THE TERRA FORMING

As planetary-scale computation enables us to measure the inner dynamics of Earth, calculating its past, present, and future, we see the dissolving of the outside/inside mythos—the "out there" is actually "in here." What we call "terraforming" is the hypothetical process of deliberately modifying a planet's atmosphere, temperature, surface topography, or ecology to make it viable for Earth-like life. But what if we thought of the Anthropocene as a headless terraforming gone wrong, and researched better ways to terraform Earth and its ecologies? This text-only survey—an introduction and four essays edited in partnership with the Strelka Institute in Moscow—dares to suggest that the response to anthropogenic disaster will need to be equally artificial, and invokes creative solutions encompassing scenario planning, quantum physics, and cosmoplanetarity.

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ABSTRACT

It has been said that planetary-scale computation caused “the disappearance of the outside”: an act of *spatiocide* resulting in a monocultural globalism from which there is no escape. But perhaps instead it revealed that there never was an outside to begin with.

More specifically, it undermined a particular idea of the outside as the mysterious Nature on the other side of the border from the domesticated Culture. That border could be a fence, a wall or a door, but each similarly reinforced a notion of separation, with culture on the inside while nature remained “out there.” No more. We’ve come to realize that exteriority was a matter of perspective, and sometimes an illusion. A world made up of linear borders and horizons can be deceiving.

The dissolving of this particular outside/inside mythos has come from how the planet now senses itself, measuring its dynamics from the surface, underwater, in low-earth orbit and on the skins of things that populate it. How the world is perceived changes how we see what the world is. Just as the microscope forever changed how we see surfaces, and telescopes forever bent the horizon into the arc of a long curve, the development of a planet capable of sensing itself, sensing its own environment, calculating its past, present, and future, has and will continue to change how we (and it) understand *planetarity*, which is a very different thing than "nature.”

This planetarity has everything to do with climate change. In fact, the very idea of “climate change”—as in the calculation of a statistically significant shift in geochemistry and median temperature—is itself a direct accomplishment of planetary-scale computation. Without a big sensing and calculation apparatus through with the planet monitors itself, the current concept of “climate change” does not exist. In truth, the most important implications of planetary-scale computation may be epistemological and philosophical, not just technical. It changes not just how we think, but how the planet thinks through us.

The “question concerning technology” posed by the world, weary

The "question concerning technology" posed by the world-weary Heidegger held that an authentic relationship between "world" and "Earth" could only come from resisting the frame of technology. We see it the other way around: it is *only* through the precious, mind-bending technical alienation from naturalistic intuition that the reality of a planet might come into view. Any "authenticity" comes from alienation. It is by getting outside of ourselves and our singular bipedal phenomenology that we can see what's happening. For us, that is the real outside—but for the planet looking back at us, everything is happening in the great big indoors. No matter where you go, you are inside the little skins of clothing, buildings, cities, and ecological niches and atmospheres. In this sense, they are all "artificial"; we can and do remake them. Put differently, what is so provocative about directing our design attention "out there," is that it is all actually "in here." In this, there is both clarity and an invitation.

The research of The Terraforming think tank at Strelka Institute begins with this presumed planetarity, which becomes not just a frame of analysis, but also the basis for design. The terraforming we speak of is not the terraforming of other planets to make them viable for Earth-like life, but rather of ensuring that Earth will be viable for Earth-like life. It considers what is called the "Anthropocene" as a headless terraforming gone wrong. We are living in the structured debris of that terraforming. We recognize that whatever happens next, human culture will continue to terraform Earth and its ecologies. It's not a matter of if, but of how. For us, "how" means, a reorientation to planetary thinking that is in contrast with those predicated on pre-Copernican hangover concepts of nature, ground, identity, and place. This is decisively different than "the global," for which the planet is a static object for gridded overview. The planetary, by contrast, is multi-scalar and multi-temporal; it moves from atomic to atmospheric scales and back again without privileging the human-scale as the normative in-between point.

We accept the artificiality of terraforming and presume that the necessary response to anthropogenic climate change will need to be equally anthropogenic. We embrace our Three A's—astronomy, artificiality, and automation—but define all three in idiosyncratic ways. Most of all, we recognize the need for a *plan*. As the post-'68 critique of verticality morphed into the post-'89 celebration of horizontality, individuality, and decentralization, we turn our attention to necessary alternatives—not simply the inverse of these (i.e., verticality, deindividuation, and centralization), but to different variables altogether.

We look at the shambolic response to COVID-19 as evidence of what not to do. Falling back on post-colonial citizenship as default mechanism to re-sort, re-divide, and encircle naturally mobile population swarms shows just how under-matched our geopolitical traditions are by the epidemiological reality of our shared biological circumstance. That rich countries would purchase vaccine supplies, that countries would be reduced to hacking one another for life-saving research data, and that waves of political populism would dissolve into 5G hydroxychloroquine conspiracy theories is so predictable as to defy humor. It is anarchy in the worst sense of term, and shows how the evangelically horizontal planlessness of the neoliberal era has failed. *Ad-hoc community care networks* are nice, and market-discovered vaccines will be going in my bloodstream as soon as the Illuminati decree it, but neither is a sufficient replacement for a viable and ubiquitous planetary-scale healthcare regime.

We realize that our initiative is swimming cross-current with the moment. We realize that intellectual habits will all-but-deliberately misconstrue what we say, no matter how clearly we say it. It is also why the work matters. The spectrum of design runs from terraforming, defined as the transformation of the planet according to plan, to what program faculty Helen Hester calls *anthropoforming*, the transformation of the human organism according to the planet. Each implies similar but not identical relations to what is "out there." Both see the wide exterior as another interior in which (for which) we can design. Both see *Homo Sapiens* as a fundamentally migratory species. Our anatomy evolved in relation to our mobility and our relation to our tools. It is more relevant that you have opposable thumbs because your ancestors gripped tools than it is that they gripped tools because they had opposable thumbs. The body is the result of its engagement with technology, and humans have thus developed technologies for the body and for the environment in ways that leapfrogged the slow speed of natural selection. You already possess many custom exoskeletons: the fur coat, the ski boot, the scuba mask—all are artificial evolution in action. For architectural and urban-scale design, this process makes furniture, or individual rooms, or groups of rooms, or building envelopes, or urban amenities, interfaces, and infrastructures. They are all ways of accommodating the Great Indoors under the thin atmosphere.

Four of the thirteen group and individual projects from the first year of The Terraforming think tank at Strelka Institute are presented below by the researchers who developed them.

Bury the Sky draws on our discussion and debates of "geoengineering" as a planetary design and policy framework. The term is in quotes because for it to be useful, it must refer to more than a portfolio of strange cloud manipulation tricks. For our program, geoengineering refers to *a scale of design effect*, one which includes both proactive and passive forms. The project addresses the pressing need not only to cut carbon emissions dramatically, but also to actively subtract existing carbon from the atmosphere. Direct carbon capture is one form of Negative Emission Technology (NET) that requires much more attention. Working back carefully from metrics that require billions of tons of CO2 removal to be successful, the project shows how to put existing extraction infrastructure in reverse, burying the carbon spewed into the sky back underground.

Black Almanac draws the history of food—from early agricultural settlements to molecular gastronomy—as a history of artificiality itself. The almanac is an early form of database-driven agriculture, an open record of past and predicted climatic events, best practices and benchmarks. The almanac proposed by this project sets an agenda for the coming decades of food production as a terraforming process by which we make the matter that we ingest (and which thus becomes us). Instead of the skeuomorphic faux traditionalism of today's kitsch cuisine, the artificiality of food is posited as the necessary means to a just and intensely heterogeneous planetary food culture.

