CSTD

BACKGROUND GUIDE

NHSMUN
National High School Model United Nations

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Dear delegates,

My name is Julia Stephen, and I am excited to be your director of CSTD for Session I. My NHSMUN journey started where you are right now. I started as a delegate at UNICEF back in 2021, the year that the conference had to be held virtually. While I loved the opportunity to debate with people worldwide, I still wanted to experience the in-person conference. Hence, I came back and debated at UNESCO in 2023, my last conference as a delegate. I instantly fell in love with the focus on education that the conference had. Even as an experienced delegate, I could learn a lot from every interaction. This fascinating experience drove me to apply to the staff for the next conference. I served as an Assistant Director for Legal, where I had the opportunity to chair one of the largest committees at NHSMUN in 2024. Now, I'm returning as the Director of CSTD alongside Lauren Sheward, who will be directing the committee in Session II.

To tell you a bit about me, I am originally from Lima, Peru, I am now a first-year student at the University of Glasgow in Scotland, where I study Molecular and Cellular Biology. I hope to one day get a PhD and carry out research in my field. Besides MUN, I do a lot of volunteering, especially in sharing awareness about important issues. I am part of Medi, a Peruvian NGO that focuses on providing menstrual health education and supplies to school-aged girls in low-income areas. Outside of academics, I love performing arts. I have trained as a stage and screen actor and even had the chance to produce my play before moving abroad. I consider myself very crafty, so you'll always find me making thread and bead bracelets, crocheting mini plushies, or doodling in a notebook in my free time. I am also a huge bookworm, and I love the Shadow and Bone and Six of Crows series by Leigh Bardugo.

Writing this background guide alongside Lauren has been a very enriching process. Both topics are very relevant to the current global reality. When discussing agricultural biotechnology, space technology, or any topic related to technology and its applications, sustainability, and ethical responsibility must be considered as central elements to any proposal. Throughout the debate, Lauren and I expect diplomatic and researched discussions about the topics. We encourage a style of leadership that uplifts others and ensures all the voices in the committee are heard. We look forward to seeing each one of you be able to step out of your comfort zones and grow to become better negotiators, public speakers, leaders, and world-changers. Do not hesitate to contact Lauren and me if you have any questions. We will be more than happy to answer them. See you in March!

Yours in diplomacy,

Julia Stephen
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Dear Delegates,

I welcome you to the Commission on Science and Technology for Development for NHSMUN 2025! My name is Lauren Sheward, and I will serve as the Director for Session II alongside Julia Stephen for Session I. Previously, I was the Assistant Director of the Convention on Migratory Species for NHSMUN 2024, so this is my second year on NHSMUN staff and my fourth year attending the conference overall. I am thrilled to be back and watch you flourish at this conference. Learning about today's critical and sensitive issues is important for everyone, and there are few better places to gain knowledge, debate, and form educated opinions on these issues than NHSMUN.Before college, my Model UN journey started at Kennett High School in Kennett Square, Pennsylvania. I joined as a freshman and enjoyed two years of leading the Kennett Model UN team as Secretary-General. I quickly developed a love of research, debate, and connecting with others about what we are all passionate about. Model UN can help you become a better researcher, writer, communicator, and public speaker. Therefore, my enthusiasm for Model UN has followed me into college and is shaping my future.

I am a second-year student at the University of Maryland, College Park, studying environmental science and technology. I hope to eventually go into environmental consultancy to reduce the impacts that industrial and technological companies have on the planet, so the topics of this committee are very close to my heart. I love getting involved with ecological restoration and discovering how much impact our local communities can make on a grand scale. I highly encourage reaching out to your community to see what environmental preservation efforts everyone makes, like food co-ops, trash cleanups, habitat restorations, and maybe more! Outside of school, I enjoy hiking, gardening, photography, listening to music, and drinking incredible amounts of coffee. My favorite places are museums and aquariums, and if I could live inside the Smithsonian Natural History Museum, I would in a heartbeat.

This year's topics are "Biotechnology for Disease and Pest Control" and "Space Technology for Sustainable Development." Each topic is vastly important in the mission to achieve the 2030 Agenda for Sustainable Development. More importantly, these topics are very interesting, and we cannot wait to see the complex discussions you have and the innovative solutions you create. NHSMUN is an amazing opportunity for you to use resources like the background guide, engage with perspectives from all around the world, and meet all sorts of cool people. Please use this opportunity to the fullest, and do not hesitate to reach out to us with any questions, concerns, or greetings!

Cheers,

Lauren Sheward
Director of CSTD
Session II
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A Note on the NHSMUN Difference

Esteemed Faculty and Delegates,

Welcome to NHSMUN 2025! We are Terry Wang and Jordan Baker, and we are this year's Secretary-General and Director-General. Thank you for choosing to attend NHSMUN, the world's largest and most diverse Model United Nations conference for secondary school students. We are thrilled to welcome you to New York City in March.

As a space for collaboration, consensus, and compromise, NHSMUN strives to transform today's brightest thinkers, speakers, and collaborators into tomorrow's leaders. Our organization provides a uniquely tailored experience for all through innovative and accessible programming. We believe that an emphasis on education through simulation is paramount to the Model UN experience, and this idea permeates throughout numerous aspects of the conference:

Realism and accuracy: Although a perfect simulation of the UN is never possible, we believe that one of the core educational responsibilities of MUN conferences is to educate students about how the UN System works. Each NHSMUN committee is a simulation of a real deliberative body so that delegates can research what their country has said in the committee. Our topics are chosen from the issues currently on the agenda of that committee (except historical committees, which take topics from the appropriate time period). We also strive to invite real UN, NGO, and field experts into each committee through our committee speakers program. Moreover, we arrange meetings between students and the actual UN Permanent Mission of the country they are representing. Our delegates have the incredible opportunity to conduct first-hand research, asking thought-provoking questions to current UN representatives and experts in their respective fields of study. These exclusive resources are only available due to IMUNA's formal association with the United Nations Department of Global Communications and consultative status with the Economic and Social Council. No other conference goes so far to deeply immerse students into the UN System.

Educational emphasis, even for awards: At the heart of NHSMUN lies education and compromise. Part of what makes NHSMUN so special is its diverse delegate base. As such, when NHSMUN distributes awards, we strongly de-emphasize their importance in comparison to the educational value of Model UN as an activity. NHSMUN seeks to reward students who excel in the arts of compromise and diplomacy. More importantly, we seek to develop an environment in which delegates can employ their critical thought processes and share ideas with their counterparts from around the world. Given our delegates' plurality of perspectives and experiences, we center our programming around the values of diplomacy and teamwork. In particular, our daises look for and promote constructive leadership that strives towards consensus, as real ambassadors do in the United Nations.

Debate founded on strong knowledge and accessibility: With knowledgeable staff members and delegates from over 70 countries, NHSMUN can facilitate an enriching experience reliant on substantively rigorous debate. To ensure this high quality of debate, our staff members produce detailed, accessible, and comprehensive topic guides (like the one below) to prepare delegates for the nuances inherent in each global issue. This process takes over six months, during which the Directors who lead our committees develop their topics with the valuable input of expert contributors. Because these topics are always changing and evolving, NHSMUN also produces update papers intended to bridge the gap of time between when the background guides are published and when committee starts in March. As such, this guide is designed to be a launching point from which delegates should delve further into their topics. The detailed knowledge that our Directors provide in this background guide through diligent research aims to increase critical thinking within delegates at NHSMUN.

Extremely engaged staff: At NHSMUN, our staffers care deeply about delegates' experiences and what they take away from their time at NHSMUN. Before the conference, our Directors and Assistant Directors are trained rigorously through hours of workshops and exercises both virtual and in-person to provide the best conference experience possible. At the conference, delegates will have the opportunity to meet their dais members prior to the first committee session, where they may engage one-on-one to discuss their committees and topics. Our Directors and Assistant Directors are trained and empowered to be experts on their topics and they are always available to rapidly answer any questions delegates may have prior to the conference. Our Directors and Assistant Directors read every position paper submitted to NHSMUN and provide thoughtful comments on those submitted by the feedback deadline. Our staff aims not only to tailor the committee experience to delegates' reflections and research but also to facilitate an environment where all delegates' thoughts can be heard.

Empowering participation: The UN relies on the voices of all of its member states to create resolutions most likely to make a meaningful impact on the world. That is our philosophy at NHSMUN too. We believe that to properly delve into an issue and produce fruitful debate, it is crucial to focus the entire energy and attention of the room on the topic at hand. Our Rules of Procedure and our staff focus on making every voice in the committee heard, regardless of each delegate's country assignment or skill level. Additionally, unlike many other conferences, we also emphasize delegate participation after the conference. MUN delegates are well researched and aware of the UN's priorities, and they can serve as the vanguard for action on the Sustainable Development Goals (SDGs). Therefore, we are proud to connect students with other action-oriented organizations to encourage further work on the topics.

Focused committee time: We feel strongly that face-to-face interpersonal connections during debate are critical to producing superior committee experiences and allow for the free flow of ideas. Ensuring policies based on equality and inclusion is one way in which NHSMUN guarantees that every delegate has an equal opportunity to succeed in committee. In order to allow communication and collaboration to be maximized during committee, we have a very dedicated administrative team who work throughout the conference to type up, format, and print draft resolutions and working papers.

As always, we welcome any questions or concerns about the substantive program at NHSMUN 2025 and would be happy to discuss NHSMUN pedagogy with faculty or delegates.

Delegates, it is our sincerest hope that your time at NHSMUN will be thought-provoking and stimulating. NHSMUN is an incredible time to learn, grow, and embrace new opportunities. We look forward to seeing you work both as students and global citizens at the conference.

Best,

Terry Wang	Jordan Baker
Secretary-General	Director-General

A Note on Research and Preparation

Delegate research and preparation is a critical element of attending NHSMUN and enjoying the debate experience. We have provided this Background Guide to introduce the topics that will be discussed in your committee. We encourage and expect each of you to critically explore the selected topics and be able to identify and analyze their intricacies upon arrival to NHSMUN in March.

The task of preparing for the conference can be challenging, but to assist delegates, we have updated our **Beginner Delegate Guide** and **Advanced Delegate Guide**. In particular, these guides contain more detailed instructions on how to prepare a position paper and excellent sources that delegates can use for research. Use these resources to your advantage. They can help transform a sometimes overwhelming task into what it should be: an engaging, interesting, and rewarding experience.

To accurately represent a country, delegates must be able to articulate its policies. Accordingly, NHSMUN requires each delegation (the one or two delegates representing a country in a committee) to write a position paper for each topic on the committee's agenda. In delegations with two students, we strongly encourage each student to research each topic to ensure that they are prepared to debate no matter which topic is selected first. More information about how to write and format position papers can be found in the NHSMUN Research Guide. To summarize, position papers should be structured into three sections:

I: Topic Background – This section should describe the history of the topic as it would be described by the delegate's country. Delegates do not need to give an exhaustive account of the topic, but rather focus on the details that are most important to the delegation's policy and proposed solutions.

II: Country Policy – This section should discuss the delegation's policy regarding the topic. Each paper should state the policy in plain terms and include the relevant statements, statistics, and research that support the effectiveness of the policy. Comparisons with other global issues are also appropriate here.

III. Proposed Solutions – This section should detail the delegation's proposed solutions to address the topic. Descriptions of each solution should be thorough. Each idea should clearly connect to the specific problem it aims to solve and identify potential obstacles to implementation and how they can be avoided. The solution should be a natural extension of the country's policy.

Each topic's position paper should be **no more than 10 pages** long double-spaced with standard margins and font size. **We recommend 3–5 pages per topic as a suitable length**. The paper must be written from the perspective of your assigned country and should articulate the policies you will espouse at the conference.

Each delegation is responsible for sending a copy of its papers to their committee Directors via myDais on or before **February 21, 2025**. If a delegate wishes to receive detailed feedback from the committee's dais, a position must be submitted on or before **January 31, 2025**. The papers received by this earlier deadline will be reviewed by the dais of each committee and returned prior to your arrival at the conference.

Complete instructions for how to submit position papers will be sent to faculty advisers via email. If delegations are unable to submit their position papers on time, please contact us at info@imuna.org.

Delegations that do not submit position papers will be ineligible for awards.

Committee History

The United Nations Commission on Science and Technology for Development (CSTD) was created in 1979 at the UN Conference on Science and Technology for Development in Vienna, Austria.[1] In 1992, the General Assembly (GA) transformed it into a commission that aims to foster an understanding of science and technology policies, specifically in developing countries, and formulate recommendations and guidelines on these matters.[2] CSTD works as a subsidiary body of the Economic and Social Council (ECOSOC) and is hosted annually in Geneva, Switzerland, by the United Nations Conference on Trade and Development. The committee has 43 member states, elected by the Economic and Social Council for four years.[3] This committee's purpose is to provide a seminar where countries can discuss challenges created by the growth of technological developments.[4] The commission advises any willing UN member to ensure they are not left behind. Also, it aims to create a safe environment where the appropriate decisions and advice relating to this topic can be made. The CSTD focuses on broad issues, including biotechnology, nanotechnology, energy, space, environmental, and health technologies. The mandate or mission has evolved over the years to reflect the changes in the global landscape and the increasing importance of science and technology for development. Currently, the mandate focuses on sustainable development, unequal access to digital technology and the internet among different groups of people, emerging technologies, and innovation ecosystems.[5]

Moreover, this committee is consultative, providing advice and recommendations to ECOSOC and the GA. Its rules of procedure allow for flexibility in addressing emerging issues and adapting to changing circumstances. This committee is different from other commissions primarily due to its specific focus on science and technology issues in the context of development. This unique mandate sets it apart from committees that may focus more broadly on economic, social, or environmental matters. The CSTD gathers experts in various science and technology fields to create informed suggestions to both ECOSOC and the GA, which is the primary form of action it can take.[6] It also strives for balanced representation to ensure that diverse perspectives are considered. The committee has 43 member states, elected by the Economic and Social Council for four years.[7] Some significant contributions have been promoting science and technology for development in a global context, developing numerous policy recommendations on a wide range of issues, fostering international cooperation, and supporting capacity-building efforts in developing countries to enhance their ability to benefit from science and technology. Sadly, the CSTD faces several challenges, such as limited resources, lack of enforcement powers, changing landscape, and political challenges. However, it delivers crucial information to the UN on inequities in the world, such as access to clean water, from the perspective of sustainable technology.[8]

Nowadays, technology has proven to be everywhere, therefore, the actions we take regarding this will have acute and enduring consequences for society's future. Furthermore, actions like this can use technology to complete goals, such as the Sustainable Development Goals, which are crucial to the CSTD's mission and are always in mind when discussing topics and policies. CSTD cooperates with experts, businesses, civil society, other branches of the UN, and other international organizations, to make decisions. These decisions can be vital in creating a more equitable and prosperous world.

1 "About the CSTD," UN Trade and Development, accessed September 20, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development/about.
2 UN Trade and Development, "About the CSTD."
3 "Commission on Science and Technology for Development" UN Trade & Development, accessed September 21, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development
4 Lynch, Cecelia, Fomerand Jacques, Levy, Michael. "Economic and Social Council" accessed September 22, 2024, https://www.britannica.com/topic/Economic-and-Social-Council
5 UN Economic and Social Council, "MANDATE," Accessed September 22, 2024, https://www.un.org/en/ecosoc/newfunct/amrmandate.shtml.
6 "Mandate and Institutional Background" UN Trade & Development, accessed September 23, 2024,https://unctad.org/topic/commission-on-science-and-technology-for-development/mandate
7 "Membership of the CSTD" UN Trade & Development, accessed September 24, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development/membership
8 "UN Commission on Science & Technology for Development (CSTD) - Global Cities Hub." 2022. Global Cities Hub. May 2, 2022. https://globalcitieshub.org/en/un-commission-on-science-technology-for-development-cstd/.

CSTD

NHSMUN 2025

TOPIC A: IMPLEMENTING BIOTECHNOLOGY FOR DISEASE AND PEST CONTROL

Photo Credit: Ibrahim Khairov

Introduction

Around 40 percent of the world's agricultural production is lost yearly due to pests and diseases.[1] The growing population requires increasing amounts of food. Yet, climate change threatens the conditions of arable land, and conventional plant breeding practices cannot sustain the current global demand.[2] Further, current methods that we have to control pests and protect plants from disease are highly toxic for human and animal health and the environment.[3] There are 25 million yearly cases of severe intoxication in farmers due to pesticide use.[4] Practices such as using chemical pesticides and tilling also actively harm the environment. Plants rely on various beneficial animals to survive, which are also negatively affected by toxic pesticides.[5] Some of these pesticides can persist in the environment, causing the death of aquatic life and rising pollution levels.[6] Biotechnology can help in this situation. It refers to applying engineering and science principles to create products of biological origin. In other words, it is the use of biological resources, such as living organisms and the substances they produce, to make tasks easier.[7] Modern biotechnology offers a wide range of tools that can help advance plant protection, increase crop yields, and counter the effects of climate change worldwide.

With biotechnology, scientists can create genetically modified organisms (GMOs) by inserting specific genes into an organism's DNA. These GMOs can resist pests, herbicides, and environmental stress due to climate change. Furthermore, specific biopesticides can be designed to target a very narrow range of pests, thus protecting the beneficial insects and the farmers that use them.[8] These biopesticides often degrade with ease under sunlight or heat, which makes their impact less harsh on the environment.[9] Some of these biopesticides can be combined with genetic editing technology to design crops that make their biological pesticides. Like most advanced technologies, biotechnology in agriculture is highly regulated. This is because altering crops and their genetics can have serious environmental consequences if not controlled. Additionally, many people have moral or religious concerns about these technologies. This has led to laws restricting the use of biotechnological products worldwide.

The Commission on Science and Technology for Development (CSTD) will explore key agricultural biotechnologies and their use in disease and pest control. While these technologies offer great potential, they are not meant to replace traditional farming practices. Frameworks like Integrated Pest Management (IPM), supported by organizations like the Food and Agricultural Organization (FAO) and the European Union, help guide the use of these technologies. IPM is a holistic approach that combines biological, cultural, and chemical methods to manage pests while minimizing risks to health, the environment, and the economy. New technologies should be integrated with existing sustainable farming practices. Arable farming and crop protection have been daily tasks for centuries.[10] As agriculture becomes more complex, modern challenges require new technologies. Since farming affects both nature and the economy, it's important to use solutions that are good for the environment, ethical, and cost-

1 Silvana Vero et al.,"Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control," *Diversity* 15, no. 3 (March 2023): 457, https://doi.org/10.3390/d15030457.
2 ISAAA, *Agricultural Biotechnology (A Lot More than Just GM Crops),* (Los Baños: International Service for the Acquisition of Agri-biotech Applications, May 2014). https://www.isaaa.org/resources/publications/agricultural_biotechnology/download/agricultural_biotechnology.pdf.
3 Gabriel Daraban, Raluca-Maria Hlihor, and Daniela Suteu,"Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," *Toxics* 11, no. 12 (December 2023): 983, https://doi.org/10.3390/toxics11120983.
4 Laurent Gaberell and Géraldine Viret, "The pesticides that poison farmers," *Public Eye*, February 20, 2020, https://www.publiceye.ch/en/topics/pesticides/pesticide-giants-make-billions-from-bee-harming-and-carcinogenic-chemicals/the-pesticides-that-poison-farmers.
5 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
6 Modupe Ayilara et al., "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides," *Frontiers in Microbiology* 14 (2023), https://doi.org/10.3389/fmicb.2023.1040901.
7 Ashish Swarup Verma et al., "Biotechnology in the Realm of History," *Journal of Pharmacy and BioAllied Sciences* 3, no. 3 (September, 2011): 321-323, https://doi.org/10.4103/0975-7406.84430.
8 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
9 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
10 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.

effective.[11] Biotechnology offers benefits in all these areas. It reduces the need for chemical pesticides and increases crop yields. This makes agriculture more sustainable and profitable.

History and Description of the Issue

Genetic Engineering and GMOs

Even though the concept of biotechnology is relatively new, humanity has used it since ancient times.[12] The idea of biotechnology comes from two core concepts: biology and technology. Biotechnology is a field that focuses on the use of biological materials to create new products that have beneficial uses for humans and the wider world.[13] It can also be understood as any technique that uses living things or substances they produce for a practical purpose.[14] The use of mold to make penicillin, the production of lactose-free milk, and rapid COVID-19 tests are just a few examples. Mutation is the naturally occurring phenomenon that made all of this possible. Mutations are small random changes in an organism's DNA. These change the traits that the organism shows. In some cases, these mutations cause a beneficial change in the organism, which they can pass on to the next generation. Traditionally, farmers selectively bred their crops based on their measurable traits, called the phenotype.[15] This process was prolonged because traits take many generations to stabilize a population.[16] Moreover, farmers had no clear understanding of the genetics behind selective breeding.

In the 1970s, scientists learned how to isolate genes and copy them into other species.[17] These genes create genetically modified organisms (GMOs). This speeds up the development of crops and cattle with desired traits. The first GMO crop was introduced in the U.S. in 1994.[18] Since then, GMO use has grown rapidly worldwide. Today, biotechnology focuses mainly on genetic engineering. This involves directly transferring genes between unrelated organisms and altering

11 Lucía Argüelles and Hug March, "Weeds in action: Vegetal political ecology of unwanted plants," *Progress in Human Geography* 46, no. 1 (2022): 44-66, https://doi.org/10.1177/03091325211054966.
12 Saurabh Bhatia, *Introduction to pharmaceutical biotechnology,* vol. 1, (Bristol: IOP Publishing, 2018), chap. 1.
13 Verma, "Biotechnology in the Realm of History," 321-323.
14 T*he State of Food and Agriculture 2003-2004: Agricultural Biotechnology: Meeting the needs of the poor?* (Rome: FAO, 2004), https://openknowledge.fao.org/server/api/core/bitstreams/8224faa7-a8fe-432d-ba54-937ff383d3d5/content.
15 ISAAA, *Agricultural Biotechnology (A Lot More than Just GM Crops),* 12.
16 ISAAA, *Agricultural Biotechnology (A Lot More than Just GM Crops)*, 4.
17 Bhatia, *Introduction to pharmaceutical biotechnology,* chap. 1.
18 Fatemeh Taheri, Hossein Azadi, and Marijke D'Haese, "A World without Hunger: Organic or GM Crops?" *Sustainability* 9, no. 4 (April 2017), https://doi.org/10.3390/su9040580.

Alexander Fleming in 1943 carrying out early investigations on the effects of penicillin on bacteria

Credit: Ministry of Information Photo Division Photographer their genetic material.[19] Genetic engineers use this technology to give organisms new traits, creating important new varieties of plants and animals.[20] Genetically modified organisms (GMOs) are essential in pest and weed control. Although crops can and have been modified to show a wide range of beneficial traits, the two most popular are insect and herbicide resistance.[21] These modifications primarily benefit farmers, making managing their fields easier and protecting their yield. These crops can produce more food using fewer chemical pesticides and heavy field labor. Around the world, adopting genetically modified crops such as soybeans, cotton, and corn has generally had favorable economic effects on producers.[22]

Additionally, their consumers digest these crops as quickly as organically developed crops. Hence, genetically modified food is considered just as efficient feed for livestock as organic food.[23] GMOs have also shown immense promise for human consumption. Genetically modified rice is an excellent example. A group of scientists in Japan crossbred two rice varieties and discovered a gene that controls the size of rice. They could isolate that gene and engineer rice to produce more prominent grain and yield more.[24] Moreover, in the 1990s, a transgenic variety of rice was developed to include Vitamin A, which is essential for health. These rice varieties can fight Vitamin A deficiency and anemia, which persist in areas without access to these nutrients.[25] Moreover, rice has also been modified to resist herbicides and produce pesticides, as will be further discussed.[26] Hence, GMOs can have both nutritional advantages for the consumer and practical advantages for the producer.

There are two main types of insects: pest insects and beneficial insects. Pest insects are undesirable insects. These insects can eat the leaves of crops, eat the produce, or otherwise interfere with the growth and harvesting of crops. Beneficial bugs keep the crops healthy and contribute to a healthy ecosystem for the crops to grow. These include pollinators and earthworms.[27] The main challenge for farmers is to get rid of pests without disrupting beneficial insects. Scientists have designed plants resistant to the specific insects that eat them. These plants can resist pests because they are engineered to produce insecticides that target a very narrow range of insects. In this way, they can kill off pests while retaining the presence of beneficial insects.[28] This is possible because very specific molecules, such as proteins made in plant cells, read the transgenes' instructions. They bind to specific structures in certain organisms and are only active at specific temperatures and pH levels. Thus, the insecticides in these crops have no effect on humans, livestock, or consumers that are not the target species since the temperature, pH, and structures of our digestive systems differ from those of pests.[29]

This method is not only faster but also economically efficient than other pesticides. Plants do not need to be constantly sprayed with insecticides because they produce their own.[30] Additionally, these crops reduce the use of chemical pesticides, as well as carbon emissions from practices such as tilling.[31] Tilling turns the soil to aerate it and rid it of weeds and insects. However, this also disturbs beneficial insects and liberates carbon trapped in the soil. This contaminates the environment and worsens soil conditions in the long run.[32] The use of GMO crops that produce their pesticides has been helpful for farmers, not only because of the reduction in production costs and labor but also because of health benefits.

19 ISAAA, *Agricultural Biotechnology (A Lot More than Just GM Crops)*.
20 Bhatia, *Introduction to pharmaceutical biotechnology,* chap. 1.
21 Taheri, "A World without Hunger: Organic or GM Crops?"
22 Taheri, "A World without Hunger: Organic or GM Crops?"
23 De Santis et al., "Case studies on genetically modified organisms (GMOs): Potential risk scenarios and associated health indicators," 36-65.
24 Kaori Kobayashi, Xiaohui Wang, and Weiqun Wang, "Genetically modified rice is associated with hunger, health, and climate resilience," *Foods* 12, no. 14 (July 2023), https://doi.org/10.3390/foods12142776.
25 Kobayashi, "Genetically modified rice is associated with hunger, health, and climate resilience."
26 Kobayashi, "Genetically modified rice is associated with hunger, health, and climate resilience."
27 "How do GMOs Affect Insects?" Purdue University College of Agriculture, accessed July 4, 2024, https://ag.purdue.edu/gmos/gmos-insects.html.
28 Purdue University College of Agriculture, "How do GMOs Affect Insects."
29 Purdue University College of Agriculture, "How do GMOs Affect Insects."
30 Purdue University College of Agriculture, "How do GMOs Affect Insects."
31 Taheri, "A World without Hunger: Organic or GM Crops?"
32 John Baker et al., "Tillage and soil carbon sequestration—What do we really know?" *Agriculture, Ecosystems & Environment* 188, no. 1 (January 2007): 1-5, https://doi.org/10.1016/j.agee.2006.05.014.

Studies show that adopting these crops dramatically reduces pesticide poisoning from farm workers in China and India.[33]

Nevertheless, the use of these GMOs has its drawbacks. For instance, if these insecticides do not entirely kill the pests, they can develop resistance. Resistance is a trait that appears in an organism due to a mutation and spreads to a population due to selective pressure; hence, it is an evolutionary phenomenon.[34] Selective pressure is created when the environment only allows individuals with specific characteristics to survive. Thus, individuals without that trait cannot pass on their genes to the next generation, and the genes of the surviving organisms spread across the population. This process takes many generations, and since pests have a short life cycle and reproduce reasonably quickly, populations can become resistant in a matter of years. The insecticides in GMO crops are not highly toxic by nature, so all the pests don't die, and some resistance is continuously developed. There are even some places where the genetically modified crops that used to be able to control insects are already ineffective.[35]

Although crops that produce their pesticides have reduced the use of toxic insecticides, a different kind of GMO has led to an increase in herbicide use: herbicide-resistant GMOs.[36] Aside from pests, farmers must protect their crops from weeds. Weeds are an undesirable plant for farmers and reproduce very fast. They take up essential nutrients from the soil and disrupt the growth of crops, ultimately reducing yield. Removing weeds manually is very tedious and time-consuming for farmers. Hence, herbicide-resistant weeds are prevalent. They allow farmers to spray their crops with substances that kill all plants but their crops, which saves them time and effort. This is because a single herbicide application is much faster than two passes of tillage equipment.[37] Over the years, however, this practice has caused many weeds to develop resistance.

An excellent example of this is the development of resistance to glyphosate. Glyphosate is the most used herbicide in the world.[38] It is a chemical absorbed by leaves that stops plants from producing the proteins they need to grow. It was invented and patented in 1974, but its use skyrocketed after 2000 when the patent expired, and its price lowered.[39] With the rise of GMO technology, the farming industry quickly developed plants resistant to this chemical's effects. They could now spray their fields with glyphosate to kill the weeds with the certainty that their crops would not be affected. However, weeds were quick to develop resistance. Only four years after these GMOs entered the market, glyphosate-resistant weeds were found in Australia in 1996. As of 2022, 40 of these "superweeds" existed in 37 countries.[40] Since one of the main characteristics of weeds is their fast reproduction, the mutation for resistance was quick to spread across populations.

