



SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

HEARING CHARTER

“Balancing Biotechnology Innovation and Biosecurity: Securing U.S. Leadership in a Global Race”

September 16, 2026

10:00 a.m.

2318 Rayburn House Office Building

Purpose

The hearing will assess the current state of U.S. biotechnology research and development, manufacturing, innovation, and security to determine whether the United States is adequately prepared to compete strategically with China and protect American economic and national security interests. The Subcommittee will examine the effectiveness of current federal policies and evaluate what is being done—and what additional actions may be necessary—to strengthen U.S. public and private biotechnology research, development, innovation, and security. The hearing will also explore opportunities to improve federal coordination, investment, and domestic biomanufacturing capacity to ensure that the United States maintains its leadership in biotechnology and is prepared to address emerging national-security challenges.

Witnesses

- **Dr. Anemone Franz**, Visiting Research Fellow, American Enterprise Institute
- **Mr. Joshua Hodges**, Visiting Fellow, Hoover Institution
- **Dr. Gigi Gronvall**, Professor, Bloomberg School of Public Health, Johns Hopkins

Overarching Questions

- Is the United States doing enough to maintain its leadership in biotechnology and biomanufacturing, particularly in the face of growing strategic competition with China?
- Are current federal policies and oversight mechanisms sufficient to support responsible biotechnology research and innovation while protecting Americans from the risks associated with high-risk biological research, including dangerous gain-of-function research?

- What additional actions should Congress and the federal government take to strengthen U.S. biotechnology research, domestic biomanufacturing, supply-chain security, and innovation while ensuring that taxpayer-funded research advances U.S. national and economic security?

Background

On June 5, 2025, the Science, Space, and Technology Committee held a hearing titled “*Pursuing the Golden Age of Innovation: Strategic Priorities in Biotechnology*.”¹ The hearing examined U.S. biotechnology leadership, opportunities for innovation, and strategies to strengthen the biotechnology sector while addressing national security, economic competitiveness, and other potential risks.² Members discussed the importance of federal investment, coordination, research and development, biomanufacturing capacity, workforce development, and maintaining U.S. leadership in biotechnology.³ That hearing focused primarily on innovation and sector strategy. This hearing will examine whether federal policy, oversight, and implementation have kept pace with the risks identified in that record, especially high-risk pathogen research, foreign dependence on the biotechnology supply chain, and PRC efforts to dominate the field.

Federal policy has continued to evolve in response to concerns about research oversight, biosecurity, and the need to protect U.S. biotechnology leadership. Executive Order 14292, signed by President Donald Trump on May 5, 2025, is titled “*Improving the Safety and Security of Biological Research*.”⁴ The order directs federal agencies to restrict or terminate certain federal support for dangerous gain-of-function and other high-risk biological research when adequate oversight and safeguards are lacking, including certain research conducted by foreign entities in countries of concern. It also calls for stronger oversight, enforcement, transparency, and screening measures for high-risk biological research and synthetic nucleic-acid activities.⁵ Further, in July 2026, the White House and relevant agencies released follow-on policy implementing those directives for high-risk life-science research and international research of concern.⁶

Congress has also taken steps to address national security concerns associated with foreign biotechnology providers. On December 18, 2025, Congress enacted the BIOSECURE Act as part

¹ *Pursuing the Golden Age of Innovation: Strategic Priorities in Biotechnology: Hearing Before the Subcomm. on Rsch. & Tech. of the H. Comm. on Sci., Space, & Tech.*, 119th Cong. (2025)

<https://science.house.gov/hearings?ID=6788C987-B83B-4608-9279-281F100FEA9D&>.

² *Id.*

³ *Id.*

⁴ Exec. Order No. 14292, *Improving the Safety and Security of Biological Research* (2025), <https://www.whitehouse.gov/presidential-actions/2025/05/improving-the-safety-and-security-of-biological-research/?query=11-page=72>.

