DEPARTMENT OF DEFENSE
DEFENSE SCIENCE BOARD

Biology

Task Force

EXECUTIVE SUMMARY

September 2020

OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

DEFENSE SCIENCE BOARD

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301–3140

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Biology

I am pleased to forward the final report of the Defense Science Board's Task Force on Biology, co-chaired by Dr. Arup Chakraborty and Dr. George Whitesides.

The DoD has a long history of developing in-house expertise in multiple scientific fields and driving technology advancement through investments in basic and applied research. However, a major area of needed emphasis in the DoD is the biosciences. While there are pockets and individuals of excellence, the Department as a whole does not have expertise, connections, or investments in life science and technology (LS&T) the way it does with other areas of scientific importance to the DoD, such as computer science and aerospace technologies.

This must change. LS&T is making rapid advancements around the world, driven by research in academia and private industry. These advancements present opportunities and threats to U.S. national security, and the DoD must prepare now to ensure it can harness those opportunities and mitigate those threats.

LS&T will in the near future create wholly novel capabilities as well as strengthen and complement existing fields from materials science to military medicine. This report covers a wide range of bioscience research with a goal of informing the Department of what it needs to know to make sound investments. I endorse the conclusions and recommendations in this report and encourage all the relevant parties in the Department to begin giving the biosciences the attention and resources it deserves.

Eric D. Evans

Dr. Eric Evans
Chairman, Defense Science Board

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DEFENSE SCIENCE BOARD

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301–3140

MEMORANDUM TO THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Biology

Attached is the final report of the Defense Science Board's Task Force on Biology. This task force brought together some of the country's top life science and technology (LS&T) experts and researchers to examine emerging biological technologies of interest to national defense. The Task Force has produced this report to inform the Department of Defense of the state of the field and to draw attention to the areas of LS&T relevant to DoD priorities.

This report contains more speculation than the average DSB report, but this is by necessity: LS&T is progressing so rapidly that specific predictions about future advancements are not always possible. This report aims to provide a description of the current and emerging LS&T landscape so DoD stakeholders can become informed about a scientific field of growing importance, and launch future studies and initiatives. This is essential because LS&T is likely to be important for the Department's mission, and the DoD has insufficient expertise in this field. Since this report was finalized, the COVID-19 pandemic has further underscored the importance of LS&T.

We hope this report will serve as a foundational document for what will become a meaningful in-house expertise in LS&T within the DoD. The threats and opportunities presented by new bio-enabled capabilities will be significant, and the DoD must ensure it does not fall behind other nations lest it lose its technological edge to competitors in a field that may play a transformational role.

Dr. Arup Chakraborty
Co-Chairman

Dr. George Whitesides
Co-Chairman

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DSB Task Force on Biology
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DSB Task Force on Biology
Executive Summary

Advancements in life science and technology (LS&T) are happening at a breathtaking pace. These emerging discoveries and inventions are poised to revolutionize many important parts of civilian and military life. Many of the transformative applications that will come out of the LS&T revolution will be pertinent to the Department of Defense (DoD). However, the LS&T revolution is being driven primarily by commercial industry and academia without significant investment by, or engagement with, the DoD. This differs from previous periods of technological advancement, in which the government played a leading role by establishing priorities and providing funding.

The Defense Science Board (DSB) Task Force on Biology was established to examine the state of play in this increasingly important field and to make recommendations for how the DoD can best leverage these emerging technologies and capabilities despite not playing a leading role in developing them. In addition to the opportunities presented by advancements in LS&T, the Task Force examined possible threats that these new technologies and capabilities might pose in the hands of malicious actors so the DoD can monitor adversary developments. The opportunities and threats presented by the rapid pace of LS&T advancements have the potential to significantly transform warfare; LS&T is now a technology area that the DoD cannot afford to ignore.