Cosmoplanetarity places each of us in the figure of the astronaut/cosmonaut, encased in their life-support apparatuses, entangled with their ship, all given unfamiliar form by reduced gravitational pressure. The research braids *anthropoforming* into terraforming directly and tests the transformations of the creature (who is us) in relation to those limits. The protagonist in the larger story is the gravitational force that not only holds form in place, but that also gives form as things evolve to suit its weight, on- or off-planet. That is, even as those creatures are "freed" from gravity and liberated from form, that form had been given in the first place by the gravity that now squeezes them. On stage is the "creatureliness" of the astronaut and their craft as the two remake each other under conditions of extreme interdependence. The lesson of the work is that the experiment up there clarifies what is already at work down here, terraforming and *anthropoforming* making and remaking one another.

In the original Cassandra myth, the daughter of the last king of Troy was less a futurist than someone uniquely sensitive to the implications of faint signals. Our namesake project, *Cassandra*, challenges the official futurism of the Intergovernmental Panel on Climate Change's scenarios of what may happen next, suggesting that they've overlooked key variables and important ways of articulating their implications. The very idea of "climate change" extends the past into the future in ways that are extremely difficult to come to terms with; in that its significance is understood in relation to its future effects, it also extends the future back into the present. This gives power to the model and weight to the scenario as genres of governmental media. This project demonstrates new ways and new voices through which they can and must be articulated. An informal motto of The New Normal, our previous program at Strelka Institute, was "the future has not been cancelled"—a rejoinder to Mark Fisher (one that he approved of) and a nod to Russian Futurism. But in the early 20th century, the future was something to be achieved; in 2020, the future as we know it is something to be *prevented*. One future must be rendered impossible so that another can be realized.

If the projects of The Terraforming speak to "speculative design," then it is of a specific kind. It works with (and sometimes as) a cold realism that cuts through comfort zones, including our own. Rather than speculation that is whimsically creative in some pretend tabula rasa, it works so directly with the disenchanted constraints of the real that its outcomes seem obtuse or even alien. The research is hyperfunctional, and so seems outlandish and unlikely, which has the effect of making whatever is most likely appear absurd. The planet should be open, and the multiplication of species should continue. To be "outdoors" is not be outside of the larger inside. Doors are only one kind of shelter. Our project is to remake the inside—and be remade by it—in ways befitting this, the only planet within light years capable of hosting complex biological intelligence.

Edited by Benjamin H. Bratton and Nicolay Boyadjiev

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The Terraforming program will be running for at least two more years. Applications for year two will be accepted in Fall 2020 at theterraforming.strelka.com, where Bratton's book *The Terraforming* is available to download.

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BLACK ALMANAC

AGRICULTURE IS TERRAFORMING

BLACK ALMANAC: NOTES TOWARDS A PLANETARY CUISINE

Philip Maughan, Andrea Provenzano, Nikolai Medvedenko

Our current food system is a monster. Humans are cooking the soil, the oceans, animals and plants, and the planet in turn is cooking us. The processes by which we convert the biotic surface of the earth to make it edible are responsible for one third of total greenhouse gas emissions. Seventy-five percent of all deforestation is caused by land clearance for agricultural use. So is the majority of biodiversity loss. Every minute, one million dollars of public money is pumped into the system—propping up outdated farming methods and forestalling change. It's not unusual to feel removed from the places and processes that produce our food. Yet the notion that there is a simple agrarian past waiting to be rediscovered is an illusion that will do greater damage in the long run. By 2050, there will be 9.6 billion people on earth. If we are going to feed them, we will need to produce seventy percent more food than we already do. If our environmental impact is to shrink as yields go up, we'll need to rethink what and how we harvest. The route to a viable food system may require more alienation rather than less.

AGRICULTURE IS TERRAFORMING

We regulate our bodies, our lives, and the environment by eating. Grocery shopping, food prep, and scheduled meal times represent a metabolic bureaucratism we employ to administer our communities and ourselves. As a result, the transformation and ingestion of food is intrinsically linked with how we understand time (as well as how we regulate labor, social roles, or simply who gets to be where when.) The rituals of bourgeois dining, an ahistorical agglomeration of faux-aristocratic signaling fused with fantasies of languid ruralism, have been interrupted by the chronological smoothie of an ambiently present, globalized work culture.

It would be a stretch to say that dining is resistance, yet eating remains the primary means by which we orient ourselves in time and space. So afraid are we of the void that lies behind our routines, we have put the planet on our clock. Historian Dipesh Chakrabarty describes precisely this hijacking of geological time, aligning planetary geophysics with the short-term cycles of intelligent apes. Integral to this process has been the cultivators, ploughs and crop dusters, centrifugal seeders and drones, multispectral satellites, and other tech used to sense and shape the landscape to make food. And yet humans have spent ninety-five percent of their career on earth as hunter-gatherers, familiar with an encyclopedia of naturally occurring edible plants, mushrooms, and seeds. Who has the right to say we cannot live according to a different clock?

NON-HUMAN ALCHEMY

We were not the first species to terraform earth. Around 2.4 billion years ago, cyanobacteria (blue-green algae) began to produce oxygen as a byproduct of photosynthesis, wiping out the majority of nitrogen-dependent lifeforms and triggered the first ice age. This event has been referred to variously as the Oxygen Catastrophe, the Oxygen Crisis, the Oxygen Holocaust, and the Oxygen Revolution. It was the first planetary extinction event. Many scientists believe we are now living through the sixth.

Algae wasn't always destructive. It is believed to have precipitated the Cambrian Explosion. "This rise in algae happens just around the time the first animals appeared on the scene," scientist Jochen Brocks told the BBC. "It was algae at the bottom of the food web that created this burst of energy and nutrients that allowed larger and more complex creatures to evolve."

Algae has already transformed the planet once and may soon do so again. Humans are expected to consume more food in the next fifty years than in the previous 10,000, and the one million species of algae believed to exist could play a central role. Algae is a vitamin, mineral, omega-3, and phytonutrient-rich food source that can be grown in all weathers and harvested year-round. First, we must expand our definition of farming to include practices like algaculture. If the dark magic of the existing food system can be seen most clearly in its ability to reformulate and distribute inputs like corn syrup and soy as primary ingredients, the food system to come will be capable of transforming and circulating a multitude of new dishes and cultures formed from more nutritious and resilient biomatter like algae.

HAPPIER MEALS

The journal *Frontiers in Nutrition* describes a 2008 study in which participants were less likely to eat a mealworm truffle after being told about its ecological benefits and more likely to eat it after being told it would make them cooler. Politics, clearly, is something we eat, where consumption according to a given script becomes a ticket to group membership. This may refer to cultural practices rooted in geography and personal history, but it could also mean the semiotic preferences at your chosen supermarket: whether you buy green-labeled products (organic, or at least *earthy* on its own terms) or white-labeled (basic, utilitarian, "no marketing can fool me").

The adoption of new food types, like fashion or political ideas, spreads through existing social groups and moves most efficiently when laced with libidinal appeal. Desire is networked, but so is disgust. The separation of clean and unclean, first observed at home as children, leaves an impression that bug evangelists may struggle to overcome. Much in the way McDonald's uses bright colors, intense flavors, and trend-adjacent Happy Meals to get kids hooked, the neurological grooves written in early life can prove difficult to rewire. There is a widely-held belief that certain colors, textures, flavors, and sensations suggest poison to humans. Yet there is a process of adoption familiar from evolutionary science: sampling a newly discovered berry in small amounts before increasing the dose, assuring its safety before returning that which has been foraged to the group. This process can be engineered and accelerated.

