Secure Tomorrow Series Scenario Workshop Facilitator Guide

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SCENARIOS WORKSHOP FACILITATOR GUIDE

Secure Tomorrow Series

***Non-federal facilitators**: The Cybersecurity and Infrastructure Security Agency (CISA) has provided this toolkit as a starting point for your organization to address these critical issues. Please feel free to expand upon or adapt these exercises and tools to your needs. In several places throughout the document, we have provided guidance for federal facilitators regarding participants, process, and information protections. This guidance is based upon federal requirements, which may differ from state and local considerations. Please consult with your organization to consider what language or actions you will need to take in hosting a workshop session.*

GOAL

This workshop uses hypothetical scenario narratives to help participants explore ways in which the operating environment for critical infrastructure (CI) owners and operators may evolve over the next 15–20 years, and how this evolution may affect the security and resilience of CI systems. In particular, the workshop's three scenarios center on plausible future changes pertaining to the topics of (1) brain-computer interfaces (BCIs), (2) quantum technologies, and (3) synthetic biology.

Participants will leave the workshop having identified a prioritized set of risk mitigation strategies that will increase CI resilience and security, regardless of future uncertainties.

KEY WORKSHOP OUTPUTS

- Identification of significant issues and questions—to address now and in the future—for the various strategic operating environments posed in each of the three scenarios
- A prioritized set of risk mitigation strategies that would increase security and resilience in most, if not all, of the three scenarios

BACKGROUND

In the context of this workshop, a scenario is a story with plausible cause and effect linkages that connect a future condition with the present while illustrating key decisions, events, and consequences throughout the narrative. By using a small set of carefully crafted scenarios, organizations can avoid focusing on just a single future (i.e., *the* future) and develop strategies and plans that are viable over a range of possible futures. This is the underlying premise behind the scenarios workshop sessions.

RECOMMENDED PARTICIPANTS

***[Please note:** Invitations to participate should focus on mid-to-senior career-level individuals who are interested in exploring longer-term risks to CI to enable effective risk mitigation. To provoke new lines of thinking about risks to CI systems (either directly or through cascading impacts), we recommend that you seek broad representation from regional CISA personnel; state, local, tribal, and territorial planners; fusion center and intelligence community representatives; and other private-sector, non-profit, think-tank, and academic stakeholders. In particular, individuals with interest and expertise in the topics, and individuals who are already familiar with strategic foresight, are encouraged to participate. Because the workshop divides participants into three groups, please consider how you will achieve mixing and balancing different perspectives and expertise.]*

[Once known, this section of the guide would list the workshop participants, their titles, and the agencies/organizations they represent. If the workshop sponsor permits, the facilitator should consider providing participant biographical information to all participants ahead of the workshop.]

WORKSHOP FORMAT

The workshop activities were designed to occur over 7 hours, either as a virtual event over two consecutive afternoons or as a one-day, in-person event. The remainder of this guide is built around a virtual execution of the workshop, which would use a virtual meeting platform.

FACILITATION STAFF

- One workshop coordinator[1]
- One lead facilitator
- Two scenario facilitators
- Three documentation leads

Note: Each facilitator is responsible for one scenario. The lead facilitator also serves as a scenario facilitator.

SUPPORT MATERIALS

- STS Scenarios Workshop: Introduction and Roadmap Slides
- STS Scenarios Workshop: Are We There Yet Results Slides

WORKSHOP PREPARATION

Hosting a virtual scenarios workshop is a major undertaking and can be considered a capstone activity that follows execution of matrix games or cross-impacts sessions. For additional details about the steps necessary to plan a virtual workshop, please see Appendix A: Workshop Planning Considerations.

Facilitators should review in detail the support materials that pertain to their assigned scenario. Although they should focus most of their attention on their assigned scenario, facilitators should also review the other scenarios.

[1] The workshop coordinator can also serve as one of the facilitators for the event.

Prior to the workshop, the workshop coordinator will assign participants (maximizing diversity of backgrounds in each group) to one of three groups. Each group will focus on one of the scenario narratives. Participants should receive their assigned scenario narrative at least one week before the workshop as a read ahead. Facilitators should review their list of assigned participants and familiarize themselves with the background and affiliation of each participant.

The lead facilitator/workshop coordinator should plan to hold at least one orientation meeting that requires attendance from all scenario facilitators and documentation leads. During this meeting, the lead facilitator/workshop coordinator should walk through the workshop agenda and sessions, allowing sufficient time for facilitation staff to ask questions about the workshop itself and detailed questions about the scenarios.

AGENDA

DAY ONE	
1–1:45 p.m.	Framing the workshop: Welcome, participant introductions, workshop objectives, and event roadmap (*plenary session*)
1:45–2:30 p.m.	Icebreaker exercise: Are we there yet? (*plenary session*)
2:30–2:45 p.m.	Break
2:45–5 p.m.	Scenario breakouts ▪ Participant introductions ▪ Scenario familiarization and build-out ▪ Identification of emerging and evolving risks and associated needs ▪ Identification and prioritization of risk mitigation strategies ▪ Preparation for Day Two stress-test rounds

DAY TWO	
1–1:10 p.m.	Welcome back and roadmap for the day's activities (*plenary session*)
1:10–1:55 p.m.	Alternative future stress-test: Round 1
1:55–2:40 p.m.	Alternative future stress-test: Round 2
2:40–2:55 p.m.	Break
2:55–3:45 p.m.	Synthesis and reflection (*plenary session*)
3:45–4 p.m.	Closing remarks (*plenary session*)

GENERAL INSTRUCTIONS

- **Foster and maintain a collaborative and respectful atmosphere.** Encourage different observations, opinions, and perspectives. The discussions will explore a variety of policies, actions, and issues, and participants will likely display different degrees of expertise on discussion topics. The breakouts are no-fault, not-for-attribution sessions focusing on the identification, analysis, and generation of solutions for upcoming issues of concern.
- **Encourage participants to speak from their perspective.** There may be strategic needs that are prominent for particular stakeholder groups. A participant's unique perspective can be used as a starting point for broadening the discussion as to how it might apply to other stakeholder groups. If a participant is speaking from the perspective of a particular stakeholder group, ask other stakeholder groups about how this might also apply to them.
- **Anchor participants in the scenarios.** Ask participants to refer to content from the scenario narrative whenever possible to make the discussion more concrete.
- **Reinforce the future context of discussions.** Include references to the time period when presenting materials and emphasize, when appropriate, the scenario time horizon of 15–20 years in discussions to prevent participants from lapsing into present-day concerns.
- **Focus on CI security and resilience.** Keep the group on topic. How does whatever is being discussed lead to a connection to risk for CI security and resilience? It can be connected indirectly, and facilitators can prompt discussion about any complexities and tradeoffs involved, but they should always return to CI security and resilience. In other words, as the group is identifying emerging or evolving threats, also have group members elaborate on the nexus to CI, if it is not obvious.

FRAMING THE WORKSHOP

DAY ONE: 1—1:45 P.M.	
Description	The workshop coordinator provides a brief introduction and welcome to all participants and introduces the lead facilitator (if necessary). The lead facilitator then explains the goal for the workshop and walks participants through how the various sessions will integrate to achieve this goal.
Session Objectives	State the goal of the workshop and discuss how the sessions in the workshop agenda fit together to achieve this goal
Outputs	Improved participant understanding of the workshop
Duration	45 minutes
Supporting Materials	Secure Tomorrow Series, Scenarios Workshop: Introduction and Roadmap Slides
Staffing Requirements	▪ Workshop coordinator ▪ Lead facilitator ▪ Senior leader representing the hosting organization
Breakdown	1. Welcome (workshop coordinator) 2. Thank you to participants (senior leader representing host organization) 3. Review of workshop objectives and desired outputs (lead facilitator) 4. Roadmap of workshop sessions (lead facilitator)
Facilitator Talking Points	Please work from the “Secure Tomorrow Series, Scenarios Workshop: Introduction and Roadmap Slides” and accompanying “Scenarios Workshop: Introduction and Roadmap Presentation Slide Notes”
Additional Notes	None

ICEBREAKER EXERCISE: ARE WE THERE YET?

DAY ONE: 1:45—2:30 P.M.	
Description	The lead facilitator will conduct an icebreaker exercise with participants. The exercise involves presenting participants with a series of topic areas (e.g., space travel, synthetic biology). Participants will be polled on their perspectives about how far society will have progressed in each area by 2035. The facilitator will ask participants to select from a list of pre-established answers.
Session Objectives	▪ Orient participants' thinking toward the longer-term future ▪ Allow participants to see how their views about the future compare with those of others ▪ Familiarize participants with the concept of underlying drivers of change by exploring participants' rationale for their answer selections
Outputs	None
Duration	45 minutes
Supporting Materials	▪ Secure Tomorrow Series Scenarios Workshop: Are We There Yet Results Slides
Staffing Requirements	Lead facilitator
Breakdown	1. Relay exercise instructions (lead facilitator) 2. Walk through each of the topic areas, then facilitate discussion of the polling results (lead facilitator)
Facilitator Guidance	▪ Initial talking points: o Thinking about the future in longer-term timeframes can be difficult, so we didn't want to shock you by throwing you straightaway into deliberations about different states of the world 15–20 years from now. In this session, we're going to try and orient your thinking toward a longer-term time horizon. o This session is fairly short. Think of it as an icebreaker to the workshop and a chance for participants to stretch their thinking forward in time in order to see how their views of the future compare with other participants. *At this point, transition to using the Secure Tomorrow Series Scenarios Workshop Are We There Yet Results Slides.* ▪ Two slides address each topic in the slide deck (please refer to the slide deck). The first slide contains images that describe the topic to participants and lists the specific polling question with associated progress milestones as answer options. These milestones are topic specific and listed in order of increasing progress. The second slide presents the polling results. After showing the polling results, ask volunteers to provide their perspectives. Call attention to interesting features of the answer distribution (e.g., extremes, most popular, explanations for bimodal distributions).

	▪ The facilitator may want to devote additional time to the topic-related questions in the Icebreaker session to allow for more elaboration on these topics. Ask the topic subject matter experts participating to comment on key concepts, misconceptions, and current trends pertaining to the topic.
Additional Notes	▪ Some virtual platforms can execute live polling. If live polling is used, facilitators should work to pre-populate the polling questions (as listed in the slides) ahead of the workshop. Facilitators should also remember to delete the second slide associated with each of the topics in the slide deck. ▪ If you will not be obtaining polling results live during this activity, please coordinate with the workshop coordinator to ensure that participants receive a polling worksheet ahead of the workshop, and that their responses have been returned, tabulated, and inserted into the slide deck ahead of time. ▪ If you are unable to perform live polling or send out a polling worksheet ahead of time, you may use the existing charts shown in the Secure Tomorrow Series Scenarios Workshop: Are We There Yet Results Slides. The results in this deck are from an execution of this exercise held with a diverse group of representatives from government agencies, think tanks, academia, and private-sector companies. ▪ Given the technical nature of some of the topics, you may want to confer with the workshop sponsor and consider developing additional read-aheads that serve as primers on these topics.

