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#### Obtrusive space advertising is coming now.

Joshi 21 “Space Billboards: A “Bright” New Marketing Tool or A Threat to Humanity?” Rucha Joshi August 23, 2021 <https://timesnext.com/space-billboards-bright-new-marketing-tool-or-threat-to-humanity/> SM

Space Billboards: A “Bright” New Marketing Tool or A Threat to Humanity?

If you thought humans in space weren't enough, now they are adding billboards. Elon Musk and a bunch of other companies are all set to launch space advertisements in upcoming months.

What are space billboards? Imagine you are gazing deeply into the infinite abyss of space and thinking about how your existence fits into the universe. Then, out of nowhere, you see bright white letters spelling “Coca Cola” or “KFC” spring across the horizon, gone within a few minutes.

That’s the idea behind space billboards, also known as orbital displays.

The idea of space advertising is not a new concept, but now several businesses, including Elon Musk’s SpaceX, are planning on executing it.

Even though it may look like a sci-fi movie coming to reality, the idea of space advertising or even satellites whose sole purpose is to be seen from the night sky has attracted a lot of criticism. Several people and astronomers have linked it with the night sky’s vandalism.

What’s The News?

This month, Business Insider (1) reported that Elon Musk plans to send an advertising billboard into space. It will include a tiny CubeSat-sized satellite with a pixelated screen on one end. They are expected to launch it in early 2022, and followers will see the screen from Earth thanks to an attached selfie stick. Wait, What? A selfie stick in space? Yes, it sounds hilarious, but we promise it gets more serious.

The company is using a CubeSat measuring 10 centimeters and will launch it via its Falcon 9 rocket.

GEC, Geometric Energy Corporation, a Canadian startup, will reportedly build the satellite. It will use a built-in selfie stick to record the billboard once it is in the space and live stream the ad on platforms like Twitch and YouTube.

Wait, there is more. Reportedly, you and I can also buy ad space on the billboard using cryptocurrency tokens like Ethereum or Dogecoin.

“What we are attempting to accomplish is something that can democratize access to space and allow for decentralized participation. Let’s hope people don’t waste their money on something insulting, inappropriate, or offensive,” said Samuel Reid, Co-founder and SEO of GEC to Insider. Yes, Sure.

How Did We Get Here?

While the idea of space advertising goes way back to the 1940s (2) (as far we went during our research, we are not so sure if the concept emerged even before), it came into the mainstream for multiple businesses in the early 1990s, when space technology was on the rise after the space race and the fall of the Soviet Union.

Since then, there have been multiple attempts to use space as an advertising tool, including SpaceX launching a Tesla car into orbit (3, 4).

But why is there a peak in interest for space billboards? Well, there is a big advantage of space advertising compared to other Earth-bound methods – its sheer scale of reach. Imagine billions of people residing in multiple nations watching your ad orbiting Earth.

So yes, space ads can offer valuable marketing capabilities. Some may argue that the relatively high cost can prohibit it from becoming common. But think about how many companies are willing to spend millions of dollars on Super Bowl commercials and popular TV shows like Friends (5). Undoubtedly, the sheer benefit that the space ad would offer is very enticing for companies.

Now, before we move forward, there are two types of space advertising:

Obtrusive Space Advertising: It is a term used for space ads that people can recognize without using binoculars or telescopes.

Non-obtrusive Space Advertising: It can be, for instance, company logos on satellites, space suits, and rockets.

#### It’s inevitable and threatens ground-based astronomy.

Farah 19 “This Russian startup wants to put billboards in space. Astronomers aren’t impressed” Troy Farah January 14, 2019 <https://astronomy.com/news/2019/01/billboards-in-space> SM

This Russian startup wants to put billboards in space. Astronomers aren’t impressed

Orbital Display is shooting for the stars ... with advertising.

Imagine this: you’ve just fled from the city to your nearest national park to gaze deeply into the infinite abyss of space and contemplate how your own existence fits into the curtain of the universe. Then, out of the corner of your eye, you see bright white letters spelling “KFC” spring across the horizon in a long arch. A few minutes later, it’s gone.

That’s the idea behind Orbital Display, a Russian startup’s effort to bring billboard advertisements to low-Earth orbit using a grid of tissue box-sized satellites called CubeSats. Orbiting approximately 280 miles above ground, these tiny satellites will unfurl Mylar sails some 30 feet in diameter to catch and reflect sunlight, creating a pixelated matrix. The company, StartRocket, has proposed using this tech to display a knockoff of the Coca-Cola logo and other brand emblems, as well as allow governments to flash urgent notifications during emergencies.

Vladilen Sitnikov, StartRocket’s CEO, describes himself as an advertising guy with a “crazy idea.” He approached SkolTech, a private university in Moscow, to figure out the technical details, contracting a team of engineers to develop a prototype. Their first test launch could happen this summer, with a full execution in 2021. That is, if the company can find the money.

“It’s human nature to advertise everything … Brands [are] a beautiful part of humankind,” Sitnikov says in a video call. He compares his efforts to Elon Musk and SpaceX, who last year launched a Tesla into space, which many considered an advertisement. Sitnikov also compared Orbital Display to banner-towing airplanes.

But the idea, unsurprisingly, attracts negative reactions from astronomers and other dark-sky advocates who fear adding more light pollution to the heavens would cause significant problems. However, those I spoke with unanimously felt the project, or something similar, is inevitable. The wait before LED lights and advertisements fill up the night sky may not be long.

A Swarm of Flashing Satellites

Many satellites are already reflective, bouncing flares of light back to Earth that are visible for a few seconds. The brightest are Iridium, a constellation of 66 telecommunication satellites tossed into orbit in the ‘90s. If launched, the Orbital Display will be as bright as these — around -8 magnitude. (For reference, the Full Moon is about -13 and the Sun is about -27.)

Like most CubeSats, the billboard will have planned obsolescence and won’t last more than a year, the company says. The Orbital Display will only be viewable in evening and morning twilight, when the cubes catch sunlight while the observer is in darkness, according to Patrick Seitzer, an astronomy professor at the University of Michigan in Ann Arbor.

“You’ll never see them at midnight, for example,” he says in an email. “Depending on the orbit chosen, they might be visible for a few days, and then not visible for a week or more.”

“Launching art projects like this with no commercial, scientific, or national security value seems unwise,” adds Seitzer, who has been studying space debris since 2000. “Space is getting increasingly crowded. There are over 20,000 objects with orbits in the official public catalog maintained by the U.S. Air Force. Less than 10 percent of those objects are active satellites — the rest are dead satellites, old rocket bodies and parts of spacecraft.”

Astronomer John Barentine agrees this isn’t a bright idea — or actually, bright is the problem. Barentine serves as both director of conservation for the International Dark-Sky Association in Tucson, Arizona, and a member of the American Astronomical Society’s Committee on Light Pollution, Radio Interference and Space Debris. He says these space billboards could qualify as both light pollution and space debris and possibly even disrupt radio signals.

“It’s a threat to the ability to do astronomical research from the ground,” he says, noting that SpaceX’s plans to add at least another 7,500 CubeSats into low-Earth orbit will also factor into the problem. “Every one of those moving blips of light in the night sky is something that can interfere with our ability to collect photons from astronomical sources.”

#### Ground-based astronomy is key to astronomy more broadly – specifically hazardous object detection and exoplanet studies.

Siegel 19 “This Is Why We Can't Just Do All Of Our Astronomy From Space” Nov 27, 2019 Ethan Siegel is a Ph.D. astrophysicist and author of "Starts with a Bang!" <https://www.forbes.com/sites/startswithabang/2019/11/27/this-is-why-we-cant-just-do-all-of-our-astronomy-from-space/?sh=6c73d3c42704> SM

While it's easy to point to the ways that space-based astronomy has superiority to ground-based astronomy, there are still substantial advantages that being on the ground offers, and that astronomers continue to take advantage of even in a post-Hubble era. We can create images, collect data, and perform scientific investigations that simply cannot occur with space-based observatories alone.

There are five major metrics where ground-based observatories should always remain leaps and bounds ahead of space-based ones, and they generally include:

size,

reliability,

versatility,

maintenance,

and upgradeability.

If we can keep our skies dark, clear, and unobstructed, ground-based astronomy is sure to enter a golden age as the 21st century unfolds. Here's what's great about the ground.

1.) Size. Simply put, you can build a larger ground-based observatory, with a larger primary mirror, than you can build or assemble in space. There's a common (but incorrect) line of thinking that if we just spent enough money on the task, we could build a telescope as large as we wanted on the ground and then launch it into space. That's only true up to a point: the point that you have to fit your observatory into the rocket that's launching it.

The largest primary mirror ever to be launched into space belongs to ESA's Herschel, with a 3.5-meter mirror. James Webb will be bigger, but that's due to its unique (and risky) segmented design, and even that (at 6.5 meters) cannot compete with the large, ground-based telescopes we're building. The largest space-based telescope ever proposed, LUVOIR (with a segmented design and a 15.1 meter aperture), still pales in comparison to the 25-meter GMT or the 39-meter ELT. In astronomy, size determines your resolution and your light-gathering power. With the addition of adaptive optics, there are some metrics by which space is simply non-competitive with being on the ground.

2.) Reliability. When we build a new telescope on the ground, there's no risk of a launch failure. If there's a piece of equipment that malfunctions, we can easily replace it. But going to space is an all-or-nothing proposition. If your rocket explodes on launch, your observatory — no matter how expensive or sophisticated — is lost. You'll never hear what the results are from NASA's Orbiting Carbon Observatory, which was designed to measure how CO2 moves through the atmosphere from space, because it failed to separate from the rocket and crashed into the ocean 17 minutes after takeoff.

The bigger the mission, the bigger the cost of failure. In January of 2018, the rocket that will launch the James Webb Space Telescope, the Ariane 5, suffered a partial failure (that would have been catastrophic for Webb) after 82 consecutive successes. Hubble's infamous defective mirror was only fixable because it was within our reach. In space, you get one shot at success per mission, and 100% reliability will never be achieved.

3.) Versatility. Once you're in space, gravity and the laws of motion pretty much fix where your observatory is going to be at any given time. While there are plenty of astronomical curiosities that can be seen from anywhere, there are a few events, many of them spectacular, that require you to control (to extreme precision) where you'll be located at a particular moment in time.

Solar eclipses are one such phenomenon, but astronomical occultations offer an incredible opportunity that require just the right positioning. When Neptune's moon Triton or 486958 Arrokoth occult a background star, we can leverage ground-based (and in some cases, mobile) observatories to control our position exquisitely; when Jupiter occults a quasar, we can use it to measure the speed of gravity.

If we were to put all our eggs in the space telescope basket, these ultra-rare events would cease to be scientifically meaningful, as we cannot control our position and motion over time from space the way we do on Earth.

4.) Maintenance. This is at the root of an infrastructure problem: you have more of it on the ground than you'll ever have in space. If some component fails or wears out, you make do with what you've got in space, or you spend an enormous amount of resources to attempt to service it. Run out of coolant? You need a mission. Gyroscopes or other pointing mechanisms wear out? Mission. Have an optical component that degrades? Mission. Sunshield failure? Struck by a micrometeor? Instrument failure? Electrical short? Run out of fuel? For any and all of these, you have to send a servicing mission.

But from the ground, you can have even extravagant facilities on-site. A faulty mirror can be swapped out. More coolant can be obtained for your infrared telescope. Repairs can be made by human or robotic hands in real-time. New parts and even new personnel can be brought in at a moment's notice. Hubble has lasted for nearly 30 years, but ground-based telescopes can last over half a century with maintained infrastructure. It's no contest.

5.) Upgradability. By the time that a space telescope is launched, the instruments aboard it are already obsolete. To get a space telescope designed and built, you have to decide what its science goals will be, and that informs what instruments will be designed, built, and integrated on-board the observatory. Then you have to design them, manufacture the components, build and assemble them, install, integrate and test them, and finally launch them.

This necessarily means that the instruments that are proposed (and then built) are years out of date even when the space telescope takes data for the very first time. On the other hand, if your observatory is on the ground, you can simply pop out the old instrument and replace it with a new one, and your old telescope is state-of-the-art once again, a process that can continue as long as the observatory remains in operation.

There's no doubt that going to space provides humanity with a window on the Universe that we'd never get to exploit if we remained on Earth. The sharp, narrow-field images we can construct are incomparable, and as we move into the next generation of space-based observatories like Athena, James Webb, WFIRST and (maybe) even LUVOIR, we'll answer many of today's mysteries concerning the nature of the Universe.

Yet there are some scientific tasks that are far better suited to ground-based astronomy than space-based astronomy. In particular, deep spectroscopic imaging of distant targets, direct exoplanet studies, identification of potentially hazardous objects, hunting for objects in the outer Solar System (like Planet Nine), all-sky surveys for variable objects, interferometry studies and much more are all superior from the ground. Losing the benefits of ground-based astronomy would be both catastrophic and unnecessary, as even a small effort can prevent it. But if we continue to be reckless and careless with our skies — two all-too-human traits — they'll disappear, along with ground-based astronomy, before we know it.