The LS&T areas that are of particular interest to the DoD include genome sequencing, bioinformatics, genome editing, synthetic biology, new materials, immunology, the microbiome, and neuroscience. New capabilities in these fields will have applications across the military and national security space. Genomics and bioinformatics could lead to tailored and personalized training, enhancing warfighter performance. Genome editing could lead to manipulation of higher organisms to improve or create combat-relevant characteristics. Synthetic biology could lead to advanced materials with special properties that improve warfighter and weapon system survivability, enable novel combat capabilities, and reduce costs and manufacturing time for materiel. Novel ways of tagging, tracking, and locating using synthetic biology and biosensors could improve intelligence, surveillance, reconnaissance, and targeting. Advances in immunology and new biological materials could transform vaccine development and enhance resilience of soldiers in environments with dangerous pathogens. Better understanding and monitoring of the microbiome can help ensure the health of warfighters in stressful environments and under difficult conditions. New discoveries about the brain can help heal the physical and psychological wounds of war. Advancements in all of these areas will contribute to advancements in military medicine, improving medical care for warfighters both in the field and during recovery. In short, the LS&T revolution can be leveraged to improve force lethality, save warfighter and civilian lives, and reduce costs if the DoD makes the proper investments and establishes the necessary expertise to do so.

Because the DoD is not playing a leading role in driving LS&T research and development, it must better position itself to quickly adopt and leverage new capabilities generated by industry and academia. This will require strong partnerships with universities, research laboratories, corporations, and even small

businesses. The DoD must promote its mission among the next generation of biology students to encourage college graduates to pursue a career working for or with the military. New relationships and mechanisms for cooperation must be built with laboratories and businesses to enable them to partner with the DoD.

The DoD must also consider driving and leading innovation in LS&T for defense-relevant applications that may not be of immediate interest to the free market. For these niche capabilities and requirements, the DoD will need to enhance the small LS&T expertise that currently exists within the Defense Advanced Research Projects Agency (DARPA), the Military Department research laboratories, and the DoD Federally Funded Research and Development Centers (FFRDCs). These organizations will need a skilled and motivated workforce of qualified scientists, including people who cycle in and out of government, bringing their private sector experience with them. Furthermore, intimate knowledge of the LS&T landscape is essential to defend against adversaries who may exploit advances in LS&T in nefarious ways.

It is the Task Force's hope that this study be viewed as a primer on the LS&T areas with relevance to national security, as well as a call to action for the DoD to become a significant player in the biosciences. We also hope that this task force will motivate more in-depth studies. The field is progressing so rapidly that specific predictions about future capabilities or outcomes are not currently possible, but it is imperative that the DoD begin to develop expertise in LS&T to better leverage commercial technologies and advance its own LS&T programs for capabilities relevant to the DoD mission. Failure to harness the great power of LS&T will mean forfeiting new opportunities and will leave the United States at risk to strategic surprise as adversaries move forward in this very important field.

Recommendations

The task force makes the following recommendations and believes that, if implemented, they will prepare the DoD to fully leverage biotechnologies to create a more effective military force.

Recommendation 1:
The DoD should leverage applied genomics for optimized warfighter talent management, performance, and health.

Recommendation 2:
The DoD should accelerate and prepare to employ autonomous systems for battlefield patient management, care, and evacuation.

Recommendation 3:
The DoD should review its posture to mitigate radiological injury on the future battlefield.

Recommendation 4:
The DoD should position itself to leverage future commercial advances in tissue and organ biomanufacturing.

Recommendation 5:
The Under Secretary of Defense for Research and Engineering (USD(R&E)) should designate biotechnology a modernization priority and establish an Assistant Director of Defense Research and Engineering for Biotechnology.[1]

Recommendation 6:
The USD(R&E) should direct the creation of a Public/Private Biotechnology for Defense Innovation Ecosystem.

[1] After the Task Force concluded its deliberations but before this final report was completed, the DoD implemented this recommendation and established an Assistant Director for Biotechnology in 2019.