SCENARIO BREAKOUTS

DAY ONE: 2:45—4:45 P.M.	
Description	Participants will break into three separate groups, each exploring an alternative future scenario. The facilitator assigned to the group will lead a discussion about the scenario, fleshing out elements of this future based on participant interests and subject matter expertise. Participants will identify and then prioritize a set of risk mitigation strategies that would better prepare CI stakeholders for any emerging or evolving risks (and opportunities) that may exist in this future scenario.
Session Objectives	▪ To engage participants with their scenario—that is, to create ties between components of the narrative and their particular backgrounds (e.g., industry, knowledge, experiences, perspectives) ▪ To understand how scenario conditions shape strategic needs and associated risk mitigation strategies necessary to address these needs ▪ To prioritize and identify a maximum of five risk mitigation strategies based on what was written or extrapolated from the scenario narrative. These will feed into sessions on Day Two that stress-test these risk mitigation strategies against alternative future scenarios
Outputs	A prioritized list of up to five recommended risk mitigation strategies to improve CI resilience and security in the world described by the scenario
Duration	2 hours
Supporting Materials	Scenario narratives: ▪ Secure Tomorrow Series Scenario Narrative 1: Technology Doldrums ▪ Secure Tomorrow Series Scenario Narrative 2: New Golden Age of Technology ▪ Secure Tomorrow Series Scenario Narrative 3: Running Free
Staffing Requirements	▪ Three facilitators (one for each scenario) ▪ Three documentation leads (one for each scenario)
Breakdown	Begin by assisting participants in discussing and fleshing out the scenario. During this discussion, you should encourage participants to identify ramifications associated with the various changes, trends, or events captured in the narrative; emerging and evolving risks (and opportunities); and other important drivers or concerns related to key elements of the scenario narrative (that were not captured). After immersing participants in their scenario, the facilitator will assist participants in identifying and then prioritizing a set of five risk mitigation strategies to address critical needs (to enhance CI resilience and security) arising from the scenario. Participants will discuss these risk mitigation strategies in the workshop's subsequent stress-testing sessions. These strategies should be prepared in slide presentation format for use in the stress-testing sessions.

Key steps during the session include the following:

1. Conduct participant introductions.
2. Allocate 10 minutes for participants to read through the scenario.
3. Assist the group with working through the scenario and highlight points of interest and how they tie potentially to concerns for CI resilience and security. For example, you may want to ask each participant—as they read through the scenario—to prepare answers to the following questions:
   - Name an element of the scenario that resonated with you—i.e., what did you find most interesting or compelling?
   - What is an emerging or evolving risk discussed or hinted at—either related to your previous answer or to another part of the scenario—that you are most concerned about?
   - What are the ramifications (direct or indirect) of this emerging and evolving risk for CI security and resilience?
   - What risk mitigation strategies might you employ to address this risk?

   If discussions stall, you may want to reference concerns and discussion points flagged in your scenario's Detailed Scenario Breakdown. You may also want to draw attention back to the identification of topic-specific risks and the development of topic-specific risk mitigation strategies. Please be aware to probe for both technical and nontechnical solutions. When relevant, please remind participants to tie their statements to the scenario write-up, so individuals can skim the narrative for context.
4. Roughly 1 hour and 15 minutes into the session, if any major issues of interest built into the scenario narrative have not been addressed, introduce them for group discussion. Please note that the facilitator, workshop coordinator, and other relevant workshop stakeholders should decide ahead of time which issues the facilitator should try to cover during the session, using the Detailed Scenario Breakdown as a starting point for such determinations.
5. If the group identifies more than five risk mitigation strategies, they will need to prioritize five of them to present during the stress-test sessions. Please allow sufficient time for prioritization. You may wish to insert a short break for participants; during the break, you can refine the participant inputs and develop a strawman list of the top risk mitigation strategies. Allocate at least 15 minutes after the break for participants to react to the strawman, select the top five risk mitigation strategies, and further refine the risk mitigation strategy statements.
6. Allocate at least 10 minutes at the conclusion of the session to discuss what will take place during the stress-test rounds in Day Two. Identify three to six members of the group (depending on the size of the group) to serve on the away team for Day Two (see Stress-Test Rounds). Discuss roles and responsibilities, including who among the home team members will brief the scenario (or if the facilitator should brief the scenario) and which away team members will be responsible for presenting which mitigation strategies. When determining who should serve on the away team, please make sure to retain at least a few strong participants for the home team. Emphasize the importance of Day Two attendance, especially for away team members.

Facilitator Guidance	▪ **State the desired output from this session.** At the end of this session, we would like to identify a prioritized set of five risk mitigation strategies. ▪ **Re-emphasize that the scenario narratives are meant to provide just enough structure and content for a productive discussion.** A three- to five-page narrative cannot fully describe a future state of the world, especially if the goal is to make the scenarios easy to read. We wanted to take advantage of the group's collective expertise to flesh out those parts of the narrative that are most pertinent to CI security and resilience. ▪ **Bend, do not break, the scenario.** If places exist where the narrative did not probe deeply enough, or where a portion of the narrative was intriguing but did not get a lot of space, we encourage participants to fill in these gaps or make refinements (as long as you feel the discussion is heading in a probative direction). However, 180-degree shifts from the proposed scenario are not permitted. ▪ **Focus on CI security and resilience.** How does whatever is being said connect to CI security and resilience? It can be indirectly connected, and we can certainly discuss any complexities and tradeoffs involved, but we always want to come back to CI security and resilience. ▪ **Encourage participants to speak from their perspectives.** Strategic needs may exist for particular CI stakeholder groups and communities. We can use this as a starting point for broadening the discussion to other CI stakeholder groups. ▪ **Engage participants with the scenario.** If a participant feels disconnected from the group, ask what resonated most for them. Was there a concern that was not explicitly addressed, but would have ramifications for their organization, industry, or mission? How might the risks mentioned translate to their circumstances? ▪ **Return them to the scenario.** Does the narrative already provide examples and evidence that a strategic need exists? Please also refer to the scenario as a means of making the discussion more concrete. ▪ **Foreshadow the other scenarios, as relevant.** Doing so should help participants orient to the upcoming stress-test sessions on Day Two. ▪ **Outline what will happen during the stress-test rounds.** The ultimate output of the workshop is a set of risk mitigation strategies that are robust against a multiplicity of futures. Thus, group members will be presenting their risk mitigation strategies to other scenario groups to discuss the relevance and efficacy of these strategies under different future operating environments. Participants need to have a firm understanding of the large role they will play in communicating the risk mitigation strategies to their peers on Day Two.
Facilitator Prompting Questions	For additional questions specific to content within the narrative, please refer to the appropriate scenario. Questions to assist with fleshing out and familiarizing participants with this future reality: ▪ What portions of the scenario resonated most with you? ▪ What emerging and evolving risks were discussed or hinted at in this scenario that you are most concerned about? ▪ What are the ramifications of these emerging and evolving risks for CI security and resilience (if not obvious)?

	▪ How might some of the issues, trends, and threats identified in the scenario affect your particular organization/industry (ask as appropriate)? Questions to assist with identifying risk mitigation strategies: ▪ What strategic needs or capabilities must be addressed by CI stakeholders as a result of the threats, as well as the prevailing conditions, that you have identified for this scenario? ▪ What risk mitigation strategies might you propose to address these needs or develop these capabilities? Are you aware of anyone who has already implemented this risk mitigation strategy successfully? ▪ Which risks do you feel your sector is currently least prepared to address? What risk mitigation strategies would you propose to address these risks? ▪ What would we wish to have done currently to be positioned better to address these challenges in the next 15–20 years? ▪ How might CI stakeholder roles and missions need to change and evolve to address the threats of concern? ▪ Are changes to existing authorities, resources, and understanding necessary? Questions to assist with prioritization of risk mitigation strategies: ▪ Why would this be among your top five strategies? ▪ Are any of the risk mitigation strategies that you have identified too generic or implausible to implement? How feasible is this risk mitigation strategy to implement? What trade-offs might arise as a result of implementing this mitigation strategy? ▪ Does this risk mitigation strategy represent a radical departure from the status quo? Are current activities occurring within the CI stakeholder community likely to address the underlying strategic need that this strategy is meant to address? ▪ Are there any risk mitigation strategies that would help address multiple threats or strategic needs associated with the scenario?
Additional Notes	▪ Before the workshop, the workshop coordinator assigns participants (maximizing diversity of backgrounds in each group) into one of three groups. Each group will focus on one of the scenario narratives, and all participants should receive their assigned scenario narrative at least one week in advance of the workshop as a read ahead. ▪ Following the end of Day One, facilitators should review and make any final refinements to the risk mitigation strategies generated by their groups. Facilitators should send copies of all risk mitigation strategies (preferably mapped to the associated risks they are meant to address) and all scenario narratives to their group members to assist with preparation for Day Two.

STRESS-TEST ROUNDS

DAY TWO: 1:10—2:40 P.M.	
Description	The facilitator for each scenario group will divide their group into a home team and away team. The away team will rotate to another scenario group and present its risk mitigation strategies to that group's home team. The home team receiving this presentation will assess the relevance and utility of implementing these risk mitigation strategies under the different operating environment and circumstances of its own scenario, engaging in discussions with the presenting group. Two rounds of stress-tests will occur; by the end of these rounds, participants will have had their risk mitigation strategies assessed for robustness against the other workshop scenarios.
Session Objectives	To discuss and perform a basic assessment of how relevant the presenting group's risk mitigation strategies are for the receiving group's scenario.
Outputs	▪ Notes on which risk mitigation strategies were judged to be more relevant and useful to alternative futures. ▪ Notes on possible modifications to risk mitigation strategies that would make them more relevant and useful to alternative futures.
Duration	1.5 hours
Supporting Materials	▪ Facilitators should be prepared to share a slide on the virtual meeting platform with the risk mitigation strategies of each visiting group. ▪ Scenario synopses one-pager ("Secure Tomorrow Series Scenarios Workshop: Scenario Synopses").
Staffing Requirements	▪ Three facilitators (one for each scenario). ▪ Three documentation leads (one for each scenario).
Breakdown	1. Divide the group into a home team and away team. The away team will rotate to present the group's risk mitigation strategies to other groups. The home team will listen to other groups' presentations of their risk mitigation strategies and discuss the relevance of these strategies to the home team's scenario. Each round will run for 45 minutes. You can simply rotate the away teams in order of the scenario numbers. For example, the Scenario 2 away team will go to the Scenario 3 breakout during Round 1, and then on to the Scenario 1 breakout in Round 2. 2. During each round, both the visiting away team and the home team should begin by presenting brief reports on their scenarios. Presenters should feel free to refer to the summary of their scenario in the scenario synopses one-pager ("Secure Tomorrow Series Scenarios Workshop: Scenario Synopses"). The facilitator should be prepared to assist with or present the home team's scenario, as based on the assignment of responsibilities from Day One. 3. The away team will then go through its risk mitigation strategies one by one. The facilitator should share a slide on the virtual meeting platform with the risk mitigation strategies of the away team.