In response, farmers are increasing their use of more toxic herbicides and harmful practices, such as increased tilling. This is worse for consumers, as they ingest the toxins, for farmers, since they are exposed to toxic substances, and for the environment, as they harm the ecosystem.[41] In the United States, for instance, infestations of glyphosate-resistant weeds have more than doubled between 2009–2014, and some 70 million acres of farmland are now affected. In 2014, these "superweeds" cost farmers in the United States around one billion US dollars in lost crops.[42] The rise of superweeds is a new and critical front in sustainability, GMOs, and crop protection.

Overall, since 1996, adopting insect—and herbicide-resistant crop technology has reduced pesticide spraying by 581.4 million kg, which accounts for an 8.2 percent reduction.[43]

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33 Taheri, "A World without Hunger: Organic or GM Crops?"
34 Bruce Tabashnik,. "Evolution of Resistance to Bacillus Thuringiensis," *Annual Review of Entomology* 39, no. 1, (November 2003): 47-79, https://doi.org/10.1146/annurev.en.39.010194.000403
35 Purdue University College of Agriculture, "How do GMOs Affect Insects."
36 Taheri, "A World without Hunger: Organic or GM Crops?"
37 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
38 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
39 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
40 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
41 Carmen Bain et al., "'Superweeds' or 'survivors'? Framing the problem of glyphosate resistant weeds and genetically engineered crops," *Journal of rural studies* 51 (April 2017): 211-221, https://doi.org/10.1016/j.jrurstud.2017.03.003.
42 Bain, "'Superweeds' or 'survivors'? Framing the problem of glyphosate resistant weeds and genetically engineered crops," 211-221.
43 Taheri, "A World without Hunger: Organic or GM Crops?"

Additionally, the environmental impact of herbicide and insecticide use on these crops fell by 18.5 percent, as indicated by the Environmental Impact Quotient Indicator. GMOs are an essential and helpful tool for the global farming industry.[44] However, recommendations must be made for using these technologies with a deep responsibility for the environment.

Biological Control Agents and Biopesticides

Pesticides are substances or chemicals that prevent, destroy, or control any pest. These pests may be insects, rodents, fungi, bacteria, or weeds.[45] These substances may take different names depending on their intended use in agriculture. For instance, insecticides target insects, herbicides target weeds, and nematicides target nematodes—a type of worm.[46] Most commonly, pesticides are toxic artificial chemicals that take a very long time to degrade in the environment.[47] They are made from inorganic or synthetic salts, such as sulfur, copper sulfate, lime, and ferrous sulfate.[48] This chemical composition allows toxins to persist in the environment, as life forms cannot digest and break down those inorganic compounds.[49] This is an issue because millions of metric tons of pesticides are pumped into ecosystems worldwide as the agricultural industry grows to support a growing population. Between 1990 and 2010, there was an increase of over 50 percent in the global consumption of pesticides used in farming practices. Since then, the levels have remained relatively stable, reaching 2.66 million metric tons in 2020.[50]

Throughout history, chemical pesticides have gained popularity for being practical and fast in controlling unwanted pests.[51] However, most of them are non-specific. This means that they can intoxicate many life forms. This is concerning because beneficial insects and animals can also be harmed. For instance, chemical pesticides hurt butterfly and bumblebee populations, leading to potential yield reductions due to a decline in pollination.[52] Additionally, man-made pesticides damage the soil on which crops are grown. These chemicals make the soil brittle, prevent soil respiration, and reduce the activities of essential organisms that live in it, such as earthworms and other beneficial insects. Out of the total amount of pesticides applied on the soil, around 98 percent affect non-target organisms. Studies in Europe show that pesticide use reduced soil respiration by 35 percent, reduced the amount of insects by 70 percent, and cut the number of farm birds in half. Both in the American and European continents, honeybee populations dropped by 30 percent.[53]

Further, it is not only plants and animals that suffer from applying chemical pesticides. Humans can become intoxicated in a lot of ways. Inhaling, touching, ingesting, or being exposed to these substances can lead to severe acute and chronic health conditions. Farmers working with chemical pesticides often experience respiratory symptoms of these conditions.[54] Less than one percent of the pesticides applied to crops reach the organisms they are intended for. Most of these chemicals are lost in spraying, deposition on non-target organisms, or degradation in the sun. Out of this percentage of lost pesticide, around 80 percent enters external ecosystems.[55] Sometimes, the effects are invisible in the short term. However, they can cause congenital disabilities, genetic disorders, and other conditions in the area's populations of plants, animals, and fungi.[56] Two of the biggest concerns arising from the amount of toxins in the environment due to pesticides are bioaccumulation and biomagnification.

44 Taheri, "A World without Hunger: Organic or GM Crops?"
45 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
46 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
47 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
48 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
49 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983."
50 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
51 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
52 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
53 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
54 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
55 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
56 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.

Small dehydrated avocado plant next to a large green weed.
Credit: Juliale8

Bioaccumulation occurs when an organism's toxins increase because it keeps consuming it and can not break it down. Biomagnification happens when this phenomenon is taken to the food chain. Since organisms can not break down the toxins in pesticides, when they are eaten, the consumer ingests those toxins, too. Predators often eat multiple organisms to stay alive; they accumulate all the toxins of all the organisms they consume, leading to the harmful chemicals being magnified in them. When these chemicals are used and over-applied, the excess often ends in water bodies and causes the death of fish and other aquatic life.[57] Currently, scientists are working on tracking the effects of pesticide accumulation and magnification in humans by investigating changes in the microorganisms that live inside us and evaluating IQ.[58]

Nevertheless, pesticides play a vital role in agriculture. They help protect the yield of crops. With them, there is more production of fruits and vegetables.[59] Hence, using an alternative to chemical pesticides that protects crops and the environment is essential for sustainable agriculture. The idea to control pests with other biological agents was initially given in 1882. However, it was in the 1940s that the research on using microorganisms to control insect pests began to advance. During the 1950s, mass production of microbial insecticides entered the market, changing the pesticide panorama.[60] Biopesticides are a tentative alternative to the most pollution-created and carcinogenic chemical pesticides currently used.[61] The definition of the term "biopesticide" varies widely across the globe. The UN defines biopesticides as an overarching concept that includes products derived from nature—including plants, microorganisms, animals, or their secretions— that are designed and applied similarly to conventional chemical pesticides.[62] Some organizations prefer the term "biocontrol agents," which also includes using natural enemies of pests to control pests.[63] It is important to note that even though biopesticides are derived from botanical, animal, and mineral sources, they are not

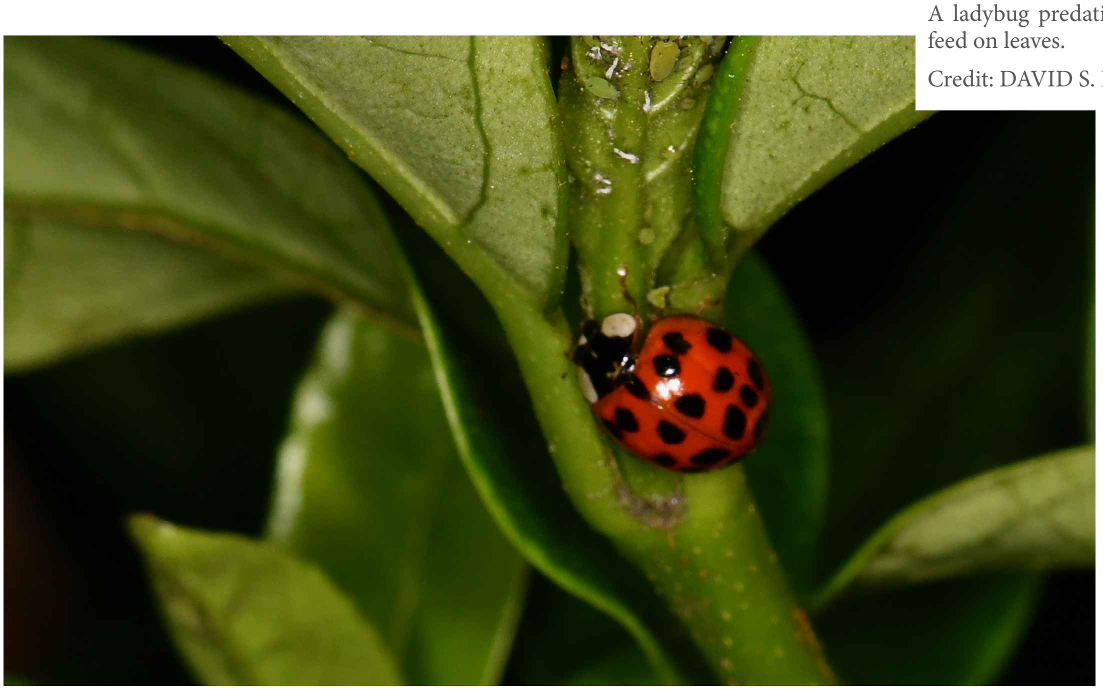
57 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
58 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
59 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
60 K. R. Aneja. S. A. Khan, and A. Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," *Kavaka* 47 (2016): 145-154, http://www.fungiindia.co.in/images/kavaka/47/19.pdf.
61 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
62 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
63 Jitendra Mishra, et al.,"Biopesticides: where we stand?" et al., "Biopesticides: where we stand?" In *Plant microbes symbiosis: applied facets*, (New Delhi: Springer India, 2014), 37-75. https://doi.org/10.1007/978-81-322-2068-8_2.

necessarily chemical-free. They might contain harmful chemicals and must be used with care.[64] However, on a larger scale, biopesticides do interfere with the ecosystem on a much smaller scale than their chemical counterparts. These types of pesticides are currently less prevalent in scientific research, meaning that fewer investigations are being conducted about them than conventional pesticides. Yet, global interest in them has been slowly increasing. There are many different types of biopesticides, and they all have various modes of action depending on their origin. They can be classified into botanical, microbial, nano, and macro biopesticides.[65]

Botanical biopesticides are those that come directly from plants. These can include pesticides produced by the plant itself. Caffeine is an excellent example of this. Throughout their evolutionary history, coffee, cacao, and tea plants developed the ability to produce it. When their leaves fall on the ground, they contaminate the soil nearby with caffeine, making it hard for weeds to grow and take up resources. Additionally, this botanical substance is an insecticide that keeps insects from eating the plant's leaves, as it is toxic to insects in large doses. Moreover, this chemical increases the activities of beneficial insects such as pollinators. Coffee plants have low doses of caffeine in their nectar. This gives animals a buzz when they take their nectar. Thus, they are more likely to return to coffee flowers and spread their pollen.[66] Botanical biopesticides also include substances extracted from plants, such as essential oils. A typical example is citronella oil, used as a repellent for certain animals. Botanicals can attract, repel, or intoxicate organisms.[67]

Microbial pesticides are the most common type of biopesticide. Over 90 percent of all biopesticides are based on microorganisms such as bacteria, fungi, or viruses.[68] This is mainly because said organisms have precise innate defense mechanisms. These pesticides work in a myriad of ways. Some become parasites of harmful organisms, others compete with them for resources, and others make antibiotics. Antibiotics are compounds produced by microorganisms that, at low concentrations, can kill or inhibit the growth of

64 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
65 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides"; Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
66 Carl Zimmer, "How Caffeine Evolved to Help Plants Survive and Help People Wake Up," *New York Times,* September 4, 2019, https://www.nytimes.com/2014/09/04/science/how-caffeine-evolved-to-help-plants-survive-and-help-people-wake-up.html.
67 Shahnawaz Dar et al., "Biopesticides–Its Prospects and Limitations: An Overview," In *Perspectives in Animal Ecology and Reproduction*. (New Delhi, India: Astral International, 2019): 300, https://www.researchgate.net/publication/330212960_Biopesticides-Its_Prospects_and_Limitations_An_Overview.
68 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.



A ladybug predating on aphids, small insects which feed on leaves.

Credit: DAVID S. FERRY III

other microorganisms.[69] Bacterial microbial biopesticides are those that use bacteria. They are usually insecticides. They can disrupt insects' digestive systems by producing toxins specific to particular pathogens.[70] Also, they can be used to make insects sick.[71] However, they can also be used to control non-insect pests.[72] Bacterial biopesticides are capable of creating colonies and crowding out other microorganisms.[73] This is because there is competition for resources everywhere in nature, and every species has a specific niche. In ecology, a niche is the condition in which a population or species persists. This includes the geographical space, altitude, temperature, and species' ecological role in the ecosystem. Two populations can not share identical niches. This leads to competition between them. Sometimes, they split the niche in two, but it is also possible for one species to be pushed entirely out of their niche and die off. Aside from competing for the same niche, predatory bacteria can eat fungi or other bacteria to control their population.[74]

Fungal pesticides are those derived from fungi and can be used to control insects and diseases that affect plants. They do this by competing with, consuming, or becoming parasites of harmful fungi, bacteria, nematodes, and weeds.[75] Competition for limited nutrients and space and predation is a common mode of action for both fungal and bacterial biocontrol agents. Furthermore, some fungi can secrete toxins that are lethal to some microorganisms. Viruses are also used as biopesticides in agriculture. Since they are usually host-specific, meaning that they typically affect one or only a few closely related species, they can be used to target specific pests. For instance, baculoviruses—which are a family of viruses that affect insects—can be used to control larval pests. When larvae ingest them, they become active, and their DNA infects the insect's digestive tract cells. After some days, the host larvae can not digest food anymore, so they die.[76] Moreover, emerging technologies use viruses that infect bacteria as pesticides. They can target and kill the bacteria that make plants sick. These viruses only affect bacterial cells, which are more primitive than plant, fungal, or animal cells. For this reason, they are considered harmless to humans, animals, and the flora around crops.[77]

Organisms that make microbial pesticides are mass-produced via industrial fermentation, and they have to be reapplied often, as they degrade easily. Because of this, they tend to be much more environmentally friendly.[78] Nano biopesticides refer to tiny particles that are used for pest control. They can be naturally occurring pure carbon structures, organic compounds, inorganic compounds, or hybrids. Many nano biopesticides come from mineral sources. The most widely used in agriculture are metals such as silver, copper, and titanium. They might also be a by-product of living organisms in the form of biological polymers. Chitin, a fibrous and firm substance made with sugar molecules, is one of the many polymers used in nanobiopesticides.[79]

Macro biopesticides, on the other hand, refer to the instances in which larger organisms are used as pesticides. This approach considers natural enemies of pests and organisms that help strengthen the defense mechanisms of crops. They include beneficial insects, parasites of pests, and nematode worms that cause insect diseases.[80] Ladybugs are an excellent example of these organisms, as they are predators of soft insects, including the larvae that eat crop leaves.[81] Overall, these types of pesticides have immense benefits. Firstly, they are highly specific in their modes of action and target,

69 Vero, "Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control," 457.
70 Mishra, "Biopesticides: where we stand?" 37-75.
71 Dar et al., "Biopesticides–Its Prospects and Limitations: An Overview," 300.
72 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
73 Mishra, "Biopesticides: where we stand?" 37-75.
74 Vero, "Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control," 457.
75 Mishra, "Biopesticides: where we stand?" 37-75.
76 Mishra, "Biopesticides: where we stand?" 37-75.
77 Vero, "Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control," 457.
78 Vero, "Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control," 457.
79 Xiaohong Pan et al., "Nanobiopesticides in Sustainable Agriculture: Developments, Challenges, and Perspectives," *Environmental Science. Nano* 10, no. 1 (January 1, 2023): 41–61, https://doi.org/10.1039/d2en00605g.
80 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
81 Anto Rashwin, and Joel Sanjeeth, "Integrated Pest Management," in *Fundamentals of Plant Protection*, (Uttar Pradesh: N D Global Publication House, 2023), 90-103, https://www.researchgate.net/publication/376953968_Integrated_Pest_Management.

meaning that they pose a lesser threat to humans and non-target animals.[82] Secondly, as they comprise molecules that living organisms can break down, they do not bioaccumulate or biomagnify.[83] This means that they degrade quickly, avoiding pollution and residue problems.[84] Thus, they are less harsh on the environment than their chemical alternatives. They are generally more affordable than industrial chemical pesticides and can be sourced sustainably.[85] Most importantly, they have proven highly efficient when used locally for short periods. They can be used on their own or with several other traditional pesticide methods.[86]

Nevertheless, some of these advantages can be seen as drawbacks. Because of their rapid degradation, they have a concise shelf life, which is inconvenient for many farming practices.[87] Biopesticides only protect the crops if they are in contact with the pests, so they must be reapplied often.[88] Further, these pesticides are not always safe or non-toxic. The toxicity of a pesticide needs to be assessed on a case-by-case basis. For instance, nicotine is a natural bioinsecticide produced by tobacco plants and is far more toxic than modern chemical pesticides.[89] The main concern when it comes to biopesticides, however, is resistance. Since their modes of action are particular, the overuse of one pesticide creates immense selective pressure for resistance.[90]

Many pesticides are new technologies that need more research and development to be safely marketed. However, companies are discouraged by the high costs of registration and development. They must invest heavily in research, packaging, storage, and materials.[91] Using biopesticides also requires careful monitoring and ecological knowledge, which is limited.[92] Farmers need to understand how these pesticides work to be used effectively. This is especially hard in developing countries, where most farmers don't know about biopesticides.[93] To use more biopesticides, production must increase. This would require large-scale cultivation, competing with land needed for food and possibly affecting food security.[94] Currently, biopesticides are not as strong in the pest control market as their conventional alternatives, but they are growing steadily. The market value of biopesticides is expected to reach about USD 2.3 Billion in 2027.[95] Delegates are encouraged to look for ways in which they can help overcome the barriers to these technologies, such as the lack of incentive in investment and user awareness of their methods of action.[96]

Integrated Pest Management

Integrated Pest Management (IPM) has its roots in ancient agricultural practices. However, it became increasingly popular as a concept during the 20th century, when worries about the environmental and health implications of methods of pest control gained momentum.[97] IPM is the solution to the unwanted side effects of using too many intoxicating pesticides. The evolution of resistant pests and increasing damage to the environment made it imperative to give structure to pest control strategies.[98] IPM refers to the way of controlling unwanted organisms by using a combination

82 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
83 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
84 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
85 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
86 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
87 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
88 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
89 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
90 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
91 Mishra, "Biopesticides: where we stand?" 37-75.
92 Mishra, "Biopesticides: where we stand?" 37-75.
93 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
94 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
95 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
96 Dar et al., "Biopesticides–Its Prospects and Limitations: An Overview," 300.
97 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
98 S. Mohankumar, and T. Ramasubramanian, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," in *Integrated Pest Management: Current Concepts and Ecological Perspective*, (United States: Academic Press, 2014), 371-99, https://doi.org/10.1016/B978-0-12-398529-3.00020-8.

of all types of crop control.[99] These include the manipulation of habitat, the use of biocontrol agents, the use of resistant varieties, the consideration of cultural practices, and the use of chemical pesticides.[100] IPM as a strategy was initially proposed in 1959. However, it was officially recognized as a requirement for sustainable agriculture in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro.[101] The central idea of having an IPM approach to manage crops is not to completely eradicate pests but to effectively control their populations by keeping them below damaging levels.[102] The Food and Agriculture Organization (FAO) of the UN defines IPM as the "careful consideration of all available pest control techniques and integration of appropriate measures that discourage the development of pest populations".[103] In this sense, new biotechnologies become a compliment, rather than a substitute, for many areas of conventional agriculture.[104] By implementing crop control, biological, genetic, physical, regulatory, and mechanical measures, IPM aims to be effective, economically sustainable, and environmentally sensitive.[105] The most economical means and least harmful for the environment are always considered better over more toxic and expensive alternatives.[106] Internationally, IPM has been recognized and recommended as a component of good agricultural practices by bodies such as the United Nations and the European Union, as well as organizations like the United States Environmental Protection Agency.[107]

IPM is a tiered approach that ensures the appropriate use of pesticides, avoiding both overuse and underuse. This means that rather than a single process, it is a series of evaluations, decisions, and controls.[108] Its first component is prevention. Before IPM farmers start arranging for pesticides to control their possible pests, they must consider methods to prevent infestations altogether.[109] These often include cultural practices such as crop rotations, planting GMOs alongside non-transgenic varieties, and optimized irrigation.[110] Cultural practices are agricultural techniques that create a hostile environment for pests without using chemicals or outside biological agents.[111] For instance, alternating between crops creates an unstable habitat for pests that can't reproduce in large numbers. This reduces the need for future chemical interventions.[112] Certain hygiene and sanitation practices are crucial to preventing infestations and unnecessary pesticide use. Removing crop residues in between harvests eliminates the nests where pests can hide and breed, thus keeping their population under control.[113] Another important aspect of prevention is the breeding of resistant varieties of crops. Host plant resistance is preferred over the use of biological control agents, as farmers do not incur further expenses when the plants produce their pesticides themselves.[114] These varieties can either be produced through traditional breeding methods or genetic engineering.

Another important component of IPM is pest threshold

99 Food and Agriculture Organization, "Integrated Pest Management."
100 Ayilara, "Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides."
101 Mohankumar, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," 371-99.
102 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
103 "Integrated Pest Management," Food and Agriculture Organization, accessed July 16, 2024, https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/.
104 "THE STATE OF FOOD AND AGRICULTURE 2003-2004 1," Food and Agriculture Organization, accessed July 16, 2024, https://www.fao.org/4/Y5160E/y5160e07.htm.
105 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
106 Food and Agriculture Organization, "Integrated Pest Management."
107 European Commission. "Integrated Pest Management (IPM)," EU Food Safety, accessed July 16, 2024, https://food.ec.europa.eu/plants/pesticides/sustainable-use-pesticides/integrated-pest-management-ipm_en.
108 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
109 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
110 European Commission, "Integrated Pest Management (IPM)."
111 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
112 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
113 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
114 Mohankumar, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," 371-99.

Crop consultant evaluates pests in a field as part of IPM system

Credit: Tim McCabe, USDA Natural Resources Conservation Service.

levels. In IPM, farmers do not implement control measures at the first sight of a pest. Rather, they wait until their presence reaches a predetermined threshold level.[115] These thresholds may vary widely across farms and even within crops in a single farm. The threshold is the point at which pests cause economic damage to the crops. This means that unless the presence of organisms is damaging the economy of the farm, no action needs to be taken.[116] These thresholds must be set under scientific guidance, assessing the status of each farm individually. Factors affecting the threshold can include climate conditions, region, and type of crop.[117]

Monitoring is another central aspect of IPM. Farmers and producers must understand that not all organisms surrounding the crops will require control, as not all are considered pests. Producers must carefully identify the plants and animals that harm the farm's economy before taking action. This also helps in determining the right pesticides to apply and to avoid unnecessary measures.[118] The organisms identified as pests must be kept under constant observation by reasonable and adequate methods. These might include visual inspection of the crops, sound forecasting, the use of early diagnosis systems, and the intervention of ecological experts.[119]

When pests get past their threshold level and preventive measures are no longer applicable or effective, control measures are taken.[120] The first methods used are selective and specific pesticides and pheromones. Effective but non-toxic methods are always chosen first.[121] At this stage of IPM, biopesticides are a core component.[122] Since biopesticides quickly degrade, they do not harm the environment as much as chemical pesticides. Additionally, they are highly specific in the types of pests they target. When controlling pest populations with any type of pesticide, it is crucial to remember that over-reliance on some control methods can lead to the development of resistance. When pests develop resistance, the pesticides used to control them are less effective over time. Hence, it is generally advised not to rely on a single control agent.[123] Control methods may also be physical. Some examples of physical control methods include rodent traps

115 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
116 European Commission, "Integrated Pest Management (IPM)."
117 European Commission, "Integrated Pest Management (IPM)."
118 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
119 European Commission, "Integrated Pest Management (IPM)."
120 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
121 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
122 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
123 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.

and the removal of weeds.[124] It is important to note that, while IPM considers the use of chemical non-specific pesticides, they are only used as a last resort.[125]

Most importantly, IPM relies on constant observation and adequate adjustment. For instance, when the development of resistance is observed to be likely, anti-resistant strategies are encouraged. These include using many specific pesticides with different methods of action.[126] Additionally, since every farm is different, no single recommendation can be applied to every scenario. While this might be less straightforward than other pest control methods, it ensures efficiency and sustainability alike. IPM is an approach that must be catered to each particular farm, but the main steps and concepts remain universally applicable. This means that IPM is a tool that can be taught to small farmers and industrial producers alike.

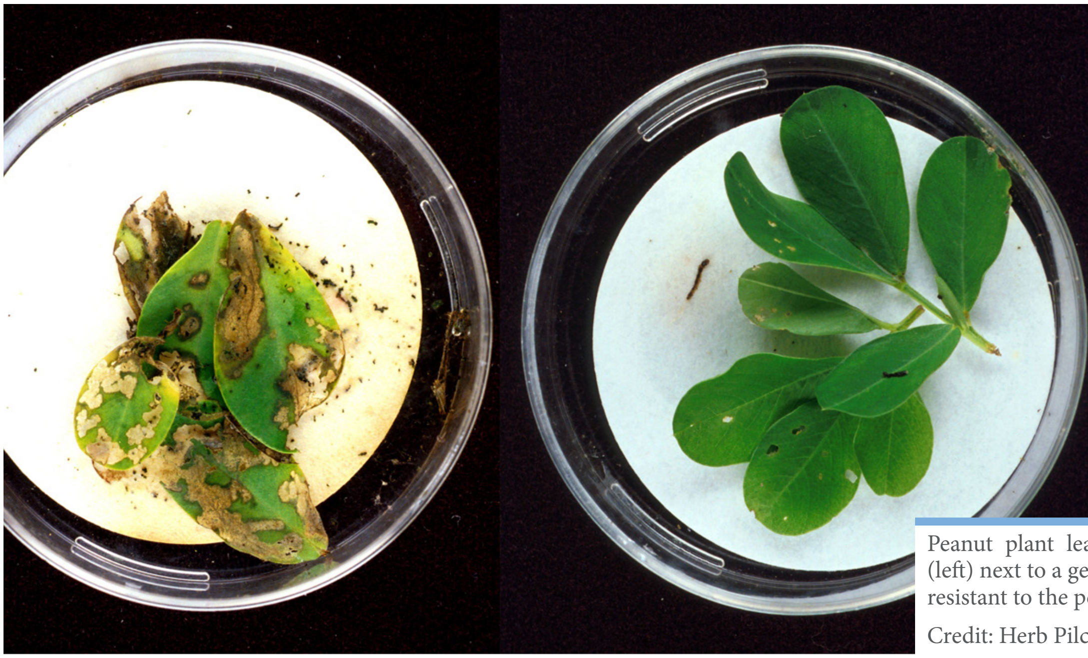
Aside from ensuring more economically sustainable farming practices, IPM improves ecosystem services such as pollination. This also improves the farm's productivity, increasing the profits of farmers who use this approach. In this way, IPM increases the income levels of farmers and is a valuable tool for producers in developing countries.[127] An example of the use of IPM in agriculture is the control of citrus greening disease in Florida.[128] Citrus greening disease is a plant disease spread by a bug called *Diaphorina citri*. This disease treated the citrus industry in Florida, leading to immense revenue losses estimated at USD 4.6 billion. Over 100,000 acres of citrus plantations were lost. IPM farmers in the area used a combination of introduction of natural predators of *D. citri,* removal of the infected citrus plants, and detection of infected trees with both drones and dogs. Later, they integrated genetic engineering techniques into their pest management, developing varieties of trees that were resistant to the disease.[129]

To some extent, all growers practice the principles of IPM. The goal is to move their practices closer to more appropriate, organized, and environmentally sensible IPM techniques.[130] Farmers try to make the most economical use of their pesticides. Over the last few years, there has been an increasing interest in sustainable farming, especially with the rising threat of global warming to farming and crop conditions. For this purpose, fostering, knowledge sharing, policy alignment, and research partnerships are crucial.[131] For IPM to be applicable, farmers' knowledge of the ecosystem and their specific local context must be strengthened.[132] Like in many other scientific fields, sustainability in agriculture requires mastery of many elements. Emerging technologies should be part of a comprehensive and integrated approach that intersects agriculture's economic, political, and ecological sectors. While these new technologies are interesting and applicable, they should not replace traditional pest control methods. These are the basis for agriculture and have been for many years. Furthermore, maintaining the use of traditional cultural practices is important for all the small farmers who do not have access to these new emerging technologies. Understanding the implications of the interconnectedness of all e aspects of agriculture is essential. This is particularly helpful when aiding countries in developing national research policies and capacity-building programs for IPM.[133]

Case Study: Bacillus Thuringiensis

Bacillus thuringiensis (Bt) is a bacteria that grows and lives in soil. These bacteria form spores during a stage of its growth cycle. Spores are tiny particles that some organisms produce to reproduce. These spores are crystal-like proteins that work as very powerful insecticides for lepidopteran pests.[134] Lepidopterans are a group of insects that include butterflies and moths. Many lepidopteran caterpillars are pests for crops,

124 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
125 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles."
126 European Commission, "Integrated Pest Management (IPM)."
127 Food and Agriculture Organization, "Integrated Pest Management."
128 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
129 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
130 Environmental Protection Agency, "Integrated Pest Management (IPM) Principles.".
131 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
132 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
133 Food and Agriculture Organization, "Integrated Pest Management."
134 Georgina Sanahuja et al., "Bacillus thuringiensis: a century of research, development and commercial applications," *Plant Biotechnology Journal* 9, no. 3, (February 2011): 283-300, https://doi.org/10.1111/j.1467-7652.2011.00595.x.