⁵ *Id.*

⁶ OFF. OF SCI. & TECH., EXEC. OFF. OF PRESIDENT, UNITED STATES GOVERNMENT POLICY FOR STOPPING HIGH-RISK LIFE SCIENCES RESEARCH (2026), https://www.whitehouse.gov/wp-content/uploads/2026/07/USG-Policy-for-Stopping-High-Risk-Life-Sciences-Research_July-2026.pdf.

of the National Defense Authorization Act.⁷ The legislation establishes restrictions on certain federal procurement and contracting involving designated biotechnology companies of concern and their biotechnology equipment, services, or related capabilities.⁸ The statute is intended to reduce national security, data security, and supply chain risks associated with reliance on certain foreign biotechnology providers while strengthening the resilience and security of the U.S. biotechnology sector.⁹

Biotechnology and Biomanufacturing

Biotechnology involves the use of biological systems, organisms, cells, or biological molecules to develop products and technologies.¹⁰ Modern biotechnology includes genetic engineering, genomics, synthetic biology, gene editing, cell and gene therapies, bioinformatics, and biotechnology applications involving artificial intelligence.¹¹ Biotechnology is used across numerous sectors. In healthcare, it supports vaccines, medicines, diagnostics, biologics, and gene therapies. In agriculture, it can contribute to crop improvement, disease resistance, food production, and agricultural productivity.¹² Industrial biotechnology can be used to develop chemicals, materials, fuels, enzymes, and other products.¹³

Biomanufacturing uses biological systems—including microorganisms, cells, enzymes, and engineered biological processes—to manufacture products at commercial scale.¹⁴ Its applications extend beyond pharmaceuticals and include fuels, chemicals, fertilizers, food ingredients, biomaterials, and other industrial products.¹⁵ Biomanufacturing is strategically important because scientific leadership does not automatically translate into manufacturing leadership.¹⁶ A country may develop important biotechnology discoveries but remain dependent on foreign facilities or suppliers to manufacture products at scale.¹⁷ Expanding domestic biomanufacturing capacity can

⁷ The BIOSECURE Act, Pub. L. No. 119-60 § 851 (2025) <https://www.congress.gov/119/plaws/publ60/PLAW-119publ60.pdf>.

⁸ *Id.*

⁹ 139 Cong. Rec. H5051 (daily ed. Sept. 9, 2024) <https://www.congress.gov/118/crec/2024/09/09/170/139/CREC-2024-09-09-house.pdf>.

¹⁰ NAT'L SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

¹¹ *Id.*

¹² NAT'L SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>.

¹³ Lucas Fluegel, *A Competitive Analysis of the Biomanufacturing Strategic Landscape and Technology Stack*, CARNEGIE ENDOWMENT FOR INTERNATIONAL PEACE (Jul. 2026), <https://carnegieendowment.org/research/2026/07/a-competitive-analysis-of-the-biomanufacturing-strategic-landscape-and-technology-stack>.

¹⁴ *Id.*

¹⁵ *Id.*

¹⁶ *Id.*

¹⁷ *Id.*

strengthen supply chain resilience, create high-skilled jobs, accelerate commercialization, and reduce vulnerabilities associated with foreign dependence.¹⁸

Biotechnology and biomanufacturing can contribute directly to national security through biodefense, medical countermeasures, biological threat detection, and the protection of critical supply chains.¹⁹ At the same time, advances in biotechnology can create risks if biological tools, knowledge, or materials are misused.²⁰ High-risk biological research can provide valuable information about pathogens and contribute to the development of vaccines, therapeutics, and preparedness strategies.²¹ However, some research can also create concerns involving laboratory accidents, deliberate misuse, or inadequate oversight. Those concerns are especially relevant to gain-of-function research and work involving potential pandemic pathogens.²²

Gain-of-Function

Gain-of-function (GoF) research is a broad term describing research in which scientists deliberately modify a biological system to produce or study changes in its characteristics or capabilities.²³ In infectious-disease research, particular attention has focused on experiments that could increase characteristics such as pathogen transmissibility, pathogenicity, or host range.²⁴ It is important to recognize that not all gain-of-function research involves dangerous pathogens or creates the same level of risk.²⁵