	4. For each risk mitigation strategy, the two teams will engage in a facilitated discussion about how well the risk mitigation strategy fits the alternative scenario and what modifications might improve the strategy's alignment to the scenario (if not initially a good fit). 5. Facilitators will lead participants in a final vote of the relevance of the risk mitigation strategy to the alternative scenario (e.g., not a fit, a partial fit, or an excellent fit). Facilitators should use the voting session to discuss differences of opinion among the participants and use these discussions to identify potential additional modifications to the risk mitigation strategies.
Facilitator Guidance	▪ **Balance the two teams in each group.** Use your best judgment to balance the strengths of both teams based on their insights and participation. For example, avoid assigning all your most active participants to the away team, as the home team will then be less capable of engaging with the groups in an active discussion about the relevance of their risk mitigation strategies. ▪ **Re-emphasize the purpose of stress-testing.** Before sending one team to another breakout room for the first round of stress-testing, facilitators should reiterate the purpose of the two stress-test rounds. Day Two focuses on stress-testing the risk mitigation strategies identified for the primary scenario against the other scenarios. A key concept in scenario-based planning is using multiple future scenarios to identify strategies that are robust against uncertainty. The underlying rationale is that because we cannot successfully predict the future, we should treat the future as a set of plausible alternatives against which our strategic planning efforts need to be robust. The two stress-test rounds are one way of executing this concept in practice.
Facilitator Prompting Questions	▪ If implemented, would this risk mitigation strategy be effective in your scenario? What concerns might you have about implementing this strategy? ▪ How would this risk mitigation strategy rank relative to the ones you identified for your scenario? ▪ Are there conditions in this alternative future that would make this strategy more difficult or easier to implement? ▪ How could you modify the existing risk mitigation strategy statement so that it is more relevant to your scenario, without destroying the intent of the team that originated it?
Additional Notes	None

SYNTHESIS AND REFLECTION

DAY TWO: 2:55—3:45 P.M.	
Description	In this plenary session, the lead facilitator asks participants to provide their perspectives on what they learned from the two rounds of stress-testing and solicits overall reactions to the concerns and ideas presented during the workshop.
Session Objectives	To provide an opportunity for participants to reflect more broadly on what they learned from the stress-test rounds and the overall workshop
Outputs	▪ Additional insight and detail on risk mitigation strategies ▪ A feeling of closure for participants, increasing their willingness to support future efforts
Duration	50 minutes
Supporting Materials	▪ None
Staffing Requirements	▪ Lead facilitator ▪ Senior leader representing the hosting organization ▪ Documentation lead
Breakdown	▪ Solicitation of remarks by scenario group (lead facilitator) ▪ Solicitation of final remarks or reactions to anything discussed at the workshop (lead facilitator)
Facilitator Prompting Questions	▪ What were your key takeaways from the workshop? ▪ Did you learn of any risk mitigation strategies from other scenario groups that surprised you or that you would like to comment on?
Additional Notes	If relevant, the lead facilitator may want to relay information about any products that will be generated from the workshop (e.g., a report) during this session.

SCENARIO #1: TECHNOLOGY DOLDRUMS

Please note: The version of the narrative that the facilitator possesses has line numbers for ease of identifying key segments of the scenario narrative (as referenced in the table below). These segments are also highlighted in green and labeled with reference numbers.

BRIEF DESCRIPTION

Private sector exuberance in developing the next transformative technology ends in disappointment as three key areas of U.S. investment in the 2020s—BCIs, quantum technologies, and synthetic biology—fail to live up to their anticipated promise. Meanwhile, events transpire—such as a problematic migration to post-quantum cryptographic algorithms and complaints about BCI attention-monitoring devices in the workplace—that stymie the adoption and maturation of these technologies. After early commercial hype, U.S. companies struggle to emerge from a period of disillusionment, exemplified by the quantum winter of the early 2030s.

SCENARIO CONTEXT

- Set up as a blog post focusing on technology investment. The blogger articulates five points for readers to consider when thinking about investing in hyped, emerging technologies by using the development trajectories of BCIs, quantum computing, and synthetic biology as case studies.
- Depicts a future in which early bets on and excitement about the promise of these technologies turn to disillusionment as progress fails to meet expectations.
- Provides several examples of stumbling blocks and challenges affecting the development and acceptance of these technologies, leading to a decline in U.S. leadership in quantum computing and synthetic biology.
- Introduces two news headlines—an agroterrorism attack and a potentially game-changing development in quantum computing—toward the end of the blog post to prompt readers to consider the ramifications of falling behind in these technologies, despite uncertainty in their progress.

FACILITATION QUESTIONS – TAILORED

Please note: Broader, more general facilitation questions—common to all three scenarios—are located in the Scenario Breakouts section of this facilitator's guide. Additional discussion points, tied to specific portions of the scenario narrative, are listed in each scenario's "Detailed Scenario Breakdown."

- The scenario describes a situation in which researchers in these emerging technologies are seeking potential use cases. Given some of the capabilities described in the scenario—whether realized or not—which CI sectors do you see as potentially most benefited or disrupted by these technologies?
    - Given the numerous different applications for these technologies, what is the best means of ensuring that application-specific security needs are addressed?
- Given the uncertainty of when certain technological capabilities may be realized, how should organizations consider the tradeoffs between costs and preparedness? Using the post-quantum cryptography situation outlined in this scenario as a specific example, when and how should organizations prepare?

- What are the implications of an operating environment in which you see growing adoption of BCI devices in the workplace? Do any sector-specific concerns warrant greater attention?
    - How might this influence your concerns about cybersecurity moving forward?
- In what ways do considerations about privacy and anonymity change (or not change) when dealing with neurodata versus other forms of data? What new concerns potentially exist?
- With the potential for data collection from third-party data brokers increasing (to include neurodata), what are the implications for government's role in their oversight? How might public expectations and perceptions of the government's role in cybersecurity oversight change?

RIDING THE SLOPE OF ENLIGHTENMENT

I'm a Ph.D. engineer from the illustrious Whyttz Institute of Technology who became a financial modeler, but then realized I'd rather work slow-paced than fast when it comes to investing. Going back to my roots, I decided to translate my love of science and technology into a long-term investing approach surrounding emerging technologies and technology ecosystems. Riding the Slope of Enlightenment *reflects my efforts to separate hype from practical potential, and search for signals as to when technologies may be ready for investment.*

Playing the Long Game with Technology

May 31, 2035 36 Comments

My friend Ricky can't understand why he's still stuck at work, 3 years after he meant to retire. In the 2020s, he invested in the technologies of the future, companies so essential to scientific progress that their share prices were guaranteed to support a life of leisure and comfort—until they weren't. Brain-computer interface stocks: down 65 percent from 2025 to 2030. The SSY&S Synthetic Biology Index: down 78 percent since 2028. Three sure-fire quantum technology initial public offerings on the BADSI Market in the mid-2020s: bankrupt by 2032. **[1]**

As someone who unfortunately gets looped in with the tech-proclaimer crowd, I'm often the target of the vitriol from people such as Ricky. I hear from lots of them. They want to know why today's tech reality is so far from yesterday's tech hype. So, I'd like to explain here why three technologies that were supposed to be societal "game changers"—brain-computer interfaces, quantum technologies, and synthetic biology—haven't quite left the sidelines (at least not here in the United States). Those technologies make good case studies for five lessons I'd like to offer about why technologies hit speed bumps—and why things don't have to stay that way.

Lesson #1: Game-changing ≠ fast-changing

Technology investing and technology development favor the patient. Progress can be so slow you barely see it. Take brain-computer interfaces (or BCIs, as most people call them now). They've been studied since the 1970s, and 60 years later, they're hardly ubiquitous. Maybe you know someone who owns a BCI wearable for virtual reality gaming that responds directly to brain signals. **[2]** The latest statistics from Sartati, a leading online statistics platform, show that about 12 percent of U.S. households own a BCI device, and in some workplaces they're just starting to become more common. There are lots of reasons why technology might develop slowly, some of which I've covered in previous posts. (See Recognizing the Express Lanes for Tech Development.)

But back in the late 2010s, patience was in short supply during a period of technology exuberance:

- The dominance of tech giants led to widespread investor belief that, with their deep pockets and access to the best minds and big data, they were poised to revolutionize other fields.
- The 2010s had seen a remarkable run of access to venture capital.
- The United States was rebranding itself as an innovation economy.

And here were three technologies that promised to change society as we knew it:

- BCIs enticed us with the potential to control devices with our minds and directly access knowledge from the internet, turning science fiction into reality.

- Synthetic biology would redesign and harness biological organisms to cure disease and end our reliance on fossil fuels for petrochemicals. [3]
- Quantum computing would reveal fundamental insights into the inner workings of matter, revolutionizing the design of materials and medicines. [4]

If you haven't noticed these changes, it's because they didn't happen. Yes, it is plausible that BCIs, synthetic biology, and quantum technologies could one day achieve these milestones. But significant technical hurdles have been and continue to be in the way. It reminds me of my grad school days, when the theoreticians and modelers in our lab group would craft papers outlining why something should work, and then talk to us engineers as if they had already figured out the hard part. I hated those folks.

Technologies don't all follow the same path for development. In the 2010s, the blinding speed of digital transformations led by software created the illusion that all technology moves that fast. Hardware is different. Take the transistor: it was developed in the 1940s, but personal computers didn't arrive until 30 years later.

The software/hardware dichotomy led to what I call the "Colprin rejoinder." Back in the 2010s, astronaut Bart Colprin famously expressed his disgruntlement about our inability to reach Mars by stating, "You promised me Mars colonies. Instead, you gave me reality TV." Similar disillusionment happened with the state of our three technologies by the close of the 2020s.

- For BCIs, "write" capabilities never emerged for noninvasive devices. I wanted to download knowledge at will from the internet directly into my brain. Instead, companies spent their time developing stylish, noninvasive wearables. These are great, but even with "read" capabilities, we still haven't reached full BCI control of complex equipment.
- More than 15 years after the first claims of "quantum supremacy" over classical computers, we have yet to produce a general-purpose quantum computer with error correction. [5] There's been some success with quantum sensors, but mostly for military applications. Individuals who bought into the promise of these sensors for mineral wealth discovery are still waiting to see their investments pay off.
- Synthetic biology has not discovered the holy grail of petrochemical synthesis—although, in fairness, the field has had numerous successes. There are good-news stories about advances in gene therapy. Unfortunately, the public seems more focused on questions of trust regarding synthetic biology in food production and vaccines, overshadowing progress.

Lesson #2: Intermediate capability or incomplete capability?

To many investors, "NISQ" is a four-letter word. The abbreviation for "noisy intermediate-scale quantum" was coined to describe the stage of capability that quantum computing had reached in the late 2010s. At the time, pundits expressed hopes that these systems would begin to address test problems, increase understanding of quantum computing, and stimulate algorithm development, which would accelerate progress in quantum computing. But without error correction, efforts to apply NISQ computers to practical problems—particularly ones that traditional computers can't address—haven't really materialized. [6]

NISQ-stage computing, which many say we're still stuck in, is a typical example of a situation where the desire to provide some kind of value proposition leads to the rollout of an incomplete capability. If you struggle to identify a use case for your technology, it's not "intermediate"—it's incomplete. In

the mid-2020s, there was enormous pressure to deliver something that would maintain interest and keep funding flowing, so companies rolled out devices with incomplete capability. And, to some extent, the same is true for BCI devices. Both technologies went through a period in which companies were actively soliciting research communities and the public for ways to apply their technologies, which I always take as a bad sign. Yes, technologies can have early, niche applications that sustain interest in developing them further. Case in point: the early application of transistors in hearing aids. But with the hype surrounding these technologies, the fact that there were no obvious applications should have been a worrisome signal to investors such as Ricky.

