using the Terra satellite. The same satellite, along with the Aqua satellite launched in 2002, has provided a global view of how the vegetation cycle changes over the course of a year and the effect the climate has on it. Those same two satellites have also allowed us to see how summer sea ice in the Arctic is decreasing, which means that more of the Sun’s light is being absorbed rather than being reflected, raising global temperatures. The EOS has helped in other ways too, such as enabling scientists to keep a close eye on the levels of toxic gases like carbon monoxide being emitted from massive fires in the atmosphere. This allows people on the ground to be alerted to these dangers, and they can in turn be advised to limit their outdoor activity to protect their health. The EOS is even helping to track and monitor rare animals, such as chameleons in Madagascar. Here, scientists have been able to use satellite imagery, combined with known habitats of the animals, to map out where they are likely to be living. It would take survey teams on the ground thousands of years to replicate this information without satellites. It’s not just NASA that has been keeping a close eye on the planet. The European Space Agency (ESA) runs the Copernicus project, billed as the world’s largest single Earth observation campaign. Previously known as the Global Monitoring for Environment and Security (GMES) programme, it began with the launch of the Sentinel-1A satellite in April 2014. This radar imaging satellite provides images both day and night and during all weather conditions, and these are being used to map sea ice, track oil spills and more. This has been followed by half a dozen more missions, with the latest – Sentinel-3B – launching on 25 April 2018. This mission is focusing on monitoring the behaviour and health of the oceans, but it has a wide range of abilities. It flies in formation with its predecessor, Sentinel-3A, and together the two of them can provide global data for Earth across an entire day. The satellitescan measure the temperature over oceans, as well as the colour and height of the sea. They can also monitor wildfires from space, check the health of vegetation and map the way that land is being used around the world. And there are more Sentinel satellites on the way. In the coming years we’ll see the Sentinel-4 and Sentinel-5 missions launch, studying the composition of our planet’s atmosphere, while Sentinel-6 will measure global sea surface height for ocean and climate studies. “Copernicus will help shape the future of our planet for the benefit of all,” said the ESA, also noting that it isthe “most ambitious Earth observation programme to date,” one that will provide accurate and timely data on the environment, climate change and more. All of this data is vital for directing climate policy and other human activities on Earth. By observing our planet around the clock from space we can see the direct effect that humans are having on it. These are not the only climate-monitoring missions run by NASA and the ESA. The former has a number of other missions, including the Deep Space Climate Observatory, which observes the sunlit side of Earth. The latter has eight missions on the books in its Earth Explorer programme, including a mission to study how Earth’s gravity field varies over the surface of the planet, called the Gravity field and steady-state Ocean Circulation Explorer (GOCE), which ended in 2013. In 2016, countries of the world came together to sign the Paris Climate Agreement, a global effort to reduce carbon emissions to prevent the global average temperature rising by two degrees Celsius above pre-industrial levels. While the US later infamously reneged from this agreement, it was proof that with enough level-headed minds, minds that can see the data from missions showing how the planet is changing, we can take action. Humans continue to have a major effect on the planet, for better or worse, and monitoring that change is vital to our planet’s survival.