#### Deflection technology inevitable – it’s just a question of its success

Koren 21 Marina Koren 11-30-2021 "NASA Is Practicing Asteroid Deflection. You Know, Just in Case." <https://www.govexec.com/technology/2021/11/nasa-practicing-asteroid-deflection-you-know-just-case/187120/> (a staff writer at The Atlantic. She covers space, including astronaut missions, robotic explorers, and the solar system and has reported from Cape Canaveral, SpaceX's launch site in south Texas, and NASA headquarters in Washington, DC. Previously, Koren was senior associate editor for The Atlantic.)//Elmer

The last thing anyone needs to think about right now is a catastrophic asteroid impact. And, thankfully, most of us don’t have to! Earth is not in immediate threat of a space rock. The chance that a known asteroid big enough to really do damage—or, you know, imperil our entire existence—will strike the planet in the next 100 years is insignificant. (If you want to worry about extinction, consider the extinctions brought on by climate change and other negative repercussions of our presence here on Earth.) But it helps to be prepared for these kinds of scenarios, and luckily there are people for whom thinking about them is a full-time job. So this week, just before Thanksgiving, NASA launched a space mission to test technology that could, someday, help humanity deflect a dangerous asteroid barreling its way. The spacecraft will now spend months zooming toward an asteroid several hundred million miles from Earth. (What did this particular asteroid ever do to us? Nothing—but NASA needs a test subject.) In September 2022, with the asteroid in its sights, the probe will line itself up and then—bam!—smash right into the unsuspecting rock at nearly 15,000 miles an hour. The impact is expected to change the orbit of the asteroid ever so slightly. Afterward, scientists will observe the shift with telescopes on Earth to determine whether this technique could work to protect our planet from a real cosmic threat. [Read: A handful of asteroid could help decipher our entire existence ] This would not be the first time a NASA spacecraft has bumped into an asteroid just minding its own business. Last year, a probe touched down on an asteroid’s surface and blasted it with nitrogen gas to stir up rocks. That mission was designed to collect some of those rocks and return them to Earth so that scientists might better understand how nature shaped the solar system and gave our planet its oceans. NASA punched that asteroid for the sake of science. This new mission is about survival. The Double Asteroid Redirection Test, or DART for short, marks humanity’s first-ever attempt to change the orbit of an asteroid. In some ways, it’s kind of rude? A bunch of “star stuff,” as Carl Sagan called us, has become sentient and smart enough to interfere with orbital mechanics and change, on a small scale, the nature of its solar system. It’s a weirdly godlike power move—you know, shifting heaven and earth for our own purposes. But here we are, throwing a spacecraft the size of a vending machine at an asteroid as big as Egypt’s Great Pyramid. The series of events that brought us to this particular point in human history can be traced back to 1998, when an astronomy institute issued an alert about a recently discovered asteroid that looked like it could hit in 2028. In astronomy time, that’s basically tomorrow, so if the asteroid was indeed a threat, we needed to do something about it soon. Scientists at NASA quickly found that this rock wasn’t going to collide with Earth, but the agency did establish a center devoted to estimating the probability of asteroids and comets hitting Earth, so that we might have a chance at actually stopping them. [Read: We’re heading straight for a demi-armageddon] The DART mission is aiming for Dimorphos, a small asteroid that orbits a bigger asteroid, Didymos, like a moon. If the mission works as intended, DART will carve a crater into the surface of Dimorphos and fling out a bunch of rocky debris, known as ejecta, esxplains Angela Stickle, a planetary scientist at the John Hopkins University Applied Physics Laboratory who leads the team that does impact simulations. “As that ejecta leaves the asteroid, it acts kind of like a rocket engine and pushes the asteroid,” Stickle told me. “You’re creating sort of a natural engine on the asteroid that then slows down its velocity.” Stickle and her team predict that the impact will shrink Dimorphos’s 12-hour orbit by about 10 minutes or so. A change in an object’s velocity translates into a change in its orbital path; if an asteroid were heading toward Earth, a version of this technique might shift an asteroid’s trajectory enough to turn a certain disaster into a near miss. In case you, like I, a person who usually assumes the worst, are wondering whether NASA could flub this mission and accidentally shove the asteroid toward Earth—don’t worry. A vending machine–size spacecraft isn’t capable of knocking Dimorphos out of its orbit around Didymos, or even inflicting serious damage. “This isn’t going to destroy the asteroid,” Nancy Chabot, the mission’s coordination lead at the Applied Physics Laboratory, told reporters earlier this month. “It’s just going to give it a small nudge.” The DART mission faces some unknowns. Astronomers think Dimorphos is probably a common kind of rocky asteroid. But asteroids have surprised them before. The asteroid that NASA touched down on last year, Bennu, turned out to be squishier than expected. And squishy asteroids would be more difficult to deflect, Cristina Thomas, a planetary scientist at Northern Arizona University who leads an observations team on DART, told me. “It’s a much simpler physics experiment if you take one hard thing and you smash it into another hard thing,” she said. [Read: How to get an asteroid named after you] In 2024, another planetary-defense mission, operated by the European Space Agency, will leave Earth for Didymos and Dimorphos to survey the scene and provide a close-up look of the aftermath of humanity’s attempt to mess with an asteroid. Meanwhile, on Earth, NASA will continue to search for and monitor near-Earth objects of a certain size. In 2005, Congress directed NASA to find at least 90 percent of the potentially hazardous asteroids that are statistically likely to exist out there. Remember when I said that no known asteroids have a significant chance of crashing into Earth in the next century? Well, NASA was supposed to meet that 90 percent goal as of 2020, but so far scientists have managed to find only 40 percent. Objects like Dimorphos appear fainter to telescopes than larger asteroids, which are easier to study and rule out as a hazard, Thomas said. “But an object of this size would actually pose a hazard to the planet,” she told me. Let’s say that someday astronomers identify a new asteroid that, unlike the 1998 discovery, could really be perilous. Scientists have practiced this scenario every year for nearly a decade in a NASA-run event about planetary defense. This year astronomers pretended that they had discovered an asteroid with a slight probability of hitting Earth in just six months. After a month of observations in this hypothetical scenario, that likelihood jumped to 100 percent. Astronomers needed more than a year to determine where exactly a hazardous asteroid would strike Earth, and they didn’t have that kind of time. Within days of impact, astronomers had only predictions about the regions at risk, including the places deemed “unsurvivable.” This particular exercise ended with a bleak conclusion: With a more powerful telescope scanning the skies, astronomers would have spotted this asteroid sooner, and space agencies would have had time to mount a mission like DART to attempt to deflect it away from Earth. And that telescope would have needed to be in place back in 2014. A starter mission such as DART is an important step in giving Earth a chance in this future. Despite what pop culture (or, more specifically, Armageddon) has led us to believe, space agencies won’t rely on a group of brave oil-rig workers but on spacecraft with good GPS to save us. (NASA actually invited Bruce Willis to attend the launch in California; the actor declined.) Any nuclear weapons—another option for destroying an asteroid headed our way—would likely be delivered by autonomous spacecraft, not astronauts. A future asteroid-redirect mission might be informed by the designs of previous spacecraft that destroyed themselves in the name of planetary defense, and guided by telescopes that have kept a watchful eye on the night sky, logging every new asteroid. When it comes to Earth-threatening asteroids, to paraphrase Aerosmith, you “don’t want to miss a thing.”

#### 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.

#### Exoplanet studies are key to solving climate change.

Mayne 16 “How looking into space can help our understanding of climate change on Earth” October 11, 2016 Nathan Mayne Senior Lecturer in Astrophysics, University of Exeter <https://theconversation.com/how-looking-into-space-can-help-our-understanding-of-climate-change-on-earth-66313> SM

How looking into space can help our understanding of climate change on Earth

Looking deep into outer space begs an obvious question. Are we alone? Does intelligent life exist elsewhere? It is a question that has preoccupied mankind ever since we became capable of rational thought. But space exploration could also hold clues to questions that have only struck us in recent decades, with the gradual awareness that carbon dioxide emissions are changing our own planet’s climate. A situation that, if unabated, could lead to an “extinction level” event.

This awareness coincided with the discovery of the first planet – or “exoplanet” – outside our own solar system. And we have now discovered thousands more.

Such exoplanets are incredibly diverse, but as many as two billion of them, within our galaxy, may be similar in size to Earth, and orbiting a star similar to our sun. The study of these exoplanets has moved from an era of simple detection to one of detailed characterisation. For some, we even have information about their atmospheric temperatures, compositions, cloudiness and wind speeds.

Exoplanets explained.

For now, these techniques are constrained to a sub-class of exoplanets termed “hot Jupiters”, large, Jupiter-sized planets, orbiting very close to their parent stars. Combining these observations with adapted Earth climate models has begun to provide information on subjects including the planets’ unexpected size, and the varying efficiency of how their atmospheric winds redistribute heat.

Extraterrestrial weather

Fascinating as these puzzles are, however, the natural focus for me is to look towards smaller, more Earth-like planets. I have always been interested in combining the study of exoplanet climatology with that of Earth climate science, which draws me back to the question of life on another world.

To keep things simple, we define a planet as being potentially life-harbouring in a very simple, Earth-centric way. Does it have a temperature range where liquid water, so fundamental to life here on Earth, could exist? This defines the “habitable zone”, a region around a star where the light received by the planet is neither so strong that it leads to total evaporation, nor so weak that it would lead to freezing of any water.

Of course, the details of how much water might be present and the actual planetary temperatures for a given amount of starlight are complex. We know in our own Solar system that the Earth, Venus and Mars are not extremely dissimilar in size, or in the amount of light they receive from the sun.

However, Venus is completely desiccated and very hot, whereas the water content of Mars is believed to be frozen at the poles.

Additionally, the earliest evidence of life on Earth dates from about three billion years ago, during the Archean period. During this time, the sun was much smaller and fainter than it is today, as sun-like stars expand over time.

Life matters

The sun will continue to expand, and in a few billion years this is likely to lead to the total evaporation of the water from Earth. So if we are to predict whether complex life might be present on an exoplanet, we must understand the reasons why Venus, Earth and Mars diverged in their evolution, how the Earth stayed “habitable” during the evolution of life, and when it might become uninhabitable.

Of course, life itself affects the environment around it, and there is significant evidence that life itself increased the “habitability” of Earth. This leads us to the next element in the search for intelligent life: a biosignature, a substance which provides evidence that life does, or did once, exist.

We know that our atmosphere is not in chemical balance, largely due to chemical emissions from life forms. Potentially, by measuring the balance of the gases in the atmospheres of Earth-like exoplanets, just as we are currently doing for hot Jupiters, we may find a similar imbalance – and a potential signature of extra-terrestrial life.

A potentially habitable Earth-like planet has been detected around the sun’s nearest neighbour, a cool, small star called Proxima Centauri. But we don’t yet really understand how its climate will differ from Earth’s given that it is exposed to the radiation from such a cool star. It also seems that photosynthesis, critical to life on Earth, is not likely to work there.

Out there.

And all of this brings us straight back down to Earth. Currently, despite the fact that a vast number of potentially habitable Earth-like planets exist in our galaxy we know of life existing in only one place: right here.

We now need to to understand in more detail the multitude of various climates that planets can support, and how they evolve over time and with changing conditions.

One of the biggest challenges facing us on our own planet is the increase in atmospheric carbon dioxide, causing an increase in the variability of our weather systems. As our climate evolves and changes, we must adapt. And this adaptation can only be aided by the lessons learned from forcing our theories, tools and brains to cope with the diversity of climates presented by the exoplanets.

#### Specifically, CCS technology.

Xin 22 Ling Xin (辛玲), Exoplanets, extraterrestrial life and beyond: an interview with Douglas Lin, National Science Review, Volume 9, Issue 2, February 2022, nwac008, https://doi.org/10.1093/nsr/nwac008 SM

NSR: How does the search for exoplanets and life help us understand earthly problems, such as climate change?

Lin: If we look at Venus and Mars, we can already anticipate some consequences of global climate changes. It was a lot warmer here on Earth during the Cretaceous period, but the climate transitions in geological history happened over a really long period of time. What is alarming about today is the astonishing rate at which carbon dioxide and other greenhouse gases accumulate in the atmosphere, largely due to human factors. Climatic models have predicted major changes in weather patterns and coastal boundaries within our children's generation. There is a sense of urgency to quell this trend.