Lesson #3: There's no revolution without scale

Scale is difficult for new technologies to achieve, but scale is critical in three ways. Scale in manufacturing is the ultimate determinant of costs and prices. And even after you've managed to create a working product, scaling up manufacturing presents a host of additional challenges. For example, Ben Cartemonne in his article, Rethinking the Bioeconomy, argues that the U.S. transition to a bioeconomy stalled partly because of an inability to foster pilot-scale testing and provide necessary supporting infrastructure. Efforts to set up noncommercial biofoundries **[7]** faltered in the mid-2020s, providing fewer opportunities for academic researchers to assemble larger fragments of synthesized DNA. Producers of cultured meats are experiencing technical hurdles in scaling up the volume of production while maintaining a sterile operating environment and controlling operating costs.

Scale in marketing launches products from the niche market for early adopters into the "gotta have it" trajectory. For better or worse, the BCI industry had this partially figured out in the 2020s. Commercial interest led engineers to prioritize simplifying these devices and developing wearables that were lightweight and comfortable, even at the expense of brain signal reading performance. The vision was to be as ubiquitous as cell phones, or even replace them. To some extent, that vision may finally be realized.

BCI's path to marketing scale has really been driven by growth in two areas: workplace monitoring and entertainment. Workplaces began using BCIs to assist with monitoring employee mental health and to alert employers about unsafe work behaviors, such as driving while drowsy. And with virtual reality coming into its own over the past few years, BCI sales have gotten a bump from early adopters who want a more engaging user experience. According to Sartati, BCI devices may have finally reached a tipping point in adoption. It's amazing that a technology that was once limited to hundreds of individuals, largely for medical reasons, has now grown to more than one billion users worldwide. And the BCI companies that survived the shakeout are starting to make a comeback.

Scale in data has been a major driver. The number of BCI users pales compared to the exabytes of neurodata that BCI users are now generating on a daily basis. Given how nearly everything in our lives is governed by algorithms, access to vast amounts of neurodata has companies drooling and represents a key part of BCI's value proposition. **[8]** It provides sellers with a more sophisticated understanding of user preferences and a wealth of unfiltered feedback on products. So, it should come as no surprise that nearly all BCI device manufacturers have strong ties to data brokers or data analytics service providers. Equally unsurprising is that user data agreements for BCI devices have remained heavily in favor of BCI manufacturers.

Lesson #4: Public perception matters

BCIs and quantum computing have been burdened by public perception issues. BCIs have come under attack from multiple directions recently. Critics have accused game developers of creating feedback loops using neurodata to create highly addictive games, contributing to a growing detachment from the real world for students and the incoming workforce. Directly monitoring employee attention and emotions has led to privacy complaints and claims of greater workplace stress. Lax cybersecurity protections on these devices and hoarding of worker neurodata have also led to numerous criminal hacking incidents. To appease anxious workers, 33 major companies have pledged not to employ BCIs on their workforce. But frankly, we've been preconditioned to accept being data profiled, mined, and targeted at this point. The federal government's stance on neurodata seems focused largely on limiting foreign access to neurodata on U.S. citizens, similar to the stance taken on genetic data. There have been some nods to neurorights at the state level, but on the whole, I don't think anyone looking back on the past 20 years can say there's been a substantial change on this front. [9]

In the case of quantum computing, investors and the public became increasingly skeptical of the practical value of quantum computing in everyday life after being burned by pundit claims about quantum annealers [10] and NISQ computers. And in the latter half of the 2020s, we were confronted with the debacle of the post-quantum cryptography transition. [11] To confront the looming threat of a quantum computer that could break public-key encryption, some companies migrated early to one of the initial National Institute of Standards and Technology (NIST)-endorsed post-quantum algorithms. They later found that this algorithm could be cracked conventionally. The hybrid period mixing pre- and post-quantum algorithms experienced numerous complications. There was even a case in which a post-quantum cryptography vendor pushed malware onto various systems. Companies are still encountering problems with legacy systems and slowdowns in performance.

As a result, public sentiment toward these technologies has shifted from enthusiasm to neutrality at best. Legislators have been unwilling to advocate for funding technologies that inspire opposition or, at best, indifference among their constituents, especially when they have few success stories to point to from previous technology initiatives. The combination of public sentiment, politics, and national debt has led to a steady withdrawal of public funding from all three technologies, including many of the National Quantum Information Science Research Centers [12] and noncommercial biofoundries. For quantum technologies, this has turned into a full-on quantum winter, [13] with public funding drying up by the early 2030s. Given bad press and vocal dissenters, many politicians have been content to let the private sector assume full responsibility for the risk-reward calculus.

Lesson #5: U.S. dominance is not guaranteed

American exceptionalism—or, more precisely, Technology Alleyway exceptionalism—is a stubborn idea. But financial capital and intellectual capital don't really care who was leading 20 years ago. In BCI, it's clear that the Unites States is no longer the frontrunner. Fictitia continues to espouse a policy of monitoring workers with BCI devices. In fact, Fictitian companies have touted it as a competitive advantage, making claims about their greater safety and productivity. Meanwhile, the neurodata gathered from these devices are also being used to enhance machine learning algorithms, further improving the performance of Fictitian BCI devices. With scale advantages leading to cheaper and better BCI devices, the adoption rate in Fictitia is nearly twice that of the United States.

It's less clear where the United States stands relative to the rest of the world in synthetic biology and quantum computing. But reading recent headlines, it's easy to worry that we may be falling behind.

It's less clear where the United States stands relative to the rest of the world in synthetic biology and quantum computing. But reading recent headlines, it's easy to worry that we may be falling behind.

- After suffering a major African swine fever outbreak in 2018, [14] Fictitia used synthetic biology to confer viral resistance to its pig herds. In contrast, the United States has generally remained reluctant to allow genetically modified animals for human consumption. [15] In April 2035, terrorists introduced African swine fever into the United States, triggering an immediate shutdown in U.S. pork exports and the collapse of the U.S. pork industry.
- Two weeks ago, a research team from Furturna announced a breakthrough in qubit hardware technology—namely qubits with both long coherence times and fast gating properties. [16] The new qubits allow for orders-of-magnitude improvement in the number of operations possible while in quantum superposition. Furthermore, they claim that a general-purpose quantum computer using this technology platform is within reach in the next few years.
- The latest immigration data show that the number of H-1B visas requested has declined for the third straight year, as the United States experiences an out-migration of technical talent in new technologies.

Despite these shifts, U.S. investor awareness inordinately follows the actions of American big tech. If Ricky had gradually started including overseas investments in his portfolio in the 2020s, when he saw Washington lose patience with new tech, he might be enjoying his retirement today.

DETAILED SCENARIO BREAKDOWN: TECHNOLOGY DOLDRUMS

Please note: The version of the narrative that the facilitator possesses has line numbers for ease of identifying key segments of the scenario narrative (as referenced in the table below). These segments are also highlighted in green and labeled with reference numbers.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
1	15	Three sure-fire quantum technology initial public offerings on the BADSI Market in the mid-2020s: bankrupt by 2032.	**INFO**: The first U.S. quantum computing company to begin being publicly traded went public in October 2021.
2	27	They've been studied since the 1970s, and 60 years later, they're hardly ubiquitous. Maybe you know someone who owns a BCI wearable for virtual reality gaming that responds directly to brain signals.	**NOTE**: Examples of BCI-based gameplay already exist, both for invasive and noninvasive devices. For example, in 2017, a neurotechnologies startup made headlines by unveiling the world's first game to combine a noninvasive BCI for hands-free control with a virtual reality headset.
3	41	…end our reliance on fossil fuels for petrochemicals.	**INFO**: Existing petrochemical manufacturing processes—which are responsible for many products modern society relies on (e.g., plastics)—require fossil fuels as inputs and can be energy intensive and harmful to the environment. Synthetic biology has the potential to re-engineer microbes and plants to produce petrochemicals, reducing reliance on fossil fuels and carbon dioxide emissions.
4	43	Quantum computing would reveal fundamental insights into the inner workings of matter, revolutionizing the design of materials and medicines.	**INFO:** Quantum simulations use quantum computers to study the properties of matter. Because quantum computers leverage quantum mechanical phenomena, they are likely well suited to examining these phenomena in molecules and compounds. This has significant potential for the design of new pharmaceuticals, catalysts, and materials.
5	63	More than 15 years after the first claims of "quantum supremacy" over classical computers, we have yet to produce a	**INFO:** Although not without subsequent controversy, in 2019, a research team published that it had achieved quantum supremacy by demonstrating that its quantum computer could carry out a specific calculation beyond the capabilities of classical computers.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
		general-purpose quantum computer with error correction.	
6	78	But without error correction, efforts to apply NISQ computers to practical problems—particularly ones that traditional computers can't address—haven't really materialized.	**INFO:** Error correction is necessary to address the errors introduced in every step of quantum computations. The accumulation of these errors is what leads to "noisy" quantum devices. Error correction introduces a significant overhead cost, requiring the spreading of quantum information over multiple redundant qubits (the quantum analog to classical bits in computing).
7	96	…noncommercial biofoundries…	**INFO:** Biofoundries are facilities that provide integrated infrastructure (e.g., liquid-handling robots, analytical equipment, software) to allow the rapid design, development, and testing of genetically reprogrammed organisms for synthetic biology research. Given the expense of setting up and operating these facilities, several noncommercial biofoundries worldwide joined together in 2019 to create the Global Biofoundries Alliance to (1) develop, promote, and support noncommercial biofoundries established around the world; (2) intensify collaboration and communication among biofoundries; (3) collectively develop responses to technological, operational, and other types of common challenges; (4) enhance visibility, impact, and sustainability of noncommercial biofoundries; and (5) explore globally relevant and societally important grand challenge collaborative projects.
8	118	Given how everything in our lives is governed by algorithms, access to vast amounts of neurodata has companies drooling and represents a key part of BCI's value proposition.	**NOTE:** The scenario identifies neurodata as a major value proposition for BCIs and alludes to a world in which artificial intelligence (AI) algorithm use continues to grow. **CONCERN:** Neurodata, if properly decoded, can be highly revelatory about an individual's physical and mental health and emotional state. This information could be valuable to retailers, insurance companies, and employers. **DP**: What potential concerns could arise from the combination of neurodata and AI?
9	136	But frankly, we've been preconditioned to accept being data profiled, mined, and targeted at this point. The federal government's stance on neurodata seems	**INFO:** Results from a June 2019 survey indicate that roughly 8 in 10 or more U.S. adults feel they have little or no control over the data that government or companies collect about them.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
		focused largely on limiting foreign access to neurodata on U.S. citizens, similar to the stance taken on genetic data. There have been some nods to neurorights at the state level, but on the whole, I don't think anyone looking back on the past 20 years can say there's been a substantial change on this front.	
10	139	…quantum annealers…	**INFO:** Although they use qubits, quantum annealers are not a circuit-based quantum computer. Quantum annealers are not as widely applicable as circuit-based quantum computers but have been used successfully to solve a specific type of optimization problem.
11	140	…post-quantum cryptography transition.	**DP**: ▪ What additional challenges might occur as NIST's post-quantum cryptography process plays out? What steps should industry be taking to build on these efforts? ▪ What do you see as potential complications in migrating IT systems over to post-quantum cryptography? Do you see any of these complications leading to vulnerabilities or risks? ▪ Since even post-quantum cryptographic algorithms could potentially be broken, what should the overall approach be for mitigating the quantum cryptographic threat? **INFO:** National Security Memorandum 10, released in May 2022, addresses policies and initiatives related to quantum computing, including specific actions that federal agencies will take to migrate to quantum-resistant cryptography.
12	153	…National Quantum Information Science Research Centers…	**INFO:** The National Quantum Initiative Act of 2018 called for the establishment of centers focusing on quantum information science (QIS) research and discovery. Each center is a partnership among national labs, universities, and private companies and