The potential benefits of carefully controlled high-risk research include improving understanding of pathogen behavior, identifying characteristics that could contribute to future outbreaks, supporting vaccine and therapeutic development, and improving pandemic preparedness.²⁶ At the same time, policymakers must consider the possibility of laboratory accidents, deliberate misuse, inadequate oversight, or the misuse of biological information and materials.²⁷

These concerns are closely connected to the concept of dual-use research. Dual-use research can produce legitimate scientific and public-health benefits while also creating the possibility of

¹⁸ *Id.*

¹⁹ *Id.*

²⁰ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

²¹ *Id.*

²² *Id.*

²³ NAT'L. SCI. ADVISORY BD., NAT'L. INST. OF HEALTH, RECOMMENDATIONS FOR THE EVALUATION AND OVERSIGHT OF PROPOSED GAIN-OF FUNCTION RESEARCH (May 2016) https://osp.od.nih.gov/wp-content/uploads/2016/06/NSABB_Final_Report_Recommendations_Evaluation_Oversight_Proposed_Gain_of_Function_Research.pdf.

²⁴ *Id.*

²⁵ *Id.*

²⁶ *Id.*

²⁷ *Id.*

harmful applications.²⁸ The National Science Advisory Board for Biosecurity has therefore recommended that the federal government apply additional oversight to dual-use research of concern and to work involving pathogens with enhanced pandemic potential, including risk-benefit review before funding and institutional responsibility for identifying and mitigating biorisks.²⁹

U.S. policy concerning high-risk GoF research has evolved significantly. In October 2014, the federal government initiated a review of certain gain-of-function studies involving influenza, MERS, and SARS viruses and paused federal funding for certain studies while the risks and benefits were evaluated.³⁰ Following this review, the federal government developed additional mechanisms for evaluating research involving enhanced potential pandemic pathogens. In 2017, the Department of Health and Human Services established the Potential Pandemic Pathogen Care and Oversight (P3CO) Framework, which provides a process for evaluating certain federally funded research involving enhanced potential pandemic pathogens.³¹ The framework considers potential scientific and public health benefits alongside potential risks and establishes criteria for review.³²

The NIH subsequently announced the removal of the 2014 funding pause following implementation of the P3CO framework.³³ Removal of the pause did not mean that all GoF research was automatically approved; qualifying research remained subject to applicable federal review and oversight requirements.³⁴ Subsequent experience, including federally supported work involving the Wuhan Institute of Virology and later policy revisions, has raised questions about whether P3CO and related agency processes consistently identified covered research and applied

²⁸ *Global Guidance Framework for the Responsible Use of the Life Sciences: Mitigating Biorisks and Governing Dual-Use Research*, WORLD HEALTH ORG. (2022) <https://iris.who.int/server/api/core/bitstreams/4f495bfb-769a-458a-92e3-ca6d3e37d749/content>.

²⁹ NAT'L SCI. ADVISORY BD., NAT'L INST. OF HEALTH, PROPOSED BIOSECURITY OVERSIGHT FRAMEWORK FOR THE FUTURE OF SCIENCE (Mar. 2023) <https://osp.od.nih.gov/wp-content/uploads/2023/03/NSABB-Final-Report-Proposed-Biosecurity-Oversight-Framework-for-the-Future-of-Science.pdf>.

³⁰ *Gain of Function Research*, NAT'L INST. OF HEALTH (last accessed Sept. 2, 2026) <https://osp.od.nih.gov/policies/national-science-advisory-board-for-biosecurity-nsabb/gain-of-function-research/>; DEP'T. HEALTH & HUMAN SERV., RECOMMENDED POLICY GUIDANCE FOR DEPARTMENTAL DEVELOPMENT OF REVIEW MECHANISMS FOR POTENTIAL PANDEMIC PATHOGEN CARE AND OVERSIGHT (P3CO) (Jan. 2017) <https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/p3co-finalguidancestatement.pdf>.

³¹ DEP'T. HEALTH & HUMAN SERV., FRAMEWORK FOR GUIDING FUNDING DECISIONS ABOUT PROPOSED RESEARCH INVOLVING ENHANCED POTENTIAL PANDEMIC PATHOGENS (2017) https://www.aspr.gov/sites/default/files/centers_documents/P3CO.pdf.