Peanut plant leaves damaged by pod borer larvae (left) next to a genetically engineered Bt variety that is resistant to the pest (right).

Credit: Herb Pilcher, USDA ARS

as they eat their leaves. Different strains of these bacteria produce different toxins that can affect different species of lepidopterans.[135] Thus, Bt proteins are specific to insect guts and do not cause any effect in humans or animal consumers.[136] The spores are activated only in the guts of lepidopterans, which have a very high pH as opposed to the low pH of human stomachs. They bind to special receptors in the digestive tract of caterpillars and cause holes to open. These pores disrupt the movement of liquids across the gut of the insect and eventually kill it.[137] Bt is the most used biopesticide in the world. Around 90 percent of all biopesticides are derived from it.[138] Furthermore, the production of Bt spores is the most common insecticidal trait engineered into GMOs.[139]

Nowadays, these proteins have been expressed in transgenic plants, but the history of Bt as a pesticide goes further back.[140] Its insecticidal properties were discovered after researchers found four moth caterpillars full of crystals. Further investigation concluded that the pesticide did not affect insects who came in contact with it, only pests who ingested it.[141] The bacteria was first isolated in 1901, and in 1938, a commercial Bt insecticide entered the market: Sporeine.[142] Sporeine was developed as a topical pesticide to be sprayed over crops and became very popular. However, farmers who used it faced some difficulties. The active ingredient of Sporeine was Bt spores, an organic compound that easily breaks down or falls off the leaves. Farmers had to reapply topical Bt insecticides frequently since Bt only works when it is present on the plant organs on which the insects feed and does not kill on direct contact. During the mid-1980s, biotechnologists developed transgenic Bt crops. In 1986, the first tests on these crops were conducted on Bt tobacco plants in the United States and France. By 1998, the adoption of Bt crops had increased largely as more data became available showing the positive impact of Bt transgenic technologies on the farming industry and the environment.[143]

The use of these crops has reduced the use of pesticides and saved the fossil fuels needed for spraying insecticides. This dramatically reduced carbon emissions by limiting the

135 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
136 ISAAA, *Agricultural Biotechnology (A Lot More than Just GM Crops),* 26.
137 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
138 Aneja, "Biopesticides an eco-friendly pest management approach in agriculture: status and prospects," 145-154.
139 Daraban, "Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health," 983.
140 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
141 Sven Hansson, "A Science-Informed Ethics for Agricultural Biotechnology," *Crop Breeding, Genetics and Genomics* 1, no. 1 (July 2019), https://doi.org/10.20900/cbgg20190006.
142 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
143 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.

need for the aggressive techniques farmers used to get rid of pests. Additionally, Bt crops such as maize have had an overwhelmingly positive impact on farmers' economies. For instance, in 2004, Spain was the only country in the European Union to grow large amounts of Bt corn. This resulted in an important income for farmers and the reduction of certain toxic chemicals that used to be present in the crop.[144] This variety of maize has been adopted in countries such as Argentina, Brazil, China, and the Philippines, where it has been shown to have a higher yield than its organic counterparts. In South Africa, reported yields for this crop average ten percent over conventional varieties. Furthermore, a Bt variety of cotton proved to be successful in controlling lepidopteran pests and reducing the use of insecticides. Scientists argue that this cotton has the potential to contribute to poverty alleviation in developing countries, which could benefit from a higher yield of the crop.[145] In Bangladesh, a 2020 study on Bt eggplants showed that these GMOs improved both yield and pesticide costs. Yields increased by 3,564 kilograms per hectare, which was 51 percent more than what was observed in the control group.[146] Moreover, there was an important reduction in pesticide costs. They spent 7,157 BDT—which is equivalent to around 80 USD— less per hectare, which is 37.5 percent less than what they spent in the control group.[147] The farmers that produced this variety of eggplant sold more fruit and earned a larger utility margin on their products. They observed a 128 percent increase in net revenues[148]. Health benefits also arose from the production of Bt eggplant. The study reports that the toxicity of Pesticides went down by 76 percent. Further, farmers with chronic pesticide poisoning were 11.5 percent less likely to experience symptoms and had fewer medical expenses overall.[149]

Nevertheless, there are some concerns over the use of these GMOs. Part of this insecticide's initial concern was its ability to affect non-target lepidopteran species. This was especially concerning since there are many endangered and protected species in this group of insects. Monarch butterflies are an important example. However, after several studies, it was determined that the chance of monarch caterpillars being affected by these crops was low.[150] This is not the only concern that has been raised. A 2023 review covering 288 case studies from 23 different countries concluded that using certain Bt pesticides might have unintended effects on the ecosystem. They discovered that Bt pesticides can persist in nature and harm local species. Overall, the use of a variety of Bt to control mosquito populations also reduced the populations of aquatic animals such as crustaceans.[151] When using Bt crops or pesticides, it is crucial to consider the potential negative impacts on non-target populations and ecosystems. Like any other method of pest control, the use of Bt must be constantly monitored and assessed to protect the environment. If not, these practices can disrupt food webs and have unintended effects on the ecosystem.[152]

One of the widespread ecological side effects of using Bt is the development of resistant pests. Resistance to Bt pesticides has been observed in pests since before Bt GMOs entered the market.[153] The selective pressure generated by farmers using only one pest control method has been recreated in the laboratory multiple times. One study found that resistance was evident after only 15 generations of selection.[154] Another study exposed populations of over ten species of moths, two

144 Joseph Huesing, and Leigh English, "The Impact of Bt Crops on the Developing World," *AgBioForum* 7, no. 1 & 2 (2004): 84-95. http://agbioforum.org/v7n12/v7n12a16-huesing.pdf.
145 Huesing, and English. "The Impact of Bt Crops on the Developing World," 84-95.
146 Ahmed, Akhter, John Hoddinott, Naveen Abedin, and Nusrat Hossain. "The Impacts of GM Foods: Results from a Randomized Controlled Trial of Bt Eggplant in Bangladesh." *American Journal of Agricultural Economics* 103, no. 4 (November 2020): 1187-1201. https://doi.org/10.1111/ajae.12162
147 Ahmed, "The Impacts of GM Foods: Results from a Randomized Controlled Trial of Bt Eggplant in Bangladesh," 1187-1201.
148 Ahmed, "The Impacts of GM Foods: Results from a Randomized Controlled Trial of Bt Eggplant in Bangladesh," 1187-1201.
149 Ahmed, "The Impacts of GM Foods: Results from a Randomized Controlled Trial of Bt Eggplant in Bangladesh," 1187-1201.
150 Mark K. Sears et al., "Impact of Bt Corn Pollen on Monarch Butterfly Populations: A Risk Assessment," *Proceedings of the National Academy of Sciences* 98, no. 21 (September, 2001): 11937–42, https://doi.org/10.1073/pnas.211329998.
151 Magnus Land et al., "Effects of mosquito control using the microbial agent Bacillus thuringiensis israelensis (Bti) on aquatic and terrestrial ecosystems: a systematic review," *Environmental Evidence* 12, (November 2023), https://doi.org/10.1186/s13750-023-00319-w.
152 Land,"Effects of mosquito control using the microbial agent Bacillus thuringiensis israelensis (Bti) on aquatic and terrestrial ecosystems: a systematic review."
153 B E Tabashnik, "Evolution of Resistance to Bacillus Thuringiensis." *Annual Review of Entomology* 39, no. 1, (January 1994): 47-79. https://doi.org/10.1146/annurev.en.39.010194.000403.
154 Sanahuja et al., "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.

species of beetles, and four species of flies to Bt. By doing so, it proved that all kinds of pests could develop resistance. The resistance increased up to 100,000 percent of the initial resistance in the lab, even when resistance had only been observed in a few species in the fields.[155] However, it has also been proved that species are unlikely to develop resistance to multiple strains of Bt, as the spore proteins are very specific and different from one another. The difference between the results observed in the lab and the reality in the farming fields can be attributed to two factors. Firstly, topical Bt degrades rapidly in ultraviolet light so it is less persistent in fields than in the lab, where concentrations are kept constant.[156] Secondly, many farmers plant Bt crops alongside non-transgenic varieties of the same crop. This practice lowers the selective pressure and encourages the breeding of non-resistant pests since not-resistant pests can survive and pass on their genes.[157]

Bioethical and Environmental Considerations

Biotechnology, like most other advanced technologies, has the potential for misuse.[158] Since agriculture interacts with many aspects of life and is a core component of contemporary ecosystems, the practices of one farmer affect all growers in the same bioregion and the surrounding areas. It is estimated that 77 percent of farmers in the United States are planning to invest in technology.[159] Nevertheless, 77 percent are also worried about accessing information and privacy. Overuse and misuse of fertilizers and pesticides can be harmful to human health and to the land.[160] Incorrect and excessive use of technologies can affect the soil's health.

For example, if a farmer overuses one pesticide, they create immense selective pressure for their crops to acquire resistance. This resistance might spread to other farms in the area.[161] This is possible because organisms such as insects and birds travel between crops and can cross-pollinate them.[162] Cross-pollination occurs when flowers are pollinated with pollen from a different plant. The risk of contamination is high between plants nearby Farmers who choose to grow their crops with no GMOs might even lose their organic certification. In 2011, an Australian farmer lost 70 percent of his farm's organic certification and sued his neighbor for this very reason. His neighbor, who also operated a farm, planted genetically engineered canola crops in the bordering territory of their farms in November of 2010. By January of the next year, some of this variety of canola plants were found on the organic farm.[163] The organic farmer lost the certification of his farm because non-organic plants—the GMOs that migrated from the neighboring farm— were present on his property. While the Supreme Court of Western Australia determined that the GMO farmer should not be charged with anything, it is still important to consider that many farmers chose not to grow GMOs and the economies of their farms depend on this decision, as many people chose to not consume GMOs because of personal, religious, or moral reasons.

Moreover, organic farmers are not the only ones who might be negatively affected by emerging biotechnologies. This is because wild varieties of plants might interbreed with genetically engineered crops, which changes the DNA of indigenous wild varieties. This causes the loss of biodiversity. Horizontal gene transfer, which happens when genetic material is shared between two unrelated organisms, is common in plants.[164] Invasiveness is also a major ecological risk associated with agricultural biotechnology. Plants with traits we have engineered or bred to benefit us can breed with wild plants, creating new weeds. It is important to bear in mind that this risk is not only associated with GMO crops but also with traditionally bred plants.[165] For example, hybrids between

155 Tabashnik, "Evolution of Resistance to Bacillus Thuringiensis," 47-79.
156 Tabashnik, "Evolution of Resistance to Bacillus Thuringiensis," 47-79.
157 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
158 Bhatia, *Introduction to pharmaceutical biotechnology,* chap. 1
159 Andrew Cooke, "Farmers Love Technology, Fear Misuse," March 9, 2018, https://www.linkedin.com/pulse/farmers-love-technology-fear-misuse-andrew-cooke.
160 "Pros and Cons of Agricultural Technology," A Managed IT Service Company, accessed July 16, 2024 https://atztechnology.com/agricultural-technology/#Pros-and-Cons-of-Agricultural-Technology.
161 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
162 Logayn Abushal, et al.,"Agricultural biotechnology: Revealing insights about ethical concerns," *Journal of Biosciences* 46, no. 3, (August 2021): 81, https://doi.org/10.1007/s12038-021-00203-0.
163 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns," 81.
164 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns," 81.
165 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."

sugar beet and wild sea beet produce weed beets. These weeds have caused important economic losses to European beet growers, as they take up nutrients and space from crops[166] Additionally, hybrids between wild and domestic coconut plants have replaced wild coconuts in the world. The original wild varieties are now extinct.[167]

This also extends to the use of biopesticides. Everything affects the larger ecosystem. For instance, Bt toxins can enter the soil through pollen, plant roots, and plant residues. While these proteins do not bioaccumulate, they can sometimes bind to clay or dirt particles and minimally affect the soil's biochemistry of ss means that, while they easily degrade, biopesticides might remain in the environment for longer than intended.

Using herbicide-resistant crops and developing superweeds can also have several ecological consequences beyond the increase in toxicity of the herbicides used. The indiscriminate use of biological control agents can have detrimental effects on human health. For instance, when glyphosate was developed, it became the best-selling herbicide for many years. Later on, cases of kidney cancer in farmers working in Sri Lanka and Central America arose, presumably due to overexposure to the herbicide. Later lab studies have shown that glyphosate can disrupt the reproductive development of male rats, but more studies are needed to confirm the extent of possible effects in humans.[168] This shows that even though the effects of selective pesticides on human and animal health are much milder than those observed with traditional chemical pesticides, it is still necessary to carry out in-depth research on their effects.

An important concern with selective pesticides is the disruptions of food webs and food chains. In multiple Bt plantations, this has become an unintended consequence.[169] While selective pesticides such as Bt do not directly affect more than the target species, the removal of one organism from the ecosystem removes competition between species and destabilizes the food web.[170] Removing a pest can lead to the rise of a secondary pest that takes its place. For example, in Northern China, Bt cotton takes up 95 percent of all cotton plantations and controls bollworm larvae, which eat cotton plants. Studies on the local ecosystem showed the impact on other bug populations. They showed that mirid bugs, a type of leaf bug, have increased populations dramatically in Bt plantations since 1997. By 2008, they had taken up the bollworm larvae's spot as a primary cotton pest. In organic plantations, this increase in population was not observed, as bollworm larvae control the populations of mirid bugs.[171] A similar situation can be observed in the Indian subcontinent. The near elimination of bollworms drastically increased the number of sucking pests, which are insects that feed on plant sap. This led to the need to use more pesticides to deal with these new pests. Between 2002 and 2011, insecticide use went up from 2,110 metric tonnes to 6,372 metric tonnes.[172]

In the early 2000s, studies in biology began adopting a new focus. As humanity understood the structure and function of DNA, the ability to edit genes became the main emphasis of biological innovation.[173] At first, the genetic modification of plants and other organisms was much more uncertain than traditional methods of developing new crops with desirable traits. Nowadays, technology allows us to be much more precise with GMOs than we ever were with traditional techniques. We can control transgenes and predict the phenotypes of the organisms that we design with outstanding accuracy.[174] This is because traditional breeding involves designing new varieties of crops and cattle that have 50 percent of the genetic makeup of each parent. There are a lot of genes transferred with

166 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
167 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
168 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns," 81.
169 Land, "Effects of mosquito control using the microbial agent Bacillus thuringiensis israelensis (Bti) on aquatic and terrestrial ecosystems: a systematic review."
170 Mohankumar, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," 371-99.
171 Sanahuja, "Bacillus thuringiensis: a century of research, development and commercial applications," 283-300.
172 Mohankumar, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," 371-99.
173 Benjamin Trump, et al., "Governing biotechnology to provide safety and security and address ethical, legal, and social implications," *Frontiers in genetics* 13 (January 2023), https://doi.org/10.3389/fgene.2022.1052371.
174 Trump, "Governing biotechnology to provide safety and security and address ethical, legal, and social implications."

this method, which can have unpredictable effects. Genetic engineering allows us to transplant the specific genes that we desire to implement.[175]

Nevertheless, the idea that GMO technology is uncertain persists amongst the international population. GMOs are seen as an unnatural advancement by many because they involve direct editing of genetic material.[176] For instance, surveys in the United States report that the public does not feel informed about synthetic biology, and they present moral reservations about biotechnological developments.[177] For this reason, GMOs have been subjected to several restrictions around the world, especially in the European Union.[178] Genetically modified crops were initially developed as a means to provide better yields and more nutritious products. However, consumer activism against these products has driven these GMOs outside of the market.[179] Currently, over 99 percent of GMO plantations are either Bt crops or herbicide-resistant crops, both traits which mostly benefit the farmers and producers.[180]

Additionally, research and development of biotechnology, especially for agriculture, faces many challenges. Aside from restrictions due to moral reservations, it is very hard for biotechnological products to enter the market because of patents and intellectual property rights. When hybrids were first introduced into the market, producers of these seeds made the farmers dependent on consistently buying seeds from them. This is because hybrid seeds only work consistently for the first generation. If hybrid plants breed with each other, offspring might have uneven and unpredictable traits.[181] Therefore, seed companies developed a monopoly on the cultivation of patented lines of these hybrid seeds. The United States was the first country to allow patents on plants, in a 2001 ruling of the US Supreme Court, and many other industrialized countries followed.[182] Big biotechnological companies can charge a lot of money to use their seeds, which creates barriers for new farmers to partake in this agricultural practice.[183]

While patents are meant to encourage innovation and make research profitable, if they are very restrictive, they can have negative effects. For instance, large companies can put up legal restrictions for independent investigations on their product. This makes it virtually impossible for scientists to investigate the properties and effects of products while also complying with research ethics regulations.[184]

Moreover, it is important to realize that technological modernization has both a geopolitical and a scientific aspect. Country economies rely on their modernization strategies while scientists look to fulfill their curiosity about the world surrounding them and innovate accordingly.[185] For a lot of time in human history, technological advancements primarily followed military and economic objectives. With biotechnology, it is imperative to understand that these elements are present, too, in addition to ecological considerations.

The relationship between independent farmers, the government, the farming industry, and ecology must be kept at equilibrium for proposed solutions to be both economically viable and environmentally sensible.[186] The use of GMOs, biopesticides, and other biotechnologies requires agronomists, ecologists, farmers, and policymakers to take an integral perspective that considers the evolutionary consequences of this economic activity.[187] For this purpose, it is necessary to inform stakeholders about the interconnectedness of this field.

175 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns," 81.
176 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns."
177 Trump, "Governing biotechnology to provide safety and security and address ethical, legal, and social implications."
178 Trump, "Governing biotechnology to provide safety and security and address ethical, legal, and social implications."
179 Trump, "Governing biotechnology to provide safety and security and address ethical, legal, and social implications."
180 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
181 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
182 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
183 Abushal, "Agricultural biotechnology: Revealing insights about ethical concerns."
184 Hansson, "A Science-Informed Ethics for Agricultural Biotechnology."
185 Trump, "Governing biotechnology to provide safety and security and address ethical, legal, and social implications."
186 Argüelles, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.
187 Mohankumar, "Role of Genetically Modified Insect-Resistant Crops in IPM: Agricultural, Ecological and Evolutionary Implications," 371-99.

Current Status

Future Trends and Innovations

In the past few years, agricultural biotechnology has seen immense growth, from the improvement of genetic modification technologies to the implementation of artificial intelligence and a focus on climate resilience.[188] In the field of genetic engineering, CRISPR-Cas9 is the most prominent gene editing tool.[189] It stands out because of its efficacy and precision.[190] CRISPR is a segment of DNA that matches the place in the genetic sequence that scientists want to edit. Cas9 is a type of biological molecule that cuts DNA at specific spots. In a way, CRISPR works as a map that guides the Cas9 molecule in cutting and editing genetic material in the right places.[191] Not only are they used to produce GM crops but also in the industrial production of many agricultural products, such as biopesticides.[192] While it is not always 100 percent precise, CRISPR-Cas9 technologies have been under constant improvement over the past few years and are a sector of the biotechnological market that is positioned for growth in the years to come.[193]

Besides improving the ways to make plants and animals express traits that they originally did not have, recent developments have shown improvements in gene silencing methods. During the past decade, RNA interference (RNAi) technologies have been the subject of many studies and are expected to enter the agricultural market soon.[194] These technologies are based on the mechanism that all living things use to produce proteins and express phenotypes. Cells copy information from sections of DNA into molecules called RNA so they can be read and translated into proteins. RNAi technologies work by interfering with the translation of RNA molecules and preventing traits from being expressed without changing the original DNA of the organism.

This phenomenon was first observed in agricultural biotechnology in 1997 when scientists found a way to silence the gene that made tomatoes spoil.[195] Later developments of this technology have resulted in pesticides that can silence the genes that make insects grow and develop, making for effective and specific pesticides.[196] An interesting aspect of this technology is that it can be implemented through both transgenic organisms or through other methods.[197] For instance, a plant can be genetically modified to produce the molecules that interfere with RNA translation of pest growth genes. When pests consume the plant, their growth will be stopped. However, crops can also be sprayed with solutions containing pesticides with this technology. Plants are also able to absorb RNAi pesticides through their roots via irrigation. Further, nanoparticles, such as metals, can be used to ensure that RNA interference is successful. The versatility of application options for this technology is because the molecules that interfere with RNA translation can be produced both inside organisms and in the lab.[198] Like most other biopesticides, RNAi technology is not stable in the environment. This means that it degrades quickly. During lab studies, the pesticide was visibly degraded after 30 minutes of exposure to UV light.[199]

Additionally, with the rise of automation technology, precision agriculture has also been trending upwards. This includes the use of smart sensors in fields, drones, and space

188 "Gene Editing – Digital Media Kit," National Institutes of Health (NIH), November 5, 2020, https://www.nih.gov/news-events/gene-editing-digital-press-kit.
189 Rashwin, and Sanjeeth, "Integrated Pest Management," 90-103.
190 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032," press release, June 26, 2024, https://www.openpr.com/news/3599535/gene-editing-market-poised-for-tremendous-expansion-projected.
191 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
192 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
193 Yali Friedman, "How Biotechnology is Being Used to Combat Climate Change," Biotechblog, July 7, 2024, https://www.biotechblog.com/how-biotechnology-is-being-used-to-combat-climate-change/
194 Li He, Yanna Huang, and Xueming Tang, "RNAi-based pest control: Production, application and the fate of dsRNA," *Frontiers* 10 (November 2022), https://www.frontiersin.org/journals/bioengineering-and-biotechnology/articles/10.3389/fbioe.2022.1080576/full.
195 Kay Ledbetter, "Natural tech for 'dimming' genes brings transformative potential to agriculture," AgriLife Today, March 6, 2024, https://agrilifetoday.tamu.edu/2024/03/06/texas-am-agrilife-researcher-helps-outline-rnai-alternative-to-knock-out-technology-in-thought-piece/.
196 He, "RNAi-based pest control: Production, application and the fate of dsRNA."
197 He, "RNAi-based pest control: Production, application and the fate of dsRNA."
198 He, "RNAi-based pest control: Production, application and the fate of dsRNA."
199 He, "RNAi-based pest control: Production, application and the fate of dsRNA."

technology such as satellite imaging to closely monitor pest populations.[200] These technologies have a promising future, as they have the potential to work in tandem with big data and artificial intelligence (AI). This way, scientists and engineers can create predictive models for pest outbreaks and make better decisions with their pest management strategies.[201]

Research and development of AI technologies has grown exponentially in the past few years with generative models such as OpenAI's ChatGPT. The increasing influence of AI in every aspect of human life has become evident, and the life sciences are no exception.[202] In agricultural biotechnology, AI is used to improve data management, organization, analysis, filtering, and sharing.[203] Artificial intelligence is a broad term that encompasses different kinds of systems that carry out tasks that usually require human intelligence.[204] Within the field of AI, deep learning is particularly interesting. It refers to the creation of networks with many layers and the ability to learn and make decisions. DALL-E2 and ChatGPT are two very well-known examples of deep learning models. This technology proves to be very good at analyzing large datasets. In agriculture, deep learning can be used to analyze and process large amounts of data collected by tools such as sensors or drones. In this way, scientists and farmers can assess the ecological and economic sustainability of different pest control strategies. This is possible through close observation of changes in soil health and the nutrient cycle. AI is also able to track plant growth and optimize almost every other technology already in use by farmers. This includes GMOs, biological control agents, and cultural practices.[205]

Another interesting application of artificial intelligence in farming is the creation of digital twins of crops. These are digital copies of crops that behave the same way that crops do but in a virtual space.[206] This technology allows farmers to identify the problem areas within their crops. Further, digital twins can help farmers adapt their agricultural management to a changing climate and other threatening conditions. This is because they can mimic abiotic factors in the digital space and see how digital twins respond without harming the environment or their real-life crops. Similarly, phenotypes that are more efficient can be quickly identified with the use of AI and digital twins.[207] This application is particularly interesting for farmers and countries who choose not to use direct genetic engineering. They can more quickly breed their crops with traditional methods using guidance from AI systems. These systems are also able to model the ecosystem and food webs below the ground, ensuring that optimal conditions are kept. This becomes especially important when considering environmental changes, which alter the condition of soil.[208]

Since soil is the medium in which plants take their nutrients from, it is considered the most important resource in agriculture.[209] In 2022, the United Nations classified a third of the world's soil as degraded. According to their projections, by 2050, 90 percent of it could be lost. It is a resource that is currently threatened by climate change, which has become an increasingly important issue in agriculture. Global warming and climate change are making it more difficult for farmers to grow their crops in the places where they always have. Agricultural biotechnology is one of the most important tools we have to combat this. Farmers can create more productive and climate-friendly crops and livestock. Biotechnology crops have contributed by reducing carbon emissions through fuel reduction, less need for tilling, and fewer instances of pesticide application.[210]

Although using smart agriculture to ameliorate climate change does not directly relate to pest control, climate change is still an important threat to crops. This is because they can fall ill

200 Rashwin, "Integrated Pest Management," 90-103.
201 Rashwin, "Integrated Pest Management," 90-103.
202 Andreas Holzinger, et al., "AI for life: Trends in artificial intelligence for biotechnology," *New Biotechnology* 74 (2023): 16-24, https://doi.org/10.1016/j.nbt.2023.02.001.
203 Friedman, "How Biotechnology is Being Used to Combat Climate Change."
204 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
205 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
206 Cor Verdouw et al., "Digital Twins in Smart Farming," *Agricultural Systems* 189 (April, 2021): 103046, https://doi.org/10.1016/j.agsy.2020.103046.
207 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
208 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
209 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
210 Friedman, "How Biotechnology is Being Used to Combat Climate Change."

due to abiotic stress, like extreme temperatures or lack of nutrients.[211] For example, RuBisCO, a molecule that plants need for photosynthesis, stops working at 35 degrees Celsius.[212] Photosynthesis is the process by which plants take up carbon dioxide and release oxygen into the atmosphere with the help of sunlight. Molecules in living organisms, such as RuBisCO, have an ideal temperature and pH in which they can perform their tasks. When exposed to environmental stress, they do not work as efficiently, and they might stop working entirely, compromising the health of the organism. For this reason, climate resilience has become one of the main traits farmers look for in biotech crops and livestock.[213]

In countries like Nigeria, there have been significant developments in the production of climate-resilient crops. Prompted by the food insecurity crisis in the country, scientists have recently developed and released Tela maize, a variety of corn that is resistant to both insects and droughts.[214] The Nigerian government's decision to approve the commercialization of this variety of corn shows the desire to optimize food production despite challenging circumstances. Other countries, such as Ethiopia, Kenya, Mozambique, and South Africa, have started implementing the same genetically modified crop.[215]

In India, a non-GMO drought-resistant variety of rice that is also tolerant to herbicides has been produced. They found the traits they wanted in naturally occurring mutant plants and interbred them with the domesticated varieties using a method called marker-assisted backcross breeding.[216] Simply put, this method works by analyzing the DNA of plants that are bred through traditional methods. Instead of mating plants based on their visual characteristics, they can select the plants by directly looking at their DNA. Because of these optimization techniques, the new crops produced need less fertilizer.[217]

Additionally, Chinese scientists recently developed chill-proof tomatoes. These tomatoes can withstand cold temperatures due to genetic modification using CRISPR-Cas9. They are engineered to have enhanced expression of a gene that allows them to maintain stable yields in colder climates.[218] Developments such as this one open the possibility for the creation of further crops that are climate-resilient, bolstering food security at a national and global level.[219]

Closely related to climate change, greenhouse gas emissions pose a huge threat to agriculture. This is because soil can absorb some of these gasses, making it unhealthy for plants.[220] With this concern, biostimulants and regenerative agriculture have taken a more protagonistic role in biotechnology for disease control.[221] For instance, the use of *Ascophyllum nodosum*, a type of rockweed, is being used as a biological stimulant for crop growth in harsh climates and soil conditions.[222] *A. nodosum* is a type of seaweed. Because of this, it takes up carbon dioxide at a much faster rate than plants do. It is also a particularly resilient type of seaweed. It grows on top of rocks on the shore of cold beaches. It spends half of the day submerged in cold water when the tide is high and the other half drying out in the sun when the tide is low.[223] Biological compounds from *A. nodosum* can be extracted in industrial processing, and they can transfer their resistance and strength to new crops. It works similarly to vaccines. They stimulate

211 Friedman, "How Biotechnology is Being Used to Combat Climate Change."
212 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
213 Venkatram Vasantvada, "Enhancing Crop Resilience in the Face of Climate Crisis," Agro Spectrum, July 1, 2024, https://agrospectrumindia.com/2024/07/01/enhancing-crop-resilience-in-the-face-of-climate-crisis.html.
214 Silas Akpe, "Biotech Revolution: Transforming Nigeria's Agriculture, Combating Food Insecurity," *Science Nigeria*, July 25, 2024, https://sciencenigeria.com/biotech-revolution-transforming-nigerias-agriculture-combating-food-insecurity/#google_vignette.
215 Akpe, "Biotech Revolution: Transforming Nigeria's Agriculture, Combating Food Insecurity."
216 Shreetu Singh, "CR Dhan 807: India's First Non-GMO Herbicide and Drought Tolerant Non-Basmati Rice Variety," *Krishi Jagran*, July 2, 2024, https://krishijagran.com/agripedia/cr-dhan-807-indias-first-non-gmo-herbicide-and-drought-tolerant-non-basmati-rice-variety/.
217 Singh, "CR Dhan 807: India's First Non-GMO Herbicide and Drought Tolerant Non-Basmati Rice Variety."
218 Nanjing Agricultural University, "Tomato Triumph: Genetic Key to Chill-Proof Crops Unveiled," Lab Manager, July 9, 2024, https://www.labmanager.com/tomato-triumph-genetic-key-to-chill-proof-crops-unveiled-32488.
219 Nanjing Agricultural University, "Tomato Triumph: Genetic Key to Chill-Proof Crops Unveiled."
220 Pushp Sheel Shukla, Emily Grace Mantin, Mohd Adil, Sruti Bajpai, Alan T. Critchley, and Balakrishnan Prithiviraj, "Ascophyllum nodosum-Based Biostimulants: Sustainable Applications in Agriculture for the Stimulation of Plant Growth, Stress Tolerance, and Disease Management," *Frontiers Plant Science* 19, (May 2019), https://doi.org/10.3389/fpls.2019.00655.
221 Holzinger, "AI for life: Trends in artificial intelligence for biotechnology," 16-24.
222 Shukla, "Ascophyllum nodosum-Based Biostimulants: Sustainable Applications in Agriculture for the Stimulation of Plant Growth, Stress Tolerance, and Disease Management."
223 Shukla, "Ascophyllum nodosum-Based Biostimulants: Sustainable Applications in Agriculture for the Stimulation of Plant Growth, Stress Tolerance, and Disease Management."

the plant's natural defenses to become stronger by activating genes that the crops already have.