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			seeks to assemble multidisciplinary teams to tackle key problems in QIS while helping build a quantum workforce.
13	154	…quantum winter…	**NOTE:** In analogy to past "AI winters" (during which AI research effectively disappeared), some have argued that a disconnect between hype and the "low-hanging fruit" variety of current-day quantum technology (not to mention the unrealistic expectations of the field as a whole) and the current state of maturity makes quantum technology ripe for its own "quantum winter." This would be a period in which the development of quantum computing technologies loses momentum (e.g., interest, investments) because of a lack of short-term applications or slow progress.
14	169	…a major African swine fever outbreak in 2018…	**INFO:** ▪ African swine fever is a highly contagious and fatal pig disease that currently threatens the wild and domestic swine population. It has been found in various locations across the world, but has not been found in the United States to date. The U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service lists African swine fever as one of the top eight animal diseases that could pose a significant risk to U.S. food and agriculture resources. ▪ A 2018 outbreak of African swine fever decimated one country's pork industry, resulting in a more than 40 percent decline in inventory (live pigs), a more than 30 percent decline in pork output, and an approximately 97 percent increase in pork prices in 2019.
15	171	…the United States has generally remained reluctant to allow genetically modified animals for human consumption.	**INFO:** Very few genetically engineered animals have received approval as a food product. The first product, a genetically engineered fast-growing salmon, was under review for more than a decade before it was approved in 2015. In 2020, the FDA did approve a line of domestic pigs, which were modified to eliminate an allergic reaction–causing sugar on the pigs' cells, for food or human therapeutics.
16	175	…qubit hardware technology—namely qubits with both long coherence times and fast gating properties.	**NOTE:** Qubit technologies generally have a trade-off between the two—i.e., long coherence times generally arise because of strong decoupling from the environment, but this also hinders the ability to drive logical gates fast or well.

SCENARIO #2: NEW GOLDEN AGE OF TECHNOLOGY

Please note: The version of the narrative that the facilitator possesses has line numbers for ease of identifying key segments of the scenario narrative (as referenced in the table below). These segments are also highlighted in green and labeled with reference numbers.

BRIEF DESCRIPTION

Greatly invigorated government interest in and coordination of scientific investment leads to major growth in three key areas, with benefits largely going to the public sector and CIs. First, advances in BCIs lead to increases in safety, security, medical treatments, and entertainment. As adoption increases, efforts to increase the privacy of neurodata and BCI cybersecurity yield multiple benefits. Second, investment in synthetic biology leads to applications for bioremediation, carbon sequestration, and biological monitoring, as well as a robust domestic biomanufacturing capability. Third, delayed realization of a quantum computer that can crack public-key encryption allows additional time for CI stakeholders to successfully transition to post-quantum cryptographic algorithms. The United States also achieves first-mover advantages in quantum applications, including quantum sensing and quantum simulations.

SCENARIO CONTEXT

- Set up as the retirement speech of the outgoing Office of Research, Science, and Technology Policy (ORSTP) director, whose career has involved him in several key policy decisions over the past 20 years.
- Focuses on the ways in which the government has collaborated with the private sector to promote the advancement of critical technologies. The imagined potential for all three technologies (BCIs, quantum computing, synthetic biology) has been realized; moreover, public-sector involvement has led to advancements that avoid narrowly focusing these technologies on only the most profitable applications.
- Encourages readers to explore their skepticism of the speaker's potentially biased and overly optimistic recollection of events.

FACILITATION QUESTIONS – TAILORED

Please note: Broader, more general facilitation questions—common to all three scenarios—are located in the Scenario Breakouts section of this facilitator's guide. Additional discussion points, tied to specific portions of the scenario narrative, are listed in the scenario's "Detailed Scenario Breakdown."

- What are some of the barriers to effective coordination between the government and the private sector?
- How might competition between Fictitia and the United States encourage cooperation between the government and the private sector or steer the development of critical technologies such as BCIs, quantum computing, and synthetic biology?
- Besides government funding, what else is necessary to provide a supportive environment for the development of key technologies?
- Given the potentially rosy picture described, what risks or challenges pertaining to these three technologies may have been glossed over or omitted entirely?

Remarks made by Christopher Foster, Director, Office of Research, Science, and Technology Policy, on the occasion of his retirement, December 10, 2040.

Good evening and thank you all for coming and for taking the time to celebrate the fact that you're finally getting rid of me. I asked my friends what I should say during my toast, and their advice was "Nobody wants to hear you go off on one of your long-winded speeches. Just let everyone get back to the party." Well, sorry to disappoint you, but since the microphone is mine, I'm going to take advantage of it to remind you all how we got to where we are today.

I've been lucky to have had a role in shaping the trajectory of some pivotal technologies during my career. It's crazy to think that just 20 years ago we were still struggling to reach human typing speeds with an invasive brain-computer interface, [1] or BCI, and now we're using noninvasive BCIs to do everything that a cell phone used to do—and more! [2] I look back and marvel at how we got here.

I started my career as a tech lawyer in private practice, but soon moved to where the action is, starting my own company, NeuroSights. [3] We were early pioneers in developing machine learning algorithms to mine neurodata for insights. After a few years, we were bought out by a bigger technology company for a small fortune, and I had to make a choice about what to do next.

In 2026, I got a call from my friend and mentor, David Chen, who had been recruited by President Smith to lead a reinvigorated Office of Research, Science, and Technology Policy (ORSTP). David brought me in to run the newly created neurotechnologies program within ORSTP, asking me to use my connections to the neurotech world to ensure that coordination between the private sector and the government on neurotechnologies was airtight. He joked that he was pulling me out of "retirement" to be his assistant, but we both believed in what he was doing.

Tensions between the United States and Fictitia at that time were, quite frankly, worrisome. Many in the tech world hoped that the transition to the Smith administration would lead to a thawing of relations, but instead the two countries remained locked on their path of strategic competition for leadership in the global economy and, of course, technology. Each raced to claim first-mover advantages in development and establish the dominant standards for several key technologies. Smith's decision to supersize ORSTP, along with bolstering organizations that supported the U.S.-led financial order, [4] was part of a competitive strategy that became a cornerstone of his foreign policy doctrine.

At first, the pace of change was frustratingly slow, but thanks to our strong connections to the private sector, changing some policies, and reworking some grants, we were able to push through a few key wins. [5] In response, the BCI field saw a swell of patents and market-ready products by the late 2020s. Innovation led to major increases in safety, performance, and security, as well as advanced training in virtual reality environments. While I can't claim credit for all of it, ORSTP definitely helped create opportunities in the field and put the technology into the hands of people who needed it.

Today we've started to take BCIs for granted. In medicine, scientists and doctors are helping diagnose and treat cognitive diseases, and they are giving amputees direct control of their artificial limbs. [6] In the workplace, BCIs enable employee attention monitoring and decision-making support across a variety of fields, thereby improving worker safety and performance and leading to greater efficiencies. [7] The industry also enabled major advances in training and education by combining brain control devices with augmented reality and virtual reality. [8] And BCIs are now standard

practice in authentication—what you all probably call “passthoughts.” [9] Who here remembers the first-generation BCI games from BrainConnect? By now, they’re probably considered antiques. [10]

After a few years at ORSTP, I transitioned from policy support to policy action in 2030, successfully running for the U.S. House of Representatives in my home district. From my perch on the Committee on Science, Space, and Technology, I sponsored and passed legislation that helped advance a number of critical technologies in the United States.

The first was the Quantum Technologies Development Act, which catalyzed faster-than-expected growth in quantum capabilities in the United States, including some simulation capabilities. (For those techies out there, I’m talking about the noisy intermediate quantum realm.)

I then cosponsored the 21st Century Biodefense Act, which enabled the United States to become the first country to achieve industrial-scale bioremediation and carbon sequestration, as well as major wins in biological monitoring that helped us close the gap on our emissions reduction targets and monitor for pollution and pandemics. Do you remember the panic when the so-called “U.S. Liberation Militia” terrorist group released a novel neurotoxin in a water purification plant in 2036? Well, the advanced biosensors that triggered an automatic stop and saved thousands of lives were in place because of the 21st Century Biodefense Act.

I helped write the Quantum Cryptographic Transition Act to mandate that owners and operators of U.S. critical infrastructure transition their systems to post-quantum cryptographic algorithms. We did catch a lucky break in that the quantum computers that could crack public-key encryption were not developed until 2035, giving us time to transition to post-quantum cryptography and protect our CI from the worst of our concerns for the post-quantum age.

Finally, I cosponsored the Neurological Information Nondiscrimination Act, [11] establishing privacy protections for neurodata, guaranteeing those data the same level of protection as genetic data. (Boy, I got a lot of angry calls from former colleagues in neurotech for that one!)

In 2036, when the Davis Administration invited me to step in and lead ORSTP, my record of making smart bets on forward-leaning technologies already spoke for itself. And after four years as Director of ORSTP under President Davis, I’m proud to have overseen a number of successes for ORSTP and for the country: most Americans now use noninvasive BCIs and augmented reality headsets, either at work or for entertainment. Such devices have become the preferred way of interacting with the metaverse. And just last month, our BCI National Laboratory announced the achievement of a ”write” capability in invasive BCIs, [12] bringing the human brain one step closer to directly interfacing with the metaverse.

Synthetic biology and biotechnology have created their own revolution with widespread applications across society and industries, particularly the development of key petrochemicals via synthetic biology.

As a global leader in quantum applications, the United States has enjoyed numerous first-mover benefits. Our engineers won the race to develop a general-purpose quantum computer. We successfully commercialized quantum sensing applications, and quantum simulation has led to advances in drug and materials development.

Wow. It's a lot. And it could tempt me to rest, but you haven't heard the last of me. I'll be taking a short break to finish my book, *Betting on the Future: Technological Change and the New American Era*, before assuming a position as a senior fellow at the Silverberg Institute.

The incoming Monroe Administration has many challenges to contend with. Some members of the public are pushing back against our advances in BCIs, opposed in principle or for philosophical reasons to what they see as an unacceptable level of human augmentation. [13] And despite their usefulness in a large number of applications and industries, BCIs—particularly invasive BCIs—remain costly, out of reach for many Americans. [14]

I wish the new administration the very best of luck, and I remind them that, if they need my assistance in any capacity, I now charge private-sector rates.

America is enjoying a new golden age of technology. Enjoy the party.