DENATURALIZING EDIBILITY

Consider the lobster—again. This once-despised creature, deemed a bottom-feeding parasite suitable only for fertilizer and animal feed until the late 19th century, is now a symbol of excess: centerpiece of grills, thermidors, and cultural festivals, and a major economic asset. Consider crayfish, or "mudbugs," too: freshwater crustaceans that subsist on decomposing matter and today give rice farmers in Louisiana a way to diversify their fields. Both came to be accepted much as Japanese staples such as raw tuna, seaweed, tofu, and matcha made their way into the global mainstream—a shift driven not by necessity, but by desire. Could lobsters, crayfish, or sushi provide a historical precedent for insects, fermented proteins, cellular meat, algae, or any other perennially harvestable, versatile, and nutrient-rich (or simply less-bad) alternative?

What it teaches us is that edibility is not innate in things. All foods needed to be discovered. Instead, edibility is constructed according to knowledge of the *matter* in question, its benefits and chemical effects, attendant cultural practices and accessibility. The latter changes over time according to environmental conditions. Insects are a major source of protein used in a wide variety of dishes in South America, Africa, and Asia. In much of the global north, the learning process and disgust reflex that serves an important evolutionary function (preventing humans from consuming rotten or toxic food) has contaminated an entire category of edible creatures via their association with decay and waste. Pigs once suffered from a comparable misrepresentation, which is why their supposed voraciousness remains encoded in our language—"greedy pig"—while connotations around tenderloin and charcuterie are unblemished.

Yet Westerners already eat insects in the form of food coloring. The ingredient known as "carmine," "crimson lake" or "E120" refers to the cactus-dwelling cochineal of South America, found in a range of yogurts, cakes, sodas, and lipsticks. The bounds of edibility and inedibility, food and non-food, are broader and more porous than we think. We eat copper and zinc to boost our immune system and must monitor the iron levels in our blood lest they fall too low. We regularly ingest that which might seem harmful and use harmful substances to suggest edibility—as in food photography, where meat is basted with motor oil to glisten on cue and ice cream is more likely to be dyed wall-filler than anything that might melt under a hot studio light.

PERVERSE SUBSIDIES

Ultimately, the main obstacle to emerging food cultures may not be picky eaters but the trillion-dollar wedge of government subsidies that is the hidden infrastructure behind the dishes, recipes, and products available on the market. Subsidized beef, consumed primarily in the global north, is one of the most destructive. There is no escaping this fact. Perverse subsidies over-incentivize land-hungry, emissions-intensive, and climate-vulnerable farming practices that are not determined by consumer demand or necessary to guarantee food security. Sixty percent of the output from one of the best-known profit landscapes, the U.S.'s corn and soy belt, is fed to animals. A further thirty percent is used for bioethanol, while just ten percent is fed to humans in the shape of corn syrup and other foods. For the most part, farmers do not choose which crops to grow: the state, precedent, technological capacity, and the small fraction of mega-corporations who control the food business do, circling a one-trillion-dollar wedge of zombie payments that can and must be redirected towards drawdown, ecosystem management, and research to increase yields and diversify the food system.

ARTIFICIAL ECOLOGIES

The most advanced field in agricultural robotics is that which concerns itself with livestock. It's a depressing observation: that the conversion of sentient life into the jellies, patties, nuggets, and pastes which we recognize as food is a process so brutalizing that we cannot stomach being near it, even as it fills our stomachs. Yet the larger truth of this situation is more harrowing still. Agricultural investment is pathetically low given the industry's size. The results of more visible agricultural practices, including deforestation, ocean dead zones produced by fertilizer run-offs, desertification, and poor soil management, may provide even harder to tolerate than the screams of animals humans are currently so desperate to inflict on machines.

There is another world where "cooks," "kitchens," "product," and "cheese" unite a planetary-scale network of insiders committed to the molecular, metabolic, and dynamic transformation of matter packaged and marketed to be appealing, addictive, and profitable. It was no accident that the storyline of TV series *Breaking Bad* contained a fried chicken franchise whose parent company, Madrigal Electromotive GmbH, provided the means of international supply to Walter White's rival Gustavo Fring. The global food system is subject to far greater obfuscation—from both producers and consumers—than the market for illegal drugs, where production and distribution methods are regularly "exposed" in unembellished form in documentary and fiction.

The future of food is artificial—but so is the present. There is almost nothing in your local supermarket that was not selected, domesticated, or cultivated to meet the logistical requirements of contemporary capitalism or by human beings striving for nutritional stability and better growing potential. We recognize that a nugget, sausage, or shake is processed, but so too is an "heirloom" tomato, prized for its pigmentation, shape, transportability, and durability—standards that emerged at the onset of industrial supply and color printing, which mechanically produced images of food and expected food itself to meet the same standards.

While many rage instinctively against the "inhumanity" of trans- and intercontinental supply, this indignation offers little in the way of concrete alternatives beyond vague homilies to localism, or mandatory subsistence farming for every other household (which would be necessary if we were to abolish industrial food production while avoiding mass starvation). Instead, wholesale rejection of industrial food should be exchanged for a greater curiosity and engagement with the ecologies of automation able to produce food at the speed and scale required. While the system clearly needs to be improved, it is not sufficient merely to signal one's opposition to the deception and inherent barbarism of much of the current food system while waiting for reality to slip back behind the veil.

ABSTRACT

BLACK ALMANAC

Born from the tradition of farmer's almanacs that reaches back as far as ancient Mesopotamia, our project *Black Almanac* was initiated during The Terraforming program at Strelka in 2020 to embrace the necessary artificiality of the food system to come and the chemical-materialist potential of food as a locus for planetary transformation. Named for the dark, fertile soil of the Nile River Delta—from which systematic agriculture and the words "alchemy" and "chemistry" descend—*Black Almanac* is a plan for 2050 that plots thirty-one fundamental steps, from infrastructure to institutions, one per growing season, to construct a viable food system by the autumn of that year.

In *Anti-Oedipus* (1972), Gilles Deleuze and Félix Guattari begin referring to a "place of healing" that will come (the reference is from Nietzsche), "a new earth where desire functions according to its molecular elements and flows." The Terraforming is concerned with continuing to sketch this earth-to-come. In part, it asks how words and images can increase their informational load so that the truth of Australian bush fires or the ecosystems lost to cattle pastures can be more fully comprehended. We did not propose the almanac because we are foodies. We are not. Nor did we intend to imply an uncomplicated recursion between farm and table. Rather, we hoped to ease the dismal burden imposed by a consumer dialectic that sees individual choice as capable of reorienting the path of human beings towards less catastrophic ends.

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OUT OF TIME

Chiara Di Leone, Anastasiia Noga, Laura Cugusi

It's not so far-fetched to imagine that the next COP will take place in *Fortnite* as a performative statement aimed at cutting down emissions needed to fly all of its participants into a single location. In this post-pandemic world, we are left wondering: what will be the new aesthetics needed to represent institutional decision-making? And what will be the role of digital spaces?

The digital space (the realm in which algorithms also exist and operate) already blends the boundaries between present, past, and future. These are spaces that exist outside of space-as-we-know-it, temporalities that exist outside of time-as-we-know-it. There is a potential for more and more institutional scenario planning and decision-making to begin taking place in the digital realm because it is a space believed to be devoid of friction. The "outside" is still seen as dangerous: the fictional idea of primeval nature that appears in the survivalist gear and hiking equipment marketing and feeds into the video game rhetoric, promising the experience of a "staged" adventure. It provides a conditional experience of the "outside" as a space of possibility, delivering a hero's journey into the comfort of your home. But most importantly, the dangerous, physical "outside" is where a protest takes place, a non-staged encounter with the Other which many institutional decision-makers and stakeholders wish to avoid as much as possible. So how can you avoid being bombarded by protesters on your way to a boardroom meeting? How can you avoid having the legitimacy of your institutional authority undermined by the crowd that questions your protocols outside the building? It's simple: stage it in *Fortnite* and reduce flight emissions.