From an economic viewpoint, biotechnology in agriculture is expected to expand rapidly. The industry as a whole is experiencing an important shift towards sustainability and environmental protection.[224] The advancements in CRISPR-Cas9 technologies and more precise methods of pest control are drivers for the market, which is expected to reach a value of USD 268.32 billion by 2033.[225] Industrial biotechnology, which is the use of biotechnology in the production and processing of products and chemicals, is anticipated to grow at a constant rate of ten percent each year.[226] These projections show the increasing interest of countries and corporations in the development of technologies to protect crops and increase yield.[227] Moreover, out of the entire biotechnology sector, plant biotechnology is anticipated to hold the largest market share for the next ten years.[228] Further, the market for genetic engineering alone is expected to expand to USD 28.4 billion within the next eight years, which shows growth in interest in GMOs.[229] Although biotechnology as a whole is expected to grow immensely in the coming years, the magnitude of this growth differs widely across regions. North America is the region with the most robust growth indicators, as they have high investment in and adoption of these technologies.[230] The Asia-Pacific sector shows potential for rapid growth, with quick adoption of new biotechnologies. On the other hand, trends in Latin America and the Caribbean show a more gradual growth due to the gradually increasing research capabilities in the region.

It is important to note that though growth trends are largely similar in countries in the same region, each country has different economic and legal restrictions and regulations for agricultural biotechnology. These differences impact the growth of biotechnology in each country.

Current Global Regulations and Limitations to Agricultural Biotechnology

Biotechnology is a very highly regulated industry. This is because, aside from moral, personal, or religious reservations that some might have, decisions around these technologies can have a deep impact on the ecosystem and markets. Therefore, regulatory bodies ensure that before any pesticide can be used, sold, supplied, advertised, or stored anywhere in the world, it is tested and approved.[231] Corporations in charge of producing biotechnology plant protection products have to prove that they are safe and effective to register them.[232] Products are regulated differently depending on what they are. For example, products containing a microorganism—such as the use of fungi or bacteria—are regulated differently than extracts from plants. Other regulated control agents include the use of macro control agents, such as the introduction of predators and parasites and semiochemicals. Semiochemicals are chemical substances that are produced by living organisms, like Bt spores or insect pheromones.[233]

While there is no single international agreement or organization that regulates the research and development of biotechnology for disease and pest control, countries can regulate it independently. This is done through national or regional regulatory bodies that oversee these processes and put different regulations in place.[234] Each country has its regulatory framework for the use of these technologies, and the approval process is different everywhere.[235] Required

224 Maximize Market Research, "White Biotechnology Market Projected Touch Approximately USD 865.50 Billion by 2030," press release, July 11, 2024, https://www.openpr.com/news/3576404/white-biotechnology-market-projected-touch-approximately-usd. .
225 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
226 Maximize Market Research, "White Biotechnology Market Projected Touch Approximately USD 865.50 Billion by 2030."
227 Spherical Insights, "Global Agricultural Biotechnology Market Size To Worth USD 268.32 Billion By 2033 | CAGR of 8.27%," press release, July 18, 2024, https://www.globenewswire.com/news-release/2024/07/18/2915655/0/en/Global-Agricultural-Biotechnology-Market-Size-To-Worth-USD-268-32-Billion-By-2033-CAGR-of-8-27.html.
228 Spherical Insights, "Global Agricultural Biotechnology Market Size To Worth USD 268.32 Billion By 2033 | CAGR of 8.27%."
229 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
230 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
231 Minshad Ansari, "Biopesticide Regulation," World Bioprotection Forum, December 14, 2021, https://www.wo.rldbioprotectionforum.com/blog/international-biopesticide-regulations-challenges-and-how-to-overcome-them/.
232 Ansari, "Biopesticide Regulation."
233 Ansari, "Biopesticide Regulation."
234 Ritika Kumari et al., "Regulation and safety measures for nanotechnology-based agri-products," *Frontiers in Genome Editing* 5 (June, 2023), https://doi.org/10.3389/fgeed.2023.1200987.
235 Kumari, "Regulation and safety measures for nanotechnology-based agri-products."

risk assessment tests often include evaluating their toxicity for mammals, persistence in the environment, and efficacy. Regulatory bodies might also require directions on how to use the product and the chemical composition of the product to be clearly stated and displayed in the product.[236]

For instance, in the European Union, the European Chemicals Agency and the European Food Safety Authority are in charge of overseeing the approval of plant protection products.[237] However, individual countries in Europe can add further restrictions and regulations on top of the ones in place by the EU.[238] In the United Kingdom, bodies such as the Food Standards Agency and the Department for Environment regulate biotechnology products.[239] In the United States, biotechnology for disease and pest control is regulated by the Food and Drug Administration, the US Environmental Protection Agency, and the US Department of Agriculture.[240] Some countries have important individual pieces of legislation that determine how these products are handled in the national market. For example, Canada's pesticides and biological control agents are regulated by the Pest Control Products Act. This legislation requires pesticide products to be registered and labeled after complying with a series of safety and efficacy requirements.[241]

GMOs are amongst the most controversial and regulated biotechnologies used in agriculture. For this reason, a large portion of the legislation around biotechnology for disease and pest control is centered around them. Many regulatory bodies require the labeling of GMOs as a means of informing consumers if they have reservations about the technology. In European countries, all GMO products have to be clearly labeled.[242] Furthermore, only one GMO crop has ever been approved for cultivation in the region, a Bt corn variety, but the license has already expired.[243] While the permit was valid, 19 countries individually chose to not allow for its cultivation. 97 percent of this corn was grown in Spain, while the remaining three percent was grown in Portugal, the Czech Republic, Romania and Slovakia.[244] Currently, eight GM crops are waiting for approval for cultivation, including the variety of Bt corn that was approved before.[245]

On the other hand, some countries have found innovative ways to introduce GMOs into the market by making the approval process more timely. In China, new regulations approved the production, sale, and distribution of genetically modified corn and soybeans in different provinces. Within a month, 51 varieties of corn and soybean were registered.[246] In China, producers need to have a biosafety certificate for their seeds for them to be approved. Additionally, they have to submit extensive genetic analysis tests to ensure the safety of their products. The country was able to speed up the registration process through the introduction of pilot trials and production certificates before official approval. In this way, producers and researchers are encouraged to invest in genetic engineering for their crops.[247] Other countries have banned or postponed the use of GMOs completely as a means to protect their biodiversity. This is the case for Peru, which, in 2021, put in place Law 31111. This decision extended a previous prohibition of GMOs in the country until 2035.

Aside from legal restrictions and regulations, agricultural biotechnology faces additional limitations. Namely, registration in many countries is highly expensive.[248] For example, in the European Union, registration for biopesticides is much more expensive than in the United States. In the EU, the fees range

236 Ansari, "Biopesticide Regulation."
237 Kumari, "Regulation and safety measures for nanotechnology-based agri-products."
238 "Agricultural Biotechnology," U.S. Department Of Agriculture, accessed July 30, 2024. https://usda-eu.org/plant-products/agricultural-biotechnology/.
239 Kumari, "Regulation and safety measures for nanotechnology-based agri-products."
240 "How GMOs Are Regulated in the United States," Food and Drug Administration, March 5, 2024, https://www.fda.gov/food/agricultural-biotechnology/how-gmos-are-regulated-united-states.
241 Kumari, "Regulation and safety measures for nanotechnology-based agri-products."
242 Kumari, "Regulation and safety measures for nanotechnology-based agri-products."
243 U.S. Department Of Agriculture, "Agricultural Biotechnology."
244 U.S. Department Of Agriculture, "Agricultural Biotechnology"; eu parliament
245 Ivana Katsarova, *Plants produced using new genomic techniques* (Strasbourg: European Parliament, May 2024),https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/754549/EPRS_BRI(2023)754549_EN.pdf.
246 Bharti Malhotra, "New GMO regulation in China: Implications for seed market." S&P Global. June 7, 2024. https://www.spglobal.com/commodityinsights/en/market-insights/blogs/agriculture/060724-new-gmo-regulation-in-china-implications-for-seed-market.
247 Malhotra, "New GMO regulation in China: Implications for seed market."
248 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."

between three and five million GBP compared to 300–400 thousand USD in the United States.[249]

The International community has also taken important steps to make agricultural biotechnology's playing field more equitable. For instance, the United Nations drafted a proposal establishing a global fund for sharing benefits derived from biotechnological genetic research.[250] This would allow countries with less research capabilities to partake in the development of new biotechnologies for disease and pest control. Furthermore, the sharing of non-monetary benefits of these scientific advancements was also proposed. Capacity building, technology transfer, and joint research partnerships are all ways in which the knowledge gained from investigations can be shared amongst the international community and reduce the limitations of biotechnological research.[251]

Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a series of 17 global goals that the United Nations set in 2015. They are meant to serve as the blueprint for achieving a better and more sustainable future for all. The United Nations aims to accomplish these goals by 2030.[252] The SDGs highlight core interconnected sectors for action, recognizing that improvement or worsening in one aspect can affect the others. For this, there is a need for a balance between social, economic, and environmental sustainability. The use of biotechnology for disease and pest control is closely related to SDGs 2, 3, 14, and 15.

The first important goal when discussing agricultural biotechnology is SDG 2: Zero Hunger. Through a combination of factors, including the COVID-19 pandemic, climate change, and deepening inequalities, food security is one of the most urgent global goals.[253] Pests and disease are among the biggest threats to crop yield. Around 40 percent of global agricultural products are currently lost to these factors, which compromises food security at a time when resources are increasingly more difficult to manage efficiently.[254] Target 2.3 of this SDG aims to double the agricultural production and income of small-scale food producers, with a focus on minorities. It also highlights the value of knowledge, financial services, markets, and other opportunities to reach this goal.[255] Further, Target 2.4 highlights the need for more sustainable production systems and more resilient crops, which have both been important focuses of the agricultural biotechnology field throughout the last decade. Important aspects of this target include resistance to climate change and natural disasters and improvement of land and soil quality.[256]

Biotechnological plant protection methods, such as genetically engineered crops, and biopesticides, and approaches such as IPM serve as direct tools to accomplish these targets. This is because, by protecting agriculture from one of its biggest threats, farmers will be able to collect more products and improve their economies. Furthermore, climate resilience is one of the most popular traits being bred and engineered into crops currently. This allows plants to grow in harsher conditions, which increases food security.

Additionally, SDG 3, Good Health and Wellbeing, is central to the discussions in the committee. Every year, tens of millions of farmers are poisoned from heavy pesticide use, which brings to light the urgent need for new ways to manage pests. Using biotechnology for pest control is not only a matter of plant and environmental protection; it is also a matter of human health. Farmers are not the only ones affected by pesticide use, as toxic chemicals can make their way into human diets. With target 3.9, the United Nations sets to substantially reduce the number of deaths and illnesses from hazardous chemicals—such as chemical pesticides—and pollution.[257] Additionally,

249 Ansari, "Biopesticide Regulation."
250 Giada Ferraglioni, "UN proposes global fund for sharing benefits derived from plant, animal DNA sequencing," Carbon Pulse, July 1, 2024, https://carbon-pulse.com/299514/.
251 Ferraglioni, "UN proposes global fund for sharing benefits derived from plant, animal DNA sequencing."
252 "Take Action for the Sustainable Development Goals - United Nations Sustainable Development," United Nations Sustainable Development, May 31, 2023, https://www.un.org/sustainabledevelopment/sustainable-development-goals/.
253 "Goal 2: Zero Hunger - United Nations Sustainable Development," United Nations Sustainable Development, October 19, 2023, https://www.un.org/sustainabledevelopment/hunger/.
254 Vero et al.,"Microbial Biopesticides: Diversity, Scope, and Mechanisms Involved in Plant Disease Control."
255 United Nations Sustainable Development, "Goal 2: Zero Hunger - United Nations Sustainable Development."
256 United Nations Sustainable Development, "Goal 2: Zero Hunger - United Nations Sustainable Development."
257 "Health - United Nations Sustainable Development," United Nations Sustainable Development, October 19, 2023, https://www.

target 3.d aims to strengthen early warning, risk reduction, and management of health risks across the globe, especially in developing countries.[258]

Biotechnology offers many tools to help achieve these targets. Biopesticides, for instance, are a promising alternative to chemical methods to control pests, as most of them degrade naturally in the environment. In Bangladesh, a study on Bt usage revealed that the biopesticide made it significantly less likely for farmers with chronic poisoning conditions to exhibit symptoms and incur cash medical expenses.[259] The use of artificial intelligence in combination with smart sensors can also help achieve SDG three targets, as they can serve as early warning systems. IPM knowledge-building is also an important way to reduce risks in farming, as it ensures the mindful use of pesticides and is widely applicable across the world. SDGs 14 and 15 go hand in hand. They both relate to the protection of biodiversity, which is a key element of the ethics surrounding the use of biotechnology for disease and pest control. SDG 14 refers to life below water, and SDG 15 refers to life on land. Target 14.1 aims to prevent and reduce marine pollution of all kinds, especially from land-based activities. This includes pesticide pollution from farming. Target 15.5 is also relevant to the committee, as it aims to reduce the degradation of natural habitats and halt the loss of biodiversity.[260] Furthermore, target 15.9 aspires to integrate ecosystem and biodiversity values into national and regional frameworks for development, ensuring sustainability is prioritized. Lastly, target 15.8 focuses on the prevention of negative impacts done by invasive alien species, which is a common effect of introducing some biological control agents.

Biotechnology is widely applicable to work towards achieving these targets, especially through the use of biodegradable and non-polluting plant protection products. Practices like IPM are also hugely influential for these goals, as it is an approach that prioritizes sustainability and biodiversity, minimizing impact on the outside environment. Furthermore, IPM's applicability and structure lend themselves to being the base of national and local frameworks for plant protection.

Bloc Analysis

Points of Division

One of the biggest points of division across countries is the amount of innovation in the biotechnological field. The Organisation for Economic Co-operation and Development (OECD) has monitored the broad technological and scientific growth in various countries. The OECD divides the emerging technology indicators into different approaches, including biotechnology and nanotechnology indicators. Some of the indicators include the presence of biotechnology firms, the number of biotechnology patents, public research and development of biotechnology.[261] High numbers of research and development in biotechnology indicate an already established sector in the countries, while increasing numbers mean that it is still an emerging field in the countries.

Another important point of division across countries is the extent of their regulations and restrictions on new and old biotechnologies. For instance, some countries are more lenient in allowing new biotechnological products to enter the market through programs such as pilot trials. Other countries might be more wary of new developments in the field and might have more regulations. They might ask for more testing from companies to approve their products or for them to be clearly labeled. Additionally, some states might have complete prohibitions on all or some of these emerging technologies. Understanding the extent of regulations in a country can help determine their degree of approval of these technologies.

Countries with Established Use of Biotechnology for Disease and Pest Control

Countries in this bloc are characterized by high investment in biotechnology research and development. For this reason,

un.org/sustainabledevelopment/health/.
258 United Nations Sustainable Development, "Health - United Nations Sustainable Development."
259 Ahmed. "The Impacts of GM Foods: Results from a Randomized Controlled Trial of Bt Eggplant in Bangladesh," 1187-1201.
260 "Goal 14 | Department of Economic and Social Affairs," accessed July 16, 2024, https://sdgs.un.org/goals/goal14#targets_and_indicators.
261 "Emerging technology indicators," OECD, accessed august 29, 2024, https://www.oecd.org/en/data/datasets/emerging-technology-indicators.html.

they are home to large industries that develop biotechnological products focused on protecting crops. These are countries that already have a widespread use of biotechnology as a means to control pests. They have a large percentage of arable land planted with GMOs and high use of biopesticides, as well as the infrastructure for further development of those technologies.[262]

A good way to tell if there is significant activity in the agricultural biotechnology sector in a country is to look at the patents registered in the country. Countries with established and strong biotechnology industries will have several patents registered throughout the years. The presence of recent patents shows that there have been recent innovations in the field, which suggests that the countries have the capabilities to carry out research.[263] Additionally, most of them have been using biotechnology crops for over two decades. The Philippines, which has been implementing Bt crops since 2002, is a prominent example.

Another example is the United States, which has the largest area of genetically modified crops worldwide, with 71.5 million hectares.[264] By 2022, they registered 2.840 firms focused on biotechnology research and 390 biopesticides.[265] In addition, the Environmental Protection Agency (EPA) and the U.S. The Department of Agriculture (USDA) regulates agricultural biotechnology in the country. They regulate biopesticides with two laws: Federal Insecticide, Fungicide, and Rodenticide Act and Food Quality Protection Act (FQPA).[266]

The bloc also includes countries such as India, Brazil, and China, which have a large percentage of arable land planted with GM crops and high use of biological pesticides.[267] The main focus of this bloc should be to improve its sustainability and create measures to prevent unwanted ecological consequences through the adoption of IPM practices. Furthermore, countries in this bloc can lead knowledge transfer initiatives to help countries that do not have a solid agricultural biotechnology sector.

Countries with Growing Use of Biotechnology for Disease and Pest Control

Countries in this bloc are those that do not have established use of biotechnology for disease and pest control but are working on growing their use of them. While these countries do not have a significant history of biotechnology use, they do not have prohibitions on their use. In recent years they have experienced an increase in biotechnology research and registration of biotechnology patents. This bloc, although not largely partaking in agricultural biotechnology, holds a very positive stance towards it.

For identifying countries in this bloc, it is helpful to look at the patents that they have registered, especially the increase in recent years. In addition, recent frameworks have been introduced to regulate new technologies. Most of these countries will have very few old plant protection product patents and more new ones. This shows the gradual growth of innovation in a previously non-existing field. Furthermore, these countries might have systems in place to make it easier for biotechnology companies to register products while still carrying out the necessary testing on them. Frameworks that allow for less-expensive registration fees, for instance, are common among this bloc.[268]

Most countries in Latin America, the Middle East, and Africa are in this bloc, as their capabilities for scientific research and development are steadily growing.[269] For example, Ghana, in June 2024, released their first biotechnological

262 Huesing, and English. "The Impact of Bt Crops on the Developing World," 84-95.
263 Helen Casanova, "Patents as Technology Innovation Indicators," Development Bank of Latin America and the Caribbean, August 26, 2019, https://www.caf.com/en/knowledge/views/2019/08/patents-as-technology-innovation-indicators/; OECD, "Emerging technology indicators."
264 "Area of genetically modified (GM) crops worldwide in 2019," Statista, accessed August, 2024, https://www.statista.com/statistics/271897/leading-countries-by-acreage-of-genetically-modified-crops/.
265 "What Are Biopesticides? | US EPA," US EPA, October 18, 2023, https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides#encourage.
266 "EPA's Regulation of Biotechnology for Use in Pest Management," United States Environmental Protection Agency, last modified January 30, 2024, https://www.epa.gov/regulation-biotechnology-under-tsca-and-fifra/epas-regulation-biotechnology-use-pest-management#role.
267 Vasantvada, "Enhancing Crop Resilience in the Face of Climate Crisis."
268 Carlos Tadeu Santana Tatum and Suzana Leitão Russo, "Patent Mapping in Emerging Countries," *Journal of Technology Management & Innovation* 15, no. 2 (August, 2020): 103–15, https://doi.org/10.4067/s0718-27242020000200103.
269 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."

crop—a pod borer-resistant variety of the black-eyed pea.[270] This historic event is the result of 12 years of research and regulations of a public-private alliance with agencies such as the African Agricultural Technology Foundation (AATF).[271] Another example is Mexico, which in 2013 had 154 firms of biotechnology research and development, while in 2016, the number increased to 426.[272]

These countries have a very large agricultural potential for biotechnology. Throughout the debate, their main focus should be on looking into ways to promote research for these technologies in their local geography, as well as increasing accessibility to biotechnological knowledge. This bloc should work towards minimizing the socioeconomic and regulatory barriers that scientists and agricultural producers face, while still upholding bioethical principles. Finally, they must also work to continue promoting research in the field through public-private partnerships.

Countries with Prohibitions and Restrictions on the Use of Biotechnology for Disease and Pest Control

The last important group of countries to consider are countries that have put legal prohibitions and restrictions in place on the use of agricultural biotechnology. These are characterized by their heavy focus on the development of ethical standards and regulatory frameworks.[273] Their main priority is the prevention of the unwanted side effects that might appear after the use of biotechnological tools in agricultural production. Countries in this bloc usually have very limited use of biotechnologies for plant and biodiversity protection.

Most European countries fall within this category. This is because the European Union has very strict regulations on biotechnological practices, and most European countries have placed additional restrictions and prohibitions on top of the regional ones. Other countries that fall within this group include Peru, for example, which has strict prohibitions on the entry and use of GMOs in national territory. The moratorium law established in 2011 by farmers aims to protect biodiversity, family farming, and cultural traditions of farming.274 The law aims to protect the ancestral indigenous knowledge on how to select and conserve seeds or manage them. Protecting family agriculture and small-scale farmers is important in Perú as 97 percent of the agricultural units of the state. The GMO-Free Peru Platform movement was created in 2007 and, nowadays, is composed of more than 30 civil society organizations.

This bloc should focus on branching out of traditional biotechnology. Furthermore, these countries must put their efforts into supporting farmers and promoting spaces that allow the transmission of sustainable knowledge in agriculture.

Committee Mission

The Commission for Science and Technology for Development has the goal of helping developing countries and all people who lack access and opportunity to benefit from scientific innovation and novel technologies.275 At a time when global demands on the agricultural sector are increasing, and arable resources are becoming more and more scarce, it is vital to make safe and environmentally responsible crop protection tools available to all. Delegates should look for ways to make these biotechnologies and the knowledge on how to operate them accessible to farmers regardless of their location or socioeconomic status. The Commission should focus on making recommendations for countries to integrate different emerging technologies into the cultural practices already in place to enhance existing frameworks. For this purpose, approaching crop protection through Integrated Pest Management is essential.

Additionally, delegates must discuss ways to foster the entry of these technologies into global markets while still effectively

270 Ama Kudom-Agyemang, "Ghana releases first biotech crop: the Pod Borer Resistant Cowpea," *EnviroNews Nigeria*, July 25, 2024, https://www.environewsnigeria.com/ghana-releases-first-biotech-crop-the-pod-borer-resistant-cowpea/.
271 Kudom-Agyemang, "Ghana releases first biotech crop: the Pod Borer Resistant Cowpea."
272 OECD, "Emerging technology indicators."
273 Ameco Research, "Gene Editing Market Poised for Tremendous Expansion: Projected Growth to USD 28.4 Billion by 2032."
274 IFOAM - Organics International e.V., "How Peru Is Keeping GMOs Out of Its Soils," Organic Without Boundaries, August 20, 2020, https://www.organicwithoutboundaries.bio/2020/08/14/peru-fights-to-keep-gmos-out-of-its-soils/.
275 "Mandate and Institutional Background," UNCTAD, accessed August 8, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development/mandate.

regulating them to protect the environment. The prevention of resistant pests, the preservation of biodiversity, and the minimization of pollution should be prioritized throughout the debate. Recommendations on the improvement of current regulations are immensely relevant to the discussions.

Delegates are tasked with finding the balance between scientific advancement and the careful protection of both the environment and the economy of the farming industry around the globe. The loss of agricultural yield due to pests and disease and the subsequent arising need for crop protection is a multifaceted issue. It has branches in economics, ecology, policy, and government.[276] As a subsidiary organ of the Economic and Social Council, the Commission does not have the power to take any direct action on the issue at hand. Rather, it issues recommendations that countries can implement. Therefore, delegates must suggest ways for all of these sectors to cooperate to achieve a common goal.

Glossary

Abiotic *(adj.)* – Non-living elements that interact with and affect living things (e.g., water, temperature, light).

Bt *(abbr.)* – *Bacillus thuringiensis,* a bacterium that produces proteins lethal to lepidopterans when ingested; also used as a prefix for genetically modified crops containing this protein.

Gene *(n.)* – The basic unit of inheritance, containing information for protein production.

GMO *(abbr.)* – Genetically Modified Organism.

Lepidopteran *(n.)* – The group of insects including butterflies and moths.

Mutation *(n.)* – A naturally occurring change in an organism's DNA sequence.

Phenotype *(n.)* – The observable or measurable traits of an organism or population.

Selective Breeding *(n.)* – The practice of breeding organisms to produce offspring with desirable traits.

Selective Pressure *(n.)* – The extent to which organisms with certain traits are favored or eliminated by environmental demands; indicates the intensity of natural selection.

Superweed *(n.)* – A weed that is resistant to herbicides.

Till *(v.)* – To turn the soil, aerating it and removing weeds and insects.

Transgene *(n.)* – A gene from one species inserted into the DNA of another species.

Transgenic *(adj.)* – An organism containing a transgene.

Weed *(n.)* – Any undesirable plant for farmers that reproduces quickly.

IPM *(abbr.)* – Integrated Pest Management.

Biomagnification *(n.)* – Accumulation of toxins within a food chain.

Bioaccumulation *(n.)* – Accumulation of toxins within an organism.