### Subpoint B

#### Mega-Constellations sabotage modern astronomy – tweaks like DarkSats don’t solve. That guts asteroid detection and preparedness, Grush 20

(“The true impact of SpaceX’s Starlink constellation on astronomy is coming into focus” Loren Grush [science reporter for The Verge] Mar 24, 2020 <https://www.theverge.com/2020/3/24/21190273/spacex-starlink-satellite-internet-constellation-astronomy-coating> SM)

Ever since SpaceX launched its first batch of internet-beaming satellites last year, astronomers have watched with dread as the company continued to blast more spacecraft into orbit. Could this ballooning constellation of bright satellites fill the night sky with artificial light and muck up observations of the Universe for years to come? Now, new data is partially validating what many astronomers have feared since that first launch. Up until now, people have been somewhat in the dark about the true impact of SpaceX’s internet-from-space project called Starlink, which envisions nearly 12,000 of these satellites orbiting Earth. SpaceX’s satellites are super bright compared to others, and astronomers have been worried that with so many luminous satellites in the sky, the odds of one passing in front of a telescope and obscuring an image will increase. It turns out, some astronomers have reason to be concerned. Certain types of astronomy may be more negatively affected than others, one peer-reviewed study shows, particularly those kinds that scour large swaths of the sky over long periods of time looking for faint, faraway objects. That means scientists looking for distant objects beyond Neptune — including the hunt for the mysterious Planet Nine — might have trouble when Starlink is complete. Additionally, Starlink may be much more visible during twilight hours, or the first few hours of the night, which could be a major problem in the hunt for massive asteroids headed toward Earth. “It depends on what science you’re doing, and that’s really what it comes down to,” Jonathan McDowell, an astrophysicist at Harvard and spaceflight expert who wrote the study accepted by Astrophysical Journal Letters, tells The Verge. Meanwhile, scientists are also learning if SpaceX’s effort to mitigate the brightness of its satellites is actually going to work. The company coated one of its satellites in an attempt to make it appear less visible in the sky. Now, the first observations of that satellite are being published, and the coating is working — but it might not be enough to make everyone happy. “It doesn’t solve the issue,” Jeremy Tregloan-Reed, a researcher at the University of Antofagasta and lead author on the study, which is undergoing peer review at Astronomy and Astrophysics Letters, tells The Verge. “But it shows that SpaceX has taken on board astronomers’ concerns, and it does appear to be trying to solve the situation.” HOW STARLINK WILL AFFECT THE ASTRONOMERS For astronomers, light is everything. Observing celestial objects in different wavelengths of light is the best method we have for exploring the Universe. That’s why adding artificial light to the sky freaks out so many scientists. Some astronomers take long-exposure images of the sky, gathering as much light as possible from distant objects — and when a bright satellite reflecting light from the Sun passes overhead, it can leave a long white streak that ruins the picture. Of course, the sky is a big canvas, and one tiny satellite isn’t going to be a major headache. A host of factors dictate exactly how and when satellites will be a problem. A satellite’s size, shape, height, and path around Earth all affect exactly how much light it reflects from the Sun and where people will see it the most. Meanwhile, the time of year and the time of night determine how much sunlight is shining on a satellite at any given moment. To figure out Starlink’s exact impression on the night, McDowell made a comprehensive simulation based on what we know about where all of the Starlink satellites are going. Ahead of launching its constellation, SpaceX had to file multiple requests with the Federal Communications Commission, detailing where the company planned to send all of its spacecraft. Using that information, McDowell came up with a snapshot of which areas will see the most satellites overhead and what times of night will be the worst for observations. In the more northern and southern latitudes, Starlink satellites will dominate the horizon during the first and last few hours of the night. In the summertime, it’ll be much worse, with hundreds of satellites visible for those in rural areas away from city light pollution. “Where I live in [Boston], I can see the planes hovering over Logan [Airport] on the horizon,” says McDowell. “That’s what it will look like, but it’ll be satellites and it’ll be a lot of them.” SpaceX declined to comment for this story. While people living in cities and towns won’t really notice, this spells bad news for those hunting really distant faint objects using long exposures. “The longer that you have the shutter open for, the more that you’re likely to have an observation impeded by one of these streaks that are quite bright,” Michele Bannister, a planetary astronomer at the University of Canterbury in New Zealand who helped McDowell with his research, tells The Verge. That means those hunting Planet Nine and objects at the edge