Although current political discussions by world leaders have mostly focused on cutting carbon emissions, it is also important to explore carbon capture technologies. We can get some inspiration in this regard by understanding atmospheric circulation and climatic dynamics on other planets. For instance, the greenhouse effect on Venus is so strong that rain evaporates before it reaches the ground. We do not want this to happen on Earth, because it would cut off a major channel of carbon return from the Earth's atmosphere to the soil and rocks on Earth's surface. We need to unravel the complex interplay between air, ocean, sea ice, land surface, atmosphere chemistry and biological and industrial activities on a global scale as well as to understand the long-term carbon deposit-and-release geophysical cycle in and beneath the Earth's rocky crust. This comprehensive knowledge will be useful for strategizing effective, holistic approaches to quench and hopefully to thwart the current trend of rapid global warming.

#### Short-term action to mitigate climate change solves extinction and nuclear war

**Pester 8/30/21** (Patrick, staff writer for Live Science. His background is in wildlife conservation and he has worked with endangered species around the world. Patrick holds a master's degree in international journalism from Cardiff University in the U.K. and is currently finishing a second master's degree in biodiversity, evolution and conservation in action at Middlesex University London. Citing **Luke Kemp, a research associate at the Centre for the Study of Existential Risk at the University of Cambridg**e in the United Kingdom AND **Michael Mann, PhD, distinguished professor of atmospheric science at Penn State**. “Could climate change make humans go extinct?” [https://www.livescience.com/climate-change-humans-extinct.html August 30](https://www.livescience.com/climate-change-humans-extinct.html%20August%2030), 2021)DR 21

According to Mann, a global temperature increase of 5.4 degrees Fahrenheit (3 degrees Celsius) or more could lead to a collapse of our societal infrastructure and massive unrest and conflict, which, in turn, could lead to a future that resembles some Hollywood dystopian films.

One way climate change could trigger a societal collapse is by creating food insecurity. Warming the planet has a range of negative impacts on food production, including increasing the water deficit and thereby reducing food harvests, [Live Science previously reported](https://www.livescience.com/58891-why-2-degrees-celsius-increase-matters.html). Food production losses can increase human deaths and drive economic loss and socio-political instability, among other factors, that may trigger a breakdown of our institutions and increase the risk of a societal collapse, according to a study published Feb. 21 in the journal [Climatic Change](https://go.redirectingat.com/?id=92X1590019&xcust=livescience_us_1191050396230939400&xs=1&url=https%3A%2F%2Flink.springer.com%2Farticle%2F10.1007%2Fs10584-021-02957-w&sref=https%3A%2F%2Fwww.livescience.com%2Fclimate-change-humans-extinct.html).

Related: [Has the Earth ever been this hot before?](https://www.livescience.com/65927-has-earth-been-this-hot-before.html)

Past extinctions and collapses

Kemp studies previous civilization collapses and the risk of climate change. Extinctions and catastrophes almost always involve multiple factors, he said, but he thinks if humans were to go extinct, climate change would likely be the main culprit.

"If I'm to say, what do I think is the biggest contributor to the potential for human extinction going towards the future? Then climate change, no doubt," Kemp told Live Science.

All of the major [mass-extinction events](https://www.livescience.com/mass-extinction-events-that-shaped-Earth.html) in Earth's history have involved some kind of climatic change, according to Kemp. These events include cooling during the Ordovician-[Silurian](https://www.livescience.com/43514-silurian-period.html) extinction about 440 million years ago that wiped out 85% of species, and warming during the [Triassic](https://www.livescience.com/43295-triassic-period.html)-[Jurassic](https://www.livescience.com/28739-jurassic-period.html) extinction about 200 million years ago that killed 80% of species, Live Science previously reported. And more recently, climate change affected the fate of early human relatives.

While [Homo sapiens](https://www.livescience.com/homo-sapiens.html) are obviously not extinct, "we do have a track record of other hominid species going extinct, such as [Neanderthals](https://www.livescience.com/28036-neanderthals-facts-about-our-extinct-human-relatives.html)," Kemp said. "And in each of these cases, it appears that again, climatic change plays some kind of role."

Scientists don't know why Neanderthals went extinct about 40,000 years ago, but climatic fluctuations seem to have broken their population up into smaller, fragmented groups, and severe changes in temperature affected the plants and animals they relied on for food, according to the [Natural History Museum](https://www.nhm.ac.uk/discover/who-were-the-neanderthals.html) in London. Food loss, driven by climate change, may have also led to a tiny drop in Neanderthal fertility rates, contributing to their extinction, [Live Science previously reported](https://www.livescience.com/65594-neanderthal-fertility-led-to-extinction.html).

Climate change has also played a role in the collapse of past human civilizations. A [300-year-long drought](https://www.livescience.com/38893-drought-caused-ancient-mediterranean-collapse.html), for example, contributed to the downfall of ancient Greece about 3,200 years ago. But Neanderthals disappearing and civilizations collapsing do not equal human extinction. After all, humans have survived climate fluctuations in the past and currently live all over the world despite the rise and fall of numerous civilizations.

Homo sapiens have proven themselves to be highly adaptable and able to cope with many different climates, be they hot, cold, dry or wet. We can use resources from many different plants and animals and share those resources, along with information, to help us survive in a changing world, according to the [Smithsonian’s National Museum of Natural History](https://humanorigins.si.edu/research/climate-and-human-evolution/climate-effects-human-evolution).

Related: [How would just 2 degrees of warming change the planet?](https://www.livescience.com/58891-why-2-degrees-celsius-increase-matters.html)

Today, we live in a global, interconnected civilization, but there's reason to believe our species could survive its collapse. A study published on July 21 in the journal [Sustainability](https://www.mdpi.com/2071-1050/13/15/8161/htm) identified countries most likely to survive a global societal collapse and maintain their complex way of life. Five island countries, including New Zealand and Ireland, were chosen as they could remain habitable through agriculture, thanks to their relatively cool temperatures, low weather variability and other factors that make them more resilient to climate change.

New Zealand would be expected to hold up the best with other favorable conditions, including a low population, large amounts of good quality agricultural land and reliable, domestic energy. So, even if climate change triggers a global civilization collapse, humans will likely be able to keep going, at least in some areas.

Turning on ourselves

The last scenario to consider is climate-driven conflict. Kemp explained that in the future, a scarcity of resources that diminish because of **climate change could** potentially create conditions for wars that threaten humanity. "There's reasons to be concerned that as water resources dry up and scarcity becomes worse, and the general conditions of living today become much, much worse, then suddenly, the threat of potential nuclear war becomes much higher," Kemp said.

Put another way, climate change impacts might not directly cause humans to go extinct, but it could lead to events that seriously endanger hundreds of millions, if not billions, of lives. A 2019 study published in the journal [Science Advances](https://advances.sciencemag.org/content/5/10/eaay5478) found that a nuclear conflict between just India and Pakistan, with a small fraction of the world's nuclear weapons, could kill 50 million to 125 million people in those two countries alone. Nuclear war would also change the climate, such as through temperature drops as burning cities fill the atmosphere with smoke, threatening food production worldwide and potentially causing mass starvation.

What's next?

While avoiding complete extinction doesn't sound like much of a climate change silver lining, there is reason for hope. Experts say it isn't too late to avoid the worst-case scenarios with significant cuts to greenhouse gas emissions.

"It is up to us," Mann said. "If we fail to reduce carbon emissions substantially in the decade ahead, we are likely committed to a worsening of already dangerous extreme weather events, inundation of coastlines around the world due to melting ice and rising sea level, more pressure on limited resources as a growing global population competes for less food, water and space due to climate change impacts. If we act boldly now, we can avoid the worst impacts."

#### Advertising independently accelerates debris creation

O’Brien 15 “Advertising in Space: Sales at the Outer Limits” Zeldine O’Brien in “Commercial space exploration [ethics, policy and governance]” 2015 <https://www.taylorfrancis.com/books/edit/10.4324/9781315572857/commercial-space-exploration-jai-galliott> SM

Environmental Concerns: Space Debris

All space objects generate space debris. Space advertising is no different. It is presumed that the object generating the debris has a purpose that outweighs the environmental consequences such as scientific experimentation, refuelling the ISS or remote sensing. In the case of space advertising, there are two concerns: first, whether that presumption is appropriate in the context of a space object whose sole purpose is to advertise and, secondly, whether the nature of space advertising generates a greater degree of risk of proliferations. On this second point, the IAU comments:

In fact most space advertising is likely to greatly outlast the enterprise that launched it, unless end-of-mission deorbiting procedures are required and implemented. Moreover, because space objects used for advertising purposes need to be very large, they also present a large cross-section to impacts of existing space debris, resulting in the creation of even more such debris. (2001, p. 3)

For states without explicit bans, each project would require a case-by-case analysis, including consideration of the impact to existing debris, the creation of debris, compliance with any applicable debris mitigation guidelines and any proposed end-of-life measures. Liability for component parts of space objects will lie on the launching state for harm on an absolute basis to the surface of Earth or aircraft in flight or on a fault basis to other space objects (Liability Convention 1972, Arts II and III). While the launching state may be able to recoup any damages paid out from the licensee, this is only if that party is still extant.

#### Debris particles wrecks satellites and collisions multiply particles

Intagliata 17 [(Christopher Intagliata, MA Journalism from NYU, Editor for NPRs All Things Considered, Reporter/Host for Scientific American’s 60 Second Science) “The Sneaky Danger of Space Dust,” Scientific American, May 11, 2017, <https://www.scientificamerican.com/podcast/episode/the-sneaky-danger-of-space-dust/>] TDI

When tiny particles of space debris slam into satellites, the collision could cause the emission of hardware-frying radiation, Christopher Intagliata reports.

Aside from all the satellites, and the space station orbiting the Earth, there's a lot of trash circling the planet, too. Twenty-one thousand [baseball-sized chunks](https://www.scientificamerican.com/article/orbital-debris-space-fence/) of debris, [according to NASA](https://www.orbitaldebris.jsc.nasa.gov/faq.html). But that number's dwarfed by the number of small particles. There's hundreds of millions of those.

"And those smaller particles tend to be going fast. Think of picking up a grain of sand at the beach, and that would be on the large side. But they're going 60 kilometers per second."

Sigrid Close, an applied physicist and astronautical engineer at Stanford University. Close says that whereas mechanical damage—like punctures—is the worry with the bigger chunks, the dust-sized stuff might leave more insidious, invisible marks on satellites—by causing electrical damage.

"We also think this phenomenon can be attributed to some of the failures and anomalies we see on orbit, that right now are basically tagged as 'unknown cause.'"

Close and her colleague Alex Fletcher modeled this phenomenon mathematically, based on plasma physics behavior. And here's what they think happens. First, the dust slams into the spacecraft. Incredibly fast. It vaporizes and ionizes a bit of the ship—and itself. Which generates a cloud of ions and electrons, traveling at different speeds. And then: "It's like a spring action, the electrons are pulled back to the ions, ions are being pushed ahead a little bit. And then the electrons overshoot the ions, so they oscillate, and then they go back out again.”

That movement of electrons creates a pulse of electromagnetic radiation, which Close says could be the culprit for some of that electrical damage to satellites. The study is in the journal Physics of Plasmas. [Alex C. Fletcher and Sigrid Close, [Particle-in-cell simulations of an RF emission mechanism associated with hypervelocity impact plasmas](http://aip.scitation.org/doi/full/10.1063/1.4980833)]

#### Collisions with early warning satellites causes miscalc and goes nuclear

Blatt 20 [Talia, joint concentration in Social Studies and Integrative Biology at Harvard, specialization in East Asian geopolitics and security issues] “Anti-Satellite Weapons and the Emerging Space Arms Race,” Harvard International Review, May 26, 2020, <https://hir.harvard.edu/anti-satellite-weapons-and-the-emerging-space-arms-race/> TG

Despite their deterrent functions, ASATs are more likely to provoke or exacerbate conflicts than dampen them, especially given the risk they [pose](https://thebulletin.org/2019/06/arms-control-in-outer-space-the-russian-angle-and-a-possible-way-forward/) to early warning satellites. These satellites are a crucial element of US ballistic missile defense, capable of [detecting missiles](https://www.globalsecurity.org/space/world/japan/warning.htm) immediately after launch and tracking their paths.

Suppose a US early warning satellite goes dark, or is shut down. Going dark could signal a glitch, but in a world in which other countries have ASATs, it could also signal the beginning of an attack. Without early warning satellites, the United States is much more susceptible to nuclear missiles. Given the strategy of counterforcing—[targeting](https://www.belfercenter.org/sites/default/files/files/publication/isec_a_00273_LieberPress.pdf) nuclear silos rather than populous cities to prevent a nuclear counterattack—the Americans might believe their nuclear weapons are imminently at risk. It could be [twelve hours](https://books.google.com/books?id=ET8lDwAAQBAJ&pg=PA1&lpg=PA1&dq=%22Protecting+Space+Assets%22+johnson-freese&source=bl&ots=6Oq0IdeBjw&sig=ACfU3U1G6Hj8QdP4JlCRNxA6i5XplZwHyg&hl=en&sa=X&ved=2ahUKEwj1n-jT2YzpAhUugnIEHUuMCu4Q6AEwA3oECAkQAQ#v=onepage&q=%22Protecting%20Space%20Assets%22%20johnson-freese&f=false) before the United States regains satellite function, which is too long to wait to put together a nuclear counterattack. The United States, therefore, might move to mobilize a nuclear attack against Russia or China over what might just be a piece of debris shutting off a satellite.