276 Argüelles and March, "Weeds in action: Vegetal political ecology of unwanted plants," 44-66.

CSTD

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TOPIC B: UTILIZING SPACE TECHNOLOGY FOR SUSTAUNABLE DEVELOPMENT

Photo Credit: NASA/Crew of STS-132

Introduction

Space technology is loosely defined by the United Nations Economic and Social Council (ECOSOC) as "the technology in satellites and ground systems used by space scientists to study the universe and the Earth."[1] Once considered a distant science-fiction concept, space technology is rising rapidly in popularity worldwide. Since the first time humans began reaching for the stars in the 1960s, over 77 countries have independent space programs; 16 can send an object into outer space, and seven can send an object to extraterrestrial locations like the moon, Mars, and beyond.[2] Nevertheless, it is a growing sector. It is estimated that since 2000, more than 35 states launched their space programs and agencies. During the last decade, space launch attempts have increased by 277 percent around the world.[3] These numbers are estimated to rise in the next few years, with the global space economy rising from USD 630 billion in 2023 to USD 1.8 trillion in 2035.[4] In addition, more and more countries are expected to develop space agencies very soon.[5] The reason why countries seem keen on developing space programs and investing a huge amount of money into space technology is because it has been found to address many different global challenges.[6]

The space sector is constantly innovating and producing technology that could benefit the health of populations and the environment, so the ability of space technology as a tool to achieve the Sustainable Development Goals (SDGs) is highly valued.[7] Although space technology has a range of global applications, it is important to remember that while we attempt to make progress on the SDGs, space itself is still a limited resource. Space cannot help us preserve the planet and its people unless we maintain the health of space itself, of which we have several legislative attempts. Documents like the Outer Space Treaty, the Artemis Accords, and several other conventions and agreements have been somewhat successful, but as space activity evolves, they lack enforcement measures.[8] The Commissions on Science and Technology for Development (CSTD) will focus on the potential of space technology and its different applications in achieving the 2030 Sustainable Development Goals. Therefore, the challenges of space technology should focus on regulations, the likelihood of global collaboration in space technology, and the development of programs for more countries to access space technology.

Space technology is not only led by government agencies like NASA, ESA, and Roscosmos. Recently, private companies like SpaceX and Blue Origin have had an impact on the industry. Space activity as known, was born in the 1960s, and up till recently, its main focus has been on research and development. A milestone occurred in May 2020; SpaceX made history by being the first private space company to send humans into space.[9] This marked a shift towards the commercialization of space. What started as a race to the moon has transformed into a more accessible industry. Satellites launched per year have grown at a rate of 50 percent. Launch costs have fallen 10-fold over the last 20 years. With cheaper costs and more

1 Shamika N. Sirimanne, Dong Wu, Bob Bell, Katalin Bokor, Nadine Mizero Hakizimana, *Exploring Space Technologies for Sustainable Development* (Geneva: United Nations Conference on Trade and Development, 2021), https://unctad.org/system/files/official-document/dtlstict2021d1_en.pdf.
2 "Countries with Space Programs 2024", World Population Review, accessed August 11, 2024, https://worldpopulationreview.com/country-rankings/countries-with-space-programs.
3 Barry Elad, "Space Technologies Statistics By Satellite Orbit, Country and Innovations," Coolest Gadgets, last modified, June 24, 2024, https://www.coolest-gadgets.com/space-technologies-statistics.
4 Nikolai Khlystov, Gayle Markovitz, "Space is booming. Here's how to embrace the $1.8 trillion opportunity," *World Economic Forum,* April 8, 2024, https://www.weforum.org/agenda/2024/04/space-economy-technology-invest-rocket-opportunity/.
5 Julia Seibert, "Countries with Space Programs: An Overview," *Space Impulse*, November 27, 2023, https://spaceimpulse.com/2023/11/27/countries-with-space-programs-an-overview/.
6 Commission on Science and Technology for Development, *Report on the twenty-third session*.
7 Simonetta Di Pippo, "Space Technology and the Implementation of the 2030 Agenda," United Nations Chronicle, December 2018, https://www.un.org/en/chronicle/article/space-technology-and-implementation-2030-agenda.
8 Di Pippo, "Space Technology and the Implementation of the 2030 Agenda."
9 Matthew Weinzierl, "The Commercial Space Age Is Here." Harvard Business Review, September 28, 2023, https://hbr.org/2021/02/the-commercial-space-age-is-here.

satellite launches, innovation has become more accessible.[10]

Space may have the power to shape the future, but only if it works in tandem with the practices of now. Current efforts to attain the Sustainable Development Goals should not be dismissed but improved upon with the use of space technology so the SDGs can be achieved by 2030. Space technology is crucial in the achievement of different goals, such as climate action, zero hunger, and sustainable cities, among others. However, as the space sector grows, it becomes more congested and complex. New challenges arise and should not be ignored: space waste management, the regulation of the use of space by different countries, and including private companies in the sector. Therefore, efforts to dismantle socioeconomic barriers and foster global unity are more important than ever. Only through international cooperation and effective space governance can delegates ensure that this shared resource benefits all humanity and contributes significantly to achieving the SDGs by 2030.

History and Description of the Issue

Evolution of Space Technology

Space technology has come a long way since philosophers began pondering the mysteries of the cosmos hundreds of years ago. Even over the past few decades, space technology has progressed from the launch of Sputnik to moon landings and advanced space vehicles.[11] Space technology is usually referred to as anything that can help support infrastructure and exploration in space. Although space technology is typically thought of as space stations and spacecraft, it can also include things like satellites, antennas, and radios, and even solar panels.[12] Many of the technologies on Earth we think of as common were either developed through space research or could be considered space technology.

The first milestones in space technology can be traced back to the 1930s, when Nazi Germany began developing long-distance rockets to use as weapons, although these endeavors were unsuccessful.[13] After World War II, the United States and the Soviet Union created their space programs to expand their artilleries, which marked a significant shift in the global attitude toward space development. Space had always been viewed as an arena for scientific discovery, but after the battle between the USSR and the United States, the opportunities that space could bring became much more apparent to leaders of the world.[14] Namely, the technology that was formerly "science fiction" was quickly becoming a reality.

Sputnik was launched by the Soviet Union in 1957, and was the first artificial satellite to successfully orbit Earth.[15] This began the Space Race, which was a battle between the USSR and the United States to see who had the superior spaceflight technology. They had previously been fighting to see who could develop an intercontinental ballistic missile (ICBM) first, but the agenda changed when Sergei Korolev, a Soviet rocket engineer and spacecraft designer, invented the R7 rocket, which carried an ICBM into space.[16] Four years later, the Soviet Union held the next milestone of having the first human orbit the Earth in 1961. However, the Space Race did not conclude until 1969, when the United States landed a man on the moon and was declared the unofficial victor. Because of the Soviet Union's four failed attempts to launch a lunar-bound spacecraft, the US's more successful space programs were heavily observed by the world.[17] Between 1969 and 1972, the US launched six more Apollo missions to explore the moon.[18] The United States's National Aeronautics and Space

10 World Economic Forum, "Space Is Booming. Here's How to Embrace the $1.8 Trillion Opportunity," April 8, 2024, https://www.weforum.org/agenda/2024/04/space-economy-technology-invest-rocket-opportunity/.
11 Jonathan O'Callaghan, "What's next in space," *MIT Technology Review*, December 22, 2022, https://www.technologyreview.com/2022/12/22/1065722/whats-next-in-space-in-2023/.
12 Mark A. Garcia, "Top Five Technologies Needed for a Spacecraft to Survive Deep Space," *NASA,* July 30, 2018, https://www.nasa.gov/missions/artemis/orion/top-five-technologies-needed-for-a-spacecraft-to-survive-deep-space/.
13 "A Brief History of Space Exploration." Aerospace, accessed July 2, 2024. https://aerospace.org/article/brief-history-space-exploration.
14 "The Space Race," History.com, last modified February 21, 2020, https://www.history.com/topics/cold-war/space-race.
15 Freddie Wilkinson, "The History of Space Exploration," *National Geographic*, accessed July 10, 2024, https://education.nationalgeographic.org/resource/history-space-exploration/.
16 Wilkinson, "The History of Space Exploration."
17 History.com, "The Space Race."
18 *Aerospace, "A Brief History of Space Exploration."*

Administration, or NASA, became one of the world's premier space technology developers during this period.

Following the Space Race, there was an international desire to continue developing space technology. In 1984, President Reagan of the United States instructed NASA to begin building the International Space Station (ISS).[19] The ISS had many different purposes: to conduct microgravity research, Earth observations, and serve as a servicing base for space vehicles.[20] It was also largely successful at accomplishing these long-term objectives, and the ISS continues to conduct research, collect data, and service vehicles since its conception.[21] Over the next ten years, the ISS would become the largest international cooperation project in the history of space technology. Ten European countries, Canada, Japan, the United States, and Russia all collaborated on the ISS, and as of 2024, the ISS has been orbiting the Earth for over 25 years.[22] Because of this record-breaking achievement, space technology has been acknowledged not only as a key aspect of scientific research but also as a tool to inspire international cooperation.

Among NASA's greatest achievements is the Deep Space Network (DSN). It was established in 1958, following the onset of the Space Race. NASA defines DSN as an "international array of giant radio antennas that supports interplanetary spacecraft missions."[23] It consists of three facilities: one in Goldstone, California, one near Madrid, Spain, and one near Canberra, Australia.[24] These sites were carefully chosen to allow constant communication between spacecraft and satellites. As the planet rotates, if one DSN site disappears from view, another will quickly come back into view and continue communication.[25] The DSN enables almost all deep space missions because, without its ability to obtain information from outer space, we would not be able to control spacecraft, satellites, or command missions.

Many other feats of space technology have been accomplished in recent years. In 2022, a global research team called the Event Horizon Telescope Collaboration used a worldwide network of radio telescopes to take the first-ever image of a black hole.[26] This achievement was a long-anticipated one and offered many new insights into how things occur in the center of our galaxy. The ability to take a picture of a black hole allows for a deeper understanding of the universe as a whole and the ability to visualize how things move and interact around the solar system.[27] Satellites also help to create imagery for what the universe looks like beyond our current understanding. The universe is unfathomably vast and still very unknown–it is estimated that we have only explored about five percent of space, so we have a very limited understanding of the cosmos currently.[28] If we expand our horizons and continue to branch out into space, we can potentially discover means to optimize resource management on Earth, find out if other planets are habitable for human life, and build stronger relationships between countries of the planet.[29]

Since the launch of the first satellite in 1957, thousands of other satellites have been launched into outer space. As of July 2024, there are 10,262 satellites orbiting Earth.[30] Many of these satellites are SmallSats, which is a class of satellites all weighing under 180 kilograms.[31] One type of SmallSat, called a CubeSat, is a nanosatellite weighing between one

19 "History and Timeline of the ISS," ISS National Laboratory, accessed July 10, 2024, https://www.issnationallab.org/about/iss-timeline/.
20 John Uri, "Space Station 20th: Historical Origins of ISS," *NASA*, January 23, 2020, https://www.nasa.gov/history/space-station-20th-historical-origins-of-iss/.
21 Uri, "Space Station 20th: Historical Origins of ISS."
22 "Building the International Space Station," The European Space Agency, accessed July 10, 2024, https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/Building_the_International_Space_Station2.
23 Heather Monaghan, "What is the Deep Space Network?" *NASA*, March 30, 2020, https://www.nasa.gov/directorates/somd/space-communications-navigation-program/what-is-the-deep-space-network/.
24 Monaghan, "What is the Deep Space Network?"
25 Monaghan, "What is the Deep Space Network?"
26 "Astronomers Reveal First Image of the Black Hole at the Heart of Our Galaxy," Event Horizon Telescope, accessed July 10, 2024, https://eventhorizontelescope.org/blog/astronomers-reveal-first-image-black-hole-heart-our-galaxy.
27 Event Horizon Telescope, "Astronomers Reveal First Image of the Black Hole at the Heart of Our Galaxy."
28 Pablo Carlos Budassi, "A Logarithmic Map of the Entire Observable Universe," *Visual Capitalist*, July 1, 2022, https://www.visualcapitalist.com/cp/map-of-the-entire-known-universe/.
29 Elena Stone, "10 Benefits of Space Exploration. (Including Medical and Economical)," *Little Astronomy*, May 10, 2022, https://littleastronomy.com/benefits-of-space-exploration/.
30 "Active satellite orbit data," Orbiting Now, accessed July 10, 2024, https://orbit.ing-now.com/.
31 "What are SmallSats and CubeSats?" NASA, accessed July 10, 2024, https://www.nasa.gov/what-are-smallsats-and-cubesats/.

Space shuttle launch
Credit: NASA; Edited by jjron

and ten kilograms. Developed in 1999, these are the most popular form of SmallSats because they are cost-effective and still capable of handling deep space missions. SmallSats are also very useful for educational purposes since they are a good model of an efficient satellite design, so students and educational facilities can use them to conduct space missions and learn how to optimize space studies.[32]

Another form of space technology that helps to capture imagery of deep space is the Hubble Space Telescope. Hubble was designed in 1990 as a general-purpose observatory and has since taken over 1.6 million photos of deep space.[33] Additionally, Hubble is capable of taking extremely high-quality images of deep space with more wavelengths depicted and less distortion. Because of this, many photos taken by Hubble are very colorful and detailed.[34] Observation plays a large role in innovation when it comes to space technology, but another primary reason is exploration.

Starting from the ground, launch vehicles are large, rocket-powered machines capable of taking a spacecraft beyond Earth's atmosphere.[35] The first launch vehicles were developed by the United States in 1958 to propel Explorer one into space. At the time, launch vehicles were designed to be expendable, but attempts to make reusable launch vehicles have been somewhat successful as countries expand their sustainability objectives. So far, China, the Democratic People's Republic of Korea, India, Israel, Iran, Japan, the Republic of Korea, Russia, the United States, and countries in the European Space Agency have all successfully developed and tested launch vehicles.[36]

Ion Propulsion is another piece of space technology capable of thrusting spacecraft deep into outer space by accelerating ions found in xenon fuel.[37] Previously, launch vehicles used chemical engines to accelerate, but ion propulsion presented many benefits to launches.[38] Ion thrusters deliver about ten times more thrust than chemical engines, which makes them accelerate much faster. Most importantly, chemical engines were only capable of burning fuel fast and pushing space vehicles a short distance until they gained enough velocity to enter outer space. Ion propulsion, however, could use the

32 NASA, "What are SmallSats and CubeSats?"
33 "Why Have a Telescope in Space?" NASA, accessed July 10, 2024, https://science.nasa.gov/mission/hubble/overview/why-have-a-telescope-in-space/.
34 NASA, "Why Have a Telescope in Space?"
35 John M. Logsdon, "launch vehicle," Britannica, last modified April 23, 2023, https://www.britannica.com/technology/launch-vehicle.
36 Logson, "launch vehicle."
37 "Dawn," NASA, accessed July 10, 2024, https://science.nasa.gov/mission/dawn/technology/ion-propulsion/.
38 "The magic of ion engines," European Space Agency, accessed August 19, 2024, https://www.esa.int/Science_Exploration/Space_Science/SMART-1/The_magic_of_ion_engines.

energy emitted from a small amount of fuel to push vehicles for months on end, making them a very sustainable approach considering the 180 or more launches that occur every year.[39] Ion propulsion systems were revolutionary for this reason–they broadened our horizons from nearby celestial bodies to beyond our solar system.[40] One notable use of ion propulsion, the Dawn Spacecraft, managed to circle the dwarf planet Ceres and the asteroid Vesta, which gave insights into the early stages of the solar system.[41]

Landing space vehicles on the moon is considered a massive feat for humanity. Neil Armstrong and Buzz Aldrin's arrival on the moon was a spectacular accomplishment for all of humanity, but vehicles have made it even further. Two identical NASA rovers, Spirit and Opportunity, landed on Mars in 2004 to assess conditions on Mars and determine whether they were conducive to life.[42] Spirit lasted over six years on Mars, collecting over 100,000 images of its landscape. Opportunity lasted over 14 years and collected over 200,000 images of Mars.[43] These two vehicles confirmed an incredible theory: that in ancient times, Mars held water on its surface.[44] Since the Spirit and Opportunity mission, a new objective to prove that microbial life existed on Mars has begun its mission. If we find these organisms on Mars, it could change the way we view the entire universe. If life exists on Mars, it could suggest that life is not unique to Earth and that there may be other life forms elsewhere in the cosmos. Additionally, finding bacteria on Mars could provide fascinating insight into Earth's history since the two are formed from the same solar nebula.[45] Learning about how life on Mars can survive or how it was potentially wiped from the planet can help discover ways to protect the integrity of the Earth.[46] Two new vehicles are still active on Mars: Curiosity, which landed in 2012, and Perseverance, which landed in 2018.[47] Several other vehicles have visited the moon, although none accomplished as much as these four NASA-monitored rovers. In 2021, a space probe known as the Parker Solar Probe flew through the Sun's upper atmosphere and sampled the magnetic field there.[48] Parker became the first space vehicle to "touch the sun" and has gotten closer to our sun than any vehicle in the past.

The Benefits and Capabilities of Satellites

Satellites were among the first pieces of space technology to be invented and remain the most prevalent in our atmosphere. Satellites are communication systems with the ability to receive signals from Earth using radio waves. One of the primary purposes of satellites is to promote global connectivity. Since their conception, satellites have revolutionized the way we communicate by quickly transmitting data over large distances. Satellites are classified by their heights in the atmosphere–they can be either low Earth orbit (LEO), medium Earth orbit (MEO), high Earth orbit (HEO), or Geostationary. LEO satellites are used for scientific research, MEO satellites are used for navigation and observation, and HEO satellites are used for weather and communication.[49] Geostationary satellites are fixed to one position in the atmosphere and are used mostly for television broadcasting, although they are also used to track atmospheric conditions in one location.[50] If satellites cannot withstand the extremely low temperature and pressure of space, they could quickly become damaged and, therefore, useful. Because of this, all the different varieties of satellites have been carefully designed and modified over decades of research to ensure that they can withstand high

39 European Space Agency, "The magic of ion engines."
40 "Ion Propulsion," NASA, accessed July 10, 2024, https://www.nasa.gov/wp-content/uploads/2015/08/ionpropfact_sheet_ps-01628.pdf.
41 NASA, "Dawn."
42 "Mars Exploration Rovers: Spirit and Opportunity," NASA, accessed July 10, 2024, https://science.nasa.gov/mission/mars-exploration-rovers-spirit-and-opportunity/.
43 NASA, "Mars Exploration Rovers: Spirit and Opportunity."
44 NASA, "Mars Exploration Rovers: Spirit and Opportunity."
45 Shige Abe, "Scientists Find Evidence of Ancient Microbial Life on Mars," *Astrobiology at NASA*, accessed August 19, 2024, https://astrobiology.nasa.gov/news/scientists-find-evidence-of-ancient-microbial-life-on-mars/.
46 Abe, "Scientists Find Evidence of Ancient Microbial Life on Mars."
47 "Mars Science Laboratory: Curiosity Rover," NASA, accessed July 10, 2024, https://science.nasa.gov/mission/msl-curiosity/.
48 "Parker Solar Probe," NASA, accessed July 11, 2024, https://science.nasa.gov/mission/parker-solar-probe/.
49 Holli Riebeek, "Catalog of Earth Satellite Orbits," NASA, last modified September 4, 2009, https://earthobservatory.nasa.gov/features/OrbitsCatalog.
50 "How Satellite Communication Works for Global Connectivity," Global Satellite Group, last modified January 24, 2024, https://globalsatellite.us/how-satellite-communication-works-for-global-connectivity/.

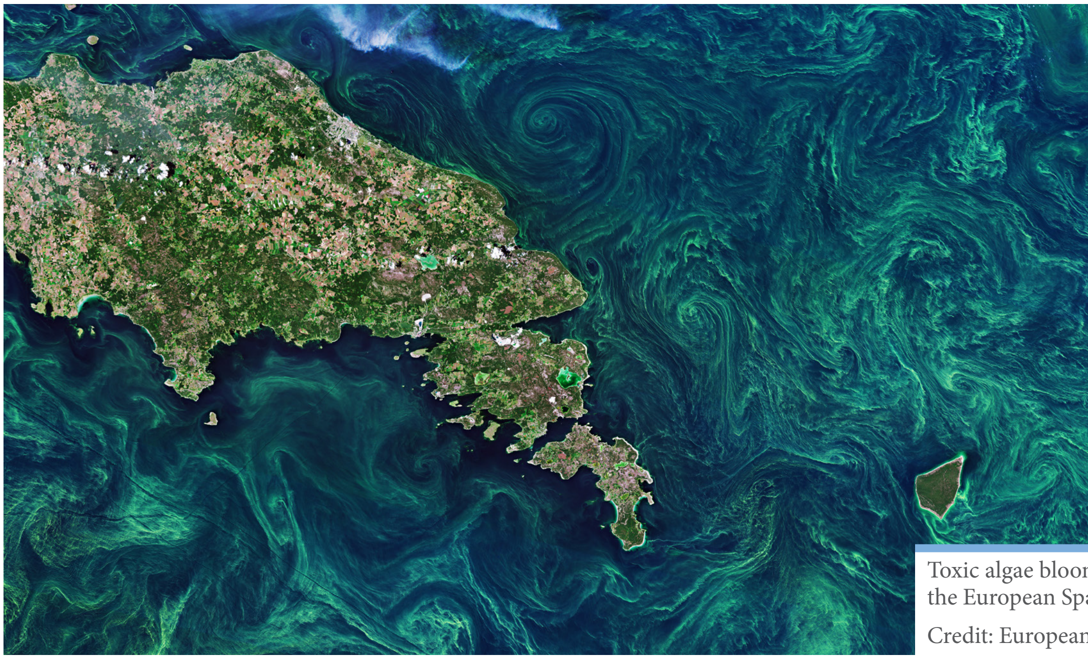
velocities and space's harsh conditions.[51] As of July 2024, over 80 countries have launched and operated at least one satellite.[52] The versatility of satellites prompted progress in telecommunication, broadcasting, and data communication services since satellites primarily deal in those sectors. However, the applications of satellites go far beyond what we would typically expect.

Satellites are especially innovative because they are not ground-based, so they are not limited to technologies found on Earth. For example, in a natural disaster, satellites can easily communicate with mobile technologies because they constantly monitor and are unaffected by the events that occur on Earth's surface.[53] In 2023, the Emergency Events Database, an open-access database aided by the UN, reported 399 natural disasters, which resulted in 86,473 casualties.[54] To combat these high numbers and prepare civilians for evacuations, NASA launched Landsat in 1972, a series of satellites orbiting Earth that constantly takes pictures and updates scientists with data. Landsat is used to keep records of Earth's changing surface and assess the danger level of natural disasters.[55] In one such case, Landsat data was collected from satellites observed in areas in Alaska, Antarctica, and Greenland to determine the rate at which glaciers were changing and how fast ice was flowing in the area.[56] By constantly transmitting images and data down to scientists, these satellites are helping scientists discover the rate of global warming and how these ice flows are impacting the surrounding area.[57] This concept is known as remote sensing, and it enables government authorities and the public to anticipate disasters and react accordingly.

Remote sensing satellites make up approximately one-third of all satellites currently in orbit.[58] These satellites are fitted with cameras and heat sensors to take all kinds of different photos and maps of the Earth's surface. Remote sensing satellites can have one of two different sensors on them: passive sensors or active sensors. Passive sensors can read almost all across the electromagnetic spectrum, which includes visible light, infrared light, and ultraviolet light.[59] However, they cannot penetrate dense cloud covers, which limits their ability to constantly transmit data down to Earth because there are places the passive sensors cannot read. To combat this issue, passive sensors are used more to read ozone levels and the chemical composition of the atmosphere than areas on the Earth's surface. Active sensors, on the other hand, use different types of radar detectors and only function in the microwave band of the electromagnetic spectrum.[60] Because of this, they can penetrate cloud cover and the dense layers of Earth's atmosphere, which allows them to be constantly transmitting data down to Earth.

These satellites are also capable of reading the electromagnetic fields on Earth without disturbing those areas. This allows scientists and engineers to collect data and monitor all kinds of natural phenomena, like the effects of climate change on the planet or the results of natural disasters.[61] Snow, ice, vegetation, soil, and bodies of water all reflect a certain amount of light, and satellites are adept at reading how much light is being absorbed or reflected by each one of those surfaces, as well as if climate change is impacting how much heat and light the Earth's surface absorbs. Because of the constant stream of data that satellites positioned all over the atmosphere are sending, scientists can create comprehensive data sets with as little bias as possible. In California and Bangladesh, remote

51 Virgil Labrador, "How satellites work," *Britannica*, last modified March 12, 2024, https://www.britannica.com/technology/satellite-communication/How-satellites-work.
52 "List of first satellites by country," Wikipedia, accessed July 12, 2024, https://en.wikipedia.org/w/index.php?title=List_of_first_satellites_by_country&oldid=1231810712.
53 "Disaster Management," NASA, accessed July 11, 2024, https://landsat.gsfc.nasa.gov/benefits/disaster-management/.
54 *2023 Disasters in numbers* (Brussels: Centre for Research on the Epidemiology of Disasters, 2023), https://files.emdat.be/reports/2023_EMDAT_report.pdf.
55 NASA, "Disaster Management."
56 Kate Ramsayer, "Landsat Provides Global View of Speed of Ice," *NASA*, December 12, 2016, https://landsat.gsfc.nasa.gov/wp-content/uploads/2019/02/Climate__Case-Studies2018.pdf.
57 Ramsayer, "Landsat Provides Global View of Speed of Ice."
58 *Six ways space technologies benefit life on Earth*, (Geneva: World Economic Forum, 2020), https://www3.weforum.org/docs/WEF_GFC_Six_ways_space_technologies_2020.pdf
59 Cynthia Hall, "What is Remote Sensing?" NASA, last modified January 3, 2024, https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing.
60 Hall, "What is Remote Sensing?".
61 "Advantages and Disadvantages of Remote Sensing: Understanding the Limits of a Powerful Technology," Skywatch, January 9, 2024, https://skywatch.com/advantages-and-disadvantages-of-remote-sensing-understanding-the-limits-of-a-powerful-technology/.



Toxic algae blooms around the Baltic Sea, captured by the European Space Agency's Copernicus satellite.

Credit: European Space Agency

sensing satellites helped scientists independently come up with a pattern for when harmful algal blooms and cholera bacteria would appear in waterways, and they developed an early warning system to prevent illnesses in the population.[62]

Not only do remote sensing satellites aid in early warning systems, but they are also capable of examining the post-disaster impacts on a region. In 2023, Landsat data was used by groups of scientists along coastal North and South America to study sediment deposits and erosion patterns to see how natural disasters were impacting populations.[63] The use of satellites was crucial for this particular study because the areas had been affected by hurricanes and were completely inaccessible. By using satellite data and imagery, the researchers were able to conclude the best times for coastal restoration efforts and disaster relief, helping locals recover their communities and landscapes in the best possible way.[64] Because satellites can warn for signs of environmental disasters and help scientists recover from those disasters, they have been acknowledged by the United Nations as a tool to achieve the 2030 Sustainable Development Goals.[65] As we have seen, satellites and other space technologies are capable of providing insight into the universe and the birth of our planets, providing data on the best opportunities for disaster management and humanitarian aid, and promoting the development of more advanced space technology.

Another interesting benefit of satellites is that their location is inaccessible to countries on the planet. Satellites operate in a "No-Man's land," which means no country can claim a region of space as their own–as agreed upon in the Outer Space Treaty.[66] Because of this, satellites can view any area on Earth with ease, and the data they record goes into open-access databases for everyone to see. In one instance, satellite imagery was used to track deforestation efforts in Peru and Brazil.[67] In 1988, the Brazilian government began using Landsat satellite

62 Sarah Beam Aldy, "VALUABLES Quantifies Satellite Benefits to Earth Science Projects," NASA, September 8, 2023, https://appliedsciences.nasa.gov/our-impact/story/valuables-quantifies-satellite-benefits-earth-science-projects.

63 Marcelo Cancela Lisboa Cohen, Adriana Vivan de Souza, Kam-biu Liu, and Qiang Yao, "A timely method for post-disaster assessment and coastal landscape survey using drone and satellite imagery," *MethodsX* 10, no. 102065 (February 2023): 260-263, https://doi.org/10.1016/j.mex.2023.102065.

64 Cohen, Vivan de Souza, Liu, and Yao, "A timely method for post-disaster assessment and coastal landscape survey using drone and satellite imagery," 260-263.