Appendix A: Task Force Terms of Reference

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION,
TECHNOLOGY,
AND LOGISTICS

FEB 09 2017

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board Task Force on Biology

The nature of conflicts has fundamentally changed since the end of the Cold War. Although preparing for conventional force-on-force combat remains a major focus of the Department of Defense (DoD), its current concepts of "national security" include the now-familiar problems of insurgency, terrorism, and attacks by individuals and groups on the United States and its allies. Strategic forms of conflict, including economic warfare and other forms of aggression, are more complex and less familiar. These forms, consisting of political and social "weapons" designed to exert their effects over decades, are intended to damage or destroy the strength and efficiency of an open society.

New technologies enable new forms of conflict. The Cold War was based largely on a competition in technologies related to nuclear weapons, radar, stealth, space, and information. Conflict has recently embraced "gray zone" operations and cyber warfare. What is next?

Out of a field of several candidates, which includes autonomous weapons and artificial intelligence, biology is the science with the most explosive growth—although not yet the greatest practical impact. The first revolution in modern biology was the discovery of the structure of DNA, and the second was genomics. A third revolution, currently underway, is the convergence of approaches from engineering, physical sciences, life sciences, and medicine to address grand challenges in biology, health care, agriculture, industrial manufacturing, and materials science. Capabilities in development include genetic and systems-based approaches designed to manipulate biological systems in desired ways at the molecular and organism level. Although this revolution is currently centered in the United States, there exist relatively minimal barriers to entry; therefore, new concepts can be rapidly disseminated internationally.

Unlike other areas of modern technology, DoD has not actively participated in the development of modern biology. As a result, the Department runs a serious risk of being surprised when bioscience is applied to strengthen or expand an adversary's capabilities. Although the United States has the strongest bioscience university/industrial complex in the world, DoD is currently not a significant part of that complex and has not pursued capabilities that are focused on problems of interest. The goal of this task force is to explore and articulate the opportunities and potential risks enabled by modern and emerging bioscience advances that could significantly impact our national security and improve our defense capabilities.

This task force will focus on the most rapidly moving areas of modern bioscience. These areas have the potential to provide the basis for technologies that either yield novel opportunities for defense innovation or, in the hands of an adversary, present a threat to national security. Its emphasis will be on new technologies, and it will include consideration of technical advances

that can be accomplished now as well as conservative speculation on what might be technically possible in 25 years. The task force will also consider non-technical issues that are critical to future developments, including: 1) the sources of innovation, 2) legal, ethical, and regulatory aspects to developing products to be used with humans/animals and plants, and 3) key areas where substantial investments would have very high payoff in both long and short term. For those areas where the task force identifies a novel risk, it will suggest potential strategies and opportunities for risk management to include the development of novel countermeasures.

The task force will leverage a number of resources in the conduct of its work. In addition to its inherent expertise and access to professional networks and information sources, the task force may, at the discretion of the co-Chairs, invite presentations from specialized experts in academia, industry, and Government. The task force will have access to relevant DoD subject-matter experts and may conduct site visits to DoD laboratories and Federally-Funded Research and Development Centers in order to ascertain the Department's capabilities in relevant technologies, tools, and scientific expertise. At the conclusion of its work, the task force will provide a briefing and a written unclassified report, with classified annexes as needed.

I will sponsor the study. Dr. Arup Chakraborty and Dr. George Whitesides will serve as co-chairmen of the study. Dr. James B. Petro will serve as Executive Secretary for the study. Captain Jeff Nowak, U.S. Navy, will serve as the Defense Science Board Secretariat Representative.

The task force members are granted access to those DoD officials and data necessary for the appropriate conduct of their study. The Under Secretary of Defense for Acquisition, Technology, and Logistics will serve as the DoD lead for the matter under consideration and will coordinate decision-making as appropriate with other stakeholders identified by the study's findings and recommendations. The nominal start date of the study period will be within 3 months of signing this Terms of Reference, and the study period will be between 9 to 12 months. The final report will be completed within six months from the end of the study period. Extensions for unforeseen circumstances will be handled accordingly.