Additionally, accidental warfare, or strategic miscalculation, is uniquely likely in space. It is [much easier](https://books.google.com/books?id=VyXTDwAAQBAJ&pg=PA339&lpg=PA339&dq=space+offense+dominant&source=bl&ots=Mw0bgJ51qf&sig=ACfU3U3DeZiEHpr9nfszlCbJZIoyyssIpg&hl=en&sa=X&ved=2ahUKEwjrs-WD3IzpAhVulHIEHbL0AE4Q6AEwCXoECAoQAQ#v=onepage&q=space%20offense%20dominant&f=false) to hold an adversary’s space systems in jeopardy with destructive ASATs than it is to [sustainably defend](https://www.cnas.org/publications/commentary/the-us-military-should-not-be-doubling-down-on-space) a system, which is expensive and in some cases not technologically feasible because of limitations on satellite movement. Space is therefore [considered](https://books.google.com/books?id=VyXTDwAAQBAJ&pg=PA339&lpg=PA339&dq=space+offense+dominant&source=bl&ots=Mw0bgJ51qf&sig=ACfU3U3DeZiEHpr9nfszlCbJZIoyyssIpg&hl=en&sa=X&ved=2ahUKEwjrs-WD3IzpAhVulHIEHbL0AE4Q6AEwCXoECAoQAQ#v=onepage&q=space%20offense%20dominant&f=false) offense-dominant; offensive tactics like weapons development are prioritized over defensive measures, such as [improving GPS](https://www.politico.com/story/2018/04/06/outer-space-war-defense-russia-china-463067) or making satellites more resistant to jamming.

As a result, countries are left with poorly defended space systems and rely on offensive posturing, which increases the risk that their actions are perceived as aggressive and incentivizes rapid, risky counterattacks because militaries cannot rely on their spaced-based systems after first strikes.

There are several hotspots in which ASATs and offensive-dominant systems are particularly relevant. Early warning satellites [play](https://www.politico.com/story/2018/04/06/outer-space-war-defense-russia-china-463067) a central role in US readiness in the event of a conflict involving North Korea. News of North Korean missile launches comes from these satellites. Given North Korea’s [history](https://www.bbc.com/news/world-asia-pacific-11813699) of nuclear provocations, unflinchingly hostile rhetoric towards the United States and South Korea, and diplomatic opacity, North Korea is always a threatening, unknowable adversary, but recent developments have magnified the risk. With the health of Kim Jong-un [potentially in jeopardy](https://apnews.com/f5d302ae65b03838173e40848223b771), a succession battle or even civil war on the peninsula [raises the chances](https://www.express.co.uk/news/world/1273890/Kim-Jong-un-dead-North-Korea-nuclear-weapon-news-latest-death-US) of loose nukes. If the regime is terminal, traditional MAD risk calculus will become moot; with nothing to lose, North Korea would have no reason to hold back its nuclear arsenal. Or China [might decide](https://foreignpolicy.com/2020/04/28/kim-jong-un-china-north-korea/) to seize military assets and infrastructure of the regime. If the US does not have its early warning satellites because they have been taken out in an ASAT attack, the US, South Korea, and Japan are all in imminent nuclear peril, while China could be in a position to fundamentally reshape East Asian geopolitics.

The South China Sea is another hotspot in which ASATs could risk escalation. China [is developing](https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/china-anti-access-area-denial-coming-soon/) Anti-Access Area Denial (A2/AD) in the South China Sea, a combination of long range radar with air and maritime defense meant to deny US freedom of navigation in the region. Given the disputed nature of territory in the South China Sea, the United States and its allies do not want China to successfully close off the region.

#### Astronomy in Africa growing now

Povic et al. 18 (Mirjana Povi

The development of astronomy and space science in Africa has grown signiﬁcantly over the past few years. These advancements make the United Nations Sustainable Development Goals more achievable, and open up the possibility of new beneﬁcial collaborations

Until recently, South Africa with the Southern African Astronomical Observatory (SAAO) and Hartebeesthoek Radio Astronomy Observatory (HartRAO), Namibia with the High Energy Stereoscopic System (HESS), and Morocco, Algeria and Egypt with their optical observatories, were almost the only astronomy references in Africa. Also, South Africa, Egypt, Nigeria and Algeria were the only four African countries with established satellite programmes. In recent years, many other countries began research activities in astronomy and space science (A&SS), starting with institutional development, human capacity development (HCD), scientific research and networking. The African Union (AU) took important steps in promoting the development of A&SS on a continental scale for improving some of the main socioeconomic and environmental challenges that Africa is facing, and for achieving United Nations Sustainable Development Goals (UN SDGs). This Comment aims to provide an overview of the current status and future prospects of A&SS in Africa.

#### Key to African scientific and technological research–backbone of other fields

**Govender 11** (Kevin Govender, [Director @ International Astronomical Union (IAU) Office of Astronomy for Development (OAD]. 6-29-2011, “Astronomy for African development“, Cambridge Core, accessed: 12-17-2021, https://www.cambridge.org/core/journals/proceedings-of-the-international-astronomical-union/article/astronomy-for-african-development/1948AF853CD49C5FAC04748FAFFB433B) ajs

2. Overview of astronomy for African development Through various discussions with rˆole players across Africa, there arose 5 areas of development in which astronomy can play a key role: Education; Research; Public understanding of Science; Partnerships; and Job Creation (specifically in the field of tourism or ‘astro-tourism’). 2.1. Education In keeping with the spirit of the New Partnership for Africa’s Development (NEPAD), which identifies education as a priority, astronomy, through its innate ability to stimulate curiosity, can be used as a rallying point for the development of a strong learning culture. This is with the view that education, which is probably the most sustainable form of development, remains one of the most important and crucial challenges facing the African continent, a challenge which could be the single most significant barrier to peace and development. In Africa, astronomy remains one of the most accessible of all sciences, with the biggest laboratory (a dark night sky) being most available to people in rural areas. Night-time satellite images of the earth clearly illustrate this. The widespread buy-in by the education and outreach sectors in South Africa has proven how powerful the impact of astronomy can be on education. 2.2. Research The need for the development of a strong research community is clear from policies and structures already in place within the African Union, more specifically NEPAD‡,not to mention the policies of individual countries such as South Africa who aim to invest over 1% of their Gross Domestic Product (GDP) in science and technology. In such an environment astronomy can stimulate research in many other science fields. In South Africa for example the development of large telescopes have had an impact on technological capabilities begging the need for high level optical, construction and data manipulation expertise. The mathematics and theoretical physics communities tend also to overlap or interact closely with the astronomy community. In fact the pre-requisite for following a career in astronomy is a solid mathematics or physics background. The development of astronomy thus leads inevitably to the development of those respective university research departments. 2.3. Public Understanding of Science In many developing countries one finds that modern scientific knowledge amongst the public is not very strong. In many cases traditional knowledge or superstitions dominate, leading to many misconceptions. Astronomy plays a key rˆole in addressing this often sensitive relationship between traditional and scientific knowledge systems since the sky is something that virtually every culture is already familiar with (in one way or the other). Indigenous astronomy is usually a very interesting topic of conversation and an easy way to start a gradual process of introducing people to the modern understanding of the universe. For example, a conversation about beliefs surrounding an eclipse followed by a practical demonstration of the principle has been found to be very effective in stimulating scientific thinking. By bringing to the public the things we know about the universe and more importantly, how we know them (technologies employed, scientific method, etc), we stimulate a public understanding and appreciation of science and technology. One must stress though that the conversation certainly goes both ways, and an acknowledgement of indigenous knowledge is important and essential in building the relationship with and pride of a people. Indigenous astronomical knowledge in Africa (such as the asterism isiLimela, aka Pleiades, which indicated the start of the planting season) serves as proof of the advanced thinking and observations of our ancestors†. In fact, archaeological finds in Timbuktu and other parts of Africa strongly suggest that Africans were doing astronomy hundreds if not thousands of years ago. Such discussions support the fact that the field of astronomy does in fact belong to us all as human beings, and is certainly not something exclusive that can only be enjoyed by the wealthy or privileged. 2.4. Partnerships The 8th United Nations Millennium Development Goal is to ‘Develop a Global Partnership for Development’‡. The need for partnerships are also highlighted in the sentiments and spirit of the African Union and regional co-operation bodies such as the Southern African Development Community (SADC), the East African Community (EAC), and the Economic Community for West African States (ECOWAS). By its very nature astronomy stimulates a need to form partnerships with other countries, not just for the large financial investments but also for the geographic distribution of observatories. The process of developing astronomy would speak directly to and support a number of bilateral and multilateral agreements already in place across Africa. 2.5. Job Creation (astro-tourism) With appropriate marketing and media coverage the field of astronomy in South Africa is growing into a significant attraction for tourists. The number of tourists to the small town of Sutherland (home to the SAAO and SALT) has become so significant that a number of small businesses have sprung up all around the town, ranging from accommodation to restaurants to souvenir shops. The demand for tours at SALT during certain times of the year far exceeds the capacity of the observatory which has resulted in the training and involvement of unemployed individuals from Sutherland. As the lights of cities continue to grow, Africa has been holding on to one of its greatest untapped resources: a dark and clear night sky. A growing number of commercial African tourism companies are making the most of this valuable resource using ‘amateur’ telescopes and attracting business from foreign visitors as well as corporate companies. In Africa there is great potential for ‘astro-tourism’ to be developed just as much as ‘eco-tourism’ already has been. The International Year of Astronomy, in bringing attention to the field, is the opportune time to explore this potential further.

#### Space solves African development via tourism

**Manikumar 21** (Samyukta Manikumar, [science communicator, ], 4-7-2021, “How Dark Skies Can Contribute to Africa’s Development“, Space in Africa, accessed: 12-17-2021, https://africanews.space/how-dark-skies-can-contribute-to-africas-development/) ajs

If you have lived in or visited parts of Africa, you have probably had the chance to experience a truly dark night sky away from city lights. You might have noticed the staggering number of stars in the sky. You may even have seen the faint glow of the band of our galaxy, the Milky Way. This is a rare sight. More than 80% of the world’s population lives under light-polluted skies.

The tourism industry contributes about [7% to Africa’s total GDP](https://qz.com/africa/1888306/africa-tourism-market-to-lose-up-to-120-billion-with-covid/#:~:text=%E2%80%9CTourism%20is%20one%20of%20the,Africa's%20GDP,%E2%80%9D%20says%20Dr.). Like the rest of the world, the African tourism sector has been hit hard by the COVID-19 pandemic. In order to bounce back from the economic effects of this crisis, the tourism industry needs robust rebuilding. We have to consider ways to innovate and improve it so that international tourists are encouraged to visit again, while also tapping into the domestic tourism market. One way to approach this is to use freely available resources that we may not have considered yet. Dark skies are one of these resources. Here are some ways that darkness can help revitalise the tourism industry and contribute to development:

Terrestrial astrotourism

Terrestrial astrotourism is any kind of travel on Earth that enables you to observe astronomical phenomena. It involves travel for special celestial events like eclipses, meteor showers, planetary conjunctions, but it also includes travelling just to see a dark starry sky. Anyone can engage in this kind of tourism, including amateur and professional astronomers, astrophotographers, or generally curious people.

Africa offers lots of rich and unpolluted skies, making it an ideal destination for astrotourists. Countries on and below the equator have an added advantage: the visibility of the southern night sky, with its many nebulae and the Small and Large Magellanic Clouds. Building tourism products around objects and events in the night sky can attract lots of curious international tourists. It is also a novelty for domestic tourists, who often reside in the city and don’t get the chance to explore the night sky.