of the Solar System have some cause for alarm. Additionally, asteroid hunters are going to be extra affected by this constellation, says McDowell. “They’re really hosed, because they need to look at twilight,” he says. Scientists looking for asteroids orbiting near Earth often look for these objects near the Sun; they observe just after sunset when they can see the part of the sky near the Sun that’s too bright to see during the day. “That’s where the problem with illuminated Starlink satellites is the worst,” he says. “Even from regular 30-degree latitude observatories, they’re going to have serious problems.” As for what that means for these astronomy fields, one obvious concern is that a potentially hazardous asteroid could go unnoticed until it’s too late to act appropriately. It’s also possible observers will have to take expensive countermeasures to get the kinds of images they want. “It may mean you have to observe twice as long, if you have to throw away half your data,” says McDowell. “So that’s expensive. Or you may need to make changes to your telescope design, to stop reflections from a satellite.” The silver lining here, at least, is that McDowell’s study found that Starlink may not really have a big effect on a lot of other astronomers’ work, especially those who only look at small slices of the night sky for certain periods of time. But his work does fly in the face of what SpaceX CEO Elon Musk has said about Starlink and its astronomy repercussions. “I am confident that we will not cause any impact whatsoever in astronomical discoveries. Zero,” Musk said during a space conference at the beginning of March. “That’s my prediction. And we’ll take corrective action if it’s above zero.” Despite Musk’s brazen proclamation, the truth is SpaceX has already taken some corrective action, but new research shows it may not be enough to silence all of the company’s critics. A COAT OF NO COLORS On its third Starlink launch in January, SpaceX included a satellite that had been painted with an experimental coating, meant to darken the spacecraft’s reflectivity. Nicknamed DarkSat, the spacecraft has been of particular interest to amateur satellite trackers. Various observatories have taken images of DarkSat as it’s passed overhead to gauge just how much fainter it appears compared to its cohort. The answer, it seems, is that DarkSat is indeed darker but only slightly. Once it reached its final orbit, the satellite appeared 55 percent fainter compared to another bright Starlink satellite, according to Tregloan-Reed’s study. That’s based on the initial observations he made using a telescope at the Ckoirama Observatory in Chile. “The DarkSat coating does push the satellite beyond being able to be seen with the naked eye,” says Tregloan-Reed. That’s a big reduction, but 55 percent may not be enough for some observatories. The Vera Rubin Observatory in Chile is still under construction, but it has the massive task of surveying the entire night sky. “It’s going to be able to give us the history of the Solar system in absolutely intricate and amazing detail,” says Bannister of the survey. “And I think that’s definitely something that is under threat.” People at the observatory have estimated that the Starlink satellites would need to be even fainter than DarkSat in order to truly stay out of the way and not saturate the images gathered. The good news is that SpaceX has hinted that more extreme countermeasures may be on their way. During its latest launch, a SpaceX employee noted that while the coated satellite showed “a notable reduction” in brightness, a future Starlink satellite may be equipped with a sunshade to further reduce reflectivity. “We have a couple other ideas that we think could reduce the reflectivity even further, the most promising being a sunshade that would operate in the same way as a patio umbrella, or a sun visor — but for the satellite,” Jessica Anderson, a lead manufacturing engineer at SpaceX, said during the live stream. Tregloan-Reed says he’s hopeful about some kind of shade. “If that was to work then in theory it would block out the sunlight completely,” he says. Still, that doesn’t solve every single astronomy problem because even a darkened satellite can still be a nuisance. Astronomers searching for planets beyond our Solar System, for instance, often take very sensitive measurements of distant stars, looking for dips in their brightness that might indicate a foreign planet passing by. If a satellite, even a dark one, were to pass in front of a star someone was observing, it could throw off the search for these alien worlds.No matter what, it seems that a giant constellation is going to have some kind of negative impact on someone — it can’t be helped. And looking at the big picture, SpaceX isn’t alone in its attempt to create a mega-constellation of satellites. The company just gets the most attention because it’s proposing the largest number of spacecraft, and its vehicles are big, bright, and lower in the sky compared to other proposed constellations. Others like OneWeb and Amazon want to also fill the sky with internet-beaming vehicles. Such a large influx of artificial bright spots is really the heart of the issue. “I understand the importance of Starlink; I can see the benefits of worldwide internet,” says Tregloan-Reed. “It’s just the sheer numbers that are worrying me.”