PROLOGUE

In Caspar David Friedrich's notorious painting, *Wanderer above the Sea of Fog* (1818), a man stands on a cliff, high and tall with his back to the viewer. Beneath him, the barely perceptible landscape stretches towards the horizon, rendered into a blank canvas by the thick layer of fog. Deep in melancholic thought, he watches the clouds move through the far-off mountains, imagining the adventures his journey will bring, anticipating the potential it holds. As the wanderer reflects on his own position on top of the world, the future seems his for the taking: it is a space of infinite possibility, an answer to his search of self-fulfillment; the exact direction of his gaze cannot be confirmed, yet it doesn't matter. What the wanderer is really looking at is not the landscape at his feet, but rather the time ahead of him. He is looking into the great unknown of his future, the limitless "out there."

The Romantic notion that nature is the ultimate exterior, the "outside" to human subjectivity, didn't die off with the tradition of 19th-century landscape painting. Romanticism is alive and well. Friedrich's painting conveys the familiar aesthetic of the hero's journey, the solitary quest to tame nature and fate, which has served as a model for narrative-building in fields beyond fiction and which continues to haunt cultural imaginations of the world to this day, through cinema, fashion, video games, and car commercials. More than a representation of the surrounding world, it speaks of how humans conceive their own position within it. In mainstream cinema, the most dystopian narratives often end with the victorious hero, even when success is dramatically challenged by his journey. (Think of the feel-good family comedy set in space of *Ad Astra* for one.) These cultural representations of "the outside" frame the spatial condition of human existence as much as they frame the temporal one, transforming the future into a product of the experience economy—an imaginary space in which uncertainty is transformed into possibility, anxiety into excitement. The conceptual paradigm propelling those narratives also extends to other kinds of fictions. It legitimizes a certain genre of stories about the future of "nature," where the two are hermetic categories separated from the cultural present by the agency of the human.

PLANNING

In the 1990s, the neuroscientist David Ingvar became known for coining the term "memories of the future." In his essay from 1985, published by the journal *Human Neurobiology*, he states that one's experience of the past is not limited to the functions of the temporal lobe, but is linked to the regions of the brain responsible for more general organization of behavior and cognition—namely, the frontal and prefrontal cortex, the same regions responsible for projection, or plans for future behavior. Those parts of the brain not only process serial information, but can also extract causality from "the enormous, mainly non-serial, random, sensory noise to which the brain is constantly exposed." In his opinion, it is their ability to do so that forms the basis for anticipation and expectation, as well as for the short and long-term planning of a goal-directed behavior. In other words, the brain prepares for the future based upon its experiences of past events and the awareness of a "Now-situation," each of which are continuously rehearsed and optimized. Without an expectation, or a *memory of the future*, the extraction of causality cannot take place. Dysfunctions of the frontal and prefrontal cortex, he adds, give rise to states characterized by a "loss of future," with consequent indifference, inactivity, lack of ambition, and inability to foresee the consequences of one's behaviors.

In relation to climate change, this paralyzing anxiety provoked by the uncertain future of the planet's biochemical makeup has by now transcended the level of personal unease and turned into a collective malaise, aggravated by the abrupt "suspension" of the future caused by the ongoing COVID-19 global outbreak.

This uncertainty, however, is not produced by a lack of "narratives" which provide a clear trajectory of where the planet could be heading—in fact, there are plenty. Instead, it stems from the cognitive dissonance between the various acknowledgements that the path from the present to the future could or should be mapped differently, and the lack of action to support those acknowledgments. In practice, the focus of planetary futures needs to shift from the act of imagination as an end in itself towards the strategic importance of planning. For this to happen, a more nuanced conceptualization of time will be necessary, but it won't be enough—an institutional framework capable of actualizing the *practice* of planetary future will need to emerge as well. Imagination and planning are not polar opposites that cancel each other out, but should be seen instead as reciprocal processes.

On the surface of institutional discourse, the future is imagined as a vague social construct, while the process of getting there is seen as a linear trajectory of an abstract vector from the present towards somewhere beyond our familiar experiences. The future habitability of Earth is viewed by governing institutions as *terra nullius*, a place to which fantasies of success get constantly deferred.

MODELING

The framework of scenario planning used by the Intergovernmental Panel on Climate Change (IPCC) maps the planetary future as five divergent alternatives, known as Shared Socioeconomic Pathways. It positions the present as a moment from which the forking paths can be seen, presuming that one of the five trajectories can be deliberately chosen. The pathways are based on predictions of how socioeconomic parameters might guide the concentration of greenhouse gases in the atmosphere for the next eighty years, and are extrapolated from mathematical projections that take into account a number of criteria. On the surface, these scenarios are grounded in scientific data and sound computational practice, although the criteria that are used to feed the projections together with the overall framing method fall short of fulfilling their ambitions, which, ultimately, are to ensure the survival of Earth-like life on the planet. By using global population, economic growth, and emissions as key variables in determining a possible "destiny" of the shared planetary space, these scenarios end up with generalized narratives that lack nuance and limit the scope of de facto measures and actionable policies aimed at managing climate change.

Social sciences and social determinism are seen as "driving forces" of these narratives, which at their core do not critically examine but rather perpetuate the economic and social paradigms that are leading humanity towards an ecological collapse in the first place. Climate change has become a mainstream issue in the public agenda on planetary scale, yet the scientific and political framing of the problem and the possible range of solutions have been limited by the cultural and ideological understanding of modern neoliberal economy. One of its main weaknesses has been identified in recent economic theory as the failure to account for the concept of "externalities," consequences which exist outside of its theoretical and practical framework—including, for example, the cost of environmental damage. The scenarios also reinforce the all-or-nothing mindset, where the future is either an equally distributed utopia or similarly overarching dystopia, as well as discursively position certain strategies as implicitly antithetical to each other. This only reinforces anxiety and paralysis, where if "we" do not get something exactly right, there is no point in trying.

The reality is more fragmented than these narratives allow it to be. There is no overarching narrative that a single (even if collective) agency can fulfill. Instead, the shared environment of the planet is continuously and simultaneously being shaped by multiple, often conflicting agencies, and is influenced not only by the processes taking place in and for the present, but by the echoes of the future as well. That is, scenario planning can be and already is effective but only when practiced by organizations with the ability to enforce their strategies, and whose mode of decision-making is not centered around consensus-building. Hence why a situation arises where the withdrawal of the United States from the Paris agreements undermines the very possibility for these objectives to be achieved at all.

NAVIGATING

Humans have developed complex technologies, techniques, and devices for navigating and organizing the spatiotemporal conditions of their inhabitation, which do not exclusively rely on human vision or other senses for logistical tasks. However, that imaginary line of the horizon keeps looming in the background of the rhetoric that surrounds climate change and the futures of planetary inhabitation. While these conversations stay futile, the infrastructures of sensing, modeling, and simulation already have the ability to bring into effect physical transformations of the material reality, so far largely unplanned.

As pointed out by Lev Manovich in his essay "Automation of Sight from Photography to Computer Vision" from 1997, the discovery of linear perspective can be seen as a precursor of technologies of automation of sight. Where linear perspective allowed the visualization of a three-dimensional structure from a two-dimensional, simplified representation, it is now possible to measure depth and navigate space directly by employing various remote sensing technologies, such as Lidar, radar, AI-assisted 3D modeling, machine vision and so on, in combination with each other.