#### African Economy is teetering – triggers instability – only focus on development can survive COVID’s aftermath.

Burke 21 Jason Burke 8-13-2021 "‘An economic calamity’: Africa faces years of post-Covid instability" https://www.theguardian.com/world/2021/aug/13/an-economic-calamity-africa-faces-years-of-post-covid-instability (Jason Burke is the Africa correspondent of the Guardian, based in Johannesburg. In 20 years as a foreign correspondent, he has covered stories throughout the Middle East, Europe and South Asia. He has written extensively on Islamic extremism and covered the wars of 2001 in Afghanistan and 2003 in Iraq.)//Elmer

Analysts and experts are warning of many years of instability across Africa, possibly leading to wars and political upheavals, as the economic impact of the Covid-19 pandemic deepens across the continent. Though many of the likely consequences are yet to become evident, recent unrest in southern Africa, increased extremist violence in the Sahel and growing instability in parts of west Africa can all be attributed in part to the outbreak, observers say. However, there has also been strong leadership and effective action by large organisations that provide hope that the worst effects of the pandemic may be avoided. “It is a story in two parts,” said Dr Comfort Ero, the Africa programme director at the International Crisis Group. “In the first chapter, the continent appeared more resilient in the face of the pandemic than many more developed parts of the world. There were lots of concerns that it would all go to hell but it didn’t. The next chapter may see all the things that didn’t play out in 2020 beginning to reveal themselves.” More than 7m cases and 180,000 deaths have been recorded in Africa, totals that most researchers believe are significant underestimates. Though many have been encouraged and inspired by the response of African countries to the pandemic, led by the newly created African Union’s Centres for Disease Control and Prevention, the economic effects of the pandemic have been drastic. One recent international study found that Covid-19 may hit Africa harder than any other recent global crisis, including the 1997 Asian financial crisis, the 2008 Great Recession, and the Ebola outbreak of 2014. Ahunna Eziakonwa, the director of the United Nations Development Programme’s regional bureau for Africa, said African countries had been disproportionately hit by the economic shock from Covid-19. “There is a faster recovery elsewhere because money is being poured into the system. The continent is at a big disadvantage. Many African countries are still lifting the key basic things, people out of poverty, providing basic eduction and health services. Now spending and investment are drying up and that translates into distress and destitution,” Eziakonwa said. Some observers describe a historic divergence between the developed world and Africa as normality returns in Europe, the US and much of the Asia Pacific region, while African economies falter and populations remain without vaccine for years to come. Kristalina Georgieva, the managing director of the International Monetary Fund, warned in June of “a two-track pandemic … leading to a two-track recovery.” She said: “Africa is already falling behind in terms of growth prospects. It is a human tragedy and an economic calamity.” The IMF projects that the global economy will grow by 6% this year, and the African economy by only 3.2%. Inflation is soaring in many places, with food prices in Nigeria increasing by almost a quarter since the start of the pandemic, pushing 7 million people into poverty. The World Bank said the pandemic had pushed up to 40 million people into extreme poverty, even before a third wave of Covid infections broke on the continent between May and July. In South Africa, 1 million jobs are thought to have been destroyed by a month’s hard lockdown last year, and there has been a significant rise in reporting of hunger among citizens of Africa’s most industrialised nation. In Nigeria, a severe depression has caused the graduate unemployment rate to surge to more than 40%. One particularly badly hit sector has been tourism. Before the pandemic, Africa had the second-fasting growing tourism sector in the world, contributing 8.5% of the continent’s GDP and employing 24 million people. “It’s been really hard. We’ve had nothing for more than a year,” said Boniface Kenn, a Tanzanian guide. The economic damage inflicted by the outbreak will make it harder for governments to fulfil the aspirations of increasingly globalised youthful populations, will exacerbate tensions in places where competition for scarce resources already causes conflict, and could force some authoritarian regimes to reinforce repression to head off widespread dissent. “The pandemic has been a major destabilising force,” said Nic Cheeseman, a professor of African politics at Birmingham University. “It will disrupt some democracies and some autocracies, but all governments will struggle with unsustainable debts and less income, and that is simply not being highlighted at the moment. The reality is that Africa’s Covid crisis is yet to come.” In the Sahel, the economic impact of the pandemic has further weakened administrations that were already struggling to find resources for security forces, and has aggravated tensions between communities that have helped Islamic extremists make inroads in recent years. Across the region, as elsewhere on the continent, trade routes have been blocked, investments abandoned, and the flow of the remittances from overseas workers and the diaspora on which millions depend for everything from school fees to food has been significantly reduced. Overseas aid is also likely to be reduced. Local and national elections have been postponed due to the virus, raising tensions and causing instability. “People have nothing to lose any more. When they are on the edge, they are that much more given to being violent or being instrumentalised by politicians who exploit their anger, and that is a clear and present danger,” said Eziakonwa, who co-authored a UN study on the impact of Covid on the continent. There are tensions too in Ghana, long seen as a paragon of democracy and stability in west Africa, while an outbreak of vandalism and looting in July in South Africa, one of the most unequal countries in the world, was exacerbated by the pandemic, experts say. “A million people lost their jobs [in South Africa] last year and Covid definitely increased hunger. So there are a lot more desperate people. The lockdown had a very negative effect on the economy and that is definitely contributing to the number of people involved in looting,” said Gareth Newham, the head of justice and violence prevention at the Institute for Security Studies, Pretoria. “The trigger was economic sabotage, then there was opportunistic looting for personal gain and by local criminal networks too.” Much of the unrest in South Africa was instigated by supporters of the jailed former president Jacob Zuma, who sought to exploit the deteriorating economic context in the country for political ends. But analysts say the violence was a foretaste of the instability the Covid pandemic may leave in its wake, threatening autocratic and democratic government. “The concern is that South Africa is a harbinger of what is to come on the continent. It is going to be uneven but the overall picture looks terribly worrying,” said Ero. Protests have gathered strength in Eswatini, Africa’s last remaining monarchy, where public sector salaries have gone unpaid for months, and repression and ostentatious consumption by elites has prompted anger. “We are fighting for democracy, freedom, jobs, and for food. We are fighting a liberation struggle,” said a 26-year-old student leader in Eswatini, who requested anonymity for fear of arrest. Eziakonwa said any increase in malnutrition and the likely diversion of resources from immunisation programmes as a result of the Covid-19 outbreak would have a significant impact on young people and infants. “It will take children’s lives and that will be unbearable,” she said.

#### It's existential---state collapse, refugees, and terror.

Perez ‘18 [Alexandra; 2018; Pepperdine University, School of Public Policy. Masters in Public Policy at Pepperdine. Project Manager, Health Policy at Cato Institute; "Food Security as U.S. National Security: Why Fragile States in Africa Matter." https://digitalcommons.pepperdine.edu/cgi/viewcontent.cgi?article=1169&context=ppr]

The United States’ role in foreign affairs is guided by an interest to keep the general peace around the world while protecting national security and economic interests. Stability in regions such as sub-Saharan Africa is crucial to national security, and one way to keep peace is by supplying the basic human need of food. According to the Fund for Peace, the three most fragile states in 2017 were in Africa— the Central African Republic, South Sudan, and Somalia. 1 Several other African countries are fragile, suffering from standard measures of instability, such as widespread corruption, weak institutions, and resource scarcity. Together, these problems create displacement, human-rights violations, and power vacuums where non-state actors can flourish. These issues should concern the United States not only for moral reasons, but also because they negatively affect American interests. Food aid and agricultural systems must be used as a tool to promote peace in Africa to decrease the region’s burden on the United States and to help stabilize a region that is often referred to as a lost continent. With bipartisan support, the Global Food Security Act became law in July of 2016. It requires the President and appropriate agencies—including USAID, State Department, and the Office of US Trade—to formulate a plan to address food-insecure countries and report on that plan annually.2 The bill cited the Worldwide Threat Assessment of the US Intelligence Community (2014): “[l]ack of adequate food will be a destabilizing factor in countries important to US national security that do not have the financial or technical abilities to solve their internal food security problems.”3 Though it is uncertain whether annual reports will continue under the Trump administration, the US has demonstrated (at least through the Global Food Security Act) that it views food security as a matter of national security. According to the most recent Worldwide Threat Assessment, Africa is among the regions most susceptible to terrorism, especially in Somalia and South Sudan.4 This paper explores the ways in which food insecurity can enable conflict, how the US can improve the ways it offers food aid, and why African food security is in America’s national security interest. Consequences of Food Insecurity Enforcing and communicating a universal conception of human rights by any party is difficult. Nevertheless, US national security strategy has placed an emphasis on human rights in recent years. The former Secretary of State under President George W. Bush, Condoleezza Rice, once remarked that: “[f]or the United States, supporting international development is a vital investment in the free, prosperous, and peaceful international order that fundamentally serves our national interest.”5 Fragile regimes in Africa cannot successfully maintain themselves, let alone pose an immediate threat to the United States. However, these regimes are likely to seek alliances with adversaries that may pose a threat, such as China, creating a region of the world adverse to American interests and values. Secondly, migrant and refugee flows are concerns for the United States due to their economic and social consequences. While many of the most serious cases of refugee crises today are nowhere near the US, they do affect some of the United States’ key allies around the globe. A clear example of this is Syrian migration into NATO member countries. In addition to military conflict, bipartisan research has shown that climate can also contribute to mass migrations by impacting harvest yields in regions still reliant on subsistence agriculture. For example, the famines in Somalia and Yemen have sparked emigration caused by food insecurity. Such crises may not be front page news compared to violent conflicts in surrounding states, but they present just as real a threat. The third reason why the US should care about weak states is that terrorist organizations thrive in such environments. Since September 11, 2001, US national security policy has been primarily driven by the war on terror. While the fear of a repeat attack on American soil has calmed since 2001, the threat of terrorism is still present, and the United States must be proactive to stay ahead of terrorist threats. Terrorists thrive in weak state environments because either the lack of rule of law inhibits the host state’s ability to act against them, or because corrupt governments refuse to act, such as when Sudan provided refuge to Osama bin Laden in the 1990s.6 As a developing region, Africa is full of potential, and the United States will have to decide whether it will help it stabilize or allow it to become a refuge and breeding ground for terrorism. Africa can potentially threaten or support American interests. As stated above, food insecurity in Africa creates problems for the US. The potential to politically align with other major powers, the destabilizing effect of refugees on the US and its allies, and the propensity to breed terrorism are all reasons to take Africa seriously as a national security concern. US interests include promoting international market economies that it can easily access, so to increase economic power at home. If the US ignores stability measures in Africa, this could negatively affect both American security interests and global economic growth, 7 which are both American priorities. The US needs a strategy that promotes food security in fragile states to address these concerns. Food prices in Africa are expected to rise in the next few years due to famine,8 which means there is a risk that instability will grow, heightening the security concern to the United States. Food insecurity, like any social ailment, does not necessarily cause instability, but the two do reinforce each other. Obviously, American food assistance by itself cannot solve every problem in these fragile states. Success will ultimately depend on these countries establishing and enforcing the rule of law and shoring up government legitimacy. That said, nation building is not a viable option in this region, as the US has already committed itself to this in the Middle East and largely failed. The US can, however, provide developmental aid to help promote stability and provide a foundation for future institutional growth. Therefore, it is important that the US not only maintain food security efforts in weak states but also incentivize recipient behavior that will make such aid more effective.

#### That means nuke terror

Bunn et al 19 – Matthew Bunn is a Professor of Practice at Harvard University’s John F. Kennedy School of Government, and the faculty leader of the Project on Managing the Atom. Nickolas Roth is a Research Associate at the Belfer Center’s Project on Managing the Atom. William H. Tobey is a Senior Fellow at the Belfer Center for Science and International Affairs at Harvard Kennedy School. (“Revitalizing Nuclear Security in an Era of Uncertainty”, Harvard Belfer Center for International Affairs, Jan 2019, https://scholar.harvard.edu/files/matthew\_bunn/files/bunn\_revitalizing\_nuclear\_security\_in\_an\_era\_of\_uncertainty\_2019.pdf)

The risk that terrorists could get and use a nuclear bomb—turning the heart of a modern city into a smoldering radioactive ruin—remains very real. Sabotage of major nuclear facilities or dispersal of radioactive material in a disruptive “dirty bomb” also remain real risks.

Motive. Apocalyptic visions or global ambitions drove groups such as al Qaeda and the Japanese terror cult Aum Shinrikyo to seek nuclear weapons. From the 9/11 attackers to Chechen rebels, who killed hundreds of children and their parents at a school in Beslan, Russia, to the Islamic State, which regularly televised its atrocities, it is clear that some terrorist groups seek to inflict as many casualties as possible, as cruelly as possible.

Means. There have been repeated cases of seizure of stolen HEU or plutonium. While there have been no such seizures since 2011, security assessments and tests continue to reveal important vulnerabilities, in the United States and elsewhere. Moreover, non-nuclear criminal thefts and terrorist attacks continue to occur that use tactics and capabilities that the security systems at many nuclear facilities would be hard-pressed to defend against—ranging from substantial teams of heavily armed, well-trained attackers, to insider conspiracies, to the use of vehicles such as helicopters to get past multiple layers of site security systems.

Opportunity. Government studies in multiple countries have concluded that sophisticated terrorist groups could plausibly make a crude nuclear device. Stopping such a device from being brought into a country and detonated remains a very challenging task, given the huge length of national borders, the immensity of normal traffic across them, and the small size and weak radiation of the materials needed for a nuclear bomb.