DETAILED SCENARIO BREAKDOWN: NEW GOLDEN AGE OF TECHNOLOGY

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1	10	…just 20 years ago we were still struggling to reach human typing speeds with an invasive brain-computer interface…	**INFO:** In 2021, a paralyzed patient broke the record for typing speed using an invasive BCI to communicate at about 90 characters, or 18 words, per minute. Able-bodied adults can type an average of 38 words per minute on a smartphone or 40 words per minute on a full keyboard.
2	11	…and now we're using noninvasive BCIs to do everything that a cell phone used to do—and more!	**NOTE:** This sentence emphasizes the transition from invasive to noninvasive BCI technologies and the development of capabilities for the general population (versus medical patients).
3	14	…NeuroSights.	**INFO:** The company name plays off the word *insights*. A lot of neural data is noisy. As a result, it can be difficult to detect and discern the specific brain signals associated with carrying out a task. Application of AI will be critical to separating signals from noise and advancing BCI capabilities, but many questions exist about what can be done using noisy neurodata. Some possibilities include insight into an individual's emotional response to a stimulus or even early detection of cognitive diseases. Some activists worry about the revelatory nature of neurodata and have called for legislation to prevent it from being collected or sold, or to allow BCI devices to collect and store data only for specific approved tasks. **CONCERN:** Neurodata, if properly decoded, can be highly revelatory about an individual's physical and mental health and emotional state. This information could be valuable to retailers, insurance companies, employers, and foreign adversaries.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
4	29	…along with bolstering organizations that supported the U.S.-led financial order…	**INFO:** This refers to Fictitia's promotion of alternative financial systems, which is seen as a strategic push to reduce U.S. control over the global financial system and reduce the diplomatic levers available to accomplish U.S. strategic goals. Additionally, this hints at several countries (including Fictitia) that use cryptocurrencies to subvert U.S. sanctions.
5	33	…thanks to our strong connections to the private sector, changing some policies, and reworking some grants, we were able to push through a few key wins.	**NOTE:** This sentence is intentionally vague to allow for participant input. Examples of some possible actions include the following: ▪ Engaging with the private sector in strategic planning ▪ Ensuring consistency across major funding mechanisms related to those strategic goals ▪ Increasing public spending on research and development ▪ Establishing direct subsidies and tax credits ▪ Imposing trade restrictions that target foreign competitors **DP:** What actions would you recommend to incentivize progress in ways that enhance (or at least do not compromise) critical infrastructure resilience and security?

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
6	39	In medicine, they are helping diagnose and treat cognitive diseases, and they are giving amputees direct control of their artificial limbs.	**INFO:** Medical applications that BCI manufacturers are exploring include the following: ▪ Giving quadriplegics and others with immobilizing neurological conditions better ways of interacting with the world (e.g., enabling communications) ▪ Stimulating nerves associated with psychological responses to help treat mental health issues ▪ Restoring motor and sensory function to those who have lost limbs or lost control of them ▪ Disrupting neural patterns associated with negative personality traits such as addiction or mental illness ▪ Assisting in rehabilitation from stroke and treating neurodegenerative diseases (e.g., Alzheimer's disease) **CONCERN:** ▪ As BCIs become more ubiquitous for diverse medical applications, issues with their cybersecurity, resilience, and reliability will likely increase. Medical patients who use BCIs may become highly dependent on them, which will exacerbate consequences if these devices are disrupted. ▪ Many of these applications are expensive and it is unclear to what extent costs will decrease over the next few decades. This raises the issue of potentially unequal access to these technologies.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
7	41	…BCIs enable employee attention monitoring and decision-making support across a variety of fields, thereby improving worker safety and performance and leading to greater efficiencies.	**NOTE:** Attention monitoring is a double-edged sword and can be used to increase safety or micromanage an employee. This scenario emphasizes the more benevolent applications of attention monitoring. **INFO:** Examples of the potential benefits of attention monitoring include the following: ▪ Detecting when an employee's attention level is insufficient for the task at hand (e.g., alerting bus drivers when they become fatigued or when their attention wanders from the road) or monitoring for high levels of stress ▪ Working in combination with augmented reality and virtual reality devices to feed information to an individual or to stimulate parts of the brain linked to concentration or absorption of new information ▪ Facilitating rapid emergency shutdowns of machines or systems **CONCERN:** Disgruntled employees may become insider threats.
8	42	The industry also enabled major advances in training and education by combining brain control devices with augmented reality and virtual reality.	**INFO:** Noninvasive BCIs, especially when combined with augmented reality or virtual reality capabilities, could run training and simulation programs that adapt to an individual's interest, including measuring the user's cognitive strain and presenting more difficult tasks to increase attention.
9	43	And BCIs are now standard practice in authentication—what you all probably call "passthoughts."	**INFO:** Each individual's brainwave patterns are unique, which could enable authentication of the individual's identity. These can be read using noninvasive methods, and can greatly increase security, particularly when used as part of multifactor authentication.
10	44	Who here remembers the first-generation BCI games from BrainConnect? By now, they are probably considered antiques.	**CONCERN:** By making games that are more immersive and addictive, BCIs may increase mental strain, distraction, inability to focus, and other psychological side effects.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
11	64	…Neurological Information Nondiscrimination Act…	**NOTE:** The scenario author envisioned this act being akin to the Genetic Information Nondiscrimination Act (GINA) of 2008, which lays out protections for genetic data—chiefly protecting individuals from discrimination at the hands of employers and the government. **CONCERN:** A noted weakness of GINA is that individuals regularly hand over genetic information to private-sector companies (e.g., ancestry and genetic profiling services). These companies frequently retain ownership of the genetic data, including the ability to sell it. At least one country has been accused of accumulating the genetic data of Americans in order to gain insights into the health and genetic makeup of the country overall. **DP:** ▪ How should neurodata be protected? ▪ What do you see as potential risks to individuals if neurodata is not protected? To the United States?
12	73	And just last month, our BCI National Laboratory announced the achievement of a ”write” capability in invasive BCIs…	**INFO:** *Write capability* refers to the ability to communicate information directly into the brain via a BCI. This is often considered a “holy grail” of BCI advancement.
13	87	Some members of the public are pushing back against our advances in BCIs, opposed in principle or for religious reasons to what they see as an unacceptable level of human augmentation.	**DP:** What might some of the controversies around human augmentation be?
14	89	And despite their usefulness in a large number of applications and industries, BCIs—particularly invasive BCIs—remain costly, out of reach for many Americans.	**DP:** How might unequal access to BCI technologies create additional challenges for CI systems and reduce their resilience and security?

SCENARIO #3: RUNNING FREE

Please note: The version of the narrative that the facilitator possesses has line numbers for ease of identifying key segments of the scenario narrative (as referenced in the table below). These segments are also highlighted in green and labeled with reference numbers.

BRIEF DESCRIPTION

In the years following the COVID-19 pandemic, the United States experienced a period of austerity in government spending as the public sector worked to recuperate from the massive financial costs incurred. Government entities focused on economic recovery and were reluctant to enact any regulations that could hinder economic development, especially from new and emerging technologies. The private sector did not share the same funding limitations. By 2035, technological advances—driven primarily by private investments—are achieved in several fields, including synthetic biology, BCIs, and quantum computing. These advances benefit Americans in many ways. However, the benefits are primarily reaped by those with economic means, furthering the socioeconomic divide in the United States.

SCENARIO CONTEXT

- Written as a magazine article that describes a future state of the world in which the private sector has dominated technology development for the past 15 years.
- Uses recovery efforts from the COVID-19 pandemic as a key driver of deregulation, which helps promote rapid technological development in emerging technologies.
- Provides numerous examples of the benefits associated with BCIs, quantum computing, and synthetic biology. In addition, the scenario identifies several shortfalls arising from development driven by commercial interests, which leads to backlash against these technologies.
- Depicts a world in which data privacy protections are lax, including for neurodata.
- Alludes to rates of technological progress and change that exceed the ability of governance structures to keep pace.
- Encourages readers to consider how the scenario might be different if technology development had been supported by cooperative initiatives between the public and private sectors.

FACILITATION QUESTIONS – TAILORED

Please note: Broader, more general facilitation questions—common to all three scenarios—are located in the Scenario Breakouts section of this facilitator's guide. Additional discussion points, tied to specific portions of the scenario narrative, are listed in the scenario's "Detailed Scenario Breakdown."

- Aside from the examples in the scenario, how might advances in BCIs, quantum technologies, and synthetic biology be applied to CI sectors? Who might some of the greatest beneficiaries be?
- How might deregulation of technology development in the United States affect its evolution? What are the benefits, drawbacks, and risks of this approach?
- What risks does reduced involvement from the public sector present for future technology needs of CI?

- How can governance structures best keep pace with technology developments and ensure adequate consideration of potential risks associated with new technological capabilities?
- With the widespread generation and use of neurodata, what are the implications for the government's role in its oversight and protection? How might public expectations and perceptions of the government's role in cybersecurity oversight change?

RUNNING FREE

January 21, 2035 [1]

The ongoing U.S. trucker strike [2] over the use of brain-computer interface devices in the transport industry does not, at first blush, seem to bear much connection to this week's 15th anniversary of the first U.S. COVID-19 case. But a path leads directly—if in winding fashion—from post-COVID deregulation to the domination of new technology in the 2030s. And that domination took its own winding path to the technology backlash occurring today.

When they first came on the market, brain-computer interface devices, BCIs for short, were embraced by the trucking industry as a way to improve safety. They monitored alertness and greatly decreased the number of accidents that occurred due to drivers becoming distracted or falling asleep at the wheel.

Now, however, BCIs have transitioned from a piece of safety equipment to a surveillance system, monitoring employee performance, productivity, and activities. [3] They are even used to track employee sentiment about specific issues. Ostensibly, the monitoring is for the detection of insider threats. However, the strikers and civil liberties organizations claim that these uses of BCIs are a violation of employee privacy and that they are misused to curtail employee efforts to unionize.

For all the benefits of BCI technology, limited and lax privacy legislation has enabled this invasion of individual rights. And it is no coincidence that this deregulation arose from the aftereffects of the COVID-19 pandemic.

Before the pandemic, legislators on both sides of the Atlantic were enacting increasingly restrictive laws to protect the privacy of individuals. The European Union's General Data Protection Regulation set the standard and led others to enact similar laws. [4]

But the regulatory environment hit an inflection point as the world transitioned from a pandemic to an endemic state. For example, the momentum that seemed to be building for privacy regulation around 2020 waned, with no major movements in data privacy laws in the mid-2020s. Across sectors and countries, the focus on economic recovery and economic competitiveness led regulators to loosen the reins on existing regulations and fostered a reluctance among some legislators to introduce new regulations. [5]

In the United States, Congress instead focused on shoring up gaps revealed by the pandemic and stimulating progress in select technologies of strategic importance. The memory of shortages of personal protective equipment in the early days of the pandemic, for example, conjured up fears of an overreliance on foreign supply chains. [6] In response, Washington enacted legislation to help domestic companies compete—not only in medical supplies but also in other key fields, from artificial intelligence to synthetic biology, including genetically modified foods and other agricultural products. These key fields in the domestic market were also bolstered by federal support and investment.

Tax cuts also favored big business as more fiscally conservative leaders were elected at the state and federal levels. Starved of revenue by both tax cuts and the economic costs of the pandemic, leaders in Washington and in state capitals shifted their focus to fiscal responsibility. At the federal level, funding for basic and translational research and development was spurned for initiatives that

were deemed to provide more near-term benefits to the U.S. economy and shore up critical supply chains.