³² *Id.*

³³ *NIH Lifts Funding Pause on Gain-of-Function Research*, NAT'L INST. OF HEALTH (Dec. 19, 2017) <https://stagetestdomain3.nih.gov/about-nih/who-we-are/nih-director/statements/nih-lifts-funding-pause-gain-function-research>.

³⁴ *Id.*; DEP'T. HEALTH & HUMAN SERV., RECOMMENDED POLICY GUIDANCE FOR DEPARTMENTAL DEVELOPMENT OF REVIEW MECHANISMS FOR POTENTIAL PANDEMIC PATHOGEN CARE AND OVERSIGHT (P3CO) (Jan. 2017) <https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/p3co-finalguidancestatement.pdf>.

equivalent standards to foreign subrecipients. Questions have also been raised about whether Congress received adequate transparency.³⁵

Strategic Competition with China

Biotechnology has increasingly become a strategic competition issue between the United States and China, extending beyond pharmaceuticals into agriculture, energy, advanced materials, defense, and industrial production.³⁶ In 2025, the U.S. National Security Commission on Emerging Biotechnology (NSCEB) concluded that the United States was at risk of losing its long-standing biotechnology advantage and argued that biotechnology should be treated as a national security and economic priority.³⁷

China has treated biotechnology as a strategic technology and has pursued a coordinated approach involving government investment, infrastructure development, research, data, regulation, and industrial policy.³⁸ In 2026, the NSCEB reported that the Chinese government was advancing biotechnology across five major areas: national strategy, regulation, infrastructure, investment, and data.³⁹

One area of particular concern is China's biomanufacturing capacity. Large-scale fermentation and other manufacturing capabilities can help biological innovations move more efficiently from laboratory development to commercial production.⁴⁰ This creates a potential strategic advantage because the ability to manufacture biotechnology products at scale can be as important as the ability to discover new technologies.⁴¹ For example, a 2025 U.S.-China Economic and Security

³⁵ DEP'T. HEALTH & HUMAN SERV., OFF. OF INSPECTOR GEN., THE NATIONAL INSTITUTES OF HEALTH AND ECOHEALTH ALLIANCE DID NOT EFFECTIVELY MONITOR AWARDS AND SUBAWARDS, RESULTING IN MISSED OPPORTUNITIES TO OVERSEE RESEARCH AND OTHER DEFICIENCIES (Jan. 2023) <https://oig.hhs.gov/oas/reports/region5/52100025.pdf>

³⁶ Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

³⁷ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/; NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf>.

³⁸ Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

³⁹ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Shaping the Future of Biotechnology* (Feb. 2026) https://www.biotech.senate.gov/2025_report/home/; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *U.S. vs. China: Government Action on Key NSCEB Recommendations* (Jun. 2026) <https://www.biotech.senate.gov/press-releases/u-s-vs-chinese-action-against-key-nsceb-recommendations/>.

⁴⁰ U.S.-CHINA ECONOMIC & SECURITY REVIEW COMM'N, *Part III: Competition in Contested Frontiers: Chapter 6: Interlocking Innovation Flywheels: China's Manufacturing And Innovation Engine* (2025) https://www.uscc.gov/sites/default/files/2025-11/Chapter_6--Interlocking_Innovation_Flywheels_Chinas_Manufacturing_and_Innovation_Engine.pdf; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *The Future of U.S.-China Biotechnology Competition* (Dec. 2025) <https://www.biotech.senate.gov/wp-content/uploads/2025/12/NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf>.