Since our last report in 2016:

• Al Qaeda and particularly the Islamic State have suffered numerous defeats which must necessarily make it more difficult for them to mount the organized effort necessary to perpetrate nuclear terrorism, although their intent to inflict massive damage abides;

• Rapid and clandestine radicalization of insiders has continued to present a threat that most personnel reliability programs have been unable to address successfully;

• The pace of seizures of fissile material outside of authorized control appears to have slowed, although what is known publicly about earlier cases offers little confidence that the leaks have been plugged;

• New technologies such as drones and cyber, expanded deployments of small, mobile nuclear weapons, and construction of bulk processing facilities will offer new opportunities for terrorists to strike and present new challenges for those attempting to defend against them.

On balance, the combination of nuclear terrorist means, motives, and opportunities presents somewhat less of a threat than it did two years ago. But as past experience makes clear, the future is highly uncertain; the world has likely not seen the last of powerful terrorist groups bent on mass destruction. And as adversaries make increasingly sophisticated use of technologies such as cyber and drones in the future, the threat to nuclear weapons, materials, and facilities could increase. To minimize risk in this uncertain future, continuous and determined efforts to improve security remain essential.

#### Nuke war causes extinction – Ice Age, famines, and war won’t stay limited

Edwards 17 [Paul N. Edwards, CISAC’s William J. Perry Fellow in International Security at Stanford’s Freeman Spogli Institute for International Studies. Being interviewed by EarthSky. How nuclear war would affect Earth’s climate. September 8, 2017. earthsky.org/human-world/how-nuclear-war-would-affect-earths-climate] Note, we are only reading parts of the interview that are directly from Paul Edwards -- MMG

In the nuclear conversation, what are we not talking about that we should be?

We are not talking enough about the climatic effects of nuclear war. The “nuclear winter” theory of the mid-1980s played a significant role in the arms reductions of that period. But with the collapse of the Soviet Union and the reduction of U.S. and Russian nuclear arsenals, this aspect of nuclear war has faded from view. That’s not good. In the mid-2000s, climate scientists such as Alan Robock (Rutgers) took another look at nuclear winter theory. This time around, they used much-improved and much more detailed climate models than those available 20 years earlier. They also tested the potential effects of smaller nuclear exchanges. The result: an exchange involving just 50 nuclear weapons — the kind of thing we might see in an India-Pakistan war, for example — could loft 5 billion kilograms of smoke, soot and dust high into the stratosphere. That’s enough to cool the entire planet by about 2 degrees Fahrenheit (1.25 degrees Celsius) — about where we were during the Little Ice Age of the 17th century. Growing seasons could be shortened enough to create really significant food shortages. So the climatic effects of even a relatively small nuclear war would be planet-wide. What about a larger-scale conflict? A U.S.-Russia war currently seems unlikely, but if it were to occur, hundreds or even thousands of nuclear weapons might be launched. The climatic consequences would be catastrophic: global average temperatures would drop as much as 12 degrees Fahrenheit (7 degrees Celsius) for up to several years — temperatures last seen during the great ice ages. Meanwhile, smoke and dust circulating in the stratosphere would darken the atmosphere enough to inhibit photosynthesis, causing disastrous crop failures, widespread famine and massive ecological disruption. The effect would be similar to that of the giant meteor believed to be responsible for the extinction of the dinosaurs. This time, we would be the dinosaurs. Many people are concerned about North Korea’s advancing missile capabilities. Is nuclear war likely in your opinion? At this writing, I think we are closer to a nuclear war than we have been since the early 1960s. In the North Korea case, both Kim Jong-un and President Trump are bullies inclined to escalate confrontations. President Trump lacks impulse control, and there are precious few checks on his ability to initiate a nuclear strike. We have to hope that our generals, both inside and outside the White House, can rein him in. North Korea would most certainly “lose” a nuclear war with the United States. But many millions would die, including hundreds of thousands of Americans currently living in South Korea and Japan (probable North Korean targets). Such vast damage would be wrought in Korea, Japan and Pacific island territories (such as Guam) that any “victory” wouldn’t deserve the name. Not only would that region be left with horrible suffering amongst the survivors; it would also immediately face famine and rampant disease. Radioactive fallout from such a war would spread around the world, including to the U.S. It has been more than 70 years since the last time a nuclear bomb was used in warfare. What would be the effects on the environment and on human health today? To my knowledge, most of the changes in nuclear weapons technology since the 1950s have focused on making them smaller and lighter, and making delivery systems more accurate, rather than on changing their effects on the environment or on human health. So-called “battlefield” weapons with lower explosive yields are part of some arsenals now — but it’s quite unlikely that any exchange between two nuclear powers would stay limited to these smaller, less destructive bombs.

#### Plan: Private entities ought not engage in the appropriation of outer space via obtrusive space advertising.

Swaminathan 05 “Making space law relevant to basic space science in the commercial space age” Sriram Swaminathan 2005 <https://reader.elsevier.com/reader/sd/pii/S0265964605000755?token=368CAFF18AE623166B0AFB2D5AF0FB792E5E75B7BD1A2886AEB029F38EB9886D0B981B9FEC85338FDA292DC91FD90678&originRegion=us-east-1&originCreation=20220317154247> SM

There is a lack of clear regulation in the area of ‘space advertising’ which may be endangering the future of ground-based astronomy. The IAU has proposed a ban on ‘obtrusive space advertising’, identifying two main characteristics of such objects. A project may be deemed as ‘advertising’ if it is without ‘factual scientific or technical function’, and/or where the revenues gained flow only to the originators. This would avoid genuine scientific missions from being prohibited, even though they are obtrusive in the astronomical sense (for example ISS). In determining the extent of obtrusiveness, the IAU names brightness, visibility period and extent of illumination as three critical criteria. It is interesting to note that the USA has already prohibited the issuing of launch licenses for ‘obtrusive space advertising’, which it defines as ‘advertis- ing in outer space that is capable of being recognized by a human being on the surface of the Earth without the aid of a telescope or other technological device’ [10]. The USA Federal Aviation Authority has recently proposed amend- ing its regulations to provide for the mandatory review of proposed payloads to see if they amount to ‘obtrusive space advertising’[11].

#### That solves and is key to protecting ground-based astronomy.

IAU 01 International Astronomical Union “Obtrusive space advertising and astronomical research : background paper / by the International Astronomical Union” 18 December 2001 https://digitallibrary.un.org/record/461281?ln=en#record-files-collapse-header SM

VII. Obtrusive space advertising: astronomical classification

23. The severity of the impacts of obtrusive space advertising may be classified according to a few basic characteristics of the corresponding space object:

(a) Brightness as seen from the surface of the Earth;

(b) Time of visibility from a given observing point on Earth;

(c) Extent and positional control of the illuminated area on Earth.

24. The brightness of a space object as seen from a ground-based observatory is clearly the main parameter determining its impact on the observations. Essentially, any object that is visible with the naked eye will ruin an astronomical observation conducted in the same direction. For the faintest, fast-moving objects, recovery may be possible through multiple exposures and digital filtering, as is already necessary to cope with existing satellites and space debris. However, the brightest such objects—as bright as or brighter than Venus or Jupiter—may damage the ultra-sensitive detector systems used on large telescopes. Protection of large telescopes by separate monitoring of the field for bright moving objects may soon become necessary.

25. In contrast, any object of a brightness comparable to the full Moon will, like the real Moon, generate so much scattered light in the Earth’s atmosphere that observations of all faint objects become impossible. Whether or not such a disturbance would spell the end of ground-based observational cosmology depends on the temporal and geographical extent of the illumination. Space observatories would be immune to only some of this type of pollution, but are also so costly and specialized that the future of astronomy cannot be based on space observatories alone.

26. The fraction of night-time in which an object is visible is another key parameter. Objects which are visible and/or bright only in evening or morning twilight are generally less detrimental to astronomy than objects which remain visible all night. Importantly, however, observations of other sunlit objects, such as near Earth asteroids inside the Earth’s orbit or space debris, must also be done at twilight and would suffer directly from a proliferation of bright objects at that time.

27. From a practical point of view, the most economical way to create a luminous object in the sky is to launch a highly reflecting surface in low orbit. The brightness and visibility of the object can be enhanced by increasing its size and optimizing its surface properties. The limitations of this type of illumination to the twilight hours can be alleviated by raising the object to a higher orbit, well out of the Earth’s shadow, and/or by installing artificial illumination on the spacecraft. Both of these techniques raise the complexity and cost of the experiment considerably.

28. Finally, the size and position of the illuminated area are of importance. If an object illuminates the entire dark hemisphere of the Earth, all night-time astronomy suffers in proportion to the brightness of the illumination. However, some experiments are intended to intensify the illumination by focusing it, through the use of mirrors, onto a geographical area of limited size. Hence, if control could be maintained over the position of this area, astronomical observatories and other sensitive sites, such as national parks, could in principle be kept free of unwanted illumination. However, first, this would require precise on-board control mechanisms for the mirrors, including fallback systems in case of malfunctions. Second, there remains the issue of a suitable international mechanism to define the protected sites and enforce the regulations.

VIII. Previous international efforts to protect astronomy

29. As the main international scientific organization in the field of astronomy, IAU has made sustained efforts to call attention to the deterioration of the environment and its effects upon the future of astronomy. The general assemblies of IAU, held every three years, have for forty years in their resolutions advocated measures to prevent adverse space activities in either the optical or the radio region, or both. The pollution of the sky affects astronomy in developing and developed countries alike, and IAU serves as the international advocate for astronomy throughout the world.

30. In fact, as early as 1961, the IAU General Assembly “viewed with great concern the grave danger that some future space project might seriously interfere with astronomical observations in the optical as well as in the radio domain” and “appealed to all Governments to refrain from launching [such projects] until it is established beyond doubt that no danger will be done to astronomical research”. In 1970, the IAU General Assembly recalled and reaffirmed this resolution, referring specifically to the United Nations Outer Space Treaty,3 in particular to its articles IV and IX, a stand that was repeated and re-emphasized in following years.

31. Notwithstanding, problems continued to increase and the twentieth IAU General Assembly in 1988 appealed to the International Council of Scientific Unions (ICSU) and its Scientific Committee on Problems of the Environment (SCOPE) to take up this aspect of the general problem of the degrading environment. A special meeting, IAU Colloquium 112, Light Pollution, Radio Interference, and Space Debris,4 was also held to discuss and highlight the specific problems and outline suitable countermeasures. This was followed up again in 1992 by the high-level International Symposium on the Adverse Environmental Impacts on Astronomy, organized jointly by IAU, ICSU, UNESCO and the Committee on Space Research (COSPAR), and resulting in the volume The Vanishing Universe5 in which, for the first time, specific high-level strategic goals were defined and a plan for pursuing them was laid out.

32. As one initiative resulting from the 1992 conference, IAU applied for status as Permanent Observer with the United Nations Committee on the Peaceful Uses of Outer Space. This was granted in 1994, and subsequent IAU efforts have been made in cooperation with the Committee. Thus, a Technical Forum, the International Astronomical Union/Committee on Space Research/ United Nations Special Environmental Symposium “Preserving the Astronomical Sky”,6 was organized in conjunction with the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) in 1999. The meeting presented its recommendations7 to the main Conference, and the Space Millennium: Vienna Declaration on Space and Human Development adopted by UNISPACE III contains corresponding policy guidelines for future activities in space “before further irreversible actions are taken affecting future utilization of near-Earth space or outer space”.8 These recommendations apply also to obtrusive space advertising.

IX. Policy recommendations

33. The future of astronomy clearly depends on the extent to which it will be possible to limit the degradation of the space environment. Obtrusive space advertising is one such grave concern for the future. Unlike several other forms of adverse environmental impact, however, there is still time for prevention before irreversible damage to astronomy is done.

34. IAU therefore appreciates and applauds the measures taken by the United States of America to prohibit the granting of a launch licence to any form of such advertising.2 As outlined above, this measure alone will by no means guarantee that astronomy will be free of interference from activities in space, be it in the optical or in the radio domain. But prohibiting space advertising that would be visible by the vast majority of the world’s population will undoubtedly greatly reduce the financial incentive to engage in such projects. This initiative should therefore be followed up by other spacefaring nations.

35. Accordingly, IAU recommends for the consideration of the Committee on the Peaceful Uses of Outer Space:

(a) That Member States should be encouraged to adopt similar legislation on obtrusive space advertising, so that this activity is regulated by all space-faring nations;

(b) That international guidelines to limit the environmental impact of space activities on astronomy be developed by the Committee, in close cooperation with IAU, to ensure that uniform principles are applied to the definition of projects to which this legislation would apply.

### FW – Tiny

#### Moral realism must start by being mind-independent – realism wouldn’t make sense if there were a plethora of moral truths contingent on the agent’s cognitively predisposed capacity because then moral truths wouldn’t exist outside of the ways we cohere them. Thus, moral naturalism is true.

#### The problem of disagreement verifies naturalism – resolving a priori conflicts requires indicting the epistemological basis of one’s judgement with a reliable process for deriving moral truths which is impossible given widespread moral disagreement about non verifiable a priori truth – grounding ethics with verifiable natural facts solve.