The study will operate in accordance with the provisions of Public Law 92-463, "Federal Advisory Committee Act," and DoD Instruction 5105.04, "Department of Defense Advisory Committee Management Program." It is not anticipated that this study will need to go into any "particular matters" within the meaning of title 18, United States Code, section 208, nor will it cause any member to be placed in the position of action as a procurement official.

James A. MacStravic
Performing the Duties of the
Under Secretary of Defense
for Acquisition, Technology,
and Logistics

Appendix B: Task Force Membership

Chairs

Dr. Arup Chakraborty
Massachusetts Institute of Technology

Dr. George Whitesides
Harvard University

Members

Dr. Vikram Bajaj
Foresite Capital

Dr. Sarah Fortune
Harvard T.H. Chan School of Public Health

Dr. Laura Kiessling
Massachusetts Institute of Technology

Dr. Dan Littman
New York University School of Medicine

Dr. Aviv Regev
Broad Institute

Dr. Phillip Sharp
Massachusetts Institute of Technology

Dr. David Walt
Harvard Medical School

Government Advisors

Dr. Carol Kuntz
Office of the Secretary of Defense for Policy

Dr. Rajesh Naik
Air Force Research Laboratory

Dr. Peter Emanuel
U.S. Army Edgewood Chemical and Biological Center

Dr. Linda Chrisey
Office of Naval Research

Executive Secretary

Dr. James B. Petro
Office of the Under Secretary of Defense for Research and Engineering

DSB Secretariat Representative

Lt Col Milo Hyde IV, PhD
Designated Federal Officer and Executive Director (acting)

Study Support

Appendix C: Recommendations

Recommendation 1:
The DoD should leverage applied genomics for optimized warfighter talent management, performance, and health.

Recommendation 2:
The DoD should accelerate and prepare to employ autonomous systems for battlefield patient management, care, and evacuation.

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[2] After the Task Force concluded its deliberations but before this final report was completed, the DoD implemented this recommendation and established an Assistant Director for Biotechnology in 2019.

Appendix D: Briefings Received

18–19 September 2017 Meeting

DoD Perspective on Biology
Office of the Under Secretary of Defense for Research and Engineering

5–6 February 2018 Meeting

Welcome and USAMRMC Overview
U.S. Army Medical Research and Materiel Command

DHP and ASBREM Overview
Defense Health Agency

Medical Informatics, Simulation, and Training
Medical Simulation and Information Sciences Research Program

Military Infectious Diseases
Military Infectious Diseases Research Program

Military Operational Medicine
Military Operational Medicine Research Program

Combat Casualty Care
Combat Casualty Care Research Program

Medical Radiological Defense
U.S. Army Medical Research and Materiel Command

Clinical and Rehabilitative Medicine
Clinical and Rehabilitative Medicine Research Program

Pharmaceutical Systems
Pharmaceutical Systems Project Management Office

Medical Support Systems
Medical Support Systems Project Management Office

Tissue Injury and Regenerative Medicine
Tissue Injury and Regenerative Medicine Project Management Office

Neurotrauma and Psychological Health
Neurotrauma and Psychological Health Project Management Office

Medical Devices
U.S. Army Medical Materiel Agency

Integrated Clinical Systems
U.S. Army Medical Materiel Agency

MEDEVAC Mission Equipment Package
Project Management Office Medical Evacuation Mission Equipment

Telemedicine and Advanced Technology Research Center
Telemedicine and Advanced Technology Research Center

Computational Biology Research at the BHSAI
Biotechnology High Performance Computing Software Applications Institute

20 March 2018 Meeting

Biological Technologies to Revolutionize Defense Capabilities
Defense Advanced Research Projects Agency

Measurements Discussion
Harvard Medical School; Broad Institute; Office of the Secretary of Defense for Policy