⁴¹ *Id.*

Review Commission analysis highlighted China's large fermentation capacity as an important advantage for synthetic biology because it allows biological innovations to move more quickly through the design-build-test-learn cycle and into commercial production.⁴²

The competition has further implications beyond economics. Biotechnology can contribute to military capabilities, medical preparedness, food security, energy security, and the resilience of critical supply chains.⁴³ The NSCEB has argued that advances in biotechnology could influence future military capabilities and that losing leadership could therefore produce broader geopolitical consequences.⁴⁴

Biotechnology, Data, and Artificial Intelligence

The strategic competition also involves biological and genomic data.⁴⁵ Modern biotechnology increasingly depends on large datasets, including genomic, clinical, biological, and molecular information.⁴⁶ Access to high-quality biological data can improve research, drug discovery, and the development of new biological products.⁴⁷

The convergence of artificial intelligence and biotechnology could further accelerate these developments. AI can assist with biological data analysis, drug discovery, molecular modeling, and other research activities.⁴⁸ However, the increasing integration of AI with biotechnology also

⁴² U.S.-CHINA ECONOMIC & SECURITY REVIEW COMM'N, *Part III: Competition in Contested Frontiers: Chapter 6: Interlocking Innovation Flywheels: China's Manufacturing And Innovation Engine* (2025)

https://www.uscc.gov/sites/default/files/2025-11/Chapter_6--Interlocking_Innovation_Flywheels_Chinas_Manufacturing_and_Innovation_Engine.pdf.

⁴³ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf; NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf

⁴⁴ *Id.*; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *The Future of U.S.-China Biotechnology Competition* (Dec. 2025) <https://www.biotech.senate.gov/wp-content/uploads/2025/12/NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf>.

⁴⁵ Michael Sobolik, *Pathogen as Policy: Defending Against Chinese Biowarfare*, Hudson Inst. (Sept. 2025) <https://s3.us-east-1.amazonaws.com/media.hudson.org/Pathogen+as+Policy+-+Defending+Against+Chinese+Biowarfare+-+Michael+Sobolik.pdf>.

⁴⁶ *Id.*; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

⁴⁷ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

⁴⁸ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *U.S. vs. China: Government Action on Key NSCEB Recommendations* (Jun. 2026) <https://www.biotech.senate.gov/press-releases/u-s-vs-chinese-action-against-key-nsceb-recommendations/>.

raises important questions about data security, intellectual-property protection, research oversight, and potential misuse.⁴⁹

Conclusion

Biotechnology is increasingly becoming a foundational strategic technology with implications for healthcare, agriculture, manufacturing, energy, economic competitiveness, public health, and national security.⁵⁰ Prior congressional hearings, Executive Order 14292, federal policies governing high-risk biological research, and the increasing volume of legislation addressing foreign biotechnology providers reflect the growing importance of biotechnology in U.S. policy.

The central challenge for Congress is to ensure that the United States can research, develop, manufacture, and commercialize biotechnology at scale while managing associated safety and security risks. Maintaining U.S. leadership will require sustained investment in research and development, domestic biomanufacturing, workforce development, secure supply chains, responsible research oversight, protection of sensitive technologies and data, and cooperation with trusted international partners. It will also require oversight of whether existing statutes, executive orders, and agency review processes are being implemented, whether gaps remain in high-risk research and research security policy, and whether federal dollars are building U.S. capacity or subsidizing a competitor.

⁴⁹ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf.

⁵⁰ NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *Charting the Future of Biotechnology* (Apr. 2025) <https://www.biotech.senate.gov/final-report/chapters/>; Drew Endy, Sarah Moront, et. al., *Biosecurity Really: A Strategy for Victory*, HOOVER INST. (Oct. 2025) https://hoover-s3-website.s3.us-west-2.amazonaws.com/s3fs-public/research/docs/Moront_BiosecurityReally_web-251007.pdf; NAT'L. SEC. COMM'N ON EMERGING BIOTECHNOLOGY, *The Future of U.S.–China Biotechnology Competition* (Dec. 2025) <https://www.biotech.senate.gov/wp-content/uploads/2025/12/NSCEB-Future-of-U.S.-China-Biotech-Competition-Dec-2025.pdf>; U.S.-CHINA ECONOMIC & SECURITY REVIEW COMM'N, *Part III: Competition in Contested Frontiers: Chapter 6: Interlocking Innovation Flywheels: China's Manufacturing And Innovation Engine* (2025) https://www.uscc.gov/sites/default/files/2025-11/Chapter_6--Interlocking_Innovation_Flywheels_Chinas_Manufacturing_and_Innovation_Engine.pdf.