65 Simonetta Di Pippo, "Space Technology and the Implementation of the 2030 Agenda."

66 United Nations General Assembly, Resolution 2222(XXI), Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, A/RES/2222(XXI), ¶ (Dec. 19, 1966), https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

67 Gabriel Popkin, "Satellite alerts track deforestation in real time," *Nature* 530, no. 7591 (February 2016): 392-393, https://doi.org/10.1038/530392a.

data to compare images and calculate how much logging was occurring in the Amazon. However, because of the lag between the time the images were taken and when researchers received them, in 2004, Brazil's National Institute for Space Research launched a new satellite imaging system. Over the next eight years, Brazil saw more than a 70 percent reduction in deforestation rates because imagery from the satellites was used as evidence in enforcing Brazil's Forest Code.[68]

In addition to combating deforestation, many companies have turned to remote sensing satellite imagery to track crop health. In many areas of the world, food safety and security are major issues that blight human health. In India, an agricultural technology company called Fasal has begun collecting satellite data to analyze weather and crop growth patterns.[69] With this technology, Fasal hopes to share this information with farmers and enable them to use water and pesticides more efficiently and sustainably. So far, they have implemented their devices on 10,000 acres of farmland, saved 82.8 billion liters of water, and increased crop yield by 40 percent in those 10,000 acres.[70]

Moving beyond the environmental benefits of satellites, they are also used to track urban growth and development. Urban areas account for roughly three percent of land on Earth, but they are responsible for over 70 percent of greenhouse gas emissions and energy consumption.[71] This disproportionate impact that urban areas have on the environment has been acknowledged as a global issue by the United Nations for decades, and recently, satellites have been recognized as a means to prevent further urban expansion. By monitoring land use and offering detailed views of urban areas, researchers and authorities can use satellite data to make informed decisions to promote sustainable growth of cities and prevent urban sprawl.[72]

In 2023, a group of researchers studied data collected from remote sensing satellites over Lagos City, Nigeria. They found that from 2000 to 2020, there was a significant reduction in grasslands and shrublands and a significant increase in artificial surfaces and urban structures.[73] Predictive models and data patterns were forwarded to researchers in the area to mitigate the negative impacts of urban expansion seen in this study. The hope is that the contents of the study will help them guide local governments in making sustainable legislation. Cases like these, and many others, are the backbones of creating laws that promote environmentally conscious and sustainable growth of urban areas, which directly correlates with several Sustainable Development Goals.

Inventions that Resulted from Space Technology

From cell phone cameras to artificial limbs, space exploration has influenced the technology found in our everyday lives.[74] Since the 1960s, NASA's work to enhance space technologies has led to hundreds of new inventions, many of which we are very familiar with. In addition, because investing in space technology has led to improvements in our daily lives, many believe that investing in space technology has the potential to help us achieve the 2030 Sustainable Development Goals.[75]

Many NASA-related inventions contribute to Sustainable Development Goal 3, which is to ensure healthy lives and promote well-being for all ages. In 1991, Diatek Corporation of San Diego released the first infrared ear thermometer. This type of thermometer can read someone's internal body

68 Aldy, "VALUABLES Quantifies Satellite Benefits to Earth Science Projects".
69 Akarsh Saxena, "Crop Health Assessment Using Satellite Imagery and Remote Sensing," *Medium*, December 8, 2020, https://medium.com/fasalapp/crop-health-assessment-using-satellite-imagery-2dcc57f76f33.
70 "How Fasal works?" Fasal, accessed August 19, 2024, https://fasal.co/.
71 "Cities and Climate Change," UN Environmental Programme, accessed July 12, 2024, https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities-and-climate-change.
72 Christian Hoffman, Maria Lemper, "Satellite Applications for Sustainable Urban Planning and Management," *Satellite-Based Earth Observation* 4, no. 15 (September 2018): 147-156, https://doi.org/10.1007/978-3-319-74805-4_15.
73 Katabarwa Gilbert and Yishao Shi, "Urban Growth Monitoring and Prediction Using Remote Sensing Urban Monitoring Indices Approach and Integrating CA-Markov Model: A Case Study of Lagos City, Nigeria," *Sustainability* 16, no. 1 (December 2023): 30, https://doi.org/10.3390/su16010030.
74 Erin Mahoney, "Human Spaceflight Technologies Benefitting Earth," NASA, April 22, 2022, https://www.nasa.gov/missions/station/iss-research/human-spaceflight-technologies-benefitting-earth/.
75 Jacob Margolis and Christopher Intagliata, "Space Spinoffs: The Technology To Reach The Moon Was Put To Use Back On Earth," *NPR*, July 20, 2019, https://www.npr.org/2019/07/20/742379987/space-spinoffs-the-technology-to-reach-the-moon-was-put-to-use-back-on-earth.

temperature by measuring the energy emitted from their eardrum.[76] The Diatek Corporation worked alongside NASA's Jet Propulsion Laboratory to develop the thermometer after seeing how the same infrared technology was used to measure the temperature of stars and planets.[77] This piece of technology was especially useful because it was extremely fast, accurate, and reduced the risk of cross-contamination.[78] These thermometers also reduce the risk of infection because they do not come into contact with any bodily fluids or mucous membranes.[79] Because of this, they became widespread in doctors' offices and among family households, and their digital displays allowed temperature readings to be converted from Celsius to Fahrenheit.[80] The creation of the infrared ear thermometer directly correlates to Sustainable Development Goal 3, which includes the aim to end preventable deaths from infectious diseases.[81] A common symptom of most communicable diseases is a fever, and by using an infrared ear thermometer, doctors may be able to form quicker and more accurate diagnoses.[82]

There are several other everyday sources of space technology, including baby formula and emergency blankets. While designing food for Mars missions in the 1980s, NASA attempted to use algae as a method of preserving food in deep space.[83] Although this endeavor ended up as a failure, they managed to accidentally engineer the omega-3 fatty acid found in breast milk. Now, this fatty acid is found in 90 percent of baby formulas produced in the United States and is added to milk substitute products and vitamin supplements.[84] Now, over 24 million babies worldwide have consumed this ingredient, which has been proven to improve brain function, visual development, and management of cardiovascular disease.[85] In 1964, NASA developed foil-like blankets for use in space emergency kits. Now, they are used by marathon runners after races to maintain their body temperature and by hikers and campers in case of freezing outdoor conditions.[86]

Due to the extremely harsh conditions of space, such as extremely low pressure and temperature, high radiation, and dense dust particles, NASA and other space agencies have dedicated intensive research to environmental control in space.[87] Since the 1950s, NASA has been interested in the idea of controlled environment farming (CEA).[88] CEA involves planting crops on structures that minimize space and simulating ideal growth conditions using greenhouse technology. They use artificial lighting, nutrient supplements, and temperature controls to ensure maximum growth output in these vertical farms. CEAs are also extremely resource-efficient because they recycle small amounts of water and energy over long periods.[89]

Originally, NASA wanted to optimize these agricultural systems to provide their astronauts with a consistent and low-maintenance food source for long space missions.[90] However, in the 1990s, the CEA industry began rapidly expanding.[91] Globally, the value of the CEA industry is projected to

76 Julie Cooper, "Infrared Ear Thermometer," *NASA Jet Propulsion Laboratory,* May 8, 2013, https://www.jpl.nasa.gov/blog/2013/5/infrared-ear-thermometer.
77 Don Vaughan, "Everyday Stuff Developed by NASA," *Britannica*, November 25, 2020, https://www.britannica.com/story/everyday-stuff-developed-by-nasa.
78 Vaughan, "Everyday Stuff Developed by NASA."
79 J.J. Nobel, "Infrared ear thermometry," *Pediatric Emergency Care* 8, no. 1 (February 1992): 54-58, doi.org/10.1097/00006565-199202000-00016.
80 Cooper, "Infrared Ear Thermometer."
81 "Health and Population," United Nations Department of Economic and Social Affairs, accessed July 22, 2024, https://sdgs.un.org/topics/health-and-population.
82 "Infectious diseases," Mayo Clinic, accessed July 22, 2024, https://www.mayoclinic.org/diseases-conditions/infectious-diseases/symptoms-causes/syc-20351173?sscid=71k8_pr0yp&.
83 Molly Wood and Kristin Schwab, "6 everyday inventions that were born from space tech," Marketplace, September 26, 2017, https://www.marketplace.org/2017/09/26/6-everyday-inventions-born-from-space-tech/.
84 Wood and Schwab, "6 everyday inventions that were born from space tech."
85 "Space Research Fortifies Nutrition Worldwide," NASA Spinoff, accessed August 19, 2024, https://spinoff.nasa.gov/Spinoff2008/ch_8.html.
86 Wood and Schwab, "6 everyday inventions that were born from space tech."
87 Mahoney, "Human Spaceflight Technologies Benefitting Earth."
88 "NASA Research Launches a New Generation of Indoor Farming," NASA Spinoff, November 23, 2021, https://spinoff.nasa.gov/indoor-farming.
89 NASA Spinoff, "NASA Research Launches a New Generation of Indoor Farming."
90 NASA Spinoff, "NASA Research Launches a New Generation of Indoor Farming."
91 Melissa Shahbandeh, "Indoor farming- statistics and facts," *Statista,* January 10, 2024, https://www.statista.com/topics/4467/indoor-farming/#topicOverview.

Three astronauts aboard the ISS drink water from the station's water recovery system
Credit: NASA

grow by over USD 17 billion in the next ten years.[92] One company, Plenty Unlimited Inc., has been expanding on the CEA technology originally developed by NASA. One vertical farming model they developed uses less than one percent of traditional farming practices' water, while still yielding the same harvest. Because the UN believes that the Earth's population will grow by about 2.3 billion people in the next 25 years, creating sustainable and efficient agricultural systems is critical if we want to preserve the state of the planet. Many industries also predict that we can improve food security through the continued development of space technologies.[93]

Space technology has also contributed to improving the state of Earth's air and water. In 1973, astronauts on Skylab, the United States' first space station, tested the air on the station and realized it had trace amounts of over 100 harmful chemicals.[94] To combat this, NASA tested a model structure similar to Skylab to test the ability of plants to eliminate toxic gas. Peace lilies, bamboo shoots, and other house plants were used in NASA buildings to clean the air. In the late 1980s, they had the idea to apply this same principle to water. They developed a plant-based water filtration system using pipes filled with aquatic hyacinths that were capable of clearing bacteria and microparticles from water. In addition to the plant-based system, NASA also developed an alternative water purification system by using fuel cells. These fuel cells were small tanks onboard the space station that used the chemical reaction between hydrogen and oxygen to generate water. Any bacteria that formed within the fuel cells would be eliminated through a small device that shot negatively charged silver ions and was then filtered out of the water.[95] Later on, Apollo bought the rights to this technology and adapted it to fit a wide range of structures. Public fountains, swimming pools, and aquarium tanks all use the adapted space technology to clear impurities and toxins from water sources. Because astronauts were not able to consistently manage these filtration systems, they were low-maintenance and very efficient.[96]

One of NASA's complex water processing systems is a part of the Environmental Control and Life Support System (ECLSS) that allows astronauts to survive for long periods in space.[97] This system specifically uses liquids produced by

92 Shahbandeh, "Indoor farming- statistics and facts."
93 NASA Spinoff, "NASA Research Launches a New Generation of Indoor Farming."
94 Tristan Hopper, "How has NASA helped us improve our air and water?" HowStuffWorks, last modified August 15, 2023, https://science.howstuffworks.com/innovation/nasa-inventions/nasa-improve-air-and-water.htm.
95 Hopper, "How has NASA helped us improve our air and water?"
96 Hopper, "How has NASA helped us improve our air and water?"
97 Melissa L. Gaskill, "NASA Achieves Water Recovery Milestone on International Space Station," *NASA*, June 20, 2023, https://www.nasa.gov/missions/station/iss-research/nasa-achieves-water-recovery-milestone-on-international-space-station/.

the body in a recycling process. In one part of the process, a dehumidifier catches moisture from breaths and sweat. Another part recovers water from urine by evaporating and separating it. Through these systems, water that astronauts produce can rehydrate them with only a two percent loss of water, which is why it is a critical part of the ECLSS.[98] Because they recycled water or relied on chemical reactions from the atmosphere, the adoption of these technologies could help achieve Sustainable Development Goals 6, clean water and sanitation, and 7, affordable and clean energy.

Another strategy for dealing with air pollutants is found in NASA's pollutant sensors. Originally developed as an early fire detection system for space vehicles, NASA created the Multi-Parameter Aerosol Scattering Sensor (MPASS).[99] MPASS is a tiny sensor box powered by a few batteries and equipped with powerful laser sensors and aerosol detectors. MPASS was quickly adapted to fit situations present on Earth due to its small size, convenience, and extreme accuracy. It is used to detect early volcanic and seismic activity, wildfires, and factory pollution. MPASS sensors have been attached to drones to detect aerosols, particulate matter, and other atmospheric toxins. MPASS is also used by firefighters, first responders, and public safety officials to detect immediate dangers and monitor their bodily health. Additionally, because of their compact nature and wireless capabilities, MPASS can be used to evaluate environments that humans cannot enter.[100] These applications, as with other space technologies, are applicable to several different Sustainable Development Goals and have the potential to be used much more widely than they currently are.

Past International Regulations

Since space exploration has grown in popularity in the past few decades, more and more space legislation and debate have occurred internationally. By far, the most widely recognized and prominent piece of space legislation is the Outer Space Treaty of 1967. The treaty is formally known as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.[101] In June of 1966, both the United States and the Soviet Union separately submitted drafts to the UN that detailed the uses of space. After several months of debate in the Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space, the treaty officially came into force on October 10, 1967.[102] As of July 2024, the Outer Space Treaty has been ratified by 111 states, making it legally binding for all those countries, meaning that it is legally enforceable.[103]

The main purpose of the Outer Space Treaty is to promote the peaceful use of space and international cooperation.[104] To achieve this, the Outer Space Treaty contains several articles covering the appropriate uses of celestial bodies. Article I states that the exploration and use of outer space should be for the benefit of all mankind without discrimination. It explicitly states that scientific investigation of space should not be limited to any country and promotes free access to outer space. The second article of the Outer Space Treaty is one sentence and prohibits any one state from owning any part of outer space. Article III declares that state members who ratify the treaty are subject to international law in the interest of maintaining international peace and security. Article IV bans the use of nuclear weapons or any weapons of mass destruction in space and allows the use of military personnel for scientific research. The rest of the Outer Space Treaty discusses individual liability and responsibility for incidents that occur in space. It also emphasizes international collaboration and communication about dangerous discoveries with the member states of the Treaty.[105]

98 Gaskill, "NASA Achieves Water Recovery Milestone on International Space Station."
99 "Multi-Parameter Aerosol Scattering Sensor (LEW-TOPS-19)," NASA Technology Transfer Program, accessed July 22, 2024, https://technology.nasa.gov/patent/LEW-TOPS-19.
100 NASA Technology Transfer Program, "Multi-Parameter Aerosol Scattering Sensor (LEW-TOPS-19)."
101 "Outer Space Treaty," Britannica, accessed July 21, 2024, https://www.britannica.com/explore/space/outer-space-treaty/.
102 Britannica, "Outer Space Treaty."
103 Sophie Goguichvili, Alan Linenberger, and Amber Gillette, "The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier?" *Wilson Center,* October 1, 2021, https://www.wilsoncenter.org/article/global-legal-landscape-space-who-writes-rules-final-frontier.
104 Goguichvili, Linenberger, and Gillette, "The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier?"
105 A/RES/2222(XXI).

Signing of the Outer Space Treaty in 1967
Credit: ITU

Although the Outer Space Treaty is considered the most comprehensive legislative work for space exploration, many have begun to criticize its relevance. As of 2024, the Outer Space Treaty is almost 60 years old. Because of this, some claim it is outdated and does not account for new advancements in space technology and exploration. Recently, private companies like SpaceX, Blue Origin, Boeing, and others have started competing for dominance in space. The first major issue with the Outer Space Treaty is that it needs to take into account these private organizations. Because the companies are not beholden to the rules outlined in the Outer Space Treaty, they could bring nuclear weapons and cause mass amounts of damage to property in space. Another criticism of the Outer Space Treaty is that the terms defined in the original document have evolved in meaning. Each article in the Treaty is also quite short and vague and does not define what knowledge or discoveries are considered dangerous or exceptionally important.[106] These criticisms of the Outer Space Treaty were largely seen as valid and generated several other treaties to resolve the issues.

Less than a year after the ratification of the Outer Space Treaty came the Rescue Agreement, formally known as the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.[107] It focused specifically on the safety and well-being of astronauts during space missions. The language of the Rescue Agreement is more enduring than the Outer Space Treaty, which allows for less confusion. It essentially states that if an astronaut or object from one country lands in another country, then that country must ensure the safe and speedy return of the astronaut or object to the country of origin. Despite the uncontroversial nature of this Agreement, it still fails to address what would happen in the case of a damaged object or injured astronaut.

To fix this, the Liability Convention, or Convention on International Liability for Damage Caused by Space Objects, was created in 1971. It addressed the main concern of the Rescue Agreement, which was liability for any damages caused by space objects to other space objects and damages to land or people on Earth. It contains several articles describing different circumstances in which space objects cause damage. The main one is the launching state responsibility article, which provides that the country that launches a space object is liable for any damage it may cause. The rest of the

106 Goguichvili, Linenberger, and Gillette, "The Global Legal Landscape of Space."
107 United Nations General Assembly, Resolution 2345(XXII), Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, A/RES/2345(XXII), ¶ (Dec. 19, 1967), https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/rescueagreement.html.

convention goes into detail about many different scenarios in which space objects cause damage, whom the liability falls onto, and the extent to which a state must compensate for the damages. Most interestingly, the Liability Convention mentions that liability for private companies or facilities falls onto the country in which those companies are based. This means that if a private company's space object causes damage to another state, the state that hosts the company is liable for the damages.[108] This directly addresses the recent introduction of private companies into the space industry and a prominent issue in the Outer Space Treaty.

Two more treaties were born as a result of the Outer Space Treaty: the Registration Convention and the Moon Treaty. The Convention on Registration of Objects Launched into Outer Space, or the Registration Convention, was developed in response to a concern with the Liability Convention. Without knowing who owns what space objects, it would be very difficult to establish who is responsible for damages.[109] The Registration Convention orders that any country launching a space object must register it with the United Nations.[110] It also begins a registry to share launch information with other countries and the general public.[111] As space becomes more crowded, the use of the registry helps to reduce the risk of lost space objects or violations of the Outer Space Treaty.[112] The Moon Treaty, or Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, was ratified in 1979.[113] It discusses the uses of the Moon but mostly echoes the articles of the Outer Space Treaty. It has also not been ratified by the major space-involved countries and, therefore, seems to be irrelevant to international law.[114]

In addition to treaties, two organizations within the United Nations were formed. In 1958, the UN Office of Outer Space Affairs, or UNOOSA, was established to aid countries in navigating the intricacies of space-based legislation.[115] UNOOSA now owns the registry mentioned in the Registration Convention and continually updates it with information. UNOOSA also has programs dedicated to using space data and technologies to reduce the risk and backlash of environmental disasters. UNOOSA is the United Nation's leading representative body in space technology and exploration.[116] One year after the development of UNOOSA, in 1959, the Committee on the Peaceful Uses of Outer Space (COPUOS) was formed.[117] COPUOS was the main contributor to the creation of the five space treaties and holds discussions surrounding the use of space technology for sustainable development.[118] These two agencies have both acknowledged that the continued development of space legislation is critical to the development of space technology and its eventual applications for sustainable development.[119]

Other recent events regarding the space regulation were hosted in June of 2018. The United Nations celebrated the fiftieth anniversary of the first conference on the Exploration and Peaceful Uses of Outer Space with the conference UNISPACE+50. [120] UNISPACE+50 was the first global space summit in the 21st century. This conference was unique as it addressed the need for cooperation among states to work on possible solutions involving sustainable development in space.[121] UNISPACE+50 inspired several other possible solutions for obtaining sustainability on Earth, some that were developed with international cooperation, and some that

108 A/RES/2777(XXVI).
109 Goguichvili, Linenberger, and Gillette, "The Global Legal Landscape of Space."
110 United Nations General Assembly, Resolution 3235(XXIX), Convention on Registration of Objects Launched into Outer Space, A/RES/3235(XXIX), ¶ (Nov. 12, 1974), https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html.
111 A/RES/3235(XXIX).
112 Goguichvili, Linenberger, and Gillette, "The Global Legal Landscape of Space."
113 United Nations General Assembly, Resolution 34/68, Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, A/RES/34/68, ¶ (Dec. 5, 1979), https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html.
114 A/RES/34/68.
115 Martin Stasko, "Roles and Responsibilities," United Nations Office for Outer Space Affairs, last modified January 21, 2015, https://www.unoosa.org/oosa/en/aboutus/roles-responsibilities.html.
116 Stasko, "Roles and Responsibilities."
117 Robert Wickramatunga, "Committee on the Peaceful Uses of Outer Space," United Nations Office for Outer Space Affairs, last modified March 16, 2015, https://www.unoosa.org/oosa/en/ourwork/copuos/index.html.
118 Wickramatunga, "Committee on the Peaceful Uses of Outer Space."
119 Stasko, "Roles and Responsibilities."
120 "UNISPACE+50," United Nations Office for Outer Space Affairs, last modified June, 2018 https://www.unoosa.org/oosa/en/ourwork/unispaceplus50/index.html.
121 United Nations Office for Outer Space Affairs, "UNISPACE+50."

were developed by individual space agencies. UNISPACE+50 was a widely successful acknowledgment of past success and dedication toward the future.[122]

The conference consisted of two major parts: the Symposium and the High-level segment.[123] During the symposium, different space experts shared their discoveries, highlighting the future role of space science and technology in fostering global cooperation. The Symposium discussed the four pillars of space cooperation: Space Economy, Space Society, Space Accessibility, and Space Diplomacy. Space Economy focuses on how different space activities can fuel economic growth, foster innovation, and create unity. Space Society focuses on how governments have the power to include space-based solutions in their duties and should be encouraged to do so to benefit society. Space Accessibility focuses on enhancing access to space technology and data for countries around the world to use for the benefit of mankind. This section allowed the discussion of the increasing gap in space technology between states. Finally, Space Diplomacy focuses on the role of the Committee on the Peaceful Uses of Outer Space (COPUOS) and related UN organizations in building international partnerships and fostering cooperation.[124]

Another part of UNISPACE+50 was the High-level Segment, which was held from June 20 to June 21, 2018.[125] During the High-level Segment, member states worked on and proposed a UNISPACE+50 resolution, which would later become the Space2030 Agenda. The High-level Segment is considered the 61st session of COPUOS and was part of UNISPACE+50, where the most substantive debate and decision-making occurred.[126] Over 40 presenters from around the world participated in the exhibition held by UNISPACE+50, including different governmental organizations, space agencies, and private sector industries.[127] This conference showed the immediate willingness of states around the world to truly collaborate, not only with each other but also with private sector companies and the public. By sharing their work, exhibitors demonstrated their ability to strive for the completion of the Sustainable Development Goals and the objectives outlined in the Space2030 Agenda.[128] As a consequence of UNISPACE+50, the General Assembly adopted the "Space2030 Agenda: space as a driver of sustainable development" in 2021.[129]

Case Study: Africa's Emerging Space Programs

Africa, a continent composed of many different countries, all of which have differing social and economic backgrounds, has recently emerged as a rising power in space technology.[130] The continent's successful shift to space innovation has shed light on the potential of space technology to improve the conditions of vastly different countries around the globe. The space industry in Africa is predicted to grow by almost 20 percent over the next couple of years, with 15 African countries already having invested almost USD five billion in various satellite projects. In the next three years, African countries like Cameroon, Egypt, Ethiopia, Morocco, Nigeria, Senegal, South Africa, Tanzania, Uganda, Zimbabwe, and others plan to develop and launch 105 satellites.[131]

There are several potential reasons for this boom in satellite development. Firstly, satellites are extremely useful for providing internet, media, and cable connections across large regions without cluttering land on Earth with infrastructure.[132] Africa has historically struggled with telecommunication and connectivity, and utilizing satellites is a rising opportunity to solve these issues in a cost-effective manner. As of 2023,

122 United Nations Office for Outer Space Affairs, "UNISPACE+50."
123 United Nations Office for Outer Space Affairs, "UNISPACE+50."
124 A/RES/76/3, 6-7.
125 Maruska Strah, "UNISPACE+50", United Nations Office for Outer Space Affairs, last modified June 8, 2018, https://natural-physics.com/wp-content/uploads/2018/06/UNISPACE50-Background.pdf.
126 United Nations Office for Outer Space Affairs, "UNISPACE+50."
127 "UNISPACE+50 Exhibition," United Nations Office for Outer Space Affairs, accessed August 7, 2024, https://www.unoosa.org/oosa/en/ourwork/unispaceplus50/exhibition.html.
128 United Nations Office for Outer Space Affairs, "UNISPACE+50 Exhibition."
129 A/RES/76/3, 1.
130 Ruvimbo Samanga, "Who Woke the Sleeping Giant? Africa's Emerging Space Programs Take Off," Stimson, November 15, 2023, https://www.stimson.org/2023/who-woke-the-sleeping-giant-africas-emerging-space-programs-take-off/.
131 Samanga, "Who Woke the Sleeping Giant? Africa's Emerging Space Programs Take Off."
132 Łukasz Bednarski, "The new space race: Africa's cosmic ambitions," *Engelsberg Ideas,* July 24, 2023, https://engelsbergideas.com/essays/the-new-space-race-africas-cosmic-ambitions/.

only 22 percent of African households have internet at home, which provides a good incentive to continue investing in space technology. Another reason for Africa's space endeavors could be because of the instability within different countries. Food security, migration, rapid and uncontrolled urbanization, terrorism, and environmental degradation are all issues that have plagued the continent for decades without much progress. A solution that tackles many of these social issues at the same time is the use of satellites. By using Earth observation technology and data collection, African countries could further address social instability and begin to solve these decades-old problems.[133] In Morocco, satellites have already played a significant role in disaster risk management.[134] In late 2023, a 6.8 magnitude earthquake struck west Morocco, leveling villages and killing almost 3,000 civilians. To establish paths through the rubble and to locate any survivors, satellite imagery was given to emergency relief teams.[135]

A positive consequence of the turn toward space technology is the attitude of African citizens. Studies have shown that recent STEM graduates are strengthening the development of technology, and many plan on emigrating for more opportunities. Despite this, professionals in Africa believe that one of the main obstacles to continued progress is access to education. Researchers are committed to combating this. Professionals are offering free training and classes to prepare students for the challenges of working in space technology engineering. Scientists hope to push Africa further toward space superiority by connecting more of the African youth toward becoming space technology experts.[136] Additionally, other countries have become increasingly interested in Africa's space industry, which could have several benefits.

In 2022, China launched a mission that enabled students from eight African countries to speak to astronauts aboard China's Tiangong space station. Another Chinese mission, named the Belt and Road Initiative, has the sole purpose of guiding African countries toward space. Through this initiative, ground-based systems, satellite infrastructure, launches, and research training have occurred.[137] China is not the only global space power to take an interest in building partnerships. In 2023, the first-ever African Union-European Union space dialogue was held for the purpose of enabling the European Space Agency to aid in Africa's space exploration efforts.[138] As well as that, a United States/Africa Space Partnership Roundtable was held in Washington DC in December 2022.[139] Through these collaborations, it is possible for Africa to soon become one of the world's top space industry performers.