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With the enhancement of such technologies, the single-POV perspective loses its privileged role, as space, objects, and phenomena can be measured and mapped through properties other than vision (the single-perspectival image being too ambiguous for computer vision systems). The implications of this epistemological paradigm shift manifest in the inadequacy of modern scenario planning in relation to climate change, where mutually exclusive representations of the future are outlined and juxtaposed against each other. The multiplicity and simultaneity of POVs, textures, and media enabled by constantly accelerating innovations in the field of non-human vision break apart the dynamic of reality and representations recursively shaping each other.

Scenario planning, as conceptual modeling of the future, is a navigational practice which needs to operate *from within what* Patricia Reed terms "horizonless perspectives." The figure of the horizon as a marker for orientation, which exists in practices that position the future as a destination point, is "no longer an adequate vehicle for navigating [the] planetary scale condition," she says in a talk given at Simon Fraser University in 2018. This brings back the imagery of the wanderer, embodying the centuries-old technology of the linear perspective, dependent on the unique advantage point of the viewer, which has deeply informed not only cultural representations and the aesthetics of mapping, but also the practice of futurology, science-fiction writing, and scenario planning to this day. When the horizon disappears, it is still possible to navigate the world sailing by sight, but only with a well-calibrated compass and the knowledge to interpret its oscillations—because, as Seneca summoned, "If a man knows not to which port he sails, no wind is favorable."

The mutually constitutive relationship between the diagrammatic structure of the space and the situated, personalized experience of it opens up possibilities for how planetary futures could be navigated. Within the shared environment of the planet, however, "a broader array of types of knowledge is required to co-construct a diagram of [the] reality—a reality that is multi-situated across bodies, materials, geographies and knowledge practices, yet one that is still coherent nonetheless," as Reed rightfully points out. The absence of the horizon within the labyrinthine complexity of this reality, made up of a meshwork of relations and agencies, shouldn't dissuade anyone from trying to make sense of how to orient themselves within it; instead, it should be seen as a necessary precondition, especially when it enables the logistics of navigating time. Speculative practices which use imagination as a point of access into different futures, in this context, can be seen as potential navigation devices, specifically, because they do not attempt an account of the reality from the perspective of encyclopedic knowledge, but rather allow one to situate and orient oneself within the present configurations of systemic relationships as well as within the probability space of the future's plurality. Such practices, like seeds, generate an array of coexisting *narrative possibilities, as late science*-fiction writer Ursula K. Le Guin proposes in the Carrier Bag Theory of Fiction, a radically different narrative device than that of the Hero's Journey. Drawing its conceptual grounding from a variety of disciplines—from quantum physics to philosophy and literature—the Carrier Bag Theory invokes and operationalizes a plurality of worlds, mapped onto historical contexts, and poses questions about the incongruities that exist between imagination, abstraction, and orientation.

EPILOGUE

Accelerating with the Age of Discovery, the exploration of planetary geography and the material conditions it produced—the legacies of which are still being grappled with to this day—transformed the world as a system of social relations and facilitated irreversible changes within the biochemical makeup of planetary ecosystems. These processes informed, and continue to inform, the very imaginations of "being" on this planet, modes of its inhabitation and worlding, and it is necessary to keep interrogating the mechanisms and ideologies through which they do so. Globalization is only a tip of the iceberg, but it is the prime paradigm that the concept of planetarity will need to overtake—the concept which, according to Bratton, "exceeds final perceptual closure in ways that the cartographic heritage of the Global does not." And it remains to be seen what new emergent practices of planning and modeling which will serve as the basis *for the new cartography* of sound planetary navigation. But if we were to bet, it will be those that do not rely on linear perspectives, do not privilege the centrality of human senses and treat imagination as a creative and open ended process but not an end in itself.

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ABSTRACT

With its excoriating radiations, warring magnetic fields, and multiple grasping gravities, outer space is often positioned as the zenith of extremity, the ultimate outside, the absolute “out there.” Marooned and enshrouded within these perpetual cosmic tempests is the Earth, a great inside wrapped in a biospheric planetary seal. But are such seals as air-tight and complete as they appear? Rather than a unified sphere enclosed within a turbulent abyss, how can the Earth instead be configured as a continuum intimately webbed within outer space? Stretched through the plastics of deep time, technologically unspooling itself into orbit as part of a dynamic realm of manifold forces and phenomena, how is the planet and its parameters unfinished and evolving? In other words, what is a planet, and where does it (ext)end?

Earth has long been visualized as a discrete sphere siphoned off from the stelliferous beyond, coterminous with the mapped longitudes and known latitudes of the globe. Such blunt Earth-Outer Space delineations establish a border from which rocket-fuelled fantasies of escape, ascent and transcendence burn themselves free of Earth’s gravitational hold. But rather than a foreclosed interiority to be controlled and surpassed, what if it is the planet itself which is increasingly unbound, embracing unknown vectors as it unspools itself outwards?

Orbital space is densely cluttered with satellites, space stations, and proliferating debris, braiding the planet and its cosmic contexts into tightening technoscientific, affective, geopolitical, and material knots. Although often understood as external eyes and passive platforms gazing upon a sealed interiority below, these microgravity infrastructures are actually active participants in sculpting planetary parameters—a planet-forming which is always unfinished. Such *provisionality* renders planetary parameters as metastable, artificially expanded and expanding. The Earth, and its techno-organic systems, is thus increasingly reconfigured and pulled out further into outer space. For a full measure of the planet to be taken, a relational ontology of the Earth as something more akin to a creature, comprising evermore verticals into its horizontal nest, must be formulated.

On its shifting surface, it may appear that such microgravity infrastructures deterministically bind Earth ever-tighter into hegemonic mappings of the world-as-globe, wherein near-Earth space is streamlined into a terrestrialized iteration of control. As Valerie Olson has stated, spaceflight programmes “build and link systems to annex outer space as a governable outer environment” (2018). Contradicting the idea of Earth as an increasingly known unity hemmed into the world of Western technomodernity, literary theorist Gayatri Chakravorty Spivak has stated that “the planetary is a species of alterity” (2003). Rather than being emblematic of the complete command and control of escalating domains, how then does the planet fold in new forms of destabilizing cosmic difference as it unwinds outwards? If the Earth’s aggregating microgravity infrastructures are embroiled in a whirling and inescapable dance, whereby the planet becomes increasingly circumscribed by the technologically conditioned knowns of world, then so too do counterbalancing vectors of planetary alterity emerge in response. These counterbalancings are enacted through the bodily mutations and shimmering inhabitations of Earthlings, inhabitants who shape the environments they move through. Re-evaluating calibrations between terrestrial *interiority* and cosmic *exteriority*, cosmoplanetarity thus considers how the planet pushes back and ruptures hegemonic notions of “world” through the flickering embrace of its Earthlings. Rather than an Earth entombed within a spherical perfection, cosmoplanetarity instead asks: what are the perils and potentials of inhabiting an increasingly creaturely, cyborgian, and restless planet?

MARBLE SMASHER

Images of Earth formulate a cosmic equation where the planetary is equal to the spherical and the discrete. Planetary icons such as *The Blue Marble* freeze and frame Earth as an incandescent orb suspended in an inky void, complete in its perfection. Taken in 1972 by a moon-bound astronaut in the last crewed lunar mission, image *AS17-148-22727*, or what would become the cropped and chromatically adjusted *Blue Marble*, was taken on the fly, as a whim. Delicate and glowing, *The Blue Marble* materialised idealizations of the planet as a finely attuned homeostatic system gone awry: a world in peril and an ideal state to be returned to (see James Lovelock and Lynn Margulis’ Gaia hypothesis). Cementing a sense of circumscription and containment alongside discourses of planetary fragility, this opportunistic shot became the archetypal symbol of the then-burgeoning environmental movement. Macroscale understandings of Earth as a closed system naturalize specific notions of worlds as objective, dictating how such worlds should be inhabited. Iconic Earth images are therefore emblematic of a cartographic stratagem, where worlds are mappings over the planetary rather than an accurate and definitive record of the planet’s ontological conditions.