#### Asteroids cause extinction and without top-notch detection technology, a hit is inevitable, Dreier 21

(Casey Dreier is Senior Space Policy Adviser for The Planetary Society, an independent nonprofit organization based in California. “Why an Asteroid Strike Is Like a Pandemic”, July 25, 2021, <https://www.scientificamerican.com/article/why-an-asteroid-strike-is-like-a-pandemic/>, accessed 12/3/21)

Imagine the following scenario. Scientists identify a potential global threat, but initial data are spotty—not enough to spur drastic action. Rapidly, relentlessly, the threat grows. What once was preventable becomes inevitable. The world has no choice but to endure the disaster at the cost of trillions of dollars and millions of lives. This is the story of COVID pandemic—but it could equally well be the story of a catastrophic strike by a large asteroid. As we emerge from the worst of COVID-19, we should heed this lesson: low-probability, high-impact events do occur; but they can be mitigated if we prepare and act early enough. Asteroids are like viruses in a sense: they number in the tens of millions but only a few types pose a threat to humans. For asteroids, it’s the “near-Earth” variety—those with orbits that come close to our own—that we must worry about. Also as with viral outbreaks, the likelihood of a catastrophe is unlikely in any given year, but almost inevitable over time. And just as we can in principle develop vaccines against emerging viruses before they cause too much damage, creating immunity without making people sick, we can similarly use modern technology to develop a level of global immune response to asteroid collisions. But this requires ongoing investments in research and preparedness—and while the U.S. spent more than $6.5 billion dollars on pandemic preparedness over the past decade (with admittedly mixed results), the nation spent less than a tenth of that on the work of asteroid detection and deflection. This is far too low. In fact, impacts from space happen all the time, but they are generally small and harmless. The Earth is peppered with meteors throughout the year that are mere inches across or less, which burn up as shooting stars when they enter our atmosphere. The threat comes from the bigger ones, which are house-sized or larger. These strike less frequently, but they do happen. In 2013, a 60-foot-diameter meteor exploded over the city of Chelyabinsk, injuring thousands of people. The really big ones—miles across—are even rarer, occurring every few hundred million years or so. But the damage they do can be catastrophic. Think of the mass extinction 65 million years ago that wiped out most of the dinosaurs. The good news is that we’ve found most of those and, fortunately for us, Earth is not in their crosshairs. But there is a middle ground that demands our attention: “city killer” asteroids that are about around the size of a football field and could unleash 10,000 times the energy of the atomic bomb that leveled Hiroshima. They seem to hit us every few thousand years, on average. There are likely many tens of thousands of them with orbits near Earth’s, yet we’ve only found about one third of these. And finding them is hard. Even the big ones are tiny, cosmically speaking, and are camouflaged against the blackness of space by their charcoal-like dark surfaces. Ground-based telescopes, which measure reflected light, struggle to see these small, dim objects. Only a few hundred are discovered each year. To significantly improve the rate of detection we need to move off the Earth, to the realm of the asteroids. We need a telescope in space. The Near-Earth Object (NEO) Surveyor is a modest space telescope currently under consideration by NASA. Instead of looking at reflected light, it would seek out heat signatures of asteroids, which glow with infrared radiation against the cold background of space. And in space, where there’s no bad weather and daytime that limit observations, the NEO Surveyor could find more city-killer asteroids in the next 10 years than have been discovered by all the telescopes on Earth over the past three decades. The mathematics of orbital mechanics that characterizes asteroids can be as heartless as the exponential growth that goes with viral outbreaks. And as with broad testing regimes that have been used during COVID, a dedicated effort to discover potentially hazardous asteroids will be the key to preventing disaster. It’s possible to alter an incoming asteroid’s orbit to protect the Earth, but that becomes increasingly more difficult depending on how close we are to impact. It is far easier to act years (if not decades) in advance. After more than a decade in bureaucratic purgatory, where the NEO Surveyor has struggled to gain approval, the project appears ready to move forward. The Biden administration recently proposed to fund this mission in its latest NASA budget; Congress should support this request. It will take years to build and launch, but as early as 2026 we may see the start of the first dedicated effort to understand the scope of the asteroid threat. We also need to invest in deflection technology, the “vaccine” of the asteroid response. Fortunately, NASA is close to launching a mission called the Double Asteroid Redirection Test (DART). In 2022, the spacecraft will ram into the tiny “moon” that orbits the near-Earth asteroid Didymos, slightly changing its orbit. Scientists will compare the exact degree of change to their predictions, which will help them understand how to alter asteroid orbits more effectively in the future. This is only a test, but it could serve the same function as the years of basic research into the field of mRNA vaccines that ultimately paid off when applied to COVID. We must also continue to support sky surveys by ground telescopes, which can support the work of space-based missions. The Vera Rubin Observatory, for example, now under construction in Chile and especially good at finding fast-moving objects in the solar system, will greatly assist in asteroid detection. (The proposed “megaconstellations” of Earth-orbiting satellites by Amazon, SpaceX, OneWeb, and others threaten to overwhelm our view of these dim objects and make asteroid detections more difficult. There is no easy solution to this, beyond further confirming the need for space-based detectors located in quieter regions of the solar system.) The coronavirus pandemic has many humbling lessons for humanity. But let this be one of them: low-probability, high-impact disasters do occur; and there is no higher impact disaster than a large asteroid collision with the Earth. We know that early awareness enables early action. Big problems later on can be prevented by small investments now. Let’s not be caught off-guard again.