Seeing as Africa emits the least greenhouse gasses but experiences a disproportionately large amount of climate disasters, they are very often the victims of environmental injustice.[140] Although this would not directly fix the issue of environmental injustice, Africa is now equipped with the means to fight back against the volume of climate disasters impacting their populations.[141] Leaders in government and space technology have been approaching the use of satellites for two main purposes: water resource monitoring and natural resource management. Flooding is a common occurrence in central Africa, but through wetland and river monitoring, scientists believe they can combat the cyclical flooding of plains to better address the disastrous effects of climate change in those regions. They also plan to monitor agricultural regions to prepare farmers so they can adapt to flooding in regions where crops rely on more stable weather cycles, which is a practice also being applied in regions of India.[142]

There are potentially many more uses for satellite technology

133 Bednarski, "The new space race: Africa's cosmic ambitions."
134 Marco Oriunto, "One woman's battle to push Africa's space race," *BBC,* April 6, 2024, https://www.bbc.com/news/world-africa-68714740.
135 Oriunto, "One woman's battle to push Africa's space race."
136 Oriunto, "One woman's battle to push Africa's space race."
137 Bednarski, "The new space race: Africa's cosmic ambitions."
138 Samanga, "Who Woke the Sleeping Giant? Africa's Emerging Space Programs Take Off."
139 Samanga, "Who Woke the Sleeping Giant? Africa's Emerging Space Programs Take Off."
140 United Nations Human Rights Office of the High Commissioner, "South Africa must tackle crude legacy of environmental racism and toxic exposure: UN expert," press release, August 11, 2023, https://www.ohchr.org/en/press-releases/2023/08/south-africa-must-tackle-crude-legacy-environmental-racism-and-toxic.
141 Tidiane Ouattara, *Space Technologies for Sustainable Development in Africa* (Addis Ababa: African Union Commission, 2019), https://unisec-global.org/pdf/uniglo7/day3/2_special_lecture/Special_Lecture1.pdf.
142 Ouattara, *Space Technologies for Sustainable Development in Africa.*

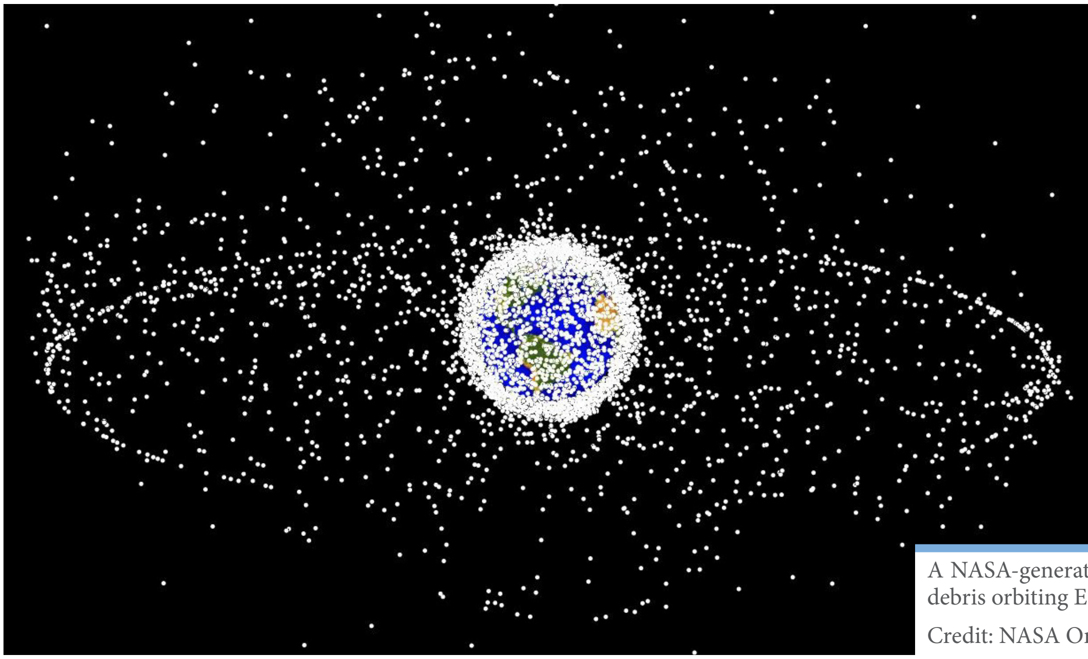
in terms of Africa's declining natural resources, but many of these are much more long-term. By surveying and collecting topographic data of Africa, researchers hope to track land degradation patterns to better understand their causes and evaluate some possible solutions.[143] In many regions of Africa, migratory animals and migratory pathways take up a lot of space, but they are frequently being disrupted by rapid urbanization into key migratory pathways.[144] Using structural map data can provide more accurate advice on where to redirect city development to protect the habitat of endangered species. Land rehabilitation efforts are also made easier with satellite data, as it enables scientists to track ecosystems and the level of vegetation in certain areas over long periods. Maintaining these efforts will take time, especially in regions where on-site satellite experts are few and far between, but with increased support from foreign states and private stakeholders, these goals could be achieved very soon.[145]

With the cooperation of established countries and plans to aid the environment and population come individual space policies. Among these are three recent and revolutionary changes to include space technology and its implications for long-term socioeconomic reform.[146] The first is Agenda 2063, which is a comprehensive strategy to achieve democracy, peace, justice, cultural expression, gender equality, and collective prosperity by the year 2063.[147] This 50-year-long plan includes quantitative goals for reaching collective prosperity and was recently modified in 2020 to include the growth of the space industry as a means toward inclusive and sustainable economic growth.[148] The Africa Free Continental Trade Agreement (AfCFTA) is an initiative aimed toward involving 55 African Union countries in an intracontinental trade agreement.[149] To reduce poverty and boost Africa's status in the global economy, policymakers have acknowledged and planned to involve the space technology industry in the free trade market, as outlined in the AfCFTA.[150] Lastly, the Digital Transformation Strategy for Africa is a framework aiming to use technological innovation to transform Africa's socioeconomic status.[151] It intends to enable digital infrastructure and skill development across many different technological sectors over ten years.[152] Like other policy modifications, it has accounted for the potential boon that space technology can offer as the African space industry continues to grow.[153]

Accessibility Implications and Other Limitations

Although the United Nations has acknowledged the importance of space technology in the Sustainable Development Goals, there are several obstacles in the way of future success. Space itself is incredibly dangerous and mostly unexplored, which means there are many opportunities for human life to be at risk. Because most organizations are hesitant to send humans up into space, they must ensure their technology is not only capable of handling launch velocities but also that it can maintain itself with no expectations for maintenance or repairs.[154] However, some space vehicles are so large and important that organizations like NASA are willing to expend time, resources, and humans to make repairs. After the initial launch of the International Space Station, several missions have occurred to conduct research using the space station's six laboratories. NASA also uses these missions to assess the risks that space poses to human health. So far, NASA has identified five main hazards: space radiation, isolation and

143 Ouattara, *Space Technologies for Sustainable Development in Africa.*
144 Judi Sandrock, "From Sky to Ground: The Impact of Space Technology on Africa's Mining Sector," *Space in Africa*, May 15, 2024, https://spaceinafrica.com/2024/05/15/from-sky-to-ground-the-impact-of-space-technology-on-africas-mining-sector/.
145 Sandrock, "From Sky to Ground: The Impact of Space Technology on Africa's Mining Sector."
146 Samanga, "Who Woke the Sleeping Giant? Africa's Emerging Space Programs Take Off."
147 "Agenda 2063: The Africa We Want," African Union, accessed July 23, 2024, https://au.int/en/agenda2063/overview.
148 African Union, "Agenda 2063: The Africa We Want."
149 Ahunna Eziakonwa, *Making the AfCFTA Work for Women and Youth* (Addis Ababa: United Nations Development Programme, 2020), https://au.int/sites/default/files/documents/39689-doc-ss_afcftafuturereport.pdf.
150 Eziakonwa, *Making the AfCFTA Work for Women and Youth.*
151 Amani Abou-Zeid, *The Digital Transformation Strategy for Africa (2020-2030)* (Addis Ababa: African Union, 2020), https://au.int/sites/default/files/documents/38507-doc-dts-english.pdf.
152 Abou-Zeid, *The Digital Transformation Strategy for Africa (2020-2030).*
153 Abou-Zeid, *The Digital Transformation Strategy for Africa (2020-2030).*
154 Megan Parisi, Tina Panontin, Shu-Chieh Wu, Kaitlin Mctigue, and Alonso Vera, "Effects of Communication Delay on Human Spaceflight Missions," *AHFE International* 98, no. 98 (2023): 64-73, https://doi.org/10.54941/ahfe1003920.



A NASA-generated plot showing the density of space debris orbiting Earth

Credit: NASA Orbital Debris Program Office

confinement, distance from Earth, lack of gravity, and closed or hostile environments.[155]

Firstly, space radiation. Every cell in the human body is vulnerable to radiation damage, and radiation damage has the potential to cause cancer, damage the heart, cause cardiovascular disease, and hinder the development of cells in the brain.[156] The risk of long-term negative health impacts increases the further humans venture into space, but NASA's Human Research Program is investigating different shielding materials, medical countermeasures, and faster rockets to reduce the risk of these health issues.[157] Different gravity fields also pose a risk for astronauts, as being weightless for an extended period can cause dizziness, bone and muscle loss, vision loss, dehydration, and balance and coordination loss.[158] The environment and ecosystem within a spacecraft are also very prone to changing, with microorganisms constantly jumping from person to person.[159] Because of this, immune systems can alter, which leads to an increased risk of allergies and illnesses while onboard a spacecraft. Astronauts aboard the International Space Station in particular, are constantly exposed to roughly 72 decibels, which is equivalent to hearing a vacuum cleaner running all the time.[160] The physical conditions astronauts are almost constantly exposed to pose a major risk to their long-term health and sometimes their lives, which is why space agencies tend to send robots instead.

Other space-related risks are mostly psychological. Although astronauts can train for years before they are allowed into the Earth's atmosphere, the hostile environment that space encompasses can be very harsh on even the most well-trained astronauts. Microgravity, or conditions where gravity levels are very low and may seem nonexistent, are very hard on the body and require a long adjustment period. Once in space, basic tasks like eating and going to the bathroom become very difficult to do, which also takes a toll on astronauts' mental health.[161] Very few humans are in space at once as well, and crews like the ones on the International Space

155 Abby Graf, "5 Hazards of Human Spaceflight," NASA, last modified July 11, 2024, https://www.nasa.gov/hrp/hazards/.
156 Amy Blanchett and Laurie Abadie, "Space Radiation is Risky Business for the Human Body," *NASA*, September 19, 2017, https://www.nasa.gov/humans-in-space/space-radiation-is-risky-business-for-the-human-body/.
157 Blanchett and Abadie, "Space Radiation is Risky Business for the Human Body."
158 Abby Graf, "Hazard: Gravity Fields," NASA, last modified January 10, 2024, https://www.nasa.gov/hrp/hazard-gravity-fields/.
159 Abby Graf, "Hazard: Hostile/Closed Environments," NASA, last modified January 10, 2024, https://www.nasa.gov/hrp/hazard-hostile-closed-environments/.
160 "How space and isolation affect astronauts' mental health," Canadian Space Agency, last modified October 27, 2022, https://www.asc-csa.gc.ca/eng/youth-educators/toolkits/mental-health-and-isolation/how-space-and-isolation-affect-astronauts-mental-health.asp.
161 Canadian Space Agency, "How space and isolation affect astronauts' mental health."

Station tend to be very small. Since its launch, the ISS has only had seven people on it at a time.[162] These limited social interactions tend to make astronauts feel very socially isolated, regardless of the close connections they may form with their fellow crew members. Over the past few decades, astronauts have reported feeling stress, anxiety, fatigue due to lack of natural light patterns, irritability, mood swings, depression, emotional distress, neurobehavioral issues due to radiation, and depression. As well as the conditions they face while in space, many astronauts also have a difficult time readjusting to life on Earth after being in space and require psychological and physical support after their missions.[163]

Along with the challenges associated with sending humans into space, there are many environmental risks involved in space missions. In recent years, the cost of launching LEO satellites into space has decreased, which has invited many more countries to increase the number of satellites they have in low Earth orbit. Because of this, space traffic has increased significantly, and alongside it, the amount of emissions polluting the atmosphere. Rocket launches, which take satellites into orbit, emit black carbon, aluminum, carbon dioxide, reactive gasses, and unburned fuel, which can linger in the atmosphere for years.[164] The production of satellite technology consumes both renewable and nonrenewable resources as well, and because launch rockets are not recoverable, they land in the oceans and degrade there. The increased amount of satellite traffic in the sky, as well as their rapid movements, also causes nighttime light pollution and an issue known as "artificial skyglow," in which the night sky seems brighter due to the manmade light sources in the atmosphere.[165] As of 2023, scientists have estimated that the night sky is roughly ten percent above natural light levels due to artificial skyglow, impacting the sleep cycles of both humans and wildlife.[166]

Another environmental risk associated with space exploration and satellite launches is space debris. Kessler Syndrome is a term for a cycle in which the number of satellites and debris becomes so high that collisions occur, which generates more debris and then more collisions over and over.[167] In this potential scenario, the atmosphere around Earth becomes so cluttered with debris that it is unusable. At the current rate at which objects are being launched into space, this irreversible tipping point could occur in less than 200 years. Because no one truly "owns" space, it is vulnerable to the tragedy of the commons, in which resources are overexploited until they can no longer recover at the expense of society. Despite this bleak outlook, there are strategies that can be adopted to lower the risk of Kessler Syndrome. Scientists have suggested using less crowded orbital routes, adjusting satellite altitudes, and programming avoidance maneuvers, but studies show these efforts would only delay the onset of Kessler Syndrome. Another strategy, active debris removal, involves manually lowering the altitude of debris so that it burns up upon impact with Earth's atmosphere. Scientists have determined through simulations that this would be the most effective strategy to rid the atmosphere of space debris, but we are currently unable to accomplish this with our current technology.[168] Ultimately, the rapid approach of Kessler Syndrome is a serious dilemma that we do not yet have a solution for.

Because space is considered a "No-Man's land", all countries on the planet are welcome to send objects and vehicles into space. However, for many countries, this poses a security risk because countries they may have tense relations with could orchestrate cyber attacks against them through the use of space technology. There are three main focuses for cyber threats: ground-based segments, space-based segments, and link segments.[169] Ground-based segments are systems and infrastructure that support space operations from the ground or flight control centers. These segments are vulnerable to

162 Mark A. Garcia, "Station Facts," NASA, May 23, 2023, https://www.nasa.gov/international-space-station/space-station-facts-and-figures/.
163 Canadian Space Agency, "How space and isolation affect astronauts' mental health."
164 Kevin Gaston, Karen Anderson, Jamie Shutler, Robert Brewin, and Xiaoyu Yan, "Environmental impacts of increasing numbers of artificial space objects," *Frontiers in Ecology and the Environment* 21, no.6 (April 2023): 289-296, https://doi.org/10.1002/fee.2624.
165 Gaston, Anderson, Shutler, Brewin, and Yan, "Environmental impacts of increasing numbers of artificial space objects," 289-296.
166 Gaston, Anderson, Shutler, Brewin, and Yan, "Environmental impacts of increasing numbers of artificial space objects," 289-296.
167 Keiko Nomura, Simon Rella, Haily Merritt, Mathieu Baltussen, Darcy Bird, Annika Tjuka, and Dan Falk, "Tipping Points of Space Debris in Low Earth Orbit," *International Journal of the Commons* 18, no.1 (January 2024): 17-31, https://doi.org/10.5334/ijc.1275.
168 Nomura, Rella, Merritt, Baltussen, Brid, Tjuka, and Falk, "Tipping Points of Space Debris in Low Earth Orbit," 17-31.
169 Vijay Varadharajan and Neeraj Suri, "Security challenges when space merges with cyberspace," *Space Policy* 67, (November 2023), 1-8.

cyber attacks through their satellite data receivers and software networks. Anyone could introduce malware or essentially "hack" into these systems to gain sensitive information or scam operators into giving up sensitive information.[170] Next are space-based segments, or the actual objects in space like satellites. The attacks on these segments tend to be more physical. Hostile entities could use electromagnetic pulses to jam radio transmissions, track the location of the satellite, or even deliberately knock a satellite off-course and render it unusable. Finally, link segments are communication networks or channels that connect ground and space-based segments. These are vulnerable in much the same way that ground-based segments are vulnerable, but mostly through eavesdropping, spying, or signal jamming.[171] Because all states that develop space technology are vulnerable to these attacks, many have begun developing defensive tactics, among which include weaponry. In February 2024, United States intelligence received notice that Russia was attempting to develop a nuclear space weapon capable of destroying multiple satellites when detonated.[172] This would be a direct violation of the Outer Space Treaty of 1967, which bans the use of weapons of mass destruction in outer space, and there is no doubt behavior like this feeds the growing panic of space cybersecurity attacks.

Current Status

The Rise of Private Actors in the Space Sector

Recently, the space sector has seen remarkable growth in the participation of private actors. This has transformed the field that traditionally was dominated by government agencies. The presence of the private sector marked a new era in space technology, characterized by continuous advances, greater accessibility, and commercialization of space.[173] Their involvement has also led to the growth of the industry. In 2022, it reached a historical record of orbital space launches, with 174, but this number is expected to rise in the next few years.[174] By 2035, it is expected that the space economy will reach a value of USD 1.8 billion.[175] Even if big companies, such as SpaceX, Blue Origin, and Rocket Lab, are leading the market, there is still room for emerging companies in the sector. In 2023, Europe reported that EUR 942 million were invested in space startups across 78 deals.[176]

The European Space Policy Institute (ESPI) identified four phases in the investments of space technology startups that allowed the consolidation of private companies in the sector. The first phase was from 2014 to 2016, when the startups were just emerging and securing small investments, reaching a peak of EUR 50 million. By the fourth phase, from 2022 to 2024, the space technology startups were securing great investments. The peak was in 2022 when EUR one billion was invested in European space startups.[177] These phases identified by ESPI have allowed us to demonstrate the consolidation and growth of the private sector in the economy and the development of space technology

Another positive effect of private sector participation is accelerating developments and advances in space technology. Space X has already achieved historical milestones. The historic launch of the Crew Dragon Mission in 2020 was the first private spacecraft to carry astronauts to orbit.[178] This successful mission was the result of over a decade of public-private partnerships (PPP) between SpaceX and NASA. Their purpose is to ensure that the International Space Station (ISS) is fully staffed to keep it running. In 2009, 13 astronauts were on the station; however, in recent years, that number has

170 Varadharajan and Suri, "Security challenges when space merges with cyberspace," 1-8.
171 Varadharajan and Suri, "Security challenges when space merges with cyberspace," 1-8.
172 Katie Lillis, Jim Sciutto, Kristin Fisher, and Natasha Bertrand, "Exclusive: Russia attempting to develop nuclear space weapon to destroy satellites with massive energy wave, sources familiar with intel say," *CNN*, February 17, 2024, https://www.cnn.com/2024/02/16/politics/russia-nuclear-space-weapon-intelligence/index.html.
173 Sabiq Mirzai, ""The Rise of Private Companies in Space Exploration: Revolutionizing the Final Frontier," Medium, July 12, 2023, https://medium.com/techcrate/the-rise-of-private-companies-in-space-exploration-revolutionizing-the-final-frontier-71d0a273b419.
174 "Space Startups - statistics & facts," Statista, last updated April 29, 2024, https://www.statista.com/topics/10756/space-startups/#editorsPicks.
175 Khlystov and Markovitz, "Space is booming. Here's how to embrace the $1.8 trillion opportunity."
176 *Space Venture Europe 2023: Investment in the European and global space sector* (Vienna: ESPI, 2024) https://www.espi.or.at/wp-content/uploads/2024/05/ESPI-Space-Venture_Final-compressed.pdf.
177 *Space Venture Europe 2023: Investment in the European and global space sector*.
178 Erik Gregerse, "Dragon," Britannica, last updated August 31, 2024, https://www.britannica.com/topic/Dragon-spacecraft.

dropped to three.[179] Since the Crew Dragon Mission, SpaceX has successfully launched thirteen human spaceflight missions for a total of 50 crew members.[180] The SpaceX and NASA PPP have proved the importance of the private sector in space programs.

Public-private partnerships are game changers in space programs. NASA is significantly reducing costs by sharing missions with SpaceX and Boeing. The cost reduction is due to new technologies brought by private companies, such as SpaceX with reusable rockets.[181] Therefore, by having PPP in space programs, government agencies are reducing costs while still maintaining high standards and reliable technology. Government agencies are limited in their ability to produce these kinds of innovations, as they usually face budget constraints.[182] However, private companies have a larger financial backing from their investors.

Another example is the New Zealand company RocketLab. The company seeks to make space more accessible, making it more affordable, efficient, and sustainable. They mainly provide fast launch services for small and medium-sized satellites. They have worked on missions of earth observation, communication, scientific research, and defense. RocketLab has consolidated in the market with Electron, a semi-reusable rocket.[183] Their reusable launch platform also positioned them in the market, as it allows them to launch small to medium rockets every 72 hours. From January to April 2024, they launched 22 Electron rockets.[184] In addition, they are planning to launch an Electron later this year with their mission, Venus Life Finder, to explore Venus's atmosphere for signs of life.[185] RocketLab is also developing Neutron, which is expected to launch into the market in 2025. This is the first mid-big rocket-size project expected to be used for human spaceflight.[186] It also will count on their distinguished technology, which makes the rocket reusable. RocketLab is changing the space market by making it more sustainable and accessible, setting it as a key player for the new era in the sector.

While private companies have driven innovation and growth in the space sector, their involvement also brings several risks and challenges. For example, the congestion of near-Earth space is caused by the massive deployment of satellites by the private sector. Since 1957 it is estimated that more than 11,000 satellites have been launched, and it is expected that 70,000 more will be launched in the upcoming years.[187] The effects of overcrowded space have already been seen since it is estimated that half a million of space junk are remaining in orbit. This may pose risks to operational satellites through collisions and affect their missions. For instance, in 2021, a piece of space junk hit the ISS and damaged a robotic arm.[188] While the exact object responsible for this damage is unknown, the space station is at risk of impact from objects too small to be tracked. These tiny objects could be pieces of rock, micrometeorites, dust particles, or even flecks of paint that chip off of satellites. While this example did not cause major damage, these can collide with satellites or space stations, consequently threatening the space environment.[189] The Global Risks Report of 2022 identified the overcrowding of space as a crucial threat in the upcoming years, which is expected to grow due to the lack of space governance.[190] Furthermore, it has been seen that private companies prioritize commercial interests over sustainability and equity

179 Jackie Wattles, "SpaceX-NASA mission: Four astronauts arrive at International Space Station," *CNN*, last updated November 17, 2020, https://edition.cnn.com/2020/11/16/tech/spacex-nasa-iss-docking-scn/index.html.
180 "Updates," Spacex, February 14, 2022, https://www.spacex.com/updates/.
181 Shelli Brunswick, "The Transformative Power Of Public-Private Partnerships In Space Exploration," *Forbes*, June 24, 2024, https://www.forbes.com/councils/forbestechcouncil/2024/06/24/the-transformative-power-of-public-private-partnerships-in-space-exploration/.
182 Mirzai, "The Rise of Private Companies in Space Exploration."
183 Theresa Cross, "Rocket Lab's expanding global footprint: Neutron rocket, reusability, and Venus Life Finder mission," Spacex, August 27, 2024, https://spaceexplored.com/guides/electron/.
184 Hamish McNicol, "New Zealand space industry prepared for takeoff," Stuff, September 16, 2016, https://spaceexplored.com/2024/04/29/rocket-lab-launches-2024/.
185 Cross, "Rocket Lab's expanding global footprint: Neutron rocket, reusability, and Venus Life Finder mission."
186 "Neutron," RocketLab, accessed September 10, 2024, https://www.rocketlabusa.com/launch/neutron/.
187 "Space congestion: An increasingly contested and crowded frontier," Zurich, July 5, 2022, https://www.zurich.com/media/magazine/2022/from-moonshot-to-musk-how-the-rules-of-the-game-are-changing-in-space.
188 Douglas Broom, "As private satellites increase in number, what are the risks of the commercialization of space?" World Economic Forum, January 12, 2022, https://www.weforum.org/agenda/2022/01/what-are-risks-commercial-exploitation-space/.
189 Ashley Strickland, "Space junk hit the International Space Station, damaging a robotic arm," *CNN*, June 1, 2021, https://edition.cnn.com/2021/06/01/world/iss-orbital-debris-robotic-arm-scn/index.html.
190 Zurich, "Space congestion: An increasingly contested and crowded frontier."

goals. The future of space depends on effective multilateral governance that fosters cooperation, transparency, and shared responsibility, allowing all states and companies to contribute to and benefit from space in a fair and equitable manner. Only through cooperation and the creation of a clear and fair framework a sustainable use of space as a resource will be ensured. Fair rules and regulations need to be established, including recognizing that the private sector is a key actor in the industry.

Global Space Collaboration

Certain initiatives have demonstrated a growing trend towards international collaboration in space exploration. However, challenges such as differing national interests, technological advancements, and the complexity of international agreements continue to shape the landscape of space cooperation. Among the most recent efforts to improve space technology and international cooperation are the Artemis Accords, the Lunar Gateway, the Chang'e Lunar Exploration Program, and the Global Navigation Satellite System (GNSS).[191]

The Artemis Accords is a document drafted by NASA that intends to build international cooperation through several principles.[192] The Artemis Accords were first drafted in October 2020 with the purpose of enabling humans to establish a sustainable presence on the moon and eventually Mars.[193] As of 2024, no woman or person of color has ever landed on the moon.[194] With the Artemis Accords, NASA plans to launch several collaborative missions aimed at reaching those milestones and promoting equal opportunity for all. All signatories have agreed to several principles within the Artemis Accords. Nevertheless, the document itself is not legally binding, meaning it is not legally necessary to obey or follow.[195]

Firstly, the Artemis Accords discusses the peaceful exploration of space under the scope of international law, like the Outer Space Treaty. The second principle urges signatories to be completely transparent in their space exploration plans to avoid conflict and foster meaningful cooperation. The third principle involves a concept called interoperability, which means that infrastructure in space must adhere to a common standard so all space agencies can utilize technology and designs.[196] Many of the principles in the Artemis Accords can also be found in the Space2030 Agenda, but interoperability is a new and more stringent concept.[197] The feasibility of interoperability is questionable, especially considering how rapidly space technology is advancing all over the world and how communication about these rapid changes is not constant, leading to different technologies and standards. Additionally, the Artemis Accords state that signatories commit to use "reasonable efforts" to achieve interoperability, which is very hard to quantify. Despite these challenges, if interoperability is incorporated into future space technologies, it could vastly improve the quantity and quality of knowledge and resources we can exchange.[198]

Several other principles of the Artemis Accords, like emergency assistance, registration of space objects, and release of scientific data, can be found in previous space legislation, such as the Outer Space Treaty. The newer and more interesting aspects involve the preservation of heritage and conditions of outer space. Outer space sites with historical significance, such as landing sites, as well as artifacts, spacecraft, and other traces of evidence, are meant to be undisturbed to cultivate a rich history of space.[199] This condition of the Artemis Accords is especially relevant to sustainable development because it may force agencies to come up with innovative ways to maintain heritage sites, which could be applied to regions on Earth.[200] Two other key principles of sustainable development are

191 Gary Daines, "The Artemis Accords," *NASA*, July 21, 2023, https://www.nasa.gov/artemis-accords/.
192 Daines, "The Artemis Accords."
193 Robert Lea, "Artemis Accords: What are they & which countries are involved?" Space.com, last modified June 3, 2024, https://www.space.com/artemis-accords-explained.
194 Jonathan Amos, "Nasa names first woman and black man on Moon mission," *BBC,* April 3, 2023, https://www.bbc.com/news/science-environment-65165845.
195 Daines, "The Artemis Accords."
196 Daines, "The Artemis Accords."
197 Lea, "Artemis Accords: What are they & which countries are involved?"
198 Daines, "The Artemis Accords."
199 Lea, "Artemis Accords: What are they & which countries are involved?"
200 "Artemis Accords," US Department of State, accessed August 9, 2024, https://www.state.gov/artemis-accords/.

the space resources and orbital debris section. The Artemis Accords require that signatories ensure that the extraction of space resources is sustainable so that celestial bodies are not stripped of their natural resources.[201] This section of the document is very similar to that of the Outer Space Treaty, but it does reaffirm that sustainable collection of resources is a priority for future space missions.

A common criticism of the Artemis Accords is that it seems to mirror the Outer Space Treaty and simply take sections from previous space legislation instead of developing new ideas. The Outer Space Treaty also has around 115 member states who have signed, while the Artemis Accords have only 43 signatories.[202] While these claims are debated, there is no doubt that the power in the Artemis Accords is found within its missions. As one of the primary authors, NASA is dedicated to following its principles in all its future missions.[203]

One such Artemis mission is called the Lunar Gateway, or simply Gateway. The Lunar Gateway is humanity's first attempt to build a space station that will orbit the moon instead of Earth.[204] It will eventually lead to long-term and consistent exploration of the moon and combine many different elements and space agencies. The Canadian Space Agency, European Space Agency, Japan Aerospace Exploration Agency, and Mohammed Bin Rashid Space Centre are all constructing different parts of the space station to be developed in 2025. More significant than that, however, is the power of the Lunar Gateway to promote a sustainable presence on the moon and Earth. Since the space station is designed for long-term use, it reduces the need for constant repairs, which reduces emissions caused by launches from Earth's surface.[205] It will also facilitate missions to the southern region of the moon's surface, where ice is believed to exist.[206] Through these missions and the research performed by crews on the Lunar Gateway, we can hopefully learn more about lunar geography, radiation, and Earth's atmosphere.[207] The technology that will enable the Lunar Gateway to exist can improve lives on Earth in a myriad of ways, as we've seen before during the development of the International Space Station.