#### The introspective connection between pain and pleasure and phenomenal conceptions of intrinsic value and disvalue is irrefutable – everything else regresses – robust neuroscience proves.

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**Pleasure** is not only one of the three primary reward functions but it also **defines reward.** As homeostasis explains the functions of only a limited number of rewards, the principal reason why particular stimuli, objects, events, situations, and activities are rewarding may be due to pleasure. This applies first of all to sex and to the primary homeostatic rewards of food and liquid and extends to money, taste, beauty, social encounters and nonmaterial, internally set, and intrinsic rewards. Pleasure, as the primary effect of rewards, drives the prime reward functions of learning, approach behavior, and decision making and provides the **basis for hedonic theories** of reward function. We are attracted by most rewards and exert intense efforts to obtain them, just because they are enjoyable [10].

Pleasure is a passive reaction that derives from the experience or prediction of reward and may lead to a long-lasting state of happiness. The word happiness is difficult to define. In fact, just obtaining physical pleasure may not be enough. One key to happiness involves a network of good friends. However, it is not obvious how the higher forms of satisfaction and pleasure are related to an ice cream cone, or to your team winning a sporting event. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure [14].

Pleasure as a hallmark of reward is sufficient for defining a reward, but it may not be necessary. A reward may generate positive learning and approach behavior simply because it contains substances that are essential for body function. When we are hungry, we may eat bad and unpleasant meals. A monkey who receives hundreds of small drops of water every morning in the laboratory is unlikely to feel a rush of pleasure every time it gets the 0.1 ml. Nevertheless, with these precautions in mind, we may define any stimulus, object, event, activity, or situation that has the potential to produce pleasure as a reward. In the context of reward deficiency or for disorders of addiction, homeostasis pursues pharmacological treatments: drugs to treat drug addiction, obesity, and other compulsive behaviors. The theory of allostasis suggests broader approaches - such as re-expanding the range of possible pleasures and providing opportunities to expend effort in their pursuit. [15]. It is noteworthy, the first animal studies eliciting approach behavior by electrical brain stimulation interpreted their findings as a discovery of the brain’s pleasure centers [16] which were later partly associated with midbrain dopamine neurons [17–19] despite the notorious difficulties of identifying emotions in animals.

Evolutionary theories of pleasure: The love connection BO:D

Charles Darwin and other biological scientists that have examined the biological evolution and its basic principles found various mechanisms that steer behavior and biological development. Besides their theory on natural selection, it was particularly the sexual selection process that gained significance in the latter context over the last century, especially when it comes to the question of what makes us “what we are,” i.e., human. However, the capacity to sexually select and evolve is not at all a human accomplishment alone or a sign of our uniqueness; yet, we humans, as it seems, are ingenious in fooling ourselves and others–when we are in love or desperately search for it.

It is well established that modern biological theory conjectures that **organisms are** the **result of evolutionary competition.** In fact, Richard Dawkins stresses gene survival and propagation as the basic mechanism of life [20]. Only genes that lead to the fittest phenotype will make it. It is noteworthy that the phenotype is selected based on behavior that maximizes gene propagation. To do so, the phenotype must survive and generate offspring, and be better at it than its competitors. Thus, the ultimate, distal function of rewards is to increase evolutionary fitness by ensuring the survival of the organism and reproduction. It is agreed that learning, approach, economic decisions, and positive emotions are the proximal functions through which phenotypes obtain other necessary nutrients for survival, mating, and care for offspring.

Behavioral reward functions have evolved to help individuals to survive and propagate their genes. Apparently, people need to live well and long enough to reproduce. Most would agree that homo-sapiens do so by ingesting the substances that make their bodies function properly. For this reason, foods and drinks are rewards. Additional rewards, including those used for economic exchanges, ensure sufficient palatable food and drink supply. Mating and gene propagation is supported by powerful sexual attraction. Additional properties, like body form, augment the chance to mate and nourish and defend offspring and are therefore also rewards. Care for offspring until they can reproduce themselves helps gene propagation and is rewarding; otherwise, many believe mating is useless. According to David E Comings, as any small edge will ultimately result in evolutionary advantage [21], additional reward mechanisms like novelty seeking and exploration widen the spectrum of available rewards and thus enhance the chance for survival, reproduction, and ultimate gene propagation. These functions may help us to obtain the benefits of distant rewards that are determined by our own interests and not immediately available in the environment. Thus the distal reward function in gene propagation and evolutionary fitness defines the proximal reward functions that we see in everyday behavior. That is why foods, drinks, mates, and offspring are rewarding.

There have been theories linking pleasure as a required component of health benefits salutogenesis, (salugenesis). In essence, under these terms, pleasure is described as a state or feeling of happiness and satisfaction resulting from an experience that one enjoys. Regarding pleasure, it is a double-edged sword, on the one hand, it promotes positive feelings (like mindfulness) and even better cognition, possibly through the release of dopamine [22]. But on the other hand, pleasure simultaneously encourages addiction and other negative behaviors, i.e., motivational toxicity. It is a complex neurobiological phenomenon, relying on reward circuitry or limbic activity. It is important to realize that through the “Brain Reward Cascade” (BRC) endorphin and endogenous morphinergic mechanisms may play a role [23]. While natural rewards are essential for survival and appetitive motivation leading to beneficial biological behaviors like eating, sex, and reproduction, crucial social interactions seem to further facilitate the positive effects exerted by pleasurable experiences. Indeed, experimentation with addictive drugs is capable of directly acting on reward pathways and causing deterioration of these systems promoting hypodopaminergia [24]. Most would agree that pleasurable activities can stimulate personal growth and may help to induce healthy behavioral changes, including stress management [25]. The work of Esch and Stefano [26] concerning the link between compassion and love implicate the brain reward system, and pleasure induction suggests that social contact in general, i.e., love, attachment, and compassion, can be highly effective in stress reduction, survival, and overall health.

Understanding the role of neurotransmission and pleasurable states both positive and negative have been adequately studied over many decades [26–37], but comparative anatomical and neurobiological function between animals and homo sapiens appear to be required and seem to be in an infancy stage.

Finding happiness is different between apes and humans

As stated earlier in this expert opinion one key to happiness involves a network of good friends [38]. However, it is not entirely clear exactly how the higher forms of satisfaction and pleasure are related to a sugar rush, winning a sports event or even sky diving, all of which augment dopamine release at the reward brain site. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure.

Remarkably, there are pathways for ordinary liking and pleasure, which are limited in scope as described above in this commentary. However, there are **many brain regions**, often termed hot and cold spots, that significantly **modulate** (increase or decrease) our **pleasure or** even produce **the opposite** of pleasure— that is disgust and fear [39]. One specific region of the nucleus accumbens is organized like a computer keyboard, with particular stimulus triggers in rows— producing an increase and decrease of pleasure and disgust. Moreover, the cortex has unique roles in the cognitive evaluation of our feelings of pleasure [40]. Importantly, the interplay of these multiple triggers and the higher brain centers in the prefrontal cortex are very intricate and are just being uncovered.

Desire and reward centers

It is surprising that many different sources of pleasure activate the same circuits between the mesocorticolimbic regions (Figure 1). Reward and desire are two aspects pleasure induction and have a very widespread, large circuit. Some part of this circuit distinguishes between desire and dread. The so-called pleasure circuitry called “REWARD” involves a well-known dopamine pathway in the mesolimbic system that can influence both pleasure and motivation.

In simplest terms, the well-established mesolimbic system is a dopamine circuit for reward. It starts in the ventral tegmental area (VTA) of the midbrain and travels to the nucleus accumbens (Figure 2). It is the cornerstone target to all addictions. The VTA is encompassed with neurons using glutamate, GABA, and dopamine. The nucleus accumbens (NAc) is located within the ventral striatum and is divided into two sub-regions—the motor and limbic regions associated with its core and shell, respectively. The NAc has spiny neurons that receive dopamine from the VTA and glutamate (a dopamine driver) from the hippocampus, amygdala and medial prefrontal cortex. Subsequently, the NAc projects GABA signals to an area termed the ventral pallidum (VP). The region is a relay station in the limbic loop of the basal ganglia, critical for motivation, behavior, emotions and the “Feel Good” response. This defined system of the brain is involved in all addictions –substance, and non –substance related. In 1995, our laboratory coined the term “Reward Deficiency Syndrome” (RDS) to describe genetic and epigenetic induced hypodopaminergia in the “Brain Reward Cascade” that contribute to addiction and compulsive behaviors [3,6,41].

Furthermore, ordinary “liking” of something, or pure pleasure, is represented by small regions mainly in the limbic system (old reptilian part of the brain). These may be part of larger neural circuits. In Latin, hedus is the term for “sweet”; and in Greek, hodone is the term for “pleasure.” Thus, the word Hedonic is now referring to various subcomponents of pleasure: some associated with purely sensory and others with more complex emotions involving morals, aesthetics, and social interactions. The capacity to have pleasure is part of being healthy and may even extend life, especially if linked to optimism as a dopaminergic response [42].

Psychiatric illness often includes symptoms of an abnormal inability to experience pleasure, referred to as anhedonia. A negative feeling state is called dysphoria, which can consist of many emotions such as pain, depression, anxiety, fear, and disgust. Previously many scientists used animal research to uncover the complex mechanisms of pleasure, liking, motivation and even emotions like panic and fear, as discussed above [43]. However, as a significant amount of related research about the specific brain regions of pleasure/reward circuitry has been derived from invasive studies of animals, these cannot be directly compared with subjective states experienced by humans.

In an attempt to resolve the controversy regarding the causal contributions of mesolimbic dopamine systems to reward, we have previously evaluated the three-main competing explanatory categories: “liking,” “learning,” and “wanting” [3]. That is, dopamine may mediate (a) liking: the hedonic impact of reward, (b) learning: learned predictions about rewarding effects, or (c) wanting: the pursuit of rewards by attributing incentive salience to reward-related stimuli [44]. We have evaluated these hypotheses, especially as they relate to the RDS, and we find that the incentive salience or “wanting” hypothesis of dopaminergic functioning is supported by a majority of the scientific evidence. Various neuroimaging studies have shown that anticipated behaviors such as sex and gaming, delicious foods and drugs of abuse all affect brain regions associated with reward networks, and may not be unidirectional. Drugs of abuse enhance dopamine signaling which sensitizes mesolimbic brain mechanisms that apparently evolved explicitly to attribute incentive salience to various rewards [45].

Addictive substances are voluntarily self-administered, and they enhance (directly or indirectly) dopaminergic synaptic function in the NAc. This activation of the brain reward networks (producing the ecstatic “high” that users seek). Although these circuits were initially thought to encode a set point of hedonic tone, it is now being considered to be far more complicated in function, also encoding attention, reward expectancy, disconfirmation of reward expectancy, and incentive motivation [46]. The argument about addiction as a disease may be confused with a predisposition to substance and nonsubstance rewards relative to the extreme effect of drugs of abuse on brain neurochemistry. The former sets up an individual to be at high risk through both genetic polymorphisms in reward genes as well as harmful epigenetic insult. Some Psychologists, even with all the data, still infer that addiction is not a disease [47]. Elevated stress levels, together with polymorphisms (genetic variations) of various dopaminergic genes and the genes related to other neurotransmitters (and their genetic variants), and may have an additive effect on vulnerability to various addictions [48]. In this regard, Vanyukov, et al. [48] suggested based on review that whereas the gateway hypothesis does not specify mechanistic connections between “stages,” and does not extend to the risks for addictions the concept of common liability to addictions may be more parsimonious. The latter theory is grounded in genetic theory and supported by data identifying common sources of variation in the risk for specific addictions (e.g., RDS). This commonality has identifiable neurobiological substrate and plausible evolutionary explanations.

Over many years the controversy of dopamine involvement in especially “pleasure” has led to confusion concerning separating motivation from actual pleasure (wanting versus liking) [49]. We take the position that animal studies cannot provide real clinical information as described by self-reports in humans. As mentioned earlier and in the abstract, on November 23rd, 2017, evidence for our concerns was discovered [50]

In essence, although nonhuman primate brains are similar to our own, the disparity between other primates and those of human cognitive abilities tells us that surface similarity is not the whole story. Sousa et al. [50] small case found various differentially expressed genes, to associate with pleasure related systems. Furthermore, the dopaminergic interneurons located in the human neocortex were absent from the neocortex of nonhuman African apes. Such differences in neuronal transcriptional programs may underlie a variety of neurodevelopmental disorders.

