Secure Tomorrow Series Alternative Futures: Synthetic Biology Player Guide

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BACKGROUND

How prepared are critical infrastructure sectors in light of potential advancements in synthetic biology? *Alternative Futures: Synthetic Biology* presents you with scenarios that could plausibly occur within the next 10 to 15 years. During each round, you and your opponents will take turns proposing initiatives and debating strategies that will mitigate risks to critical infrastructure in light of potential advancements in synthetic biology. How successfully you manage to present your arguments for (or against) these initiatives determine their chances of success. Depending on your role for the round, you can score points for either successfully implementing or countering initiatives.

The Cybersecurity and Infrastructure Security Agency's (CISA) National Risk Management Center has developed this game to assist stakeholders across the critical infrastructure community to self-facilitate and conduct foresight activities that will enable them to derive actionable insights about the future, identify emerging risks, and proactively develop corresponding risk management strategies to implement now. One goal of the Secure Tomorrow Series is to develop a repeatable and defensible process that (1) identifies emerging and evolving risks to critical infrastructure systems, and (2) identifies and analyzes the key indicators, trends, accelerators, and derailers associated with those risks to help critical infrastructure stakeholders direct their risk management activities.

For players, the game hopefully represents a fun and interactive way for you to think broadly about future threats and opportunities, learn from your peers, and identify strategies to inform preparedness activities.

The game takes about three hours to complete. This includes an introduction and description of the current state, three rounds of gameplay (each about 45 minutes long), and a final 20-minute open-discussion period to collect any final feedback from players and wrap up the game.

PLAYER ROLES AND ASSIGNMENTS

At the start of the game, each player will be assigned one of three roles. Players will rotate roles in subsequent rounds, so that they fill different roles through the course of the game. The three roles are as follows:

- The Innovator(s): Responsible for developing initiatives and arguments in support of those initiatives.
- The Devil's Advocate: Responsible for developing counterarguments to the initiatives proposed by the Innovator.
- The Judge: Responsible for adjudicating the validity of the Innovator's arguments versus the counterarguments made by the Devil's Advocate for a particular initiative and determining the initiative's likelihood of success.

Players will bring their personal knowledge, experience, and perspectives to debate strategies that will shape critical infrastructure resilience and security considering potential advancements in synthetic biology. Players should consider policies, programs, investments, public-private partnerships, research and development, or other actions that, if successfully put into motion today, they believe will better position and prepare one or more critical infrastructure sectors for the future. In preparing for the game, players may want to think about the following questions:

- What risks and opportunities are associated with current trends in synthetic biology?
- What are the implications for future critical infrastructure resilience and security?

- Are there specific ramifications for one or more critical infrastructure sectors?
- Is there a role for CISA to address threats and uncertainties associated with potential advancements in synthetic biology?

PRESENT STATE

For the purposes of this game, we define synthetic biology as the redesigning and harnessing of biological organisms to impart new or improved abilities and produce products. The many potential applications for synthetic biology include diagnostics and therapeutics, environmental remediation, control of infectious of disease vectors, water treatment, energy and fuel production, chemical manufacturing, improvement of agricultural yields, and food production.

Some drivers underlying recent advances in synthetic biology include the following:

- The significantly falling cost and rising speed of genetic sequencing technology
- Developments in bioinformatic tools such as artificial intelligence to parse and analyze genomic data
- Highly targetable methods for gene editing, such as CRISPR-associated protein methods
- Automation of gene synthesis and assembly, including high-throughput and liquid-handling robots
- Advances in lab-on-chip and organ-on-chip systems that allow for rapid testing of new products

The recent response to the COVID-19 pandemic reflects some of the significant progress within the field that has taken place. This includes decoding the SARS-CoV-2 virus genome in just 40 hours, deploying mRNA technology to develop COVID-19 vaccines, and using genetic sequencing to conduct surveillance for new variants.

Moving forward, experts believe that synthetic biology will be a critical area of economic and geopolitical competition with national security implications.

PLAYING THE GAME

Alternative Futures: Synthetic Biology has three rounds, each of which will present the players with a scenario that could plausibly occur within the next 10 to 15 years. In Round 1, the Innovator(s) will have 15 minutes to identify up to three initiatives that will support critical infrastructure resilience and security in response to the specified scenario disruptor. For each initiative, the Innovator(s) will then describe up to three supporting arguments for why the initiative will succeed. The Devil's Advocate will then have 10 minutes to describe up to three counterarguments for each initiative. Each counterargument can be directed at one or more of the arguments presented in favor of the initiative's success or underscore a new concern that may cause the initiative to fail. The Innovator(s) will then have 5 minutes to rebut any or all of the counterarguments. The Judge will listen to both sides of the debate and ultimately determine if each initiative has a high, medium, or low likelihood of success. The Judge will have 5 minutes to present the rationale for his or her determinations and roll a 20-sided die to see if each initiative succeeds or fails.