The Artemis mission has inspired other countries to explore the moon. For instance, Chang'e-6 is the sixth of eight scheduled missions in the Chang'e series carried out by China to put astronauts on the moon in the coming years. On May 3, China launched the Chang'e six lunar sample return mission. This 53-day mission aims to scoop up two kilograms of lunar rocks and soil from the lunar far side and bring it back to Earth. Samples will be analyzed, and the results could help scientists peer back into the evolution of the moon, the Earth, and the solar system. Lunar soil collected from the mission could be used for 3-D printing to produce bricks for constructing research bases on the moon or to extract gasses like Helium-3, oxygen, and hydrogen from the soil, which could support further lunar exploration. Chinese scientists are expected to share data and carry out joint research with international partners. Nevertheless, controversy has surrounded Chang'e six, as international teams had to wait three years to apply for access to samples from the Chang'e-5 mission, hindering the process of international cooperation. Regardless, this mission has shown a lot of progress in terms of moon exploration, and China aims to expand it. Chang'e-7 mission to the lunar south pole region is scheduled for 2026, and Chang'e-8 will be launched in 2028 to carry out tests aimed at the utilization of lunar resources in preparation for the lunar research station.[208]

Another effort on international cooperation is the Global Navigation Satellite System (GNSS), which is a constellation of satellites that transmits signal ranges used for positioning and location anywhere on the globe. The space segment describes the GNSS constellations orbiting between 20,000 and 37,000 kilometers above the Earth. These satellites

201 Daines, "The Artemis Accords."
202 US Department of States, "Artemis Accords."
203 "Gateway," NASA, accessed August 9, 2024, https://www.nasa.gov/mission/gateway/.
204 "Gateway Space Station," NASA, accessed August 9, 2024, https://www.nasa.gov/reference/gateway-about/.
205 NASA, "Gateway Space Station."
206 "The Lunar Gateway," Canadian Space Agency, accessed August 9, 2024, https://www.asc-csa.gc.ca/eng/astronomy/moon-exploration/lunar-gateway.asp.
207 Canadian Space Agency, "The Lunar Gateway."
208 Simone McCarthy, "China's Chang'e-6 moon mission returns to Earth with historic far side samples," *CNN*, June 25, 2024, https://edition.cnn.com/2024/06/25/china/china-change-6-moon-mission-return-scn-intl-hnk/index.html.

broadcast signals that identify which satellite is transmitting and its time, orbit, and status or health.[209] It is used in all forms of transportation: space stations, aviation, maritime, rail, road, and mass transit. Additionally, GNSS plays a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, and scientific research.[210]

Some of the operating GNSSs include the Global Positioning System (GPS) launched by the USA. It was the first constellation to be established in space, with its first satellite being launched in 1978 with its first series of satellites fully operational by 1993. Moreover, GLONASS was first developed in the Soviet Union to compete with GPS during the 70s and is currently operated by Russia. The first GLONASS satellite was launched in 1982 and has 24 satellites in orbit today. China did not fall far behind, and in 2000, BeiDou was launched out of China by the China National Space Administration (CNSA). Additionally, the European Satellite Navigation System (GALILEO), is a more recent constellation first launched in 2011. It is operated by the European Global Navigation Satellite Systems Agency, and it currently has 30 satellites in orbit.[211]

All of these are global efforts. However, it is worth highlighting the regional systems or the regional navigation satellite systems (RNSS) as well. Japan's Quasi-Zenith Satellite System (QZSS) is operated by the Japan Aerospace Exploration Agency (JAXA). QZSS was launched in 2010 and maintains Asia-Oceania regional coverage between Japan and Australia. Another major regional constellation is the Indian Regional Navigation Satellite System (IRNSS). The constellation's coverage centers around India, reaching west to include Saudi Arabia, north and east to include all of China, and as far south to include both Mozambique and Western Australia.[212]

Today, most GNSS and RNSS receivers can receive and decode signals simultaneously from more than just a single satellite constellation. Therefore, these can be used globally for immediate deployment and can be used more widely than receivers that are limited to a single GNSS constellation. Combining them with terrestrial technologies will open the door to new applications for socio-economic benefits. Thus, the United Nations has as a priority the further development of GNSS and RNSS, aiming for prospective modernization.[213]

The Artemis Accords, Lunar Gateway, Chang'e six, and Global Navigation Satellite System (GNSS) represent significant strides in space technology and international cooperation. These initiatives highlight the growing importance of space exploration and the need for international cooperation to achieve ambitious goals. Space-based solutions may offer innovative and sustainable approaches as the world continues to deal with global challenges. As CSTD delegates, it is your task to promote space-based collaborations to ensure that these efforts are conducted peacefully and provide worldwide benefits.

Sustainable Development Goals

The United Nations' Sustainable Development Goals (SDGs) are the main focus of the 2030 Agenda for Sustainable Development. Adopted in 2015 by all UN member states, it aims to create a future with peace and prosperity for people and the planet.[214] There are 17 SDGs in total, all of which focus on specific problems that need urgent global action. The goals cover a wide range of themes, ranging from gender equality to sustainability.[215]Among the many efforts to accomplish the goals, using space technology can contribute directly to some of the SDGs. As previously mentioned, space is associated with research and exploration, but discoveries can help life on Earth through the many applications of technology.

SDG nine aims to build resilient infrastructure, promote sustainable industrialization, and foster innovation. The topic specifically covers target 9.1: "Develop quality, reliable, sustainable and resilient infrastructure, including regional and

209 "What are Global Navigation Satellite Systems?" Novatel, accessed September 11, 2024, https://novatel.com/tech-talk/an-introduction-to-gnss/what-are-global-navigation-satellite-systems-gnss.
210 "Global Navigation Satellite Systems (GNSS)," United Nations Office for Outer Space Affairs, accessed September 11, 2024, https://www.unoosa.org/oosa/en/ourwork/psa/gnss/gnss.html.
211 Novatel, "What are Global Navigation Satellite Systems?"
212 Novatel, "What are Global Navigation Satellite Systems?"
213 United Nations Office for Outer Space Affairs, "Global Navigation Satellite Systems (GNSS)."
214 "THE 17 GOALS | Sustainable Development," United Nations, 2015, https://sdgs.un.org/goal.
215 "THE 17 GOALS | Sustainable Development,"

transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all."[216] Space technology can help infrastructure planning and monitoring, especially with telecommunications. Technologies like satellite communication can help reduce infrastructure needs on Earth and provide remote communities with faster and more efficient access to important services like healthcare and emergency responses.[217]

Another goal that can benefit from space technology is SDG 11, which aims to make cities inclusive, safe, resilient, and sustainable. By 2050, the percentage of the world's population will grow up to 68 percent.[218] As populations continue to grow, cities face the need to expand sustainably. Target 11.3 especially, aligns more with the topic, "By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries."[219] Remote sensing and earth observation allow for accurate data collection regarding land, population, and environmental aspects. This data can be used for better urban planning, making it easier for cities to be sustainable and well-managed.

SDG 17 is focused on partnership for the goals.[220] Today's challenges are global and require constant cooperation and collaboration between countries. Space technologies have been the pioneers of international collaboration, with international programs like the International Space Station (ISS). The ISS is a great example of international cooperation that is used for international benefit. The ISS has been a way of bringing people from different nationalities together to do research and develop new technologies.[221] Furthermore, satellites make exchanging data from one country to another easier, enabling international cooperation for challenges like natural disasters.

Space technology has the potential to play a vital role in addressing global challenges and contributing to the achievement of the Sustainable Development Goals. By leveraging space-based solutions, we can build more resilient infrastructure, create sustainable cities, and promote international cooperation to create a better future for all.

Bloc Analysis

Points of Division

Many points of division have arisen throughout the history of space technology and exploration, but several outstanding points have not been resolved through decades of legislation. Firstly, there is a gap between more and less developed countries when it comes to space technology.[222] A major aspect of most space technology-related legislation is the need for constant communication and shared data. However, when a technological divide is present, many countries are unable to access space technology, the associated data, and the resulting benefits. When this occurs, there becomes inequitable access to space technology and sustainable development, which means these countries become even further behind in the effort to preserve the planet from the effects of climate change.[223]

Another point of division is the complications of resource allocation. Smaller island states, for example, lack the land space to even consider launching satellites, which limits their ability to develop space technology and collect data.[224] Other countries have poor education rates, which means training and educating professionals to operate launch facilities and

216 "THE 17 GOALS | Sustainable Development,"
217 André Baumgart, Eirini Ioanna Vlachopoulou, Jorge Del Rio Vera, and Simonetta Di Pippo, "Space for the Sustainable Development Goals: Mapping the Contributions of Space-based Projects and Technologies to the Achievement of the 2030 Agenda for Sustainable Development." *Sustainable Earth Reviews* 4, no. 1 (December 1, 2021), https://doi.org/10.1186/s42055-021-00045-6.
218 "68% of the World Population Projected to Live in Urban Areas by 2050, Says UN | United Nations," United Nations, accessed September 7, 2024, https://www.un.org/uk/desa/68-world-population-projected-live-urban-areas-2050-says-un.
219 "THE 17 GOALS | Sustainable Development,"
220 "THE 17 GOALS | Sustainable Development,"
221 "International Space Station - NASA," NASA, October 2, 2023, https://www.nasa.gov/reference/international-space-station/#hds-sidebar-nav-5.
222 United Nations, "Delegates Underline Need for Equitable Use of Outer Space Technology, Welcome Innovative Digital Peacekeeping Tools, as Fourth Committee Continues Debate," press release, October 22, 2021, https://press.un.org/en/2021/gaspd738.doc.htm.
223 United Nations, "Delegates Underline Need for Equitable Use of Outer Space Technology."
224 Shamika N. Sirimanne, Dong Wu, Bob Bell, Katalin Bokor, Nadine Mizero Hakizimana, *Exploring Space Technologies for Sustainable Development* (Geneva: United Nations Conference on Trade and Development, 2021), https://unctad.org/system/files/official-document/dtlstict2021d1_en.pdf.

conduct research is extremely difficult. In these countries, their already limited resources go directly toward solving prominent socioeconomic issues, which means that space technology is often not a priority.[225]

Despite the abundance of legislation surrounding space technology that has appeared in the past few decades, regulation and governance remain an issue for many countries. Around 115 countries adhere to the rules set by the Outer Space Treaty, which remains the largest and most comprehensive space legislation to this day. However, several issues remain within the Outer Space Treaty that have not been resolved through different attempts. For example, over 23,000 unclaimed space objects are being tracked, with millions more that are currently untracked and orbiting Earth. Because of this, we are unable to identify which countries are responsible for clearing away that debris, which places us behind in terms of sustainable use of outer space.[226] In addition to that, all around the world, space technology is advancing rapidly.[227] Because satellites are constantly launching around the world and mission technology is developing fast, complicated legislative procedures cannot keep up with the pace of space technology. Therefore, the gap between governance and space technology is growing without any current means to close it.[228]

Finally, a huge point of division for many countries is concerns around data privacy and security.[229] As of May 2024, there is evidence that cyber attacks have occurred on every digital platform relating to space activities.[230] Because of this, there have been disruptions to satellite communications, navigation systems, and data communications.[231] In 1998, the United States and German-owned ROSAT satellite was destroyed after hackers gained control of the satellite and aimed its solar panels directly at the sun, frying the batteries.[232] Cyber attacks like this are fairly frequent, with over 6,000 cyber attacks having occurred between 2017 and 2021. This is a source of tension among countries because these hacking attempts are usually untraceable, meaning there is no way to punish those who successfully commit a space cyber crime.[233]

Countries with Established Space Programs

These countries are widely acknowledged as leaders in space technology development. These are often the countries reaching out to smaller space agencies to offer them opportunities and support since countries with established space programs have a wealth of knowledge and resources. Some of the countries in this bloc are Canada, China, Japan, India, Italy, Russia, the United Arab Emirates, the United States, and many countries in the European Union (through the ESA).

For example, India owns the Indian Space Research Organization (ISRO), one of only a few space agencies around the world capable of launching satellites and extraterrestrial missions.[234] As such, they are capable of collecting data independently without the help of other space agencies and can apply that data to socioeconomic issues within the country.[235] In India, the ISRO is a major constituent of the Department of Space within the government, so it works together with the government to establish sustainability objectives.[236] On March 22, 2024, the ISRO carried out its second successful reusable launch vehicle experiment, which could drastically change the outlook for emissions during rocket launches.[237] Because these

225 Sirimanne, Wu, Bell, Bokor, Hakizimana, *Exploring Space Technologies for Sustainable Development.*
226 Sirimanne, Wu, Bell, Bokor, Hakizimana, *Exploring Space Technologies for Sustainable Development.*
227 Landry Signé, Hanna Dooley, "How space exploration is fueling the Fourth Industrial Revolution," *Brookings,* March 28, 2023, https://www.brookings.edu/articles/how-space-exploration-is-fueling-the-fourth-industrial-revolution/.
228 Signé, Dooley, "How space exploration is fueling the Fourth Industrial Revolution."
229 Sirimanne, Wu, Bell, Bokor, Hakizimana, *Exploring Space Technologies for Sustainable Development.*
230 "Protecting Space: Privacy Challenges in Satellite Imaging and Surveillance," AMLEGALS Legal Strategists, May 15, 2024, https://amlegals.com/protecting-space-privacy-challenges-in-satellite-imaging-and-surveillance/#.
231 AMLEGALS Legal Strategists, "Protecting Space: Privacy Challenges in Satellite Imaging and Surveillance."
232 Patrick Tucker, "The NSA Is Studying Satellite Hacking," *Defense One,* September 20, 2019, https://www.defenseone.com/technology/2019/09/nsa-studying-satellite-hacking/160009/.
233 AMLEGALS Legal Strategists, "Protecting Space: Privacy Challenges in Satellite Imaging and Surveillance."
234 "Countries with Space Programs 2024," World Population Review, accessed August 11, 2024, https://worldpopulationreview.com/country-rankings/countries-with-space-programs.
235 "About ISRO," Indian Space Research Organisation, Department of Space, accessed August 11, 2024, https://www.isro.gov.in/profile.html.
236 Indian Space Research Organisation, Department of Space, "About ISRO."
237 Ajey Lele, "ISRO Tests Reusable Launch Vehicle For Sustainable Space Exploration," *Society for the Study of Peace and Conflict,* March 29, 2024, https://sspconline.org/opinion-analysis/isro-tests-reusable-launch-vehicle-sustainable-space-exploration.

rockets are still relatively new, there is not much data on the actual environmental benefits of reusable rockets, but there is no doubt that they result in less waste and dangerous fuel ending up in oceans after launches.[238]

Countries in this bloc may operate similarly to India, with individual efforts to expand their space technology and targeted efforts to improve sustainability. It is important to remember that countries with established space programs may not always be economically developed countries, according to UNCTAD. India is officially considered a developing country by UNCTAD, but they have still made remarkable progress in the space sector and have identified their priorities and missions for the future.[239]

While these countries have been successful at some aspects of space technology development, they may struggle in other areas. For example, the environmental impact of space technology is extremely detrimental, with hundreds of metric tons of physical waste and gaseous pollutants released into the atmosphere and ocean.[240] Despite their status, countries with established space programs are still struggling to develop technology that mitigates this problem. Countries in this bloc should focus on keeping their resource consumption sustainable while addressing the issues laid out in the Sustainable Development Goals.

Countries with Emerging Space Programs

These countries are in the early stages of developing space technology capabilities. They are in the 77 countries that have space programs, but they may not be a part of the 16 countries that can conduct a space launch or the seven countries that can send a probe to extraterrestrial locations. Examples of these countries may include Greece, Indonesia, Mexico, Nigeria, Norway, Spain, and Vietnam. These are often the countries receiving support and partnership opportunities from much larger space agencies.

For example, Nigeria's space agency, the National Space Research and Development Agency (NASRDA) had ambitious plans for its future in space, including launching a Nigerian satellite, sending a Nigerian astronaut to outer space, and creating a Nigerian launch vehicle.[241] Only one of these goals has been achieved since the NASRDA's conception in 1998, and only partially. NASRDA owns seven satellites as of 2024, but these satellites were manufactured and launched by either China, Russia, the United Kingdom, or Ukraine.[242] Additionally, NASRDA announced in March of 2024 that they would cancel their plans to launch a satellite from Nigeria due to lack of funds.[243] In 2008, a Nigerian-owned satellite failed in orbit and was recovered to avoid destroying other satellites.[244] Its replacement satellite, launched in 2011, is also nearing the end of its lifespan and is set to be recovered soon to prevent another failure in orbit.[245] Despite these weaknesses, Nigeria still has great hopes for the future success of NASRDA, and countries in this bloc may feel very similarly.

These countries need more equitable access to space technology, making it very difficult for them to accomplish any significant space mission or develop any revolutionary space technology on their own. Like Nigeria, they may have to rely on the generosity of larger space agencies to conduct research, launch satellites, and gather data. Because of these limitations, countries with emerging space programs may not yet be focused on sustainable development. While established space agencies are working toward a sustainable future, emerging space agencies are still trying to achieve the basic measures of success in space technology, like building satellites and manufacturing launch vehicles. As such, they do not focus as much on using space technology to contribute

238 Adam Stockley, "The Rise of Reusable Rockets: Transforming the Economics of Space Travel," *KDC Resource,* April 12, 2023, https://www.kdcresource.com/insights-events/the-rise-of-reusable-rockets-transforming-the-economics-of-space-travel/.
239 "Classifications of economies," UNCTAD, accessed August 11, 2024, https://hbs.unctad.org/classifications/.
240 Kevin Gaston, Karen Anderson, Jamie Shutler, Robert Brewin, and Xiaoyu Yan, "Environmental impacts of increasing numbers of artificial space objects," *Frontiers in Ecology and the Environment* 21, no.6 (April 2023): 289-296, https://doi.org/10.1002/fee.2624.
241 Tyler Way, "Challenges and Opportunities of Nigeria's Space Program," *CSIS Aerospace Security Project*, June 24, 2020, https://aerospace.csis.org/challenges-and-opportunities-of-nigerias-space-policy/.
242 Tyler Way, "Challenges and Opportunities of Nigeria's Space Program."
243 Ifeoma Joy Okorie, "Nigeria's space agency to develop four satellites in partnership with Proforce," *Techpoint,* August 9, 2024, https://techpoint.africa/2024/08/09/nigeria-partners-firm-to-build-satellites/.
244 Grace Ashiru, "Nigeria Prepares to Launch New Satellite as Current One Nears End of Service," *Tech in Africa,* July 16, 2024, https://www.techinafrica.com/nigeria-prepares-to-launch-new-satellite-as-current-one-nears-end-of-service/.
245 Grace Ashiru, "Nigeria Prepares to Launch New Satellite as Current One Nears End of Service."

to the Sustainable Development Goals. Countries in this bloc may also be extremely involved in their issues because they have recognized the ability of space technology to solve socioeconomic problems. Countries in this bloc shift their focus toward making more substantial contributions to the Sustainable Development Goals by recommending long-term partnerships with larger space agencies so that the focus can be shifted from vehicle development to sustainable development.

Collaborative Beneficiary Countries

There are only 77 countries worldwide with a national space program, which means every other country either has a small private agency or no space program at all. Small island states are likely to have no space agency, as well as many countries on UNCTAD's list of Least Developed Countries.[246] Some of these countries have plans to begin a national space agency, such as Armenia, Cambodia, Guatemala, Malta, Nicaragua, Oman, and Tanzania.

For example, Nicaragua became the tenth country to join China's International Lunar Research Station on April 25, 2024.[247] Nicaragua does not have a space agency of its own due to economic and technological resource limitations, but it does utilize some space technology and data and is a signatory to the Outer Space Treaty.[248] Despite not having its official space agency, Nicaragua has displayed a desire to invest in space technology as a means to solve national issues and a willingness to adhere to international law. This makes Nicaragua a collaborative beneficiary or a country that gains advantages as a result of working with much larger and more established space agencies. This partnership may seem very beneficial for Nicaragua, but there are some security concerns from other countries about the influence China may have on Nicaragua, not only in the space sector but also in the economic and social sectors.[249]

Like Nicaragua, many of the countries in this bloc will be eager to form relationships with space sector powerhouses to further their space technology development and improve the social issues within their countries. However, while these relationships may help them achieve their goals, these countries establish their parameters for the use of space technology so political tensions between member states do not influence them. If countries with established space programs easily sway countries in this bloc, then the international cooperation that space technology can foster will be lost, and space technology will become an overly competitive and hostile field. Collaborative beneficiary countries should ensure that they do not sacrifice their objectives while making partnerships. That way, they can take the fastest route toward developing space technology without the help of foreign agencies and make individual contributions toward reaching the Sustainable Development Goals.

Committee Mission

The Commission on Science and Technology for Development (CSTD) is a subsidiary of the Economic and Social Council of the United Nations, with 43 member states that meet annually.[250] As society rapidly integrates technology, data science, and innovation into daily life, the CSTD provides a forum for its member states to discuss prominent issues within the field of science and technology to recommend the UN on policy-making. In addition, after reports are released from the World Summit on the Information Society (WSIS), the CSTD is responsible for reviewing and assessing the progress made by countries who commit to the actions presented in the WSIS reports.[251] They then share the issues, successes, and important measures with the member states to promote further implementation of the WSIS documents

246 "UN list of least developed countries," UN Trade and Development, accessed August 12, 2024, https://unctad.org/topic/least-developed-countries/list.
247 Andrew Jones, "Nicaragua signs up to China's ILRS moon program," *SpaceNews*, April 25, 2024, https://spacenews.com/nicaragua-signs-up-to-chinas-ilrs-moon-program/.
248 Jones, "Nicaragua signs up to China's ILRS moon program."
249 Julieta Pelcastre, "Nicaragua Gets Closer to China through Lunar Program," *Diálogo Américas,* July 5, 2024, https://dialogo-americas.com/articles/nicaragua-gets-closer-to-china-through-lunar-program/.
250 "About the CSTD," UN Trade and Development, accessed August 11, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development/about.
251 "Mandate and Institutional Background," UN Trade and Development, accessed August 11, 2024, https://unctad.org/topic/commission-on-science-and-technology-for-development/mandate.

and dialogue among UN countries and organizations.[252] This work, combined with the advice that the CSTD provides to UN organizations, helps immensely in making sure that policy is drafted with the newest technological advancements and their implications in mind.

During this new era of space technology, closely observing rapid advancements of new technologies is critical in ensuring that all countries have equal standing in this "21st-century space race."[253] Space technology has shown a remarkable versatility and the ability to aid in most, if not all, of the Sustainable Development Goals. Because of this, delegates of the CSTD should be prepared to monitor the space sector's interactions with other economic sectors, private companies, other agencies, and governments. The accessibility of space technology is critical in determining its success in decelerating the rate of climate change impacts, improving socioeconomic issues and global health, and fostering international cooperation. Therefore, this should be a major priority to CSTD delegates as they work to consider how space technology could expedite or inhibit sustainable development on a global scale.

A major challenge in writing outer space legislation in the past has been accountability and liability.[254] As space agencies outpace existing frameworks and operate unchecked, the volume of waste orbiting the Earth and clogging our oceans will continue to grow unless regulations that can track countries' actions and ensure compliance are put in place. If space debris renders outer space unusable and begins impacting life on the planet, then instead of becoming a tool to aid humanity, space technology will just be another hazard. The CSTD is more than capable of addressing these issues within the scope of its mandate, and its delegates have the power to make the future of space technology safe, sustainable, and equitable for all.

Glossary

CubeSat: A type of SmallSat weighing between one and ten kilograms, or a nanosatellite.[255]

Deep Space Network (DSN): NASA's interplanetary communication system, which provides radio and radar observations. It consists of giant radio antennas that support space missions.[256]

Electromagnetic spectrum: The range of all types of electromagnetic radiation (microwaves, UV, X-rays).[257]

Geostationary orbit (GEO): An orbit by any satellite that sits at an altitude of 35,786 kilometers (approximately 22,240 miles), keeping the satellite fixed in that position and in tune with Earth's rotation.[258]

High Earth orbit (HEO): Any satellite orbit above 36,000 kilometers. Geostationary orbits are high earth orbits.[259]

Intercontinental ballistic missile (ICBM): Missiles with a range greater than 5,500 kilometers (around 3420 miles). They possess greater risk because of their range, potentially going for global consequences.[260]

International Space Station (ISS): Launched in 1998, it is the largest station in space. An international program that aims to explore and do research outside of Earth. It is mainly managed by the US, Russia, Europe, Japan and Canada.[261]

252 UN Trade and Development, "Mandate and Institutional Background."
253 Oliver Holmes, "'We're in a new era': the 21st-century space race takes off," *The Guardian,* May 3, 2024, https://www.theguardian.com/science/article/2024/may/03/were-in-a-new-era-the-21st-century-space-race-takes-off.
254 Sophie Goguichvili, Alan Linenberger, and Amber Gillette, "The Global Legal Landscape of Space: Who Writes the Rules on the Final Frontier?" *Wilson Center,* October 1, 2021, https://www.wilsoncenter.org/article/global-legal-landscape-space-who-writes-rules-final-frontier.
255 "What Are SmallSats and CubeSats? - NASA," NASA, accessed September 7th, 2024,. https://www.nasa.gov/what-are-smallsats-and-cubesats/.
256 Heather Monaghan, "What Is the Deep Space Network? - NASA." *NASA* (blog), September 29, 2023,. https://www.nasa.gov/directorates/somd/space-communications-navigation-program/what-is-the-deep-space-network/.
257 "Electromagnetic Spectrum - Introduction," NASA, accessed September 7, 2024, https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html.
258 Shunlin Liang, and Jindi Wang, *Advanced Remote Sensing: Terrestrial Information Extraction and Applications*, Academic Press, 2019.
259 "Catalog of Earth Satellite Orbits," NASA Earth Observatory, accessed September 7, 2024, https://earthobservatory.nasa.gov/features/OrbitsCatalog.
260 "Intercontinental Ballistic Missiles," ICBM, accessed September 7, 2024, https://nuke.fas.org/intro/missile/icbm.htm.
261 "International Space Station - NASA," NASA, October 2, 2023, https://www.nasa.gov/reference/international-space-station/#hds-

Ion propulsion: A form of electric propulsion mainly used for spacecraft propulsion. It works by using an electrical charge that accelerates xenon fuel ions.[262]

Landsat: Longest running program that provides data and images of Earth's surface. It has been active since 1972.[263]

Launch vehicle: Complex systems used to carry spacecraft from the surface of Earth into space.[264]

Low Earth orbit (LEO): A satellite orbit relatively close to Earth's surface. This can mean an altitude between 1,000 and 160 kilometers (620 and 100 miles) above the surface.[265]

Medium Earth orbit (MEO): Any satellite orbit between LEO and GEO. Commonly used by navigation satellites.[266]

Remote sensing: The acquiring of data/information from a distance.[267]

SmallSat: Any satellite weighing below 180 kilograms (roughly 400 pounds). They can be broken down into minisatellites, microsatellites, nanosatellites, etc., based on weight.[268]

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262 "Ion Propulsion - NASA Science," NASA, accessed September 7, 2024, https://science.nasa.gov/mission/dawn/technology/ion-propulsion/.
263 "Landsat Missions," U.S. Geological Survey, August 12, 2024, https://www.usgs.gov/landsat-missions.
264 Meyers, Robert A, *Encyclopedia of Physical Science and Technology*, Academic Press, 2002.
265 "Low Earth Orbit," ESA, accessed September 7, 2024, https://www.esa.int/ESA_Multimedia/Images/2020/03/Low_Earth_orbit.
266 "Types of Orbits," ESA, accessed September 7, 2024, https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits.
267 Cynthia Hall, "What Is Remote Sensing?" Earthdata, January 3, 2024, https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing.
268 Pete Kogut, "Small Satellites: Technology That Democratizes Space," *EOS Data Analytics* (blog), January 1, 1970, https://eos.com/blog/small-satellites/.

Research and Preparation Questions

Your dais has prepared the following research and preparation questions as a means of providing guidance for your research process. These questions should be carefully considered, as they embody some of the main critical thought and learning objectives surrounding your topic.

Topic A

1. How can developed countries assist developing nations in transitioning to more sustainable agricultural practices that minimize pesticide use without compromising food production?
2. What are the long-term ecological consequences of pesticide use, including biodiversity loss, soil degradation, and water pollution? How can these impacts be reversed or mitigated?
3. What are the challenges and opportunities in establishing a global regulatory framework for biotechnology that balances innovation, safety, and environmental protection?
4. Given the potential environmental and health risks associated with pesticide use, is it justifiable to continue their application in agriculture, especially in developing countries where food security is a major concern?
5. How much of your nation's economy is dependent on agriculture, and how much could it benefit from increased security and value from bioengineering?
6. Considering your country's history, what actions, laws, policies, or developments. have been placed toward this issue? How much biotechnology for agriculture is available in your country currently?
7. Are agricultural subsidies contributing to the overuse of pesticides, and if so, how can they be reformed to promote more sustainable practices?

Topic B

1. How can space technology be used to revolutionize education? Could this ensure equitable access to knowledge and resources for students around the world?
2. How can space technology contribute to the goals of Agenda 2063 and the AfCFTA, promoting regional integration, economic development, and social progress?
3. How can we address the disproportionate environmental impacts of space activities on marginalized communities and vulnerable ecosystems?
4. What measures can be taken to ensure that space technology is accessible to people with disabilities, promoting inclusivity and equal participation?
5. How can we leverage the rapid advancements in space technology to bridge the digital divide and improve access to information and services in remote or underserved areas?
6. What are your country's most effective strategies for mitigating the growing problem of space debris, and how can they be improved upon?
7. What bodies govern your country's space program? How do they collaborate, and how would you improve current collaborative efforts?

Important Documents

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