ON COSMOPLANETARITY

Re-spinning *The Blue Marble* to account for the technologies which generated it, another planet comes into view. Revealed is a planet-extending ecology of microgravity infrastructures, photographic processes and astronautic crew, all coming into relation as a new layer of planetary musculature. Thus, representations of the planet as a sealed interior are undergirded by a multiscalar assemblage of organic and synthetic Earthlings. As we will see, this technological infrastructure, although seemingly determined by the world of technomodernity from which it emanates, is nonetheless always contaminated by the morphological alterities of the planet it seeks to control. These new foldings of multivarious technoscientific assemblies, social relations, and conceptual reorientations do not just hem outer space within Earthly knowns. The "out there" is not curtailed, but rather blooms across these new terrestrial folds. These cosmic foldings are composed of various disorientations that offer, necessitate even, the unearthing of other forms of planet which latently reside within the current Earth.

MICROGRAVITY POETICS

Low Earth Orbit (LEO) is populated by defunct devices, operational satellites, and spinning space stations, an aggregating artificial layer lobbed aloft to whir and glitter in orbital blizzards. Rather than mere watchers remote monitors and passive sensors—this algorithmically chanting brood enacts an incantatory merging of former near-Earth outsides with planetary conditions. Within these orbital folds, various Earthlings twist, buoyed by the nudging insistences of microgravity.

Up past the conventional border between planetary and outer space domains known as the Kármán line, an artificial strata of microgravity infrastructure profoundly shape conceptions of vision and being for those below. Transmuting anthropocenic weirding and glitching into digital images, satellites beam down data which formats the mega-sublimes of climate collapse into a more cognizable form. Like with *The Blue Marble*, such visualizations of Earth often obscure the means of their production, disguising how cluttered orbital zones are themselves a site and layer of anthropocenic mutation, a deepening of the planet's heights.

Amongst this mechanical horde, the International Space Station (ISS) tests the viability of long-term spaceflight through experiments on various non-human Earthlings. These experiments create artificial assemblages which transversally cut across and web together various planetary (and formerly near-Earth) realms. Such infrastructure is characterised by bodies in flight: bodies which, while orbitally hurtling in free fall, float within a groundless home. Human and non-human bodies are thus sensitized to new gravitational relations which disorientate and interrupt the replication of terrestrial coordinates, throwing their contingency into sharp relief. Modes of microgravity inhabitation cause bodies to mutate, introducing new forms of alterity into the parameters of the planet, necessitating new entanglements and other ways of being throughout the Earth.

In 1945, Russian astronomer Gavriil Andrianovich Tikhov coined the term "Astrobotany," an appellation defining the combined nurturing and study of plants in the extremes of solar radiation and microgravity. A year later, maize became the first organism to be launched beyond the biosphere. Since then, astrobotanical experiments have flourished within multiple space stations, yielding surprising results. In 1982, cosmonauts grew Arabidopsis onboard Salyut 7, a model organism which became the first to flower in space. *Zinnia* has since bloomed in the ISS. Some astrobotanical experiments, such as by the Canadian Space Agency (CSA), have found that space-sprouted white spruce seedlings exhibit enhanced growth, surpassing their terrestrial siblings (2010). These various blooms and mutations demonstrate how the stressors of microgravity and solar radiation can catalyze unexpected alterations on a molecular level.

Such vegetal vitality adds weight to the possibility of bioregenerative human/plant life support systems in future deep space missions to Mars. Now, as a garden of myriad species (dubbed "salad machines") bloom in the ISS, so too do Moon trees (grown from seeds which traversed cislunar space during the Apollo 14 mission) thrive on Earth. Hybrid plants thus transgress perceived boundaries between the planetary and the cosmic, sprouting in free-falling splendor to foreground forms of care in more-than-human worlds. Increasingly, then, botanical and human metabolisms re-blend through new entanglements in the artificial worlds of the space station. Donna Haraway framed her infamous figure of the cyborg as a bodily fusion of technological and organic matter. The new forms of symbiosis and modulations enabled by the space station thus demonstrates the ways in which the Earth increasingly expands through a cyborgian embrace.

Alongside astrobotanicals, fruit flies have long inhabited microgravity infrastructures, leading to the birth of what I will call "astroflies." These astroflies don't fly, but rather glide and scuttle, utilizing new mobilities which elide biomedicine, various gravities, spaceflight technoscience, and artificial environments into one differently moving Earthling body. At present, an expanding thousand-strong brood of astroflies are housed on the ISS for bioastronautical experiments testing the viability of long-term human spaceflight. But rather than being completely controlled through the command of a space station's sterile lab, how can astroflies instead offer a means through which, in the words of Noreen Giffney & Myra J. Hird, to "undo normative entanglements and fashion alternative imaginaries"? (2008) How do inhabitations of microgravity infrastructures and space station labs propagate new relations which extend the planet's parameters? In other words, in other worlds, what new forms of togetherness are entailed by the glitching glide of astroflies?

Similar hairs plume both fruit fly wings and the inner-ears of humans: delicate sensors imbuing both species with balance and orientation within Earth's gravity. These gravity sensitive hairs are one example of the multiple gravitational and physiological bonds configured through, between, and across interspecies Earthling bodies, coordinates which become skewed and reconfigured in microgravity. With its physiological remixes, microgravity offers an alternative lateral web of relations where all Earthlings are tied together in new mobilities, new multispecies inhabitations which challenge normative assumptions around the stability of bodies and their boundaries. Rather than one serving as a proxy for another, astrofly test subjects and human scientists both become astronautic bodies, mutually mutating in the spinning holds of microgravity. These new relations make perceptible how gravitation (in its various expressions) is a force which perpetually shapes bodies and binds those bodies together. As anthropologist David Valentine contends, such microgravitational co-evolution "potentiates worlds and experience" (2017). Hence, microgravity could be seen to enact what Rosi Braidotti has elsewhere outlined as the posthuman "recognition of trans-species solidarity on the basis of our being environmentally based." (2013) These environmentally held solidarities become more pronounced through inhabitations of microgravity. Such solidarities, and the new modes of techno-organic interspecies symbiosis they engender, are contiguous with, not divorced from, Earthly parameters.

Rather than an exemplar of "a grid of control" (Haraway, 1985) buttressing hegemonic technoscientific formations, the strange whirl of astrobotanicals and the gliding mobilities of astroflies trace out a potential path toward another sociality, one forged within the crucible of microgravity. As the ultimate expression of synthetically engineered environments, the "naturecultures" (Haraway, 2003) of the space station demonstrate how Earth is not solely extended through infrastructure, but also through the inhabitations such infrastructure affords. Inhabitations of microgravity infrastructure begin to unmake habituated ways of being as they are understood on the grounds below. There is thus a need for a philosophy of gravity—that is, a thinking through the ontological impacts of differential gravities on collective forms of being and their constitutive effects on Earthly conditions.