17–18 April 2018 Meeting

Synthetic Biology Applications
Massachusetts Institute of Technology

DoD Capabilities and Activities
Office of the Under Secretary of Defense for Research and Engineering; Army Research Laboratories; Office of Naval Research; Air Force Research Laboratory; and Massachusetts Institute of Technology

Manufacturing Discussion
Massachusetts Institute of Technology

CRISPR Discussion
Broad Institute

11–12 June 2018 Meeting

Subgroup 1 Presentation: Materials, Manufacturing, and Remediation
Harvard University; Massachusetts Institute of Technology

Subgroup 2 Presentation: Manipulation of Higher Organisms to Change Phenotype
Massachusetts Institute of Technology; Harvard University

Subgroup 3 Presentation: Manipulation of Immune System and Microbiome
Massachusetts Institute of Technology

Subgroup 4 Presentation: Tag, Track, and Locate
Harvard Medical School; Foresight Capital

23–24 July 2018 Meeting

Cognition
Massachusetts Institute of Technology

20–21 September 2018 Meeting

Millennium Cohort Study
Naval Health Research Center

VA Million Veterans Program
Department of Veterans Affairs

27–28 November 2018 Meeting

Naval Air Warfare Center Briefing
Naval Air Warfare Center, Weapons Division

Lockheed Martin Briefing
Lockheed Martin Corporation

Appendix E: Acronyms and Abbreviated Terms

ADDRE	Assistant Director for Defense Research and Engineering
AI	artificial intelligence
ASO	antisense oligonucleotide
BWC	Biological Weapons Convention
CB	chemical and biological
CCDR	Combatant Commanders
CFIUS	Committee on Foreign Investment in the United States
CNS	central nervous system
CLP	clean, lubricate, protect
COCOM	Coordinating Committee for Multilateral Export Controls
CoE	Center of Excellence
CRISPR	clustered regularly interspaced short palindromic repeats
CRISPR/Cas	CRISPR/CRISPR Associated
CTE	Chronic Traumatic Encephalopathy
DARPA	Defense Advanced Research Projects Agency
dbGAP	genotypes and phenotypes
DIUx	Defense Innovation Unit Experimental
DNA	deoxyribonucleic acid
eDNA	environmental DNA
EMRs	electronic medical records
FFRDCs	Federally-Funded Research and Development Centers
GA4GH	Global Alliance for Genomics and Health
GDPR	General Data Protection Regulation
GRIN	gradient index
GWAS	genome-wide association study

ICBM	intercontinental ballistic missile
IED	improvised explosive device
ILCs	innate lymphoid cells
IND	improvised nuclear device
LS&T	Life Science and Technology
MTF	medical treatment facility
MHS	Military Health System
MOS	Military Occupational Specialties
mRNA	messenger RNA
MURI	Multidisciplinary University Research Initiative
MVP	Million Veterans Program
NAS	National Academy of Sciences
NATO	North Atlantic Treaty Organization
NDS	National Defense Strategy
NDSEG	National Defense Science and Engineering Graduate
NIH	National Institute of Health
NSF	National Science Foundation
OSD	Office of the Secretary of Defense
OTA	Other Transaction Authorities
pheWAS	phenome-wide association study
POL	petroleum, oil, lubricants
PTSD	post-traumatic stress disorder
R&D	research and development
RDD	radiological dispersal device
RNA	ribonucleic acid
S&T	science and technology
SASP	senescence-associated secretory phenotype

SBME	Synthetic Biology for Military Environments
SCFA	short-chain fatty acids
siRNA	short interfering RNA
Tregs	regulatory T cells
TTL	tag, track, and locate
UAV	unmanned aerial vehicle
USD(P&R)	Under Secretary of Defense for Personnel and Readiness
USD(R&E)	Under Secretary of Defense for Research and Engineering
UUV	unmanned underwater vehicle
VA	Department of Veterans Affairs
VBFF	Vannevar Bush Faculty Fellowship