In simpler terms, the system controls the production of dopamine, a chemical messenger that plays a significant role in pleasure and rewards. The senior author, Dr. Nenad Sestan from Yale, stated: “Humans have evolved a dopamine system that is different than the one in chimpanzees.” This may explain why the behavior of humans is so unique from that of non-human primates, even though our brains are so surprisingly similar, Sestan said: “It might also shed light on why people are vulnerable to mental disorders such as autism (possibly even addiction).” Remarkably, this research finding emerged from an extensive, multicenter collaboration to compare the brains across several species. These researchers examined 247 specimens of neural tissue from six humans, five chimpanzees, and five macaque monkeys. Moreover, these investigators analyzed which genes were turned on or off in 16 regions of the brain. While the differences among species were subtle, **there was** a **remarkable contrast in** the **neocortices**, specifically in an area of the brain that is much more developed in humans than in chimpanzees. In fact, these researchers found that a gene called tyrosine hydroxylase (TH) for the enzyme, responsible for the production of dopamine, was expressed in the neocortex of humans, but not chimpanzees. As discussed earlier, dopamine is best known for its essential role within the brain’s reward system; the very system that responds to everything from sex, to gambling, to food, and to addictive drugs. However, dopamine also assists in regulating emotional responses, memory, and movement. Notably, abnormal dopamine levels have been linked to disorders including Parkinson’s, schizophrenia and spectrum disorders such as autism and addiction or RDS.

Nora Volkow, the director of NIDA, pointed out that one alluring possibility is that the neurotransmitter dopamine plays a substantial role in humans’ ability to pursue various rewards that are perhaps months or even years away in the future. This same idea has been suggested by Dr. Robert Sapolsky, a professor of biology and neurology at Stanford University. Dr. Sapolsky cited evidence that dopamine levels rise dramatically in humans when we anticipate potential rewards that are uncertain and even far off in our futures, such as retirement or even the possible alterlife. This may explain what often motivates people to work for things that have no apparent short-term benefit [51]. In similar work, Volkow and Bale [52] proposed a model in which dopamine can favor NOW processes through phasic signaling in reward circuits or LATER processes through tonic signaling in control circuits. Specifically, they suggest that through its modulation of the orbitofrontal cortex, which processes salience attribution, dopamine also enables shilting from NOW to LATER, while its modulation of the insula, which processes interoceptive information, influences the probability of selecting NOW versus LATER actions based on an individual’s physiological state. This hypothesis further supports the concept that disruptions along these circuits contribute to diverse pathologies, including obesity and addiction or RDS.

#### Evolution proves the reliability of phenomenal introspection – when we introspect on data from our eyes or ears, such as whether one sees or smells food or a predator, we use the same part of the brain that introspects on hedonic tones and identifies their moral relevance.

#### Thus, the standard is consistency with hedonic act utilitarianism.

#### Warming causes Extinction

Kareiva 18, Peter, and Valerie Carranza. "Existential risk due to ecosystem collapse: Nature strikes back." Futures 102 (2018): 39-50. (Ph.D. in ecology and applied mathematics from Cornell University, director of the Institute of the Environment and Sustainability at UCLA, Pritzker Distinguished Professor in Environment & Sustainability at UCLA)//Re-cut by Elmer

In summary, six of the nine proposed planetary boundaries (phosphorous, nitrogen, biodiversity, land use, atmospheric aerosol loading, and chemical pollution) are unlikely to be associated with existential risks. They all correspond to a degraded environment, but in our assessment do not represent existential risks. However, the three remaining boundaries (**climate change**, global **freshwater** cycle, **and** ocean **acidification**) do **pose existential risks**. This is **because of** intrinsic **positive feedback loops**, substantial lag times between system change and experiencing the consequences of that change, and the fact these different boundaries interact with one another in ways that yield surprises. In addition, climate, freshwater, and ocean acidification are all **directly connected to** the provision of **food and water**, and **shortages** of food and water can **create conflict** and social unrest. Climate change has a long history of disrupting civilizations and sometimes precipitating the collapse of cultures or mass emigrations (McMichael, 2017). For example, the 12th century drought in the North American Southwest is held responsible for the collapse of the Anasazi pueblo culture. More recently, the infamous potato famine of 1846–1849 and the large migration of Irish to the U.S. can be traced to a combination of factors, one of which was climate. Specifically, 1846 was an unusually warm and moist year in Ireland, providing the climatic conditions favorable to the fungus that caused the potato blight. As is so often the case, poor government had a role as well—as the British government forbade the import of grains from outside Britain (imports that could have helped to redress the ravaged potato yields). Climate change intersects with freshwater resources because it is expected to exacerbate drought and water scarcity, as well as flooding. Climate change can even impair water quality because it is associated with heavy rains that overwhelm sewage treatment facilities, or because it results in higher concentrations of pollutants in groundwater as a result of enhanced evaporation and reduced groundwater recharge. **Ample clean water** is not a luxury—it **is essential for human survival**. Consequently, cities, regions and nations that lack clean freshwater are vulnerable to social disruption and disease. Finally, ocean acidification is linked to climate change because it is driven by CO2 emissions just as global warming is. With close to 20% of the world’s protein coming from oceans (FAO, 2016), the potential for severe impacts due to acidification is obvious. Less obvious, but perhaps more insidious, is the interaction between climate change and the loss of oyster and coral reefs due to acidification. Acidification is known to interfere with oyster reef building and coral reefs. Climate change also increases storm frequency and severity. Coral reefs and oyster reefs provide protection from storm surge because they reduce wave energy (Spalding et al., 2014). If these reefs are lost due to acidification at the same time as storms become more severe and sea level rises, coastal communities will be exposed to unprecedented storm surge—and may be ravaged by recurrent storms. A key feature of the risk associated with climate change is that mean annual temperature and mean annual rainfall are not the variables of interest. Rather it is extreme episodic events that place nations and entire regions of the world at risk. These extreme events are by definition “rare” (once every hundred years), and changes in their likelihood are challenging to detect because of their rarity, but are exactly the manifestations of climate change that we must get better at anticipating (Diffenbaugh et al., 2017). Society will have a hard time responding to shorter intervals between rare extreme events because in the lifespan of an individual human, a person might experience as few as two or three extreme events. How likely is it that you would notice a change in the interval between events that are separated by decades, especially given that the interval is not regular but varies stochastically? A concrete example of this dilemma can be found in the past and expected future changes in storm-related flooding of New York City. The highly disruptive flooding of New York City associated with Hurricane Sandy represented a flood height that occurred once every 500 years in the 18th century, and that occurs now once every 25 years, but is expected to occur once every 5 years by 2050 (Garner et al., 2017). This change in frequency of extreme floods has profound implications for the measures New York City should take to protect its infrastructure and its population, yet because of the stochastic nature of such events, this shift in flood frequency is an elevated risk that will go unnoticed by most people. 4. The combination of positive feedback loops and societal inertia is fertile ground for global environmental catastrophes **Humans** are remarkably ingenious, and **have adapted** to crises **throughout** their **history**. Our doom has been repeatedly predicted, only to be averted by innovation (Ridley, 2011). **However**, the many **stories** **of** human ingenuity **successfully** **addressing** **existential risks** such as global famine or extreme air pollution **represent** environmental c**hallenges that are** largely **linear**, have immediate consequences, **and operate without positive feedbacks**

. For example, the fact that food is in short supply does not increase the rate at which humans consume food—thereby increasing the shortage. Similarly, massive air pollution episodes such as the London fog of 1952 that killed 12,000 people did not make future air pollution events more likely. In fact it was just the opposite—the London fog sent such a clear message that Britain quickly enacted pollution control measures (Stradling, 2016). Food shortages, air pollution, water pollution, etc. send immediate signals to society of harm, which then trigger a negative feedback of society seeking to reduce the harm. In contrast, today’s great environmental crisis of climate change may cause some harm but there are generally long time delays between rising CO2 concentrations and damage to humans. The consequence of these delays are an absence of urgency; thus although 70% of Americans believe global warming is happening, only 40% think it will harm them (http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/). Secondly, unlike past environmental challenges, **the Earth’s climate system is rife with positive feedback loops**. In particular, as CO2 increases and the climate warms, that **very warming can cause more CO2 release** which further increases global warming, and then more CO2, and so on. Table 2 summarizes the best documented positive feedback loops for the Earth’s climate system. These feedbacks can be neatly categorized into carbon cycle, biogeochemical, biogeophysical, cloud, ice-albedo, and water vapor feedbacks. As important as it is to understand these feedbacks individually, it is even more essential to study the interactive nature of these feedbacks. Modeling studies show that when interactions among feedback loops are included, uncertainty increases dramatically and there is a heightened potential for perturbations to be magnified (e.g., Cox, Betts, Jones, Spall, & Totterdell, 2000; Hajima, Tachiiri, Ito, & Kawamiya, 2014; Knutti & Rugenstein, 2015; Rosenfeld, Sherwood, Wood, & Donner, 2014). This produces a wide range of future scenarios. Positive feedbacks in the carbon cycle involves the enhancement of future carbon contributions to the atmosphere due to some initial increase in atmospheric CO2. This happens because as CO2 accumulates, it reduces the efficiency in which oceans and terrestrial ecosystems sequester carbon, which in return feeds back to exacerbate climate change (Friedlingstein et al., 2001). Warming can also increase the rate at which organic matter decays and carbon is released into the atmosphere, thereby causing more warming (Melillo et al., 2017). Increases in food shortages and lack of water is also of major concern when biogeophysical feedback mechanisms perpetuate drought conditions. The underlying mechanism here is that losses in vegetation increases the surface albedo, which suppresses rainfall, and thus enhances future vegetation loss and more suppression of rainfall—thereby initiating or prolonging a drought (Chamey, Stone, & Quirk, 1975). To top it off, overgrazing depletes the soil, leading to augmented vegetation loss (Anderies, Janssen, & Walker, 2002). Climate change often also increases the risk of forest fires, as a result of higher temperatures and persistent drought conditions. The expectation is that **forest fires will become more frequent** and severe with climate warming and drought (Scholze, Knorr, Arnell, & Prentice, 2006), a trend for which we have already seen evidence (Allen et al., 2010). Tragically, the increased severity and risk of Southern California wildfires recently predicted by climate scientists (Jin et al., 2015), was realized in December 2017, with the largest fire in the history of California (the “Thomas fire” that burned 282,000 acres, https://www.vox.com/2017/12/27/16822180/thomas-fire-california-largest-wildfire). This **catastrophic fire** embodies the sorts of positive feedbacks and interacting factors that **could catch humanity off-guard and produce a** true **apocalyptic event.** Record-breaking rains produced an extraordinary flush of new vegetation, that then dried out as record heat waves and dry conditions took hold, coupled with stronger than normal winds, and ignition. Of course the record-fire released CO2 into the atmosphere, thereby contributing to future warming. Out of all types of feedbacks, water vapor and the ice-albedo feedbacks are the most clearly understood mechanisms. Losses in reflective snow and ice cover drive up surface temperatures, leading to even more melting of snow and ice cover—this is known as the ice-albedo feedback (Curry, Schramm, & Ebert, 1995). As snow and ice continue to melt at a more rapid pace, millions of people may be displaced by flooding risks as a consequence of sea level rise near coastal communities (Biermann & Boas, 2010; Myers, 2002; Nicholls et al., 2011). The water vapor feedback operates when warmer atmospheric conditions strengthen the saturation vapor pressure, which creates a warming effect given water vapor’s strong greenhouse gas properties (Manabe & Wetherald, 1967). Global warming tends to increase cloud formation because warmer temperatures lead to more evaporation of water into the atmosphere, and warmer temperature also allows the atmosphere to hold more water. The key question is whether this increase in clouds associated with global warming will result in a positive feedback loop (more warming) or a negative feedback loop (less warming). For decades, scientists have sought to answer this question and understand the net role clouds play in future climate projections (Schneider et al., 2017). Clouds are complex because they both have a cooling (reflecting incoming solar radiation) and warming (absorbing incoming solar radiation) effect (Lashof, DeAngelo, Saleska, & Harte, 1997). The type of cloud, altitude, and optical properties combine to determine how these countervailing effects balance out. Although still under debate, it appears that in most circumstances the cloud feedback is likely positive (Boucher et al., 2013). For example, models and observations show that increasing greenhouse gas concentrations reduces the low-level cloud fraction in the Northeast Pacific at decadal time scales. This then has a positive feedback effect and enhances climate warming since less solar radiation is reflected by the atmosphere (Clement, Burgman, & Norris, 2009). The key lesson from the long list of potentially positive feedbacks and their interactions is that **runaway climate change,** and runaway perturbations have to be taken as a serious possibility. Table 2 is just a snapshot of the type of feedbacks that have been identified (see Supplementary material for a more thorough explanation of positive feedback loops). However, this list is not exhaustive and the possibility of undiscovered positive feedbacks **portends** even greater **existential risks**. The many environmental crises humankind has previously averted (famine, ozone depletion, London fog, water pollution, etc.) were averted because of political will based on solid scientific understanding. We cannot count on complete scientific understanding when it comes to positive feedback loops and climate change.