CONCLUSION: TOWARDS COSMOPLANETARITY

The Earth as a complete and perfect *Blue Marble* reinforces the notion that hard geophysical boundaries exist between Earth and outer space—but no such borders exist. And yet, there are increasing calls to engineer a return to the *Blue Marble's* idealized homeostatic world, a unified system which was always a fantasy. This fantasy asserts that there is only one viable form of world, and mandates that ever-increasing technological mastery over a controllable Earth is possible. Artificial environments such as the ISS are hyperbolically narrated as emblematic of this mode of technological mastery, symbolizing command and control over an increasingly docile Earth. However, a cursory glance at some of the many forms of inhabitation enabled by space stations demonstrates how these technoscientific installations do not reveal or stabilize controllable conditions. Instead, such microgravity infrastructure catalyses new forms of alterity, different ways of being which unmoor habitualized conceptions of Earthlings and the planet, highlighting the myriad forms these different orders and scales of bodies can manifest. Bodies, then, are never given, but always in the process of becoming something else. Rather than being "lost," there is a sense in which Earth does not yet exist; rather than a discrete sphere, knowable and known, Earth is instead seeded with myriad other folded Earths. This is the process to which Cosmoplanetarity refers.

Sensitization to the techno-spatial practices of an extended and extending Earth thus offers crucial opportunities for destabilizing and reorganizing life as it is lived on the ground, as well as aloft. Learning how to inhabit a cyborgian creature-planet thus involves collaborating with the uncontrollable agencies and mutations of multispecies Earthlings. Rather than reinforcing the illusory ideals and fantasies of complete control over closed homeostatic systems, any new designed intervention into the Earth must be done with an awareness of the planet's multiscalar agencies. It must incorporate the creaturely, the unnameable, and the unpredictable into its calculations. In other words, interventions into the Earth must be done with an awareness of the planet itself as a species, as a creature. Rather than further entrenching knowns, then, terraforming should instead be understood as the catalyzation of further creature-ings. It is no longer useful to think in the dichotomized terms of Earth as part of outer space, or outer space as part of Earth. Instead, it is necessary to think of Earth as a creaturely mode which folds in new cosmic alterities as it unfolds outwards. The Earth is a cyborgian, cosmic, and creaturely continuum, within which the "out there" lies curled, like the final comma in a broken sentence,

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Dear Applicant,

Thank you for choosing to bury the sky as your fulfillment of the MEFESA (Mandatory Enrollment For Environmental Services Act), and congratulations on being selected for your first pick preference.

As part of the act established by the UN, you will fulfill your service with a three-year cycle in Sector 78 of the SSG (Siberian Sky Grounds), 160 km inland from the Chatanga Port.

Your proficiency in Mandarin was your determining skill, as the bordering Sector 79 of the SSG is administered by the People's Republic of Chinasia. Contact with your fellow Sky Watchers can be established ahead of time by registering at www.toburythesky.ru.

As you're well aware, the Sky Burying Stations capture excess CO^2 and sequester it in the Earth. The stations are mostly automated, and your main tasks will involve manual check-ups and maintenance in cases of malfunction. A familiarizing workshop of the minimal required handling of machinery will commence at the introduction day, two weeks from now.

Burying the sky is the most-chosen service of the MEFESA, mainly due to the appeal of its tranquil lifestyle. SSG is the most-chosen region for deployment, due to its state-of-the-art virtual connection and assistance.

But a Sky Watcher's historical importance should not be underestimated. In fact, we think a sense of pride is essential to motivate you through your service. Hence, we've included the original FAQ first published in 2020, prior to the creation of the MEFESA.

Today's noticeable deviations from the original plan set forth in 2020 point to the efficiency of the work of the last decades. Sky burying has been instrumental in recreating the viable planet we enjoy today—and, with your help, will continue to enjoy tomorrow.

MOTIVE: WHY THE SKY MUST BE DRAINED

All IPCC (Intergovernmental Panel on Climate Change) pathways that limit warming to 1.5 to 2 degrees imply that we must actively remove carbon dioxide from the atmosphere. You can think of our atmosphere as a filled-up bath tub. The tap can't be turned off, since we can't stop all emissions, so the overflowing tub needs to be drained as well. Removing CO^2 from the atmosphere is our draining, and IPCC estimates that we need to remove in the range of 100 to 1,000 Gigatons of CO^2 by 2100, a project that spans the course of a century.

This is meant to happen in conjunction with global emissions declining, starting this year, but based on current projections, this is unlikely to happen for the remainder of the 2020s. Thus, we have to aim for the higher end of capturing 1,000 Gt of CO^2. Afforestation and regenerative agriculture can capture carbon, too, and are sometimes referred to as passive Negative Emission Technologies. But on their own, they won't be enough. The full portfolio of passive Negative Emission Technologies could still only capture up to 500 Gigatons, and that's if we see some extreme changes to current deforestation and agricultural paradigms. (That's a big if.) Additionally, passive Negative Emission Technologies themselves are vulnerable to the effects of climate change. A bad season of wildfires can instantly release years of passively captured carbon as forests burn.

With the majority of CO^2 emissions coming from burned fossil fuels (83% in 2017), most of the excess carbon in the atmosphere was mechanically extracted from deep below the earth's surface. This begs the question: Can we use similar industrial techniques to return excess carbon to where it came from?

TECHNIQUES: WHAT CAPTURES THE AIR

Carbon Capture and Storage, or CCS, is the active Negative Emission Technology we need, but it comes with its own challenges. To start, where can the carbon be captured?

This can happen at point sources such as power plants and metal refineries. Adding CCS filtration to these processes is an essential step in the emission-reduction portfolio, but transporting captured carbon to a storage location generates new emissions along the way, and is expensive.

Direct Air Capture, or DAC, pulls in ambient air. CO^2 is evenly distributed throughout the planet's atmosphere, meaning that DAC units can be placed anywhere in proximity to a carbon-neutral power source and where the captured carbon can be stored.

There are two main DAC processes, and reductively, they can be described in similar terms. First, turbines pull in ambient air. The CO^2 from the air is adsorbed, and the adsorbents are heated to release the CO^2 as pure gas. Finally, the leftover adsorbents are treated to be reused in step 2. That's DAC in a nutshell.

Now, DAC requires land too. According to Climeworks, 1 Gt of CO_2 per year would require 62 square km in machines alone, or 8,600 football fields. The good news is that this can be non-arable land. Once the carbon is captured, it's a question of where it can be stored.

There are three main options:

- Depleted oil and gas reservoirs have an estimated global capacity of 675–900 Gt of CO_2. Unfortunately, they require all content to be extracted first.
- Suboceanic Saltwater Aquifers have an estimated global capacity 1,000 Gt of CO_2 or more, but the majority of them are located deep beneath the ocean floor and are challenging to access.
- Underground rock formations are yet to have a solid capacity estimate, but the Columbia River Basalt can store 100 Gt of CO_2, and there are other Basalt traps 10 to 30 times larger.

Capturing carbon is energy intensive, so which power source can keep this a negative emission? Bioenergy and waste heat both present challenges, but renewables are the main consideration. Hydro, solar, and wind each have their own specific land-use requirements and limitations. Hydro energy can currently support industrial operations, but is restricted to riverine areas, while the capture of 1 Gt of CO_2 would call for 2,000 square km when using solar panels.

That's why nuclear, despite its stigmas, is most promising for carbon capture and storage: it's carbon-neutral and small modular reactor technology, which is currently coming to market, could be easily deployed to carbon storage sites. And, unlike CO_2, nuclear waste is dense, opaque, and tangible, much easier to assign ownership over.

But before any of these steps can be taken, there's the question of financing.

Carbon can be sold to whoever can use it in a product like synthetic fuel, construction, even vodka. However, the transport and production requirements create not only greater costs, but also new emissions, often negating the point of drawdown.

So what viable options for capturing carbon exist within current economic paradigms?