#### Asteroids threats are existential – increasingly likely, Spencer 18

(Senior editor for Salon. He manages Salon's science, tech, economy and health coverage Keith Spencer, “The Asteroids Most Likely to Hit Earth,” Salon, January 14, 2018, <https://www.salon.com/2018/01/14/the-asteroids-most-likely-to-hit-earth/>.)

Like earthquakes and volcanoes, the most frightening thing about asteroid strikes is their inevitability. Our solar system formed from a planetary nebula of dust and gas that slowly coalesced into rocks, planets, moons, and the Sun. And there are plenty of rocks still floating around. Astronomers estimate that between 37,000 and 78,000 tons of solar system debris hit Earth every year, though luckily these usually rain down in tiny pieces that burn up in the atmosphere — rather than large chunks that explode on the ground. (Although those hit us too.) As a result, our planet is littered with little geologic memento mori that foreshadow what is to come. The Chesapeake Bay looks the way it does because of a massive impact of a three- to five-kilometer-wide asteroid that hit about 35 million years ago; even today, the region’s freshwater aquifer is at risk of being contaminated by an adjacent salty underground reservoir that was created in the wake of the impact. Oil drillers and water management agencies in the region must mitigate for a 35-million-year-old natural disaster. Unsurprisingly given how often we get hit with space debris, meteors rank high on the list of existential horrors; some of our civilization’s most popular books and films are about the fear of a meteor impact–related disaster. Likewise, scientists periodically sound the alarm bells over the lack of resources being devoted to hazardous asteroid detection and — perhaps someday — diversion. Luckily, NASA, the California Institute of Technology and other agencies have done a fair bit of sky-scouring to track and monitor nearby hazardous space rocks of varying sizes. The trick with estimating likely impact candidates is knowing that while many of the things on this list have a low probability of hitting us in the next century, they have higher — but more difficult to estimate accurately — probabilities of striking Earth in coming centuries. So why do most lists of potentially hazardous asteroids only estimate their orbits as far as a hundred years in advance? Partly because we are trapped in our own human perspectives — 100 years is about as long as our children will live — and partly because any orbital uncertainty is compounded year to year. In estimating the precise location of an asteroid and extrapolating its future path, precision is key; being off by, say, 40 kilometers today will equate to an orbital uncertainty thousands of times greater many years in the future. That could easily mean the difference between a strike and a miss. (Incidentally, 40 kilometers of uncertainty is the approximate uncertainty of 3200 Phaethon, a near-miss that grazed Earth last month.) All of this is to say that the asteroids on this list move in and out of our planet’s orbit — on a long enough timescale, we’re either going to have a close encounter or an impact, provided ours or another planet doesn’t gravitationally slingshot these space rocks into a less hazardous orbit. In picking and choosing asteroids for inclusion here, I tried to pick ones that were A) big enough to at least cause a nuclear winter, and B) that have a decent likelihood of eventual collision. The way that near-Earth objects are ranked by astronomers takes into account the number of opportunities for the orbit to intercept Earth; most of these have elliptical orbits that will swing past our planet many times. 3200 Phaethon The aforementioned asteroid, which I wrote about last month when it had a close encounter with Earth, is rumored to be the source of the Geminid meteor shower. An asteroid creating meteor showers on Earth is unusual; but 3200 Phaethon is a weird asteroid. The atmosphere-free, 3.6 mile-wide rock swings very close to the Sun, rapidly heating the asteroid's surface, and — scientists believe — creating fractures in its surface as its temperature changes, thus releasing dust. That dust then creates the Geminid meteors, tiny particles that rain down periodically on Earth. 