Over the next decade, the return to trickle-down economics [7] achieved much of the desired effect. The U.S. economy thrived. The private sector clearly benefited from a looser regulatory environment and experienced an influx of capital due to a strong economy. Technology developed at a rapid pace, with advances focusing primarily on lucrative ventures. By 2030, a few key technologies—which had been just emerging around the time of the COVID-19 pandemic—became established in everyday life. [8]

One of those technologies was BCIs. By 2030, advances in noninvasive BCIs [9] led to a prevalence of wearables for gaming, accessing the metaverse, [10] and other augmented reality and virtual reality applications, such as online shopping. BCIs also began to enable rapid communications, essentially cutting out the hardware of a keyboard; as a result, they became a preferred way—if not *the* preferred way—of interacting with the digital world.

Invasive BCIs also matured, primarily for use in the medical field, finding applications for stroke rehabilitation, treatment of cognitive diseases, and mental health treatment. Some progress, albeit limited, was also made in controlling robotic limbs and restoring lost motor control and communications capabilities for those patients who were "locked in."

Two other areas of rapid technology development were in synthetic biology and quantum computing. [11] The private sector had made incredible strides in these fields by 2030. For example, the mRNA technology used to create the first COVID-19 vaccines was applied to create treatments for a number of diseases, including cancer and cystic fibrosis. Meanwhile, a breakthrough for the food industry came when U.S. researchers used synthetic biology to develop the first pig resistant to African swine fever. [12] Although farming this pig has not yet taken hold in the United States, the regulatory environment to do so is favorable. The research team behind the modified pig recently sold the patent to the second-largest pig producer in the United States, which announced plans to begin mass production this year.

Quantum computing also made significant strides. During the 2020s, large technology firms reaped the benefits of providing academia with early access to their quantum computers, establishing a robust applied research community that drove advancements in quantum simulation. [13] Early access also allowed these firms to identify promising researchers and recruit them to work in house. [14] The decade also saw some companies beginning to offer access to quantum processers as a cloud service.

Additionally, quantum simulation became an active area of commercial research for development of new catalysts, materials, and pharmaceuticals. Large pharmaceutical companies harnessed AI and quantum capabilities to understand how genetic mutations affect protein folding, which led to a renaissance of novel pharmaceuticals that target misfolded proteins. [15] At present, gene editing for therapeutic purposes [16] is in the clinical trial phase for several fatal diseases caused by misfolded proteins (e.g., the neurodegenerative diseases of Parkinson's and Alzheimer's).

The United States experienced some technological advances in areas beneficial to the public sector and CI. For example, BCIs helped to increase operator safety and to control semiautonomous vehicles, drones, and robots. And the Food and Agriculture Sector achieved benefits from more genetically engineered pest-resistant crops. But federal support for cooperative strategies and

advanced technologies by the public sector remains a patchwork, in both application and distribution. As a result, the private sector has reaped most of the rewards from these advances in technology.

Eventually, the primarily capitalistic focus, minimally restrictive legislative and operating environments, and rapid technological development in some areas served as the foundation for a backlash against technology. Today, there is a growing sentiment that many of these new technologies are being used for inappropriate purposes, are poorly regulated, and have created new and unacceptable risks. Critics—including some of the early leading researchers in these fields—have compiled a growing list of concerns, such as the following:

- The truckers and unions claim that BCI adoption and a lack of protection of neurodata have together increased "surveillance capitalism." **[17]** Beyond evaluating employee performance, it is clear that neurodata are frequently bought and sold by third-party data brokers **[18]** and used to market products to individuals, allowing companies to take advantage of insights into an individual's health or cognitive state.[2]
- There are renewed fears surrounding the ability of quantum technology to break legacy cryptographic protections **[19]** following the realization of practical achievements in quantum computing.
- Systems can be deployed with quantum cryptographic protections, but the deployment of these quantum capabilities varies across industries and jurisdictions. Many CI sectors and local jurisdictions are lagging in transitioning to post-quantum cryptographic algorithms, leaving them vulnerable to cyberattacks.
- Organizations and jurisdictions are concerned about the quantum threat but have a poor understanding of it. This want for expertise has led to a rapid growth of commercial services that can support these entities; however, the reliability of some of these vendors and consultants is questionable.
- Synthetic biology and gene-editing techniques are proving to be effective strategies for combating some diseases. Personalized medicine, based on one's genetic makeup, is also rapidly progressing. However, the techniques and approaches are costly and thus only available to those with significant means, increasing inequity.
- The burgeoning field of large-scale biomanufacturing, driven by advances in synthetic biology, has placed stress on the agriculture community. Biomanufacturing companies require extraction of biomass from the environment to fuel their operations, and they have purchased wide swaths of land to support those needs. This shift has dramatically changed the use of some land and displaced many small farmers.
- In the past five years, the United States has experienced a few high-profile instances of the release of a synthetic-biology product into the environment with unintended negative consequences. **[20]** For example, in 2034, a bacterium genetically modified to degrade oil was released into the Gulf of Mexico following an oil spill; however, an intermediary byproduct of the bacterial degradation began getting into shrimp and killing them. This decimated the area's shrimp population and will have a detrimental effect over many years.
- More broadly, environmentalists are concerned that, similar to what geoengineering has done to climate change, advances in synthetic biology capabilities have shifted the narrative

[2] Of note: Quantum computers have further enhanced the ability to leverage neurodata for machine learning; researchers have shown that quantum machine learning is superior to classical machine learning, especially for identifying subtle correlations in neurodata.

away from environmental protection. Many believe they can simply “fix” environmental problems later with, for example, bioremediation capabilities. [21]

Like with the ongoing trucker strike, a chorus of opinions is now calling for legislative change—specifically for more regulation and privacy and equity protections across these areas and more. Disagreements about the appropriate level of legislation for emerging technologies are far from new. And although it has always been important not to stymie technological development with too many restrictions, based on these emerging trends, it might be time to rethink the existing environment, with an eye toward understanding where it came from in the first place.

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DETAILED SCENARIO BREAKDOWN: RUNNING FREE

Please note: The version of the narrative that the facilitator possesses has line numbers for ease of identifying key segments of the scenario narrative (as referenced in the table below). These segments are also highlighted in green and labeled with reference numbers.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
1	2	January 21, 2035	**NOTE:** The date is intentionally selected to coincide with the 15th anniversary of the first confirmed COVID-19 case in the United States.
2	3	The ongoing U.S. trucker strike…	**NOTE:** Although the deregulation discussed in this scenario could likely enable autonomous vehicles on the roadways, this scenario anticipates that by 2035, autonomous trucking will not have completely replaced human truckers, especially in specialized areas, uncommon routes, and the "final mile" of distribution.
3	13	Now, however, BCIs have transitioned from a piece of safety equipment to a surveillance system, monitoring employee performance, productivity, and activities.	**CONCERN:** If not adequately protected and secured, BCIs could be used to capture personal information on individuals (e.g., activities, behaviors, purchases, thoughts) and the data could be misused.
4	22	Before the pandemic, legislators on both sides of the Atlantic were enacting increasingly restrictive laws to protect the privacy of individuals. The European Union's General Data Protection Regulation set the standard and led others to enact similar laws.	**INFO:** For example, the California Consumer Privacy Act was enacted in 2020. The International Association of Privacy Professionals has developed a table to keep track of state-level privacy legislation. For information on which states have proposed and enacted comprehensive privacy bills, visit: https://iapp.org/resources/article/state-comparison-table/.
5	28	…led regulators to loosen the reins on existing regulations and fostered a reluctance among some legislators to introduce new regulations.	**NOTE:** One example of an action that would promote a less restrictive regulatory environment would be decreasing the number of approvals or testing required to bring goods to market. Federal actions, such as subsidies and tax breaks, are other ways in which regulators could loosen the reins on regulations to promote development.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
6	32	The memory of shortages of personal protective equipment in the early days of the pandemic, for example, conjured up fears of an overreliance on foreign supply chains.	**INFO:** During the COVID-19 pandemic, there were severe shortages nationwide in medical supplies, such as PPE (gloves, masks, gowns), ventilators, and reagents needed for polymerase chain reaction (PCR) testing. Many medical entities (e.g., hospitals), public health authorities, and others were left to their own devices to source the needed products, often resorting to reusing products intended for a one-time use and using inferior products (e.g., surgical masks instead of N95 masks), which put them at greater risk of exposure. Additionally, price gouging and fraudulent products were rampant. **DP:** ▪ What are other current or future supply chains that present significant security and resilience concerns for the United States? Can you elaborate on the risks and ramifications to U.S. CI associated with their disruption or compromise? ▪ Which materials, supplies, and products are critical for the United States to produce domestically? How can domestic production be incentivized?
7	42	…the return to trickle-down economics…	**INFO:** *Trickle-down economics* is characterized by reduced taxation, reduced federal spending and government regulation, and increased free market activity with fewer restrictions.
8	46	Technology developed at a rapid pace, with advances focusing primarily on lucrative ventures. By 2030, a few key technologies—which had been just emerging around the time of the COVID-19 pandemic—became established in everyday life.	**NOTE:** A key component of this scenario is that technological progress is driven by economic potential and profitability considerations. The scenario highlights the progress of three burgeoning technologies with great economic potential—synthetic biology, quantum computing, and BCIs. For example, synthetic biology markets are growing rapidly, and future products and capabilities have great economic potential. Current experts believe that synthetic biology will be foundational to the 21st century economy, and that it will play a critical role in global and geopolitical competition, with national security implications.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
9	48	One of those technologies was BCIs. By 2030, advances in noninvasive BCIs…	**INFO:** A BCI device translates signals from the wearer's brain into an action (as defined by the application of the BCI). There are two broad categories of BCIs: invasive and noninvasive. Noninvasive BCIs read neuronal activity from outside of a person's body (e.g., through sensors placed on or very close to the head) and invasive BCIs read neuronal activity from sensors inside of the person's body (e.g., through sensors surgically implanted into the brain).
10	49	…accessing the metaverse…	**INFO:** The metaverse is a hypothetical future virtual world enabled by the internet and technologies, such as virtual reality and augmented reality.
11	58	Two other areas of rapid technology development were in synthetic biology and quantum computing.	**INFO:** ▪ For this scenario, we consider a broad definition of synthetic biology to include the concepts, approaches, and tools that enable redesigning and harnessing the production ability of biological organisms. ▪ Quantum computing is a technology that makes use of quantum mechanical properties (e.g., superposition, entanglement) to perform computations.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
12	62	Meanwhile, a breakthrough for the food industry came when U.S. researchers used synthetic biology to develop the first pig resistant to African swine fever.	**INFO:** ▪ Very few genetically engineered animals have received approval as a food product. The first product, a genetically engineered fast-growing salmon, was under review for more than a decade before it was approved in 2015. In 2020, the FDA did approve a line of domestic pigs, which were modified to eliminate an allergic reaction–causing sugar on the pigs' cells, for food or human therapeutics. ▪ African swine fever is a highly contagious and fatal pig disease that currently threatens the wild and domestic swine population. It has been found in various locations across the world, but has not been found in the United States to date. The USDA Animal and Plant Health Inspection Service lists African swine fever as one of the top eight animal diseases that could pose a significant risk to U.S. food and agriculture resources. **CONCERN:** The current regulatory environment could leave the United States vulnerable to animal disease outbreaks that might otherwise be mitigated with genetic modification techniques.
13	68	During the 2020s, large technology firms reaped the benefits of providing academia with early access to their quantum computers, establishing a robust applied research community that drove advancements in quantum simulation.	**INFO:** Quantum simulations use quantum computers to study the properties of matter. Because quantum computers leverage quantum mechanical phenomena, they are likely well-suited to examining these phenomena in molecules and compounds. This has significant potential for the design of new pharmaceuticals, catalysts, and materials.
14	70	Early access also allowed these firms to identify promising researchers and recruit them to work in house.	**NOTE:** This sentence hints at growing private-sector influence within academia for key emerging technologies. **DP**: What concerns might arise if boundaries between industry and academia blur, particularly for emerging technologies? Does this scenario present any security risks?