Three options present themselves:

- Carbon taxes: when taxed emissions can be offset with carbon capture, even for a direct fee.
- Carbon credits: when cap and trade programs allow those who stay under emission limits to earn credits that they can sell to those who need to go over.
- Enhanced Oil Recovery, or EOR: A process that uses injected gas to increase oil recovery by 30 to 60 percent. Captured carbon can be used as well—and when it uses more CO_2 than the recovered oil will emit, it becomes a negative emission.

CO_2 -Enhanced Oil Recovery could be the financial bridge that carbon capture and storage technology needs, but actively monitoring injected CO_2 gas is essential to count the true negative emissions. And with the limited capacity of EOR, even with all oil and gas extracted, CO_2-Enhanced Oil Recovery alone remains insufficient.

This then brings us to the question of location.

LOCATION: WHERE THE SKY SHOULD GO

We need a carbon sink which is long-lasting, thermodynamically stable, environmentally benign, and big enough to hold at least 1,000 Gt. Geological formations are the only carbon sinks which satisfy these criteria. But carbon dioxide can't be injected into just any formation: the ideal formation would need to chemically convert CO_2 into a solid.

Luckily, this is exactly what happens in the pores of Basalt. When injected in a mix with water, CO_2 is converted to a mineral rock. Carbfix and Carbfix2, in partnership with Climeworks, represent the biggest practical application of this process. By the end of 2017, they successfully injected 23,200 metric tons of CO_2 into the basalt of Iceland, proving that 95% of injected CO_2 reacts within two years, and 60% within four months.

The more porous the basalt, the faster the conversion can take place.

Now, water requirements are significant. But with current technology, 1 gigaton of CO_2 injection would require less than 0.6% of the world's annual usage of fresh water.

Every continent has prominent flood basalt provinces, but each come with a unique set of challenges. Some are off-shore, located beneath densely populated areas, covered in jungle, or are beneath politically unstable territory. While each of the world's traps might eventually become part of the full carbon storage portfolio, the question is: which of the continental flood basalts is the largest and best suited?

Answer: The Siberian Traps of Russia.

The Siberian Traps are the largest continental flood basalt in the world, with an estimated storage capacity between 2,000 Gt and 2,720 Gt of CO_2 storage capacity, which is at least twice our goal. The main city of the basalt region is already a major infrastructural access point: Norilsk. Beyond Norilsk, Siberia counts as many as sixty cultural groups amongst its inhabitants, even though large state projects often fail to take their interests into account. But as DAC units are well-suited for non-arable land, and can be sparsely distributed, life could continue generally unobstructed.

Alternatively, it could offer new opportunities, whether in the form of jobs, or new commerce that extends along infrastructure corridors to areas that currently have limited access. Plans to extend the rail system are already underway, based on Russia's strategic plan for 2030. But new infrastructure isn't the only change coming to the region. Permafrost, a layer of perennially frozen land, is changing as the planet warms. It will certainly pose major challenges for any infrastructural endeavor.

It's clear that the challenges of Siberia are as large as its opportunities. But as Russia looks to develop its regional resources, the expertise is already focused on innovations for extreme conditions—a huge benefit for realizing Direct Air Capture on the Siberian Traps.

So what's the plan?

PLAN: HOW TO BURY THE SKY

The sky buriers would consist of four pieces of infrastructure: Thermosyphon Foundation Platforms, Direct Air Capture intake turbines, Small modular reactor facilities, and integrated direct injection wellheads. Similar to current state-of-the art DAC facilities, these stations would capture 1 Mt of CO^2 per year, and need 250 meters between each station to avoid recapturing recently decarbonized air.

They'd be powered by a new generation of nuclear energy that is already planned for remote Russian regions: Small Modular Reactors, or SMRs, can fit into shipping containers, and can be transported anywhere that a boat, truck, or train can travel.

Thermosyphon foundations are designed to support Arctic infrastructure. They actively circulate freezing liquid throughout the foundation's structure to keep the supportive permafrost frozen. They can support industrial facilities that weigh over a million tons.

Finally, injection wellheads heat the CO^2-and-water mixture to high temperatures before injecting into the basalt, both for the efficiency of the process and to avoid frozen pipes.

[redacted]

1,000 Gt of CO^2 by the end of the century means an average of 12.5 Gt per year, or 12,500 DAC stations. Of course, these can't be built overnight, and would be constructed in a series of phases—but then again, the effectiveness of the technology will inevitably improve, so fewer stations might eventually be required to achieve the same ends. Either way, a network of Direct Air Capture Stations would span hundreds, even thousands, of kilometers across the Siberian Traps or could later be distributed between several basalt regions of the world. How does a network like this expand across the Siberian Traps?

Today, one in three cities in Russia are monotowns, and while Norilsk is thriving, others are plagued by degradation of the urban environment, catastrophic ecological problems and low social mobility. But with DAC facilities needing labor, too, this would usher in a new form of temporary urbanism based on the shift method, with workers inhabiting cities based on production and maintenance cycles. Such systems already exist in offshore oil production; it's a proven model, with work on a rotational basis and minimum urban functions for towns which only exist for years, rather than decades or centuries.

[redacted]

ACTORS: WHO TAKES RESPONSIBILITY

By now, it should be self-evident that burying the sky requires a major paradigm shift.

Efforts around construction, labor, and resources would have to refocus on this new goal. But in order to avoid more than 2 degrees of warming, burying the sky is inevitable.

Who pays is a question of cost, and projecting the price of nascent technologies eighty years into the future is challenging. In a leading comparative analysis, Climeworks' price goal of $100 per ton of CO^2 is concluded to be in line with many of the other price projections for 2050—but to base Sky Burial on this figure would be to ignore specific costs and benefits of Siberia, of nuclear SMR technology, and cost fluctuations over the century. With that in mind, assuming the majority of our goal would be reached after 2050, this gives a ballpark cost of $100 trillion to bury 1,000 Gt of CO^2, or $1.25 trillion per year.

Trillions of dollars become less daunting when put in perspective: $142 trillion was the Global GDP of 2019 and $30-50 trillion is estimated to be spent in the next ten years on infrastructure alone. A single hurricane can cause $1 trillion worth of damage.

Still, the question remains: Who will pay? Three precedents show a path forward.

The growing global carbon market is valued at $214 billion USD, after charting a five-fold increase between 2017–2019. This market will reach $1 trillion within the coming decade.

As Russia has one of the lowest oil recovery rates, there's a big opportunity for CO^2-Enhanced Oil Recovery to become the country's catalyst for carbon capture. This growing carbon market could easily incentivize Russia to become the exclusive operator of a leading sequestration region.

Initial investments into the region may come from outside of Russia. In recent years, China has invested several billion dollars to develop agricultural projects between their key farming belts in Russia's Far East. South Korea's Lotte Corporation also grew its land rental holdings in the region to 150,000 hectares. This land-lease structure could easily apply to carbon capture infrastructure. Russia is positioned to create a land rental system that provides the basic infrastructure to operationalize the territory for Carbon Capture and Storage.

While these initial financial structures might catalyze the development, the total goal would imply the major powers of the world collaborating on a multinational research and development endeavor. The prospect of future damages due to climate change looms large, yet the costs of solving them are too high for any single country to be successful on its own.

[redacted]

The International Space Station, the ITER Fusion Project, and the Thirty Meter Telescope are planetary-scale precedent projects, each made possible only through international coordination. Multiple countries contribute proportionate value and expertise to the project, and every nation collectively benefits.

When each nation can prove that its economic contribution to the Carbon Drawdown project is less than the net cost of climate change to its domestic economy, then contribution is not just merited, but should be outright demanded.

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