The die simulates the unpredictability of the supporting environment for initiatives, and the game's inability to account for all positive and negative factors that might influence success.

- An initiative with a **high** likelihood of success will be implemented with a roll of 6 or higher (75 percent chance).

- An initiative with a **medium** likelihood of success will be implemented with a roll of 11 or higher (50 percent chance).
- An initiative with a **low** likelihood of success will be implemented with a roll of 16 or higher (25 percent chance).

An open-discussion period may occur after resolving the success or failure of the initiatives to continue any discussions cut short by previous time constraints.

In Rounds 2 and 3, the participants will rotate roles.

DISRUPTORS

Social, technological, environmental, economic, and political (STEEP) influences have the potential to alter the trajectory of future trends or disrupt them altogether. For example, urbanization is a social disruptor that has the potential to significantly affect the resilience of lifeline sectors; an unexpected election result is a political disruptor that could significantly affect funding for critical infrastructure projects; and cyberattacks are a technological disruptor with a wide range of cascading implications for all critical infrastructure sectors.

To account for a changing future environment, each round features a STEEP disruptor scenario that may limit player actions, alter the trajectory of potential advancements in synthetic biology, or require players to consider the implications of an event. The possible scenarios to choose from during the game are described in Appendices I–V. As an added incentive for players to craft compelling arguments and counterarguments, the winning player of each round is awarded the ability to select the STEEP disruptor category for the next round.

WINNING THE GAME

If the Innovator(s) successfully implement(s) a majority of the initiatives, the Innovator(s) win(s) the round. Alternatively, if the Devil's Advocate counters a majority of the initiatives, he or she wins the round. While the game is designed to encourage competition between the players, its main purpose is to generate discussions that develop well-conceived and thought-provoking initiatives. Your collective subject matter expertise is what matters, regardless of the outcomes of each round.

GAME SCHEDULE

TABLE 1—SCHEDULE FOR CONDUCTING THE MATRIX GAME

MATRIX GAME STAGES (~3 HOURS)				
Introduction	-	Welcome participants and discuss game purpose (Controller)	3 Min	18 Min Total
	-	Explain game rules (Controller)	5 Min	
	-	Practice round	7 Min	
	-	Introduce current state and potential implications (Controller)	3 Min	
Round 1	-	Introduce future scenario based on STEEP disruption (Controller)	5 Min	41–51 Min Total
	-	Craft initiatives and present arguments (Innovator(s))	15 Min	
	-	Present counterarguments (Devil's Advocate)	10 Min	
	-	Rebuttal (Innovator(s))	5 Min	
	-	Adjudicate arguments and roll die (Judge)	5 Min	
	-	(Optional) Open-discussion period	< 10 Min	
	-	Select STEEP disruptor	1 Min	
Round 2	-	Introduce future scenario based on STEEP disruption (Controller)	5 Min	41–51 Min Total
	-	Craft initiatives and present arguments (Innovator(s))	15 Min	
	-	Present counterarguments (Devil's Advocate)	10 Min	
	-	Rebuttal (Innovator(s))	5 Min	
	-	Adjudicate arguments and roll die (Judge)	5 Min	
	-	(Optional) Open-discussion period	< 10 Min	
	-	Select STEEP disruptor	1 Min	
Round 3	-	Introduce future scenario based on STEEP disruption (Controller)	5 Min	40–50 Min Total
	-	Craft initiatives and present arguments (Innovator(s))	15 Min	
	-	Present counterarguments (Devil's Advocate)	10 Min	
	-	Rebuttal (Innovator(s))	5 Min	
	-	Adjudicate arguments and roll die (Judge)	5 Min	
	-	(Optional) Open-discussion period	< 10 Min	
Wrap Up	-	Determine final game status of critical infrastructure security and resilience (Controller)	5 Min	20 Min Total
	-	Open-discussion period (Players)	15 Min	

Participants are reminded that any information shared during this game is provided on a voluntary basis. Sensitive information, to include confidential or proprietary information, should not be shared. Information shared during this game may be recorded for the purposes of facilitating the program and discussions. However, discussion or disclosure of information in these sessions is not a substitute for submission under the Protected Critical Infrastructure Information Program. Therefore, information may be subject to Freedom of Information Act requests or other mechanisms that would publicize any information shared or recorded.

CISA has produced these scenarios to initiate and facilitate discussion. The situations described here are hypothetical and speculative and should not be considered the position of the U.S. Government. All names, characters, organizations, and incidents portrayed in these scenarios are fictitious.

APPENDIX I: SOCIAL DISRUPTOR

BACKLASH AGAINST CULTURED MEAT PRODUCTS

By 2030, approximately 15 percent of meat products consumed in the United States are derived from a laboratory (as opposed to conventional animal harvest). The success of cultured meat products on the West Coast and in the Mid-Atlantic has increased demand for such products in major Midwestern cities. When a prominent meat packing company announces plans to fund an industrial-scale meat culture laboratory near the Midwestern city of Sheltonvale, a blogger shares a conspiracy theory. This theory claims that the company—a subsidiary of a larger foreign holding company—intends to replace conventional meat products with cultured meat, drive smallholder livestock operations out of business, and increase U.S. dependency on foreign imports. The theory goes viral, gaining particular traction with disaffected livestock producers in the Midwest and Plains states, who have struggled to breakeven in recent years.

Leading into the 2032 election season, politicians representing states with large conventional livestock industries, as well as large professional and political lobby groups representing livestock producers, begin calling for protections for traditional animal meat production and for investigations into the business and marketing practices of cultured meat producers and their investors. Through social media and the larger national organizations, producers begin organizing protests at state capitals, academic and commercial cultured meat laboratories, and government facilities across the country. Some demonstrations turn unruly and even violent. Grocery stores carrying cultured meat products report vandalism, destruction, and theft of displays and cases of product; major cities report blockages of roads and public spaces by protestors in large farm vehicles; academic laboratories on university campuses report break-ins, destruction of cell lines and equipment, and threats against laboratory staff; and a rural commercial laboratory is fire-bombed, destroying the facility and nearby grasslands.

What initiatives are necessary for the cultured meat industry to address consumer perceptions and counter misinformation and disinformation that could hinder the adoption of synthetic biology-based foods and increase physical threats against this emerging industry and its supply chains?

APPENDIX II: TECHNOLOGICAL DISRUPTOR

LOSS OF PROPRIETARY INFORMATION FROM CYBERSECURITY LAPSES

While research and applications of synthetic biology have blossomed in the last 10 years, the ability of some organizations, especially startups, to implement cybersecurity best practices has not kept pace. Insufficient cybersecurity at several startups has resulted in the theft of intellectual property and the collapse of promising companies. Examples include the following:

- *In 2026, a synthetic biology startup company, AquaBiozys, demonstrated results from a synthetically engineered bacteria that can consume atrazine (a common herbicide). Within hours of its press release, AquaBiozys's computer systems were bombarded with cyberattacks and the social media sites of the company's chief scientists were infiltrated and taken offline. Post-incident analysis showed the cyberattacks resulted in theft of critical information about the scientific breakthrough. By 2027, AquaBiozys was bankrupt, with foreign companies marketing similar products.*
- *In 2027, a facility that provided large-scale biomanufacturing services fell victim to a cyberattack less than a year after going online. The cyberattack modified the temperature of several bioproduction processes underway; loss of critical samples resulted in significant costs to both the facility owners and the service users. Lack of confidence in the security of the facility resulted in its eventual demise.*
- *The most widely known incident, occurring in 2032, involves the intellectual property theft of the groundbreaking creation of bacteria that, when added to soil, would significantly reduce the need for chemically derived fertilizer. Importantly, this would also reduce worldwide agricultural demand for ammonia fertilizer, which relies heavily on the energy-intensive and greenhouse gas–emitting Haber-Bosch process. While the U.S. company that patented the discovery tackled regulatory hurdles to take its product to market, it experienced a massive cyberattack and data breach of the DNA sequence and protocols for creating the bacteria. Soon afterward, the same engineered bacterial products were sold widely by other foreign companies.*

What initiatives can you think of to improve the cybersecurity of synthetic biology organizations?

APPENDIX III: ECONOMIC DISRUPTOR

NOVEL FOOD STARCH DISRUPTS U.S. MARKETS

In 2032, after decades of research, companies in the country of Fictitia finally begin mass production of synthetic, food-grade starch made from carbon dioxide. As early as 2021, Fictitita researchers pioneered the process in the lab, but they needed another decade to solve scalability issues (e.g., mass-produce the required enzymes, generate enough low-cost renewable energy) to make large-scale food starch synthesis economically viable and climate friendly. Fictitia companies have developed different variants of synthetic starch that can be used to make bread, rice, and other grain products. Preliminary results indicate that synthetic starch production is 8.5 times faster than production using traditional agriculture and at a much lower cost. Additionally, this process consumes carbon dioxide and substitutes for carbon- and land-intensive agricultural production. Experts predict that Fictitia will have ramped up production to be a net exporter of food starch by 2035.

In the United States, Congress and the public are deeply divided on how to respond. Consumers, food processors, and environmental groups point to estimates of food prices cut in half and global reductions in carbon emissions of 30 percent relative to the status quo if the world switched entirely to consuming synthesized starch. Conversely, the U.S. agriculture industry vehemently opposes imported synthesized starch and is actively lobbying Congress to impose protective tariffs or to ban the import of synthetic starch. Furthermore, there is a small but vocal minority of consumers who distrust synthesized food products, believing them to be unsafe. One extreme conspiracy theory even claims that synthetic starch is part of a foreign plot to alter Americans' brain chemistry.

U.S. federal agencies are also divided about the economic security implications of importing Fictitia-produced synthetic starch. While recognizing synthesized starch's massive benefits in mitigating climate change and lowering food prices, the United States would ideally like to be self-sufficient in domestic starch synthesis to ensure economic security amid U.S.-Fictitia tensions. However, the average cost for U.S.-produced synthetic starch is still 1.5 times that of Fictitia producers; absent substantial government intervention, domestic prospects for this industry remain limited for at least the next five years.

What initiatives can you think of to address the economic effects on the United States of Fictitia synthetic starch exports and the ripple effects on global food security?

APPENDIX IV: ENVIRONMENTAL DISRUPTOR

DEVASTATING POULTRY DISEASE

Climate change and rising average temperatures allow viruses and bacteria previously limited to tropical and sub-tropical climates to flourish in more temperate environments. In spring 2028, migratory birds returning north carried a novel strain of highly pathogenic avian influenza virus, known as H9N11. While not harmful to the wild carriers, H9N11 proved to be extremely contagious and lethal to domestic chickens. The virus was introduced to flocks in major poultry states along the migratory route. What began as a series of localized outbreaks quickly escalated into an epidemic, forcing rapid mass depopulation of commercial broiler and broiler-breeder flocks.

By summer 2029, approximately 130 million broiler and broiler-breeder chickens—approximately 25 percent of the total U.S. flock—were depopulated. Poultry meat production declined drastically, causing a shortage of chicken meat and driving chicken prices to all-time highs in grocery stores. Agricultural experts project that the industry will need at least six months to rebuild flocks to pre-epidemic levels and that the United States will need to increase imports of chicken meat—at exorbitant prices—in order to meet demand.

In response to the chicken crisis, a prominent billionaire announced that she would provide seed money to laboratory facilities seeking to expand cultured meat production capacity to offset demand and reduce reliance on imports while flocks were rebuilt. However, ramping up production has proven to be challenging for several reasons:

- *Western states traditionally more friendly toward cultured meat are experiencing severe drought. There is concern from these states about supporting a water-intensive industry and providing the tax breaks and other incentives the investors are requiring.*
- *Domestic consumption of chicken meat—both conventionally harvested and cultured in the laboratory—has declined by nearly 15 percent, as consumers question the safety of poultry meat and protest the conventional industry practices (e.g., mass housing of birds) that facilitated the outbreak. The companies question whether they will be able to turn a profit on cultured chicken meat based on current trends.*

What initiatives can you think of to support the rapid increase in production of cultured meat products?

APPENDIX V: POLITICAL DISRUPTOR

DO-IT-YOURSELF (DIY) BIOLOGY THREAT

Thanks to the advent of CRISPR, DIY genetic engineering and other biology kits, DIY biology communities, and an open data and open science environment, the DIY biology community is well established by the mid to late-2020s. A few instances of groundbreaking successes from the DIY biology community (leading to very lucrative results for the DIYers) further fueled interest in the possibilities of synthetic and DIY biology.

As the capabilities of civilian scientists advance, legitimate academic, synthetic biology, and biotech companies recruit DIY biologists into their organizations for temporary and permanent work. Incorporating them into the "gig" economy and permanent workforce is helping address a workforce shortage of individuals formally trained in biology and synthetic biology techniques.

However, in 2028, a coworker of an individual hired from a DIY biology community alerted their company's leadership to concerns about the activities of a DIY biologist, noting concerning conversations about ways to make pathogens more virulent, a habit of working odd hours, and inappropriate access to the lab's animal facilities. After the organization looked into the employee, it found internet browser activity on genome sequences of pathogens, international organizations that do not screen Deoxyribonucleic acid (DNA) sequences ordered, and how to create a biocontainment lab from scratch. The organization alerted law enforcement who searched the individual's residence. They found a small biological laboratory with materials marked as hazardous, evidence that the individual ordered and received DNA sequences from offshore companies, and a plan to infect animals in the company's animal testing facilities with smallpox DNA. Further analysis of the biological samples seized from the individual's residence demonstrated that he had successfully synthesized the smallpox virus DNA.

While no one was harmed, the incident garnered national media attention and many concerned citizens and politicians called for wide-spread restrictions on the sale of the kits and reagents that could be used to produce this type of threat. Additionally, the DIY biology and synthetic biology community came under intense scrutiny and legislators proposed a number of safeguards meant to prevent this type of nefarious activity in the future. However, many in the synthetic biology and biotechnology research and development community claim the restrictions will stymie progress into many beneficial applications of synthetic biology.

What regulations or other government actions may be necessary to manage the growth of DIY synthetic biology efforts?