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
15	75	Large pharmaceutical companies harnessed AI and quantum capabilities to understand how genetic mutations affect protein folding, which led to a renaissance of novel pharmaceuticals that target misfolded proteins.	**INFO:** Protein folding is a complex process in which the amino acids that make up a protein form intramolecular bonds with each other, creating folds in the protein that determine its three-dimensional (3D) shape. Genetic mutations can change the amino acids present in the protein and thus affect how a protein folds, sometimes resulting in a disease. Determining the 3D shape of a protein is difficult and traditionally involves years of research and complex techniques, such as x-ray crystallography. Some modeling techniques—particularly those using AI algorithms—have provided insight into how a genetic modification could affect a protein's 3D shape. Quantum computers, with their ability to process highly complex problems and models, could provide a significant advancement in scientists' ability to model and understand protein folding and misfolding, based on genetic sequences.
16	76	…gene editing for therapeutic purposes…	**INFO:** One of the first patients to undergo gene therapy died because of an immune and inflammatory response to the adenoviral vector delivering the gene, which set the field back for almost a decade. However, with advances in synthetic biology (especially with the advent of CRISPR/Cas-driven modifications) this type of therapy is rapidly developing. The first gene therapy in the United States was approved in 2017 for the treatment of a form of acute lymphoblastic leukemia. Gene editing could provide a cure or treatment for a vast array of diseases with a genetic cause or component (e.g., sickle cell anemia, cancer, Alzheimer's disease, HIV/AIDS, diabetes, and cystic fibrosis).

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
17	93	…a lack of protection of neurodata have together increased "surveillance capitalism."	**INFO:** *Surveillance capitalism* involves the monetization of data about an individual, such as information about their activities and actions, behaviors, purchases, and thoughts. This data is sold and used for profit-making ventures (e.g., directed marketing) or other purposes. **NOTE:** For this scenario, the author also wanted *surveillance capitalism* to convey the unwanted and restrictive nature of the monitoring occurring. **CONCERN:** Neurodata, if properly decoded, can be highly revelatory about an individual's physical and mental health and emotional state. This information could be valuable to retailers, insurance companies, employers, and malicious actors.
18	94	…neurodata are frequently bought and sold by third-party data brokers…	**INFO:** Third-party data brokers aggregate data from a variety of websites and sources and then sell the aggregated data. **CONCERN**: ▪ Foreign adversary intelligence collection through third-party data brokers ▪ Micro-targeting of key individuals for cyber and physical attacks **DP:** To what extent does the neurodata exacerbate or change existing concerns about privacy and third-party data brokers?
19	98	…fears surrounding the ability of quantum technology to break legacy cryptographic protections…	**CONCERN:** A sufficiently powerful quantum computer could break public-key encryption. If/when this happens, it could be a major threat to data and transactions secured by all widely used public-key algorithms. **INFO:** National Security Memorandum 10, released in May 2022, addresses policies and initiatives related to quantum computing, including specific actions that federal agencies will take to migrate to quantum-resistant cryptography.

Ref No.	Line #	Narrative Reference Text	Additional Comments DP = Discussion Point INFO = Additional Information NOTE = Clarification/Rationale CONCERN = Potential issue, threat, or vulnerability
20	119	…the release of a synthetic-biology product into the environment with unintended negative consequences.	**NOTE:** Introduction (intentional or accidental) of genetically modified organisms or products into a natural environment could have unintended and unanticipated consequences. Biological systems are inherently complex, which makes predicting all consequences of system modification difficult. In addition, much is still not known about many organisms' biological systems, such as their immune systems and microbiomes. **INFO:** The controlled release of synthetic biology–modified microbes and other organisms (e.g., bacteria engineered to be sensors, mosquitos modified by gene drives to be resistant to malaria) into the environment is severely limited by the lack of a mechanism to understand and evaluate the potential short- and long-term effects to the environment. Currently, no clear process to assess environmental applications exists, including which regulatory bodies would be responsible for oversight. **CONCERN:** Once a modification is made, changes can be difficult if not impossible to undo, and engineered organisms, like natural organisms, will change and evolve over time, possibly in unanticipated ways. Additionally, they can grow and spread beyond the initial area of introduction.
21	126	Many believe they can simply "fix" environmental problems later with, for example, bioremediation capabilities.	**INFO:** *Bioremediation* is the use of organisms (e.g., bacteria) to break down environmental pollutants.

APPENDIX A: WORKSHOP PLANNING CONSIDERATIONS

Step 1: Set a target date for the event at least three months in advance.

Step 2: Identify workshop staff.

Staffing the workshop requires a time commitment from at least six individuals—three facilitators and three document leads. Facilitators should expect to spend at least 30 hours on the workshop, and document leads, at least 15 hours. In addition, a workshop coordinator should expect to spend 10–15 percent of their time in the three months prior to the event in organizing the workshop and engaging with invitees. Workshop planning efforts may also require periodic input from a planning committee (e.g., to tailor the workshop goals).

Step 3: Identify potential invitees.

A scenarios workshop requires 40–50 participants. Thus, hosts may need a list of 55–70 candidates to secure the necessary number of participants. When identifying candidates, the workshop sponsor/planning committee/coordinator should target the following groups:

- Mid-to-senior career-level individuals interested in exploring longer-term risks to CI to enable effective risk mitigation.
- A mix of representatives (e.g., CISA personnel; state and local planners; fusion center personnel; private-sector representatives; subject matter experts from non-profits, think tanks, and academia).
- Individuals with interest and expertise in brain-computer interfaces, quantum technologies, and synthetic biology.
- Individuals familiar with strategic foresight.

Because the virtual workshop divides participants into three breakout rooms (one for each scenario), consider the best way to achieve a mix of different perspectives and expertise among the groups when identifying candidates. The workshop coordinator should tap into the networks of the Regional Director, senior leaders, Protective Security Advisors, Cybersecurity Advisors, and members of the planning committee to identify participants. The workshop coordinator may also need to coordinate engagement efforts within the region to identify additional participants for the workshop. Thus, the workshop coordinator may want to develop and circulate a one-page flyer on the scenarios workshop. An example can be requested at SecureTomorrowSeries@cisa.dhs.gov.

As prospective participants are identified, it would be useful to record additional information about them in a spreadsheet to help prioritize invitations (and potential backup candidates). Possible data fields include the following:

- Name
- Position
- Organization
- Subject matter expertise in one or more of the topic areas (brain-computer interfaces, quantum technologies, and synthetic biology)

- Stakeholder group (e.g., private sector, public sector, nongovernmental organization, academia)
- Experience/expertise in strategic foresight
- Link to professional bio

Step 4: Start sending invitations and tracking responses.

Roughly two months before the workshop, the workshop coordinator should begin issuing invitations and tracking RSVPs. Invitations should come from a senior leader within the sponsoring organization. Invitation language may require leadership review and coordination with the leader's executive assistant on invitation roll out. Candidates should send RSVPs to the workshop coordinator, who should respond immediately with a save-the-date meeting invitation.

Step 5: Review scenarios and identify key discussion points.

Each of the topics addressed by the scenarios is broad, providing opportunities for hosts to tailor the workshop to their interests. Facilitators are unlikely to have time to address all the discussion points listed in the detailed scenario breakdowns. The workshop sponsor, planning committee, and coordinator should review the scenarios and select the key discussion points that facilitators should prioritize for the participants in their group. It may be useful to invite facilitators to participate in or observe these deliberations so they can gain a better idea of leadership intent and begin familiarizing themselves with the scenarios.

Step 6: Train the facilitators and document leads.

Five weeks prior to the workshop, the workshop coordinator should hold a meeting with all workshop personnel to walk through the agenda and train them on specific responsibilities and desired outputs of each session (using this facilitation guide as a reference). The coordinator should introduce each of the facilitator-document lead pairings at this time and give them their assigned scenarios (if they have not yet received them).

A second, follow-on meeting should be held for the facilitators to talk through their scenarios with one another and to receive additional training on workshop priorities. This meeting will help the facilitators to gain a more holistic understanding of the scenarios to help with stress-test rounds and to discern the distinctions between different directions explored by each scenario.

Step 7: Determine scenario assignments.

Three weeks prior to the workshop, the workshop coordinator should finalize the assignment of attendees to scenarios. As noted earlier, because the workshop divides participants into three groups, consideration should be given to the mix and balance of different perspectives and expertise among the groups when making group assignments.

Step 8: Send out participant information.

Two weeks before the event, each participant should receive the following:

- Assigned scenario narrative

- One-page brief describing the three scenarios
- Workshop feedback form (optional)
- Are We There Yet? Participant Form (if receiving polling information beforehand)
- Participant biographical information

If participants are receiving a polling form, remind them to complete and return the form one week before the workshop to allow sufficient time for compiling and analyzing the results and updating the "Are We There Yet?" results slides.

Step 9: Make final preparations.

A few days before the event, conduct a final review of the slides, emphasizing transitions between speakers and between plenary and breakout sessions, and selecting files to share on the virtual meeting platform. During this review, the workshop coordinator should confirm assignments for supporting workshop sessions (e.g., who will be presenting/manipulating the slides, providing technical support, monitoring chat).

Facilitators should review in detail the support materials that pertain to their assigned scenario. Although they should focus most of their attention on their assigned scenario, facilitators should also review the remaining scenarios.

APPENDIX B: IN-PERSON WORKSHOP AGENDA

The scenarios workshop facilitation guide is written for a two-afternoon, virtual execution of the workshop. However, the workshop can also be configured as a one-day, in-person event (see below for alternative agenda). Unless otherwise indicated as plenary, the sessions occur in breakout groups.

TIME	ACTIVITY
8–8:30 a.m.	Registration
8:30–9:15 a.m.	Framing the workshop: welcome, participant introductions, workshop objectives, and roadmap for the day's activities (*plenary session*)
9:15–10 a.m.	Icebreaker exercise: Are we there yet? (*plenary session*)
10–10:15 a.m.	Break
10:15–12:15 p.m.	Scenario breakouts • Scenario familiarization and build out • Identification of emerging and evolving risks and associated needs • Risk mitigation strategies
12:15–1 p.m.	Lunch
1–1:10 p.m.	Divide breakout group and prepare for stress-test rounds
1:10–1:55 p.m.	Alternative future stress-test: Round 1
1:55–2:40 p.m.	Alternative future stress-test: Round 2
2:40–2:55 p.m.	Break
2:55–3:45 p.m.	Synthesis and reflection (*plenary session*)
3:45–4 p.m.	Closing remarks (*plenary session*)