3200 Phaethon has a very elliptical orbit, meaning it passes close to the Sun before swinging far out again. Its motion moves it in and out of Earth’s near-circular orbit, which is how it ended up grazing us by 6.2 million miles back in December, at which point it was visible from Earth with a small telescope. A 3.6 mile-wide asteroid like 3200 Phaethon probably wouldn’t end most life on Earth, but it would certainly muck things up for a bit. This size is just slightly bigger than the asteroid implicated in the aforementioned Chesapeake Bay asteroid impact. That asteroid created a crater over 50 miles wide and almost a mile deep, according to the US Geological Survey. Even outside that 50-mile-wide diameter, earthquakes, dust clouds and heat levels made a large swath of North America uninhabitable for a while. Accordingly, NASA lists 3200 Phaethon as “potentially hazardous.” 2017 XO2 Despite being only 330 feet wide, 2017 XO2 merits inclusion on this list solely because this 2-million-ton rock keeps crossing Earth’s path. Like the bee that won’t stop buzzing you at the picnic, 2017 XO2 will take many passes at Earth, each with their own small probability of collision. Notably: April 28, 2041, April 29, 2047, April 28, 2053, April 29, 2059, and April 28, 2065, all have impact probabilities greater than 0.00001 percent. The Center for Near-Earth Object Studies (CNEOS) only calculates trajectories up to 2111 — uncertainties rise after that point — but it seems to swing near us around the end of April every few years, up to April 30, 2111. CNEOS calculates a cumulative impact probability of 0.002 percent between now and 2111. Threateningly, it may keep swinging by Earth for thousands more years. 2017 YZ1 Some asteroids on this list are going to cross Earth’s path again and again and keep scaring us, but 2017 YZ1 has one shot before it loses it. If it were overtime in the NBA championship game and the score were tied, 2017 YZ1 is trying desperately to dunk — by which I mean, violently collide with Earth. This 1,000-foot-wide asteroid has a non-zero chance (0.00015 percent) of hitting Earth on June 30, 2047. Those aren’t great odds, but still a much better chance than you have of winning the lottery. I suspect some actuary at Lloyd’s of London is selling 2017 YZ1 insurance by now. Fortunately, 2017 YZ1 is only about a thousand feet in diameter, which isn’t big enough to cause an extinction event. Yet if it struck land it might create a cataclysmic explosion that would mess up our weather for a few years. Jot down June 30, 2047, in your calendar, and then pull out your telescope, watch it sail by and toast your good fortune. 2018 AE2 As its “2018” designation hints, 2018 AE2 is hot off the observational data tables. Between 2094 and 2112, 2018 AE2 will have a number of low-probability chances to hit Earth. At 50 million tons with an impact velocity of 53,000 miles per hour, 2018 AE2 would have a destructive capacity (3,200 megatons) equal to about half the world’s nuclear arsenal. If the theory of nuclear winter is true — that the amount of smoke and ash sent into the troposphere from such a large explosion could temporarily dim the Sun’s flux on Earth, resulting in crop loss, colder days, and the probable deaths of millions or billions — we would indeed be in for trouble. If you glean any politics from this article, take away the moral imperative for our civilization to improve our long-term thinking and invest well in planetary asteroid detection and deflection. We’re in the middle of a political era of “individual responsibility,” where it’s every person for themselves, but space hazards like these hint at the long-term absurdity of that kind of right-wing positioning. No number of tax credits or bootstrap-yanks are going to stop the asteroid from personally affecting you (and everyone else); these are equal-opportunity planet destroyers that require cooperative solutions. In a future article, I'll explore the ways that humanity might come together to deflect a hazardous asteroid, many of which are actually quite simple if done far